BGE Calvert Cliffs Nuclear Power Plant

License Renewal Project

Aging Management Review Report

for the

Containment Structure

(System 059)

Revision 3

May, 1996

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LIST OF EFFECTIVE PAGES

Revision	Pages	Summary of Change
0	All	Initial revision prepared using LCM-10S, Revision 0.
1	All	Implemented new steps added to LCM-10S to accomplish program evealuation.
2	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.
3	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 CONTAINMENT STRUCTURE DESCRIPTION

This section describes the scope and boundaries of the Containment Structure (System 059) as it was evaluated. Section 1.1.1 provides a brief synopsis of the Containment Structure as described in existing plant documentation. The Containment Structure 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 Containment Structure intended functions for license renewal and is provided as a basis for component scoping and the identification of component-specific functions.

1.1.1 Containment Structure LCM Description

The Containment Structure is a Class I structure, housing the reactor and other NSSS components. The Containment Structure consists of a reinforced concrete cylinder and a shallow domed roof which rests on a reinforced concrete foundation slab. The concrete cylinder and dome have a post-tensioned contraction design. Attached to the inside of the Containment Structure is a carbon steel liner. There are three personnel and equipment access openings in the Containment Structure: a two-door personnel lock, a large diameter single door equipment hatch, and a two-door personnel escape hatch.

The Containment Structure has numerous penetrations for piping and electrical connections. These penetrations are leak tight, inerted assemblies, welded to the Containment liner. A fuel transfer tube penetration in the Containment Structure is provided to permit fuel movement between the refueling pool in the Containment Structure and the spent fuel pool in the Auxiliary Building.

Two sumps are provided in the Containment Structure floor: a normal sump and an emergency sump.

1.1.2 Containment Structure LCM Boundary

The Containment Structure and its structural components provide support and shelter to safety related and non-safety related equipment inside the Containment Structure. The LCM boundary addressed by this scoping and evaluation included all in-Containment structural components serving such functions and components comprising the pressure boundary but did not include commodity items such as pipe supports and snubbers. Structural components within this Containment Structure include supports for the following major device types:

Accumulators (ACCUMU), boilers (BOILER), compressors (COMP), fans (FAN), heat exchangers (HX), motors (MOTOR), motor control centers (MCC), penetrations (PEN), pumps (PUMP), vessels (VESSEL), hydrogen recombiners (RECOMB), and screens (SCREEN).

Also included in the Containment Structure boundary are structural or functional supports for non-safety related equipment of the above device types. During an abnormal event such as a seismic event, failure of these non-safety-related equipment supports must not adversely affect the operability of other safety related components.

Per the BGE Integrated Plant Assessment Methodology, Containment components which have unique identifiers in the NUCLEIS Equipment Technical database (such as doors and penetrations) were evaluated using the Aging Management Review procedure for systems. The results of this task are documented and a separate AMR Report entitled "Aging Management Review Report for the Containment System."

1.1.3 Containment Structure Intended Functions

A detailed review of the Containment Structure intended functions was completed during the scoping process described in the BGE Integrated Plant Assessment Methodology. The following functions for the Containment Structure were identified as structural intended functions on Table 1S of "Component Level Scoping Results for the Primary Containment Structure (Sys. 059)."

1.1.3.1 Function LR-S-1

Provides structural and/or functional support to safety-related equipment.

1.1.3.2 Function LR-S-2

Provides shelter/protection to safety-related equipment.

1.1.3.3 Function LR-S-3

Serves as a pressure boundary or fission product retention barrier to protect public health and safety in the event of any postulated DBEs.

1.1.3.4 Function LR-S-4

Serves as a missile barrier (internal or external).

1.1.3.5 Function LR-S-5

Provides structural and/or functional support to non-safety-related equipment whose failure could directly prevent satisfactory accomplishment of any of the required safety-related functions.

1.1.3.6 Function LR-S-6

Provides flood protection barrier (internal flood event).

1.1.3.7 Function LR-S-7

Provides rated fire barriers to confine or retard a fire from spreading to or from adjacent areas of the plant.

1.2 EVALUATION METHODS

Containment structural components within the scope of license renewal were evaluated in accordance with BGE procedure EN-1-305,[1] 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 CONTAINMENT STRUCTURE SPECIFIC DEFINITIONS

This section provides the definitions for any specific terms unique to the Containment structural component level evaluation.

Term	Definition
None	N/A

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

1.4 CONTAINMENT STRUCTURE SPECIFIC REFERENCES

References utilized in the completion of the Containment structural 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 the task for Revision 1. The update performed in Revision 2 of this report incorporated several TPRs. The update performed in Revision 3 was performed to address a new strategy for the aging management of corrosion effects of structural steel. Only references affected by the Revision 2 and 3 update have been updated.

Table 1-1

Containment Structure 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 Results for Primary Containment Structure (Sys. 059)	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 the Unit 1 Containment Structure - Calvert Cliffs Nuclear Power Plant	---	8/92	Report
---	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
---	Troxell, G.E., Davis, H.E., and Kelly, J.W., "Composition and Properties of Concrete," McGraw Hill	2nd Edition	1968	Text
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
---	"Concrete Manual," U.S. Department of the Interior	8th Edition	1975	Code
6750-C-23E	Specification for Furnishing and Installation of Piezometer - Calvert Cliffs Nuclear Power Plant Unit No. 1 and 2	0	11/73	Spec
ASTM C-289-66	"Potential Reactivity of Aggregates (Chemical Method)," American Society of Testing and Materials	---	1966	Code
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

Table 1-1

Containment Structure Specific References

Document ID.	Document Title	Revision No.	Date	Type
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	11th Edition	7/68	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	2	4/96	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-31	Specification for Furnishing, Detailing, Painting, and Delivering Containment and Auxiliary Building Structural Steel	2	5/70	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
---	"Specification and Load Data for Wej-Its," Vendor's product catalog by Wej-It Corp., Brownfield, CO.	---	1977	Catalog
6750-C-16	Specification for Furnishing, Fabricating, Delivering and Erection of the Containment Structure Liner Plate and Accessory Steel	8	5/71	Spec
6750-C-28	Specification for Stainless Steel Liner Plate and Spent Fuel Pool Bulkhead Gate	5	6/73	Spec
M-665-1/2	"Containment Liner Plate Surveillance," Surveillance Test Procedure (STP)	---	---	Procedure
NUREG-0797	Safety Evaluation Report Related to the Operation of Comanche Peak Steam Electric Station, Units 1 and 2	---	7/81	SER
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

Table 1-1

Containment Structure Specific References

Document ID.	Document Title	Revision No.	Date	Type
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
M-663-1 and M-663-2	Containment Tendon Surveillance, Calvert Cliffs Nuclear Power Plant	6 4	10/85 9/85	Procedure
---	"Prestressing Report - Containment Structure," Calvert Cliffs Nuclear Power Plant, Unit 2	---	---	Report
ASME Section III, Division 2	"Code for Concrete Reactor Vessels and Containments," American Society of Mechanical Engineers Boiler and Pressure Vessel Code	---	1986	Code
60-340-E, 60-341-E, and 60-342-E	"Reactor Cooling System," Calvert Cliffs Nuclear Power Plant	10 7 6	2/75 11/70 7/73	Drawing
60-346-E and 62-346-E	"Encapsulation Details - Main Steam System," Sheets 1 and 2, Calvert Cliffs Nuclear Power Plant Units 1 and 2	7 4	10/74 6/80	Drawing
60-235-E and 62-235-E	"Component Cooling Water System," Calvert Cliffs Nuclear Power Plant Units 1 and 2	37 28	1/93 1/92	Drawing

2.0 STRUCTURAL COMPONENTS WITHIN THE SCOPE OF LICENSE RENEWAL

The Containment structural components were scoped in accordance with the process described in the BGE Integrated Plant Assessment Methodology. The Containment Structure was scoped using procedure LCM-11S for structural components. The purpose of component scoping is to identify all structural components that provide one of the structure's intended functions identified in Section 1.1.3. These structural components are designated as components within the scope of license renewal.

As a result of the scoping, 31 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

Containment Structural Components Within the Scope of License Renewal

STRUCTURAL COMPONENT TYPE	INTENDED FUNCTION(S)
Concrete Column	LR-S-1 and 5
Concrete Beams	LR-S-1 and 5
Concrete Slabs and Equipment Pads	LR-S-1 and 5
Elevated Floor Slab	LR-S-1 and 5
Cast-in-Place Anchors	LR-S-1 and 5
Grout	LR-S-1 and 5
Concrete Dome	LR-S-1, 2, 3, 4, 5, and 7
Concrete Containment Wall	LR-S-1, 2, 3, 4, 5, 6. and 7
Concrete Basemat	LR-S-1, 2, 3, 4, 5, 6, and 7
Primary Shield Wall	LR-S-1, 2, and 4
Secondary Shield Wall	LR-S-1, 2, and 4
Refueling Pool (Concrete)	LR-S-1 and 6
Removable Missile Shield	LR-S-4
Steel Column	LR-S-1 and 5
Steel Beams	LR-S-1 and 5
Baseplates	LR-S-1 and 5
Floor Framing	LR-S-1 and 5
Steel Bracings	LR-S-1 and 5
Platform Hangers	LR-S-1 and 5
Decking	LR-S-1 and 5
Floor Grating	LR-S-1 and 5
Checkered Plates	LR-S-1 and 5
Post-Tensioning System	LR-S-1, 2, 3, and 4
Crane Girder	LR-S-5
Containment Liner	LR-S-3
Basemat Liner	LR-S-3
Refueling Pool (Liner)	LR-S-3
Post-Installed Anchors	LR-S-1
Lubrite Plates	LR-S-1 and 5
Coating	LR-S-1, 2, 3, 4, 5, and 7
Partitions and Ceilings	LR-S-7

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 evaluation of the Containment structural components within the scope of license renewal was completed in accordance with BGE procedure, "Component Aging Management Review for Structures," EN-1-305, Revision 0. This procedure evaluated all 31 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 shown in 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 aging management review 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 coatings

(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 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 Containment structural components. The plausibility determination is made through a careful consideration of all the factors required to allow the aging degradation 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 3 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 Containment Structure.

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 period of extended operations. If existing programs would not manage the effects of aging during the period of extended operation, a one-time inspection could be conducted, modifications could be made to existing 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 programs 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 Containment Structure identified a total of 16 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, the conclusion that the aging mechanism is

PLAUSIBLE was made 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:

Outside Containment

(1) Sample the water quality of groundwater using the existing groundwater monitoring wells. If samples fail to confirm that groundwater quality precludes degradation of below grade concrete, take additional corrective action such as including below grade concrete in an age-related degradation inspection program.

(2) Continue the existing tendon surveillance program to monitor the condition and performance of the tendon system.

(3) Update the time-limited aging analysis for allowable prestress losses of the post-tensioned tendon system to reflect the period of extended operations. If necessary, retension any tendons to account for predicted prestress losses during the period of extended operations.

Inside Containment

(1) Continue to perform visual inspections of coated surfaces of structural steel and the corrosion liner in accessible areas.

(2) Develop an age-related degradation inspection program for coated surface of structural steel and the containment liner that are not readily accessible.

(3) Continue to monitor leakage from the refueling pool to ensure that no corrosion mechanisms have degraded the refueling pool liner weld and heat affected regions.

Table 4-1

List of Potential Aging Mechanisms for Containment Structural Components

Aging Mechanism Description	Potential to Affect Containment Structure?	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	Yes	Concrete
Shrinkage	Yes	Concrete, Partitions and Ceilings
Abrasion and Cavitation	No	Concrete
Cracking of Masonry Block Walls	No*	Block Walls
Settlement	Yes	Structure
Corrosion in Steel	Yes	Steel
Corrosion in Liner	Yes	Steel Liners (Carbon and Stainless)
Corrosion in Tendons	Yes	Steel
Prestressing Losses	Yes	Steel
Weathering	Yes	Coating, Partitions and Ceilings
Elevated Temperature	Yes	Concrete, Coating
Irradiation	Yes	Concrete, Steel, Coating, Partitions and Ceilings
Fatigue	Yes	Concrete

* There are no block walls inside the Containment

Table 4-2

Containment Structure Aging Effects Summary

STRUCTURAL COMPONENTS	PLAUSIBLE AGING MECHANISM	RECOMMENDATION	REMARKS
Concrete Columns	None	None	See justification in Appendices D and T.
Concrete Beams	None	None	See justification in Appendices D and T.
Ground floor slabs & Equipment Pads	None	None	See justification in Appendices D and T.
Elevated Floor Slabs	None	None	See justification in Appendices D and T.
Cast-in-place Anchors	Corrosion in steel	See recommendation for "Steel Columns"	See justification in Appendix K.
Grout	None	None	None.
Post-installed Anchors	Corrosion in steel	See recommendation for "Steel Columns"	See justification in Appendix K.
Steel Columns	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: MN-3-100, Painting and Other Protective Coatings Program. QL-2-100, Issue Reporting 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.
Steel Beams	Corrosion in steel	See recommendation for "Steel Columns"	See justification in Appendix K.
Baseplates	Corrosion in steel	See recommendation for "Steel Columns"	See justification in Appendix K.
Floor Framing	Corrosion in steel	See recommendation for "Steel Columns"	See justification in Appendix K.
Steel Bracings	Corrosion in steel	See recommendation for "Steel Columns"	See justification in Appendix K.
Platform Hangers	Corrosion in steel	See recommendation for "Steel Columns"	See justification in Appendix K.

Table 4-2

Containment Structure Aging Effects Summary

STPUCTURAL COMPONENTS	PLAUSIBLE AGING MECHANISM	RECOMMENDATION	REMARKS
Decking	Corrosion in steel	See recommendation for "Steel Columns"	See justification in Appendix K.
Floor Grating	Corrosion in steel	See recommendation for "Steel Columns"	See justification in Appendix K.
Checkered Plate	Corrosion in steel	See recommendation for "Steel Columns"	See justification in Appendix K.
Coatings (including galvanizing material)	None	None	See justification in Appendices O and S.
Post-tensioning System	Corrosion in tendons Prestressing losses	The tendon surveillance program STP-M663-1/2 should be continued throughout the license renewal period to monitor the condition and performance of the tendon system. The current prestress losses which were specifically predicted for a service life of 40 years should be updated to reflect the period of extended operations. If necessary, tendons should be retensioned to reflect the predicted prestress losses.	See justification in Appendices M and N.
Crane Girder	Corrosion in steel	See recommendation for "Steel Columns"	See justification in Appendix K.
Concrete Dome	None	None	See justification in Appendices A, B, C, D and E.
Concrete Containment Wall	Aggressive chemicals Corrosion in embedded steel/rebar	See recommendation for "Concrete Basemat"	aging mechanisms are plausible only for the below grade portion of the Containment wall. See justification in Appendices A, B, C, D, E and R.
Concrete Basemat	Aggressive chemicals Corrosion in embedded steel/rebar	The observation wells, installed during construction, can be restored to sample the groundwater for water quality testing. This data can be used to evaluate the impact of chemical attack on the exterior surfaces of exposed components.	See justification in Appendices B, C, D, E, J, and S.

Table 4-2

Containment Structure Aging Effects Summary

STRUCTURAL COMPONENTS	PLAUSIBLE AGING MECHANISM	RECOMMENDATION	REMARKS
Containment Liner	Corrosion in liner	All exposed surfaces of the containment liner 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: MN-3-100, Painting and Other Protective Coatings Program. QL-2-100, Issue Reporting For portions of the containment liner 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 L.
Basemat Liner	Corrosion in liner	See Concrete basemat.	See justification in Appendix L.
Primary Shield Wall	None	None	See justification in Appendices D, R, S, and T.
Secondary Shield Wall	None	None	See justification in Appendices D, S, and T.
Refueling Pool (Liner)	Corrosion in liner	Continue to monitor leakage from the refueling pool to ensure that no corrosion mechanisms have degraded the liner welds and heat affected regions.	See justification in Appendix L.
Refueling Pool (Concrete)	None	None	See justification in Appendix D.
Removable Missile Shield	None	None	See justification in Appendix D.
Lubrite Plate	Corrosion in steel	See recommendation for "Steel Columns"	See justification in Appendix K.
Partitions and Ceilings	None	None	See justification in Appendices G, O, and S.

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 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 effects 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 Containment Structure structural components that are degraded by identified plausible aging mechanisms. Components that can be managed by an existing program are as follows:

All structural steel components in accessible areas. MN-3-100 in combination with QL-2-100 for identifying, documenting, and correcting significant coating degradation are adequate for managing the effects of corrosion.

Accessible portions of the containment liner. MN-3-100 in combination with QL-2-100 for identifying, documenting, and correcting significant coating degradation are adequate for managing the effects of corrosion.

Refueling pool stainless steel liner. Monitoring refueling pool leakage per established system summary and improvement plan performance indicators is adequate to manage the effects of corrosion mechanisms.

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 period of extended operations. The evaluation started from evaluating structural component types and applicable aging mechanisms and has focused on specific components or locations. Components that can be managed by modifying an existing program or activity are as follows:

Prestress tendons: The tendon surveillance inspection procedure should be revised to include a lift-off force versus time curve for 60 years. Based on additional surveillance testing results and the updated (60-year) lift-off force versus time curve, retensioning of selected tendons may be necessary to meet the lift-off requirements in the 60-year curve prior to the period of extended operations.

5.2.3 New Programs

This section provides the summary results for those structural components that were determined to require a new CCNPP Program/Activity to be created as an adequate program to manage the effects of aging during the renewal period. Components that can be managed by the creation of such new programs or activities include the following:

Below grade portion of Containment wall: An investigative program to test the water quality of the groundwater should be developed to determine if there is any possibility of aggressive chemical attack on Containment wall. Inspection of the exterior, below grade surfaces and additional excavation and testing may be necessary if results from the investigative tests are not favorable.

Basemat: An investigative program to test the water quality of the groundwater should be developed to determine if there is any possibility of aggressive chemical attack on Containment basemat. Inspection of the exterior, below grade surfaces and additional excavation and testing may be necessary if results from the investigative tests are not favorable.

Basemat Liner. An investigative program to test the water quality of the groundwater should be developed to determine whether there is any possibility of corrosion of the basemat liner should any groundwater come into contact with the liner.

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.

Non-Accessible Portions of the Containment Liner: An age related degradation inspection, as defined in the BGE Integrated Plant Assessment Methodology, should be conducted for portions of the containment liner 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 Containment Structure Aging Management Review

Attachment 1

Potential Aging Mechanisms Applicable to Structural Components

ATTACHMENT 1: POTENTIAL AGING MECHANISMS APPLICABLE TO STRUCTURAL COMPONENTS

REVISION: 3

DATE: May 1996

STRUCTURE NAME: Containment Structure

SYSTEM NUMBER: 059

STRUCTURAL COMPONENTS	POTENTIAL AGING MECHANISMS APPLICABLE TO CONCRETE/ARCH. COMPONENTS															REMARKS
	A	B	C	D	E	F	G	H	I	J	R	S	T	O		
Concrete Columns	-	-	-	√	-	-	-	-	NA	-	-	-	√	-		LR Functions LR-S-1, 5
Concrete Beams	-	-	-	√	-	-	-	-	NA	-	-	-	√	-		LR Functions LR-S-1, 5
Concrete Slabs & Equip. Pads	-	-	-	√	-	-	-	-	NA	-	-	-	√	-		LR Functions LR-S-1, 5
Elevated Floor Slabs	-	-	-	√	-	-	-	-	NA	-	-	-	√	-		LR Functions LR-S-1, 5
Concrete Dome	√	√	√	√	√	-	-	-	NA	-	-	-	-	-		LR Functions LR-S-1 through 5, 7
Concrete Containment Wall	√	√	√	√	√	-	-	-	NA	-	√	-	-	-		LR Functions LR-S-1 through 7
Concrete Basemat	-	√	√	√	√	-	-	-	NA	√	-	√	-			LR Functions LR-S-1 through 7
Primary Shield Wall	-	-	-	√	-	-	-	-	NA	-	√	√	√	-		LR Functions LR-S-1, 2, 4
Secondary Shield Walls	-	-	-	√	-	-	-	-	NA	-	-	√	√	-		LR Functions LR-S-1, 2, 4
Refueling Pool (Concrete)	-	-	-	√	-	-	-	-	NA	-	-	-	-	-		LR Functions LR-S-1, 6
Removable Missile Shield	-	-	-	√	-	-	-	-	NA	-	-	-	-	-		LR Function LR-S-4
Grout	-	-	-	-	-	-	-	-	NA	-	-	-	-	-		LR Functions LR-S-1, 5
Coating	-	-	-	-	-	-	-	-	NA	-	-	√	-	√		LR Functions LR-S-1 through 5, 7
Partitions and Ceilings	-	-	-	-	-	-	√	-	NA	-	-	√	-	√		LR Function LR-S-7

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	Not applicable
F	Creep	L	Corrosion in Liner	R	Elevated temperature	-	Not potential

ATTACHMENT 1: POTENTIAL AGING MECHANISMS APPLICABLE TO STRUCTURAL COMPONENTS

REVISION: 3

DATE: May 1996

STRUCTURE NAME: Containment Structure

SYSTEM NUMBER: 059

STRUCTURAL COMPONENTS	POTENTIAL AGING MECHANISMS APPLICABLE TO STEEL COMPONENTS							REMARKS
	K	L	M	N	R	S	T	
Steel Columns	√	-	-	-	-	-	√	LR Functions LR-S-1, 5
Steel Beams	√	-	-	-	-	-	√	LR Functions LR-S-1, 5
Baseplates	√	-	-	-	-	-	√	LR Functions LR-S-1, 5
Floor Framing	√	-	-	-	-	-	√	LR Functions LR-S-1, 5
Steel Bracings	√	-	-	-	-	-	√	LR Functions LR-S-1, 5
Platform Hangers	√	-	-	-	-	-	√	LR Functions LR-S-1, 5
Decking	√	-	-	-	-	-	√	LR Functions LR-S-1, 5
Floor Grating	√	-	-	-	-	-	-	LR Functions LR-S-1, 5
Checkered Plates	√	-	-	-	-	-	-	LR Functions LR-S-1, 5
Post-Tensioning System	-	-	√	√	-	-	-	LR Functions LR-S-1 through 4
Crane Girder	√	-	-	-	-	-	√	LR Function LR-S-5
Containment Liner	-	√	-	-	-	-	-	LR Function LR-S-3
Basement Liner	-	√	-	-	-	-	-	LR Function LR-S-3
Refueling Pool (Liner)	-	√	-	-	-	-	-	LR Function LR-S-3
Cast-in-place Anchors	√	-	-	-	-	-	-	LR Functions LR-S-1, 5
Post-Installed Anchors	√	-	-	-	-	-	-	LR Function LR-S-1
Lubrite Plates	√	-	-	-	-	-	-	LR Function LR-S-1, 5

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 Not applicable
- \- Not potential

Attachment 2

Plausible Aging Mechanisms Applicable to Structural Components

ATTACHMENT 2: PLAUSIBLE AGING MECHANISMS APPLICABLE TO STRUCTURAL COMPONENTS

REVISION: 3

DATE: May 1996

STRUCTURE NAME: Containment Structure

SYSTEM NUMBER: 059

STRUCTURAL COMPONENTS	PLAUSIBLE AGING MECHANISMS APPLICABLE TO CONCRETE/ARCH. COMPONENTS (SEE ATTACHMENT 4 FOR JUSTIFICATION)															REMARKS
	A	B	C	D	E	F	G	H	I	J	R	S	T	O		
Concrete Columns	-	-	-	104	-	-	-	-	NA	-	-	-	109	-		
Concrete Beams	-	-	-	104	-	-	-	-	NA	-	-	-	109	-		
Concrete Slabs & Equip. Pads	-	-	-	104	-	-	-	-	NA	-	-	-	109	-		
Elevated Floor Slabs	-	-	-	104	-	-	-	-	NA	-	-	-	109	-		
Concrete Dome	101	102	103	104	105	-	-	-	NA	-	-	-	-	-		
Concrete Containment Wall	101	102	PA	104	PB	-	-	-	NA	-	107	-	-	-		
Concrete Basemat	-	102	PA	104	PB	-	-	-	NA	106		108	-	-		
Primary Shield Wall	-	-	-	104	-	-	-	-	NA	-	107	108	109	-		
Secondary Shield Walls	-	-	-	104	-	-	-	-	NA	-	-	108	109	-		
Refueling Pool (Concrete)	-	-	-	104	-	-	-	-	NA	-	-	-	-	-		
Removable Missile Shield	-	-	-	104	-	-	-	-	NA	-	-	-	-	-		
Grout	-	-	-	-	-	-	-	-	NA	-	-	-	-	-		
Coating	-	-	-	-	-	-	-	-	NA	-	-	108	-	110		
Partitions and Ceilings	-	-	-	-	-	-	111	-	NA	-	-	108	-	110		

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

REVISION: ___ DATE: May 1996

STRUCTURE NAME: Containment Structure SYSTEM NUMBER: 059 Sheet 3 of 3

STRUCTURAL COMPONENTS	PLAUSIBLE AGING MECHANISMS APPLICABLE TO STEEL COMPONENTS (SEE ATTACHMENT 4 FOR JUSTIFICATION)															REMARKS
	K	L	M	N	R	S	T									
Steel Columns	PD	-	-	-	-	-	109									
Steel Beams	PD	-	-	-	-	-	109									
Base Plates	PD	-	-	-	-	-	109									
Floor Framing	PD	-	-	-	-	-	109									
Steel Bracings	PD	-	-	-	-	-	109									
Platform Hangers	PD	-	-	-	-	-	109									
Decking	PD	-	-	-	-	-	109									
Floor Grating	PD	-	-	-	-	-	-									
Checkered Plates	PD	-	-	-	-	-	-									
Post-Tensioning System	-	-	PF	PG	-	-	-									
Crane Girder	PD	-	-	-	-	-	109									
Containment Liner	-	PE	-	-	-	-	-									
Basement Liner	-	PE	-	-	-	-	-									
Refueling Pool (Liner)	-	PE	-	-	-	-	-									
Cast-in-place Anchors	PD	-	-	-	-	-	-									
Post-Installed Anchors	PD	-	-	-	-	-	-									
Lubrite Plates	PD	-	-	-	-	-	-									

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 Component - Aging Mechanism Matrix Codes

ATTACHMENT 3

STRUCTURAL COMPONENT - AGING MECHANISM MATRIX CODES

Revision: 3 Date: May 1996

STRUCTURE NAME: Primary Containment Structure

SYSTEM NUMBER: 059 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	
107	See Appendix R	
108	See Appendix S	
109	See Appendix T	
110	See Appendix O	
111	See Appendix G	

ATTACHMENT 3

STRUCTURAL COMPONENT - AGING MECHANISM MATRIX CODES

Revision: 3 Date: May 1996

STRUCTURE NAME: Primary Containment Structure

SYSTEM NUMBER: 059 Sheet 3 of 3

CODE	JUSTIFICATION	REMARKS
PA	See Appendix C	
PB	See Appendix E	
PC	Not Used	
PD	See Appendix K	
PE	See Appendix L	
PF	See Appendix M	
PG	See Appendix N	

Attachment 4

Summary of Aging Management Review Results

Attachment 4

SUMMARY OF AGING MANAGEMENT REVIEW RESULTS

Revision: 3

May 1996

STRUCTURE/SYSTEM NUMBER: 059   STRUCTURE NAME: Containment

	COMPONENTS AFFECTED		
AGING MECHANISMS	CONCRETE/ARCH.	STEEL	PROGRAM/COMMENT
Freeze-Thaw	None	None	Not Needed
Leaching of $Ca(OH)_2$	None	None	Not Needed
Aggressive Chemicals	1. Below grade portion of containment wall 2. Basemat	None	None existing. Need to investigate ground water.
Reaction with Aggregates	None	None	Not Needed
Corrosion of Embedded Steel/Rebar	1. Below grade portion of containment wall 2. Basemat	None	None existing. Verify water quality of ground water.
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.
Settlement	None	None	Not Needed
Corrosion in Steel	None	All structural steel members	MN-3-100, QL-2-100, ARDI.

Attachment 4

SUMMARY OF AGING MANAGEMENT REVIEW RESULTS

Revision: 3 May 1996

STRUCTURE/SYSTEM NUMBER: 059 STRUCTURE NAME: Containment

	COMPONENTS AFFECTED		
AGING MECHANISMS	CONCRETE/ARCH.	STEEL	PROGRAM/COMMENT
Corrosion in Liner	None	1. In-containment dome and wall liner 2. Exterior basemat 3. Sensitized zone of the refueling canal liner	1. MN-3-100, QL-2-100, ARDI. 2. None existing. Need to investigate ground water. 3. PEG-19, QL-2-100.
Corrosion in Tendons	None	Prestressed tendons	STP-M-663-1/2
Prestressing Losses	None	Prestressed tendons	STP-M-663-1/2
Weathering	None	None	Not Needed
Elevated Temperature	None	None	Not Needed
Irradiation	None	None	Not Needed
Fatigue	None	None	Not Needed

Attachment 5

Adequate Program Evaluations

Attachment 5

ADEQUATE PROGRAM EVALUATION

REVISION: 3 May 1996
STRUCTURE/SYSTEM NUMBER: 059 STRUCTURE NAME: Containment

STRUCTURAL COMPONENT DESCRIPTION: Accessible portions of In-Containment Wall/Dome Liner

AGING MECHANISM DESCRIPTION: Corrosion of liner

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

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

DISCOVERY DESCRIPTION/BASIS:

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

   YES X NO ____

   Basis: MN-3-100 requires an inspection of all coated surfaces inside the containment at the beginning of each refueling and maintenance outage to verify the condition of coatings. Deficiencies are documented and reported via QL-2-100 for prioritization and corrective action.

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

   YES X NO ____

   Basis: The every-major-outage inspection interval is a common industry practice and is considered acceptable for areas in the containment.

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

   YES X NO ____

   Basis: All coated surfaces that are readily accessible are visually inspected during the MN-3-100 activity.

REVISION: 3 **May 1996**

ARDM DESCRIPTION: Corrosion of liner

CCNPP PA or TASK ID: MN-3-100, 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. The need is based on the judgement of the inspector and the safety significance of the structural component needing re-coating. The procedure prioritizes painting categories which dictate the urgency of corrective actions.

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: MN-3-100 performs a thorough inspection of accessible portions of the containment liner coated surfaces. Indications of deterioration of coatings are documented, prioritized and corrected well before corrosion of the liner could impact the intended function of the liner even under design loading conditions.

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 prescribed in MN-3-100 are based on the surface condition of the coated component. This approach does not need to be revised during the renewal period.

ARDM DESCRIPTION: **Corrosion of liner**

CCNPP PA or TASK ID: **MN-3-100, QL-2-100**

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

YES _X_ NO ____

Basis: Procedure MN-3-100 assigns priorities to determine the need for corrective painting, preventive painting, appearance painting, or no painting required. To ensure proper application and qualified protective coating is used, the appropriate coating application performance standard is invoked in the procedure.

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

YES _X_ NO ____

Basis: MN-3-100 implements corrective action via QL-2-100 which assigns a due date for corrective action to occur. The completion date is driven by engineering judgement based on the condition of the degraded coating and its contribution to the component's intended function.

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 the appropriate level 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: MN-3-100 and QL-2-100 are controlled by the site procedure for preparing and revising procedures.

ADEQUATE PROGRAM EVALUATION

Revision: 3 May 1996

STRUCTURE/SYSTEM NUMBER: 059 STRUCTURE NAME: Containment

STRUCTURAL COMPONENT DESCRIPTION: Prestressed Tendons

AGING MECHANISM DESCRIPTION: Prestress losses

CCNPP PA or Task ID: STP-M-663-1/2

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

DISCOVERY DESCRIPTION/BASIS:

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

   YES X NO __

   Basis: Both the Unit 1 and Unit 2 procedures are implemented in accordance with the frequency intervals specified in plant technical specification section 4.6.1.6.1.

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

   YES X NO __

   Basis: The frequency interval is in accordance with the requirements in Position C.1.2 in Regulatory Guide 1.35. This interval was developed during the containment design based on the predicted degradation rate for the time dependent tendon force/condition losses.

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

   YES X NO __

   Basis: The procedure is applicable to tendons in the Unit 1 system except those which have been exempted from inspection as documented in Appendix 5A of the FSAR. The procedure would be extended to Unit 2 tendons should the Unit 1 results warrant.

ARDM DESCRIPTION: Prestress Losses

CCNPP PA or TASK ID: STP-M-663-1/2

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: The tendon surveillance procedure provides acceptance criteria for prestress level and tendon system component physical conditions over a 40-year operating life. These action values include tendon lift-off forces as a measure of prestress level, strength testing of tendon wires for physical condition, chemical testing of sheathing filler for grease properties to assure continued protection of the tendon wires and extensive visual inspection for broken wires and corrosion levels. The procedure and plant Technical Specification 4.6.1.6.1 also comply with Position 7 in Regulatory Guide 1.35 to evaluate the inspection results.

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: Expected lift-off forces incorporated in the procedure were developed for the tendon system based on a service life of 40 years. The prestress force data and physical condition data obtained in each surveillance will be evaluated in accordance with guidance in Position 7 of Regulatory Guide 1.35 such that the integrity of the prestressed tendon system is ensured prior to the next PA. The prestressed tension system is a passive, and highly redundant system. A research of industry data (LERs, SOERs) reported very few incidents of random malfunction of the tendons or its components. The high redundancy provides additional assurance that individual tendon reduced performance has a negligible effect on the functional capability (prestress level) and the system is reliable. Therefore, criteria proposed in the Regulatory Guide and adopted by Calvert Cliffs will ensure the tendon system (and subsequently, the containment) will perform its intended functions at the time of the inspection and as projected through the time interval to the next surveillance.

ARDM DESCRIPTION: Prestress Losses

CCNPP PA or TASK ID: STP-M-663-1/2

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

YES __ NO X (See Item 1 in Attachment 6)

Basis: Action values and condition parameters will remain the same during the renewal period to maintain the containment boundary prestress level and acceptable physical conditions to ensure the integrity of the tendon system components. It should be noted that prestress losses are a time-limited aging analysis and are reflected in the curves of expected Lift-off Force versus Time in the plant technical specification and the procedure. These curves were developed during initial plant license assuming a service life of the tendon system for 40 years. These curves will need to be re-evaluated to establish the predicted prestress levels during the renewal period. However, the minimum prestress level and physical condition requirements will remain the same.

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

YES X NO __

Basis: The procedure and the Technical Specification (4.6.1.6.1) comply with the guidance for inspection and evaluation of inspection results in Regulatory Guide 1.35. The steps adopted will ensure tendons, or groups of tendons not meeting the predetermined lift-off forces or physical condition assessment will be further evaluated and appropriate corrective actions prescribed and implemented. Any abnormal occurrence will also have to meet reportable requirements to ensure proper corrective actions and documentation as required by evaluation.

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

YES X NO __

Basis: If a low lift-off force or degraded physical condition is considered evidence of possible abnormal degradation of the component, EED must be notified of this condition and Shift Supervisor must enter a 90 day action statement.

ARDM DESCRIPTION: Prestress Losses

CCNPP PA or TASK ID: STP-M-663-1/2

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: This procedure has a review/approval process per EN-4-104.

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

   YES X NO __

   Basis: This procedure has a change/revision process per EN-4-104.

Attachment 5

ADEQUATE PROGRAM EVALUATION

Revision: 3 May 1996
STRUCTURE/SYSTEM NUMBER: 059 STRUCTURE NAME: Containment

STRUCTURAL COMPONENT DESCRIPTION: All accessible internal structural steel members

AGING MECHANISM DESCRIPTION: Corrosion of steel

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

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

DISCOVERY DESCRIPTION/BASIS:

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

   YES X NO __

   Basis: MN-3-100 requires an inspection of all coated surfaces inside the containment at the beginning of each refueling and maintenance outage to verify the condition of coatings. Deficiencies are documented and reported via QL-2-100 for prioritization and corrective action.

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

   YES X NO __

   Basis: The every-major-outage inspection interval is a common industry practice and is considered acceptable for areas in the containment.

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

   YES X NO __

   Basis: All coated surfaces that are readily accessible are visually inspected during the MN-3-100 activity.

ARDM DESCRIPTION: Corrosion of Steel

CCNPP PA or TASK ID: STP-M-663-1/2

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. The need is based on the judgement of the inspector and the safety significance of the structural component needing re-coating. The procedure prioritizes painting categories which dictate the urgency of corrective actions.

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: MN-3-100 performs a thorough inspection of the coated surfaces of accessible structural steel components inside containment. Indications of deterioration of coatings are documented, prioritized and corrected well before corrosion of the liner could impact the intended function of the liner even under design loading conditions.

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 prescribed in MN-3-100 are based on the surface condition of the coated component. This approach does not need to be revised during the renewal period.

ARDM DESCRIPTION: Corrosion of Steel

CCNPP PA or TASK ID: STP-M-663-1/2

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

YES X NO __

Basis: Procedure MN-3-100 assigns priorities to determine the need for corrective painting, preventive painting, appearance painting, or no painting required. To ensure proper application and qualified protective coating is used, the appropriate coating application performance standard is invoked in the procedure

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

YES X NO __

Basis: MN-3-100 implements corrective action via QL-2-100 which assigns a due date for corrective action to occur. The completion date is driven by engineering judgement based on the condition of the degraded coating and its contribution to the component's intended function.

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 the appropriate level 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: MN-3-100 and QL-2-100 are controlled by the site procedure for preparing and revising procedures.

Attachment 5

ADEQUATE PROGRAM EVALUATION

Revision: 3 May 1996

STRUCTURE/SYSTEM NUMBER: 059 STRUCTURE NAME: Containment

STRUCTURAL COMPONENT DESCRIPTION: Prestressed Tendons

ARDM DESCRIPTION: Corrosion in tendons

CCNPP PA or Task ID: STP-M-663-1/2

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

DISCOVERY DESCRIPTION/BASIS:

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

   YES X NO __

   Basis: Both the Unit 1 and Unit 2 procedures are implemented in accordance with the frequency intervals specified in plant technical specification section 4.6.1.6.1.

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

   YES X NO __

   Basis: The frequency interval is in accordance with the requirements in Position C.1.2 in Regulatory Guide 1.35. This interval was developed during the containment design based on the industry's experience with the corrosion resistant properties of the material and the environment it is exposed to.

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

   YES X NO __

   Basis: The procedure is applicable to all tendons in the system except those which have been exempted from inspection as documented in Appendix 5A of the FSAR.

ARDM DESCRIPTION: Corrosion of Steel

CCNPP PA or TASK ID: STP-M-663-1/2

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: The surveillance test procedures contains guidance, criteria and/or refers to appropriate standards which serve as acceptance criteria for the corrosion inspection.

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: The procedures in both units mandate visual inspection of the tendons for indications of corrosion and laboratory testing for sheathing filler to maintain its protective function. Historic data from Calvert Cliffs and from the industry reported very few incidents of malfunction of the system or its components, which provides additional assurance that such systems are reliable. Therefore, criteria proposed in the Regulatory Guide and implemented in the Calvert Cliffs tendon surveillance procedures will ensure the tendon system (and subsequently, the containment) will perform its intended functions at the time of the inspection and as projected through the time interval to the next surveillance.

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

   YES X NO __

   Basis: Historic data from Calvert Cliffs and from the industry reported very few incidents of malfunction of the system or its components, this provides additional assurance that the methodology has been successful in maintaining the reliability of the system. Since the surveillance procedures and the acceptance criteria in the procedures are to ensure the availability and the reliability of the system, this acceptance criteria should not be changed during the renewal period.

ARDM DESCRIPTION: Corrosion of Steel

CCNPP PA or TASK ID: STP-M-663-1/2

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

YES X NO __

Basis: The surveillance test procedures require that any inspection results determined to be unsatisfactory be reported to the STE for investigation and to ensure all reporting requirements are met.

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

YES X NO __

Basis: All corrective actions must meet reporting requirements specified in Section 4.6.1.6.4 of both Units 1 and 2.

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: This procedure has a review/approval process per EN-4-104.

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

YES X NO __

Basis: This procedure has a change/revision process per EN-4-104.

Attachment 5

ADEQUATE PROGRAM EVALUATION

Revision: 3 May 1996

STRUCTURE/SYSTEM NUMBER: 059 STRUCTURE NAME: Containment

STRUCTURAL COMPONENT DESCRIPTION: Refueling Pool Liner

ARDM DESCRIPTION: Corrosion in liners

CCNPP PA or Task ID: PEG-19, System Summary and Improvement Plans (Indicator for Refueling Pool Leakage) and QL-2-100 Issue Reporting

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

DISCOVERY DESCRIPTION/BASIS:

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

   YES X NO _

   Basis: The Refueling Pool SSIP contains an indicator to monitor pool structural leakage when the pool is filled. SSIP indicators must be reviewed and updated on a set frequency.

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

   YES X NO _

   Basis: The refueling pool is only filled for a short time period each refueling cycle. The leakage is monitored frequently during this period and reported as an SSIP indicator on a periodic basis. This interval is considered to be sufficient to detect and trend any corrosion of the pool liner.

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

   YES X NO _

   Basis: The procedure is applicable to the refueling pools in both units.

ARDM DESCRIPTION: Corrosion in liners

CCNPP PA or TASK ID: System Summary Performance Indicator for Refueling Pool Leakage

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: The Refueling Pool SSIP requires assignment of a grade for structural leakage. If leakage were to increase, the lower grade assigned for the Refueling Pool would require an improvement plan to determine the cause and correct the degrading trend.

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: The Refueling Pool Liner is a fluid retaining boundary only. It does not provide any structural support function. Structural integrity is maintained by the surrounding concrete. Therefore, leakage detection and trending is an acceptable technique for ensuring that the refueling pool liner is capable of performing its intended function under all design conditions required by the CLB. The surrounding concrete has been evaluated for the effects of borated water leakage and a determination made that minor leakage will not affect the structural integrity function of the concrete including embedded rebar.

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

   YES X NO __

   Basis: There will continue to be a SSIP indicator to detect and trend any refueling pool leakage.

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

   YES X NO __

   Basis: The SSIP procedure requires a system improvement plan for any reported grade below a specified level. System improvement plans receive appropriate supervisory attention on a periodic basis in order to ensure that the degrading trend is corrected.

ARDM DESCRIPTION: Corrosion in liners

CCNPP PA or TASK ID: System Summary Performance Indicator for Refueling Pool Leakage

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

   YES X NO __

   Basis: Any corrective action required would be implemented via QL-2-100 which contains a process for prioritizing and scheduling corrective action.

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 SSIP procedure requires approval from the appropriate level of supervision.

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

   YES X NO __

   Basis: The SSIP procedure is controlled by appropriate processes to ensure changes do not invalidate the bases for the procedure.

Attachment 6

Program/Activity (PA) Modification

Attachment 6

PROGRAM/ACTIVITY (PA) MODIFICATION

Revision: 3

May 1996

STRUCTURE/SYSTEM NUMBER: 059	STRUCTURE NAME: Containment	
STRUCTURAL COMPONENT: Prestressed tendons	AGING MECHANISM: Prestressed losses	
CCNPP PA OR TASK ID: STP-M-663-1/2		
DOCUMENT/ SUBTASK	**PRESENT TASK APPROACH**	**NEW/REVISED CORRECTIVE ACTION/RECOMMENDATION**
1. Force versus Time curves for predicted prestress loss	1) The existing lift-off force curves in the procedure and the plant technical specification were developed for 40 years operation.	1) Re-evaluate the existing curves to reflect the required prestress levels for the renewal period. Based on the surveillance data and test results of the wires, develop the 60-year curve that best projects the remaining service life of the tendons. Basis: The predicted tendon lift-off forces during the renewal period are not available from the existing curves.

Attachment 7

Walkdown Report - Examination of the Containment Structure

The examination of the Containment Structure is documented in a separate report entitled "Examination of the Unit 1 Containment Structure - Calvert Cliffs Nuclear Power Plant." The report contains photographs and is complemented by video tape.

Attachment 8

Attributes in New Program

STRUCTURE/SYSTEM NUMBER: 059

STRUCTURE NAME: Containment

STRUCTURAL COMPONENT DESCRIPTION: Below grade portion of containment wall and concrete basemat

AGING MECHANISM: Aggressive chemicals

APPLICABLE APPENDIX: Appendix C

BACKGROUND: The intended functions of the containment wall and the basemat is to provide support, protection, and shelter to safety related and non-safety related equipment inside the containment. Chemical attack is plausible only if the water chemistry of groundwater has become significantly more aggressive than was originally anticipated.

RECOMMENDED ATTRIBUTES: Since degradation of the below grade portion of the containment wall and basemat would be plausible if the water chemistry has become more aggressive, the proposed program will begin with investigative tasks followed by corrective action if necessary. The recommended approach is:

1. Restore the groundwater observation wells installed during initial plant construction for sampling purposes.

2. Secure samples of the groundwater for water chemistry testing. If the water chemistry meets the original design requirements (Cl ions < 500 ppm, SO_4 ions < 1500 ppm), no further action is necessary.

3. If the water chemistry tests conclude that the concrete components are being degraded by chemical agents, the levels of chemical concentration will need to be assessed to determine the appropriate corrective action.

BASIS: Because of the design and construction of the containment wall and basemat, and the knowledge of the water chemistry during the design of the plant, it is unlikely that chemical attack to concrete is a major concern.

STRUCTURE/SYSTEM NUMBER: 059

STRUCTURE NAME: Containment

STRUCTURAL COMPONENT DESCRIPTION: Exterior (surface) basemat liner

AGING MECHANISM: Corrosion of liner

APPLICABLE APPENDIX: Appendix L

BACKGROUND: The intended function of the basemat liner is to provide a leaktight barrier to minimize the release of radioactivity in the event of a design basis accident. The only possibility that the exterior basemat liner can be degraded by corrosion is from exposure to underground water which may leak through construction joints and cracks of the concrete basemat.

RECOMMENDED ATTRIBUTES: Since degradation of the exterior basemat liner would be plausible if the water chemistry has become more aggressive, the proposed program will begin with investigative tasks followed by corrective action if necessary. The recommended approach is:

1. Restore the groundwater observation wells installed during initial plant construction for sampling purposes.

2. Secure samples of the groundwater for water chemistry testing. If the water chemistry meets the original design requirements ($pH > 4.0$, Cl ions < 500 ppm, SO_4 ions < 1500 ppm), no further action is necessary.

3. If the water chemistry tests conclude that the concrete components are being degraded by chemical agents, the levels of chemical concentration will need to be assessed to determine the appropriate corrective action.

BASIS: Because of the design and construction of the exterior basemat liner, and the knowledge of the water chemistry during the design of the plant, it is unlikely that corrosion of the basemat liner is a major concern.

STRUCTURE/SYSTEM NUMBER: 059

STRUCTURE NAME: Containment

STRUCTURAL COMPONENT DESCRIPTION: Below grade portion of containment wall and containment basemat

AGING MECHANISM: Corrosion of Embedded Steel/Rebars

APPLICABLE APPENDIX: Appendix E

BACKGROUND: The intended function of the containment wall and the basemat is to provide support, protection, and shelter to safety related and non-safety related equipment inside the containment. Corrosion of below grade portion of containment wall and concrete basemat is plausible only if they are exposed to an aggressive environment on a continual basis.

RECOMMENDED ATTRIBUTES: Since degradation of the below grade portion of the containment wall and the basemat would have been plausible only if the water chemistry has become more corrosive, the proposed program will begin with investigative tasks followed by corrective action if necessary. The recommended approach is::

1. Restore the groundwater observation wells installed during initial plant construction for sampling purposes.

2. Secure samples of the groundwater for water chemistry testing. If the water chemistry meets the original design requirements ($pH > 4.0$, Cl ions < 500 ppm, SO_4 ions < 1500 ppm), no further action is necessary.

3. If the water chemistry tests conclude that the concrete components are being degraded by chemical agents, the levels of chemical concentration will need to be assessed to determine the appropriate corrective action.

BASIS: Because of the design and construction of the containment basemat and below grade portions of the containment walls, and the knowledge of the water chemistry during the design of the plant, it is unlikely that corrosion of embedded steel/rebar is a major concern.

ATTRIBUTES IN NEW PROGRAM (continued)

STRUCTURE/SYSTEM NUMBER: 059

STRUCTURE NAME: Containment

STRUCTURAL COMPONENT DESCRIPTION: Non-accessible structural steel

ARDM DESCRIPTION: Corrosion of Steel

APPLICABLE APPENDIX: Appendix K

BACKGROUND: Safety related structural steel in the Containment 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 Containment 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 Containment. The ARDI Program must consist of the following:

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

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 Containment will be capable of performing their intended functions under all design conditions required by the current licensing basis.

ATTRIBUTES IN NEW PROGRAM (continued)

STRUCTURE/SYSTEM NUMBER: 059

STRUCTURE NAME: Containment

STRUCTURAL COMPONENT DESCRIPTION: Non-accessible portions of the Containment Liner

ARDM DESCRIPTION: Corrosion of Liner

APPLICABLE APPENDIX: Appendix L

BACKGROUND: All exposed surfaces of the Containment liner are covered with an appropriate protective coating. Corrosion of the liner can only occur if these protective coatings have been degraded. Aging management of degraded coating conditions on the accessible portions of the carbon steel liner in the Containment is accomplished through the combination of existing plant programs. However, portions of the liner which are 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 portions of the containment liner. The ARDI Program must consist of the following:

1. Identification of non-accessible locations.

1. Selection of representative locations of the liner for inspection.

2. Development of an inspection sample size.

3. Use of appropriate inspection techniques.

4. Requirements for reporting of results and corrective actions if aging concerns are identified.

BASIS: The ARDI Program will ensure that degraded conditions due to corrosion of the liner are identified and corrected such that non-accessible portions of the Containment liner 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 containment because they are exposed to outside cold weather:

- Concrete dome — LR functions LR-S-1 through 5, and 7
- Concrete containment wall above the frost line (which is 2 feet below grade) — LR functions LR-S-1 through 7

where:

LR-S-1: Provides structural and/or functional support to safety-related equipment.

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

LR-S-3: Serves as a pressure boundary or fission product retention barrier to protect public health and safety in the event of any postulated DBEs.

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

LR-S-5: Provides structural and/or functional support to non-safety-related equipment whose failure could directly prevent satisfactory accomplishment of any of the required safety-related functions.

LR-S-6: Provides flood protection barrier (internal flooding event).

LR-S-7: Provides rated fire barriers to confine or retard a fire from spreading to or from adjacent areas of the plant.

Other concrete structural components are either below the frost line or are located inside the containment building. Therefore, freeze-thaw is not a potential aging mechanism for all other structural components.

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 containment dome and containment wall 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 Unit 1 containment conducted during 1992[8] documented no evidence of damage from freeze-thaw. Therefore, freeze-thaw is not a plausible aging mechanism for the containment dome and containment wall.

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 containment 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 Unit 1 containment structure performed in 1992 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 containment.

4.0 RECOMMENDATION

Freeze-thaw is not a plausible aging mechanism for any concrete structural components of the containment. 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. "Design and Control of Concrete Mixtures," Portland Cement Association, Thirteenth Edition.

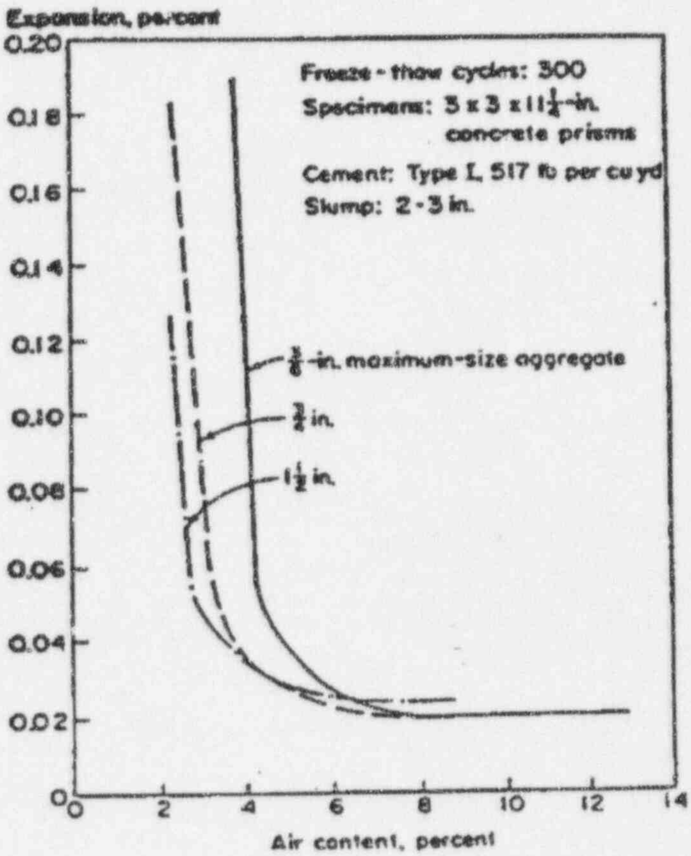
4. "Standard Specification for Concrete Aggregates," American Society of Testing and Materials, ASTM C33-82.

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 the Unit 1 Containment Structure - Calvert Cliffs Nuclear Power Plant," August 1992.



Effects of Air Content
on Durability, Compressive Strength, and
Required Water Content of Concrete
(Source: Reference 3)

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] Figures B-1 and B-2 show the impact on permeability due to water-to-cement ratio, aggregate size, and curing time.

2.0 EVALUATION

2.1 Conditions

The containment wall and the dome are exposed to the outside environment and are expected to have rainwater passing over the exterior surface. The containment dome is provided with a roof drainage system to prevent ponding. The containment basemat is in contact with underground water. A permanent dewatering system was installed during construction to maintain a stable groundwater table at El. 10'-0", which is the elevation at the top of the basemat.

2.2 Potential Aging Mechanism Determination

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

- Concrete dome — LR functions LR-S-1 through 5, and 7
- Concrete containment wall — LR functions LR-S-1 through 7
- Concrete basemat — LR functions LR-S-1 through 7

where:

LR-S-1: Provides structural and/or functional support to safety-related equipment.

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

LR-S-3: Serves as a pressure boundary or fission product retention barrier to protect public health and safety in the event of any postulated DBEs.

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

LR-S-5: Provides structural and/or functional support to non-safety-related equipment whose failure could directly prevent satisfactory accomplishment of any of the required safety-related functions.

LR-S-6: Provides flood protection barrier (internal flooding event).

LR-S-7: Provides rated fire barriers to confine or retard a fire from spreading to or from adjacent areas of the plant.

Leaching of calcium hydroxide is not a potential aging mechanism for other structural components of the containment because they are inside the containment building.

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.)*	*Maximum Aggregate Size*	*Use and Location*
C-2	4,000	2	± ½	1-½ in.	Containment Base Slab and Other Structural Concrete
C Grout	4,000	--	--	#4	Containment Joints
D-1	5,000	3	± ½	3/4 in.	Walls and Slabs less than 12" thick and Congested Rebar
D-2	5,000	2	± ½	1-½ in.	Containment Walls and Dome and Other Structural Concrete
D Grout	5,000	--	--	#4	Construction Joints
Dry Pack	4,000	0	--	#4	As Directed
Tremie Concrete	4,000	6	--	3/4 in.	As Directed

> *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 containment dome and containment wall are exposed to water passing over the surface. The containment basemat is located below the designed underground water table and may be subjected to some hydraulic pressure. However, as discussed in Section 2.4, concrete used for the containment 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] in 1992 observed only slight traces of leaching on the containment dome and wall and were judged to have no adverse impact on the integrity of these components. Therefore, leaching of calcium hydroxide is not a plausible aging mechanism for the containment dome, the containment wall, and the concrete basemat.

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 containment structural components, no management program is necessary.

3.0 CONCLUSION

The containment dome and containment wall surfaces in CCNPP are exposed to water. No ponding or hydraulic pressure will form to leach the calcium hydroxide. Although the containment basemat could be subjected to hydraulic pressure due to underground water, the concrete mix was designed for low permeability and high compressive strength which provide the best protection against leaching.

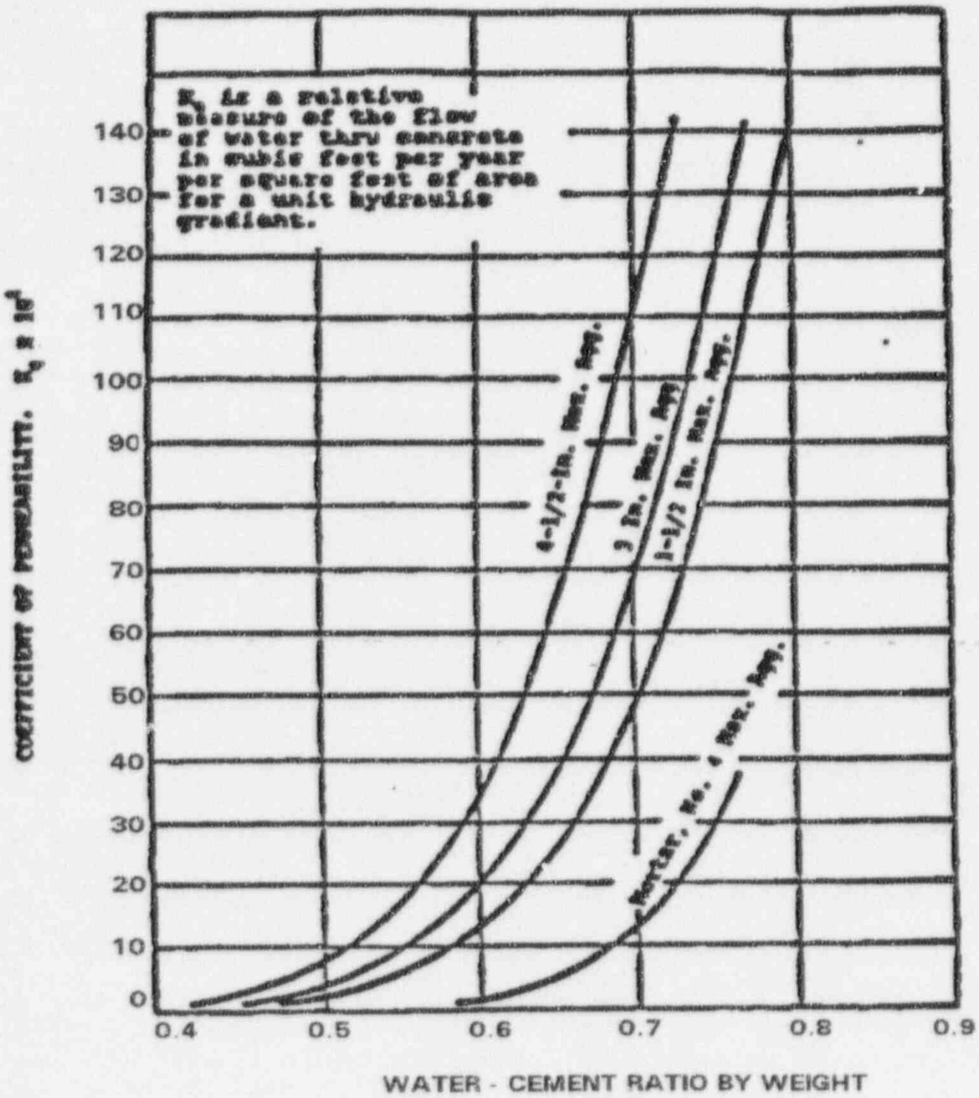
This conclusion is supported by a 1992 walkdown inspection[6] during which only minor traces of leaching marks were detected in various areas of the containment dome and wall. These indications were judged to have no impact on containment integrity. Therefore, leaching of calcium hydroxide is not a plausible aging mechanism for any concrete structural components of the containment.

4.0 RECOMMENDATION

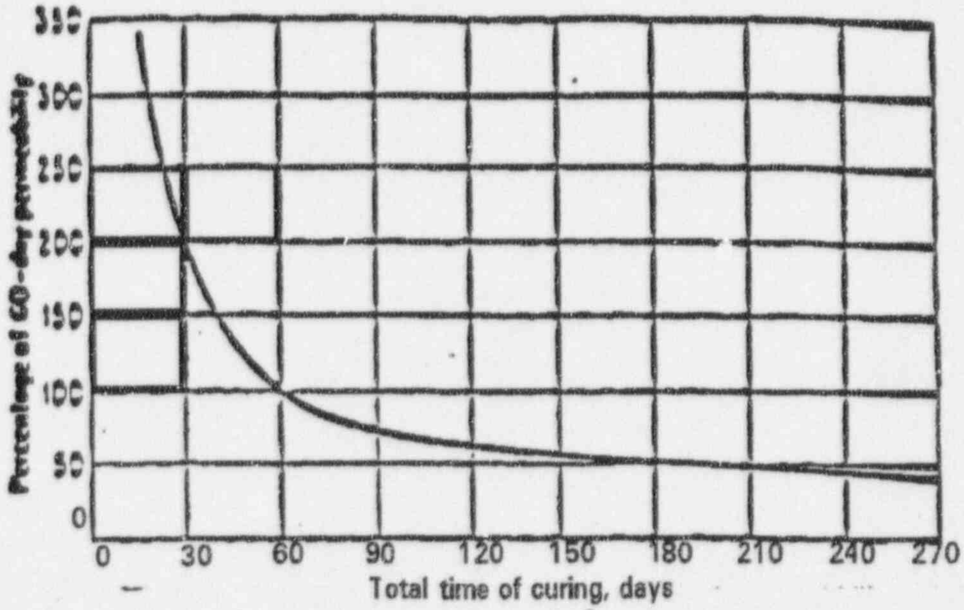
Leaching of calcium hydroxide is not a plausible aging mechanism for any concrete structural components of the containment. No further evaluation or recommendation is required.

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 Unit 1 Containment Structure - Calvert Cliffs Nuclear Power Plant," August 1992.
7. *Concrete Manual*, Eighth Edition, U.S. Department of the Interior, 1975.



Relationship Between Coefficient of
Permeability and Water-to-Cement Ratio
(Source: Reference 7)



Effects of Curing Period on Permeability
(Source: Reference 2)

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 aggressive chemicals stored inside the containment is borated water, and it is primarily in safety-related systems such as the primary coolant system, safety injection system, and chemical volume control system. Because of the safety significance of these systems, undetected leakages of borated water for an extended period of time cannot occur. Therefore, the containment's 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 containment dome and the above-grade portion of the containment wall are exposed to an environment containing chloride ions due to the containment's proximity to the Chesapeake Bay.

The outside, below-grade surface of the containment is exposed to soil and groundwater. The potential for degradation by aggressive chemicals depends on the quality of concrete, the chemical composition of soil and groundwater, and the level of groundwater in relation to below-grade portions of the structure.

2.2 **Potential Aging Mechanism Determination**

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

- Concrete dome — LR functions LR-S-1 through 5, and 7
- Concrete containment wall — LR functions LR-S-1 through 7
- Concrete basemat — LR functions LR-S-1 through 7

where:

LR-S-1: Provides structural and/or functional support to safety-related equipment.

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

LR-S-3: Serves as a pressure boundary or fission product retention barrier to protect public health and safety in the event of any postulated DBEs.

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

LR-S-5: Provides structural and/or functional support to non-safety-related equipment whose failure could directly prevent satisfactory accomplishment of any of the required safety-related functions.

LR-S-6: Provides flood protection barrier (internal flooding event).

LR-S-7: Provides rated fire barriers to confine or retard a fire from spreading to or from adjacent areas of the plant.

Other concrete structural components are located inside the containment building; therefore, attack by aggressive chemicals is not a potential aging mechanism.

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 containment was constructed with concrete that complies with CCNPP's design specification No. 6750-C-9[2] to assure low permeability. Another design consideration was the use of prestressed tendons to minimize crack development in the concrete. 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 containment dome and the containment wall above grade.

Because chemical contents of groundwater are not known, attack by aggressive chemicals to the below-grade portion of the concrete containment wall and the concrete basemat is 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 all concrete components inside containment, the containment dome, and the containment wall above grade, no management program is needed for these components.

3.0 CONCLUSION

Attack by aggressive chemicals is not plausible for the containment dome and the containment wall above grade because concrete with low permeability and prestressed tendons, which minimize concrete cracking, were used in construction of the containment dome and wall. Additionally, there is no heavy industry near the CCNPP site to release aggressive chemicals. Attack by aggressive chemicals is also not plausible for concrete components inside the containment because excessive leakages of borated water inside the containment cannot occur.

The below-grade portion of the containment wall and the concrete basemat are exposed to groundwater. Because the quality of groundwater is not known, degradation due to aggressive chemicals is plausible.

4.0 RECOMMENDATION

During initial plant construction, groundwater observation wells were installed to monitor the fluctuation of the groundwater table, and samples were taken for groundwater quality testing.[3] Although the wells are still in place, the monitoring activities have been discontinued. It is recommended that the groundwater water quality be tested using these wells. This data can be used to evaluate the effects of chemical attacks on the exterior surface of the containment structure below grade.

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. "Specification for Furnishing and Installation of Piezometers - Calvert Cliffs Nuclear Power Plant Unit No. 1 and 2," CCNPP's Design Specification No. 6750-C-23E, Revision 0, November 1973.

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 containment 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.

2.2 Potential Aging Mechanism 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 columns	LR functions LR-S-1, 5
· Concrete beams	LR functions LR-S-1, 5
· Ground slab and equipment pads	LR functions LR-S-1, 5
· Elevated floor slabs	LR functions LR-S-1, 5
· Concrete dome	LR functions LR-S-1 through 5, and 7
· Concrete containment wall	LR functions LR-S-1 through 7
· Concrete basemat	LR functions LR-S-1 through 7
· Primary shield walls	LR functions LR-S-1, 2, 4
· Secondary shield walls	LR functions LR-S-1, 2, 4
· Refueling pool	LR functions LR-S-1, 6
· Removable missile shield	LR function LR-S-4

where:

LR-S-1: Provides structural and/or functional support to safety-related equipment.

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

LR-S-3: Serves as a pressure boundary or fission product retention barrier to protect public health and safety in the event of any postulated DBEs.

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

LR-S-5: Provides structural and/or functional support to non-safety-related equipment whose failure could directly prevent satisfactory accomplishment of any of the required safety-related functions.

LR-S-6: Provides flood protection barrier (internal flooding event).

LR-S-7: Provides rated fire barriers to confine or retard a fire from spreading to or from adjacent areas of the plant.

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 containment structure 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 containment 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 2.4, the aggregates used in CCNPP's containment 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 1992 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 containment 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 containment.

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 containment 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 containment 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 containment 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 Unit 1 Containment Structure - Calvert Cliffs Nuclear Power Plant," August 1992.

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. Liner plate anchorages, either steel studs or structural shapes, used in the containment liner, the refueling canal, and the spent fuel pool are also considered as embedded steel. Reinforcing steel (rebar) and cast-in-place anchors are both treated as embedded steel in the evaluation of corrosion effects, because the environment and the technical basis for their corrosion induction are similar. The base plates under the columns or those used as part of attachments to the concrete surface are treated as structural steel, and the evaluation of their corrosion effects is addressed in Appendix K. Because the design and inspection requirements of liner plates differ significantly from those of structural steel, the corrosion effect on liner plates is discussed separately in Appendix L.

2.1 Conditions

The only significant inventory of aggressive chemicals stored inside the containment is borated water, and it is primarily in safety related systems such as the primary coolant system, safety injection system, and chemical volume control system. Because of the safety significance of these systems, undetected leakages of borated water for an extended period of time cannot occur. Therefore, the containment's interior surface and all internal structural components are not exposed to the risk of aggressive chemicals.

The primary area of concern is the exterior surface of the containment where moisture and oxygen may have access to the embedded steel and rebars. Chlorides in the atmosphere from the Chesapeake Bay could gain access to the steel. However, only the above-grade portion of the containment is exposed to this environment. The below-grade exterior surface could be exposed to groundwater on a more or less continuous basis. A dewatering system, installed during construction, would maintain a stable groundwater level at El.+10.0 ft, which is the same elevation as that of the basemat's top surface. However, there is no known program to determine if the dewatering system continues to perform its function after construction.

2.2 Potential aging mechanism Determination

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

- Concrete dome — LR functions LR-S-1 through 5, and 7
- Concrete containment wall — LR functions LR-S-1 through 7
- Concrete basemat — LR functions LR-S-1 through 7

where:

LR-S-1: Provides structural and/or functional support to safety-related equipment.

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

LR-S-3: Serves as a pressure boundary or fission product retention barrier to protect public health and safety in the event of any postulated DBEs.

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

LR-S-5: Provides structural and/or functional support to non-safety-related equipment whose failure could directly prevent satisfactory accomplishment of any of the required safety-related functions.

LR-S-6: Provides flood protection barrier (internal flooding event).

LR-S-7: Provides rated fire barriers to confine or retard a fire from spreading or from adjacent areas of the plant.

Other concrete structural components are located inside the containment building; therefore, corrosion of embedded steel/rebar is not a potential aging mechanism.

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 containment structure 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. Another design consideration was the use of prestressed tendons to minimize crack development in the concrete containment. In addition, CCNPP's UFSAR[4] specifies the rebar requirement to minimize concrete crack development as follows:

> *0.25 percent reinforcing shall be provided at the tension face for small members; 0.2 percent, for medium size members; 0.15 percent, for large members.*
>
> *A minimum of 0.2 percent bonded reinforcing steel is provided in two perpendicular directions on the exterior faces of the wall and dome for proper crack control.*

During initial plant construction, a cathodic protection system was installed at the CCNPP site to mitigate steel corrosion,[4] including the rebars in the containment wall and concrete basemat of the containment.

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 containment dome, the above-grade portion of containment wall, and all components inside containment. This conclusion is supported by a 1992 walkdown inspection report[5] that documented no indications of damage to concrete due to corrosion of embedded steel/rebar.

As discussed in Section 2.1, only the below-grade portion of the containment wall and the concrete basemat could be exposed to an aggressive environment on a continuous basis and could be susceptible to embedded steel/rebar corrosion. Because the chemical quality of the underground water is not known, corrosion of embedded steel/rebar is a plausible aging mechanism for the below-grade portion of the concrete containment wall and the concrete basemat.

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 inside the containment, the containment dome, and the above-grade portion of the containment wall. No further evaluation is required for these concrete structural components.

Because the quality of the groundwater is not known, corrosion of embedded steel/rebar is a plausible aging mechanism for the below-grade portion of the containment wall and the concrete basemat.

4.0 RECOMMENDATION

During initial plant construction, groundwater observation wells were installed to monitor the fluctuation of the groundwater table, and samples were taken for groundwater quality testing.[6] Although the wells are still in place, the monitoring activities have been discontinued. It is recommended that the groundwater water quality be tested using these wells. This data can be used to evaluate the effects of chemical attacks on the below-grade portion of the containment structure due to aggressive groundwater exposure.

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 Unit 1 Containment Structure - Calvert Cliffs Nuclear Power Plant," August 1992.

6. "Specification for Furnishing and Installation of Piezometers - Calvert Cliffs Nuclear Power Plant Unit No. 1 and 2," CCNPP's Design Specification No. 6750-C-23E, Revision 0, November 1973.

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. Its effect is reflected in terms of prestressing loss in tendons, which is discussed in Appendix N.

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.

2.2 Potential Aging Mechanism Determination

Creep is not a potential aging mechanism for any containment 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 containment structural components.

2.4 Design and Construction Considerations

At CCNPP, all reinforced concrete components, except the containment dome and the cylinder, were designed based on the working stress design method. The induced stresses are much lower than the ultimate strength of the concrete, which is specified as $f'_c = 5{,}000$ psi for all concrete structural components except for containment basemat. The containment basemat was constructed of concrete with $f'_c = 4{,}000$ psi[3]. However, the containment basemat is subject 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. "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.

APPENDIX G - SHRINKAGE

1.0 MECHANISM DESCRIPTION [1]

1.1 Concrete

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.

The other effect of concrete shrinkage is the prestress losses in tendons of the prestressed concrete Containment Structure, which is discussed in Appendix N.

1.2 Marinite XL Board

The Marinite XL board is fabricated from calcium silicate with inert fillers and reinforcing agents. Shrinkage of Marinite XL board material may occur due to exposure to elevated temperatures.

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.
The Marinite XL boards are located in the Containment Structure. The normal environmental conditions (outside the primary shield) are as follows [8] :

Temperature 120°F (average limit)
Humidity 70 % (max.)
Radiation 0.35E6 rads (40 years integrated gamma dose under normal operating

2.2 Potential Aging Mechanism Determination

Shrinkage is not a potential aging mechanism for any Containment Structure concrete structural components because shrinkage in concrete proceeds at a decreasing rate with age and is not expected to continue after 40 years.

Shrinkage is a potential aging mechanism for the following components based on environmental conditions inside the Containment Structure:

- Partitions and Ceilings (Marinite XL board) LR function LR-S-7

where:

LR-S-7: Provides rated fire barriers to confine or retard a fire from spreading to or from adjacent areas of the plant.

2.3 Impact on Intended Functions

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

Degradation due to shrinkage could result in the Marinite XL board being unable to perform its intended function of serving as a fire barrier.

2.4 Design and Construction Considerations

Concrete

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]. As stated in paragraph 12.1.2.1 of CCNPP design specification No. 6750-C-9,[4] a low slump of 2 inches was specified for all concrete used in the CCNPP Containment Structure.

The development of concrete cracking due to shrinkage can also be minimized by providing adequate reinforcing steel. For this purpose, CCNPP has specified the minimum rebar requirement in Section 5.1.2.5 of the UFSAR: [5]

> *0.25 percent reinforcing shall be provided at the tension face for small members; 0.2 percent, for medium size members; and 0.15 percent, for large members.*
>
> *A minimum of 0.2 percent bonded reinforcing steel is provided in two perpendicular directions on the exterior faces of the wall and dome for proper crack control.*

Since low slump concrete is used at CCNPP to minimize concrete cracks from shrinkage and additional rebars are used to mitigate crack propagation, shrinkage of any concrete component of the Containment Structure is minimal.

Marinite XL Board

The Marinite XL board is used as a fire separation barrier on cable trays within the Containment Structure. The board is designed to meet Appendix R criteria. The Marinite XL board is used only on cable trays outside the primary shield in the Containment Structure[7]. The Marinite XL board is fabricated from calcium silicate with inert fillers and reinforcing agents. Shrinkage of Marinite XL board material begins to occur at temperatures above 300°F[6]. The board is required to maintain its integrity during normal environmental conditions within the Containment Structure in order to provide the barrier function.

2.5 Plausibility Determination

Based on the discussion in Sections 2.1 and 2.4, no architectural components of the Containment Structure are subject to conditions higher than their design threshold. Also, shrinkage is not a potential aging mechanism for structural components of the Containment Structure. Therefore, shrinkage is not a plausible aging mechanism for any structural or architectural components of the CCNPP Containment Structure.

2.6 Existing Programs

There are no existing programs at CCNPP designed to identify damages to components of the Containment Structure due to shrinkage. However, since this is not a plausible aging mechanism that could degrade these components, no program is necessary.

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.

All Marinite XL board in the Containment Structure are exposed to the normal environmental conditions. As indicated in Section 2.0 above, the temperature level inside the Containment Structure are predicted to be below the degradation threshold for the Marinite XL board. Therefore, shrinkage is not a plausible age-related degradation mechanism for the Marinite XL board in the Containment Structure.

4.0 RECOMMENDATION

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

Shrinkage of Marinite XL board is not a plausible aging mechanism for the Containment Structure. 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. "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. "Calvert Cliffs Nuclear Power Plant, Units 1 and 2, Updated Final Safety Analysis Report (UFSAR)," Baltimore Gas and Electric Co.

6. Manville Products Catalog IND-336 10-80 (page 3).

7. Drawing 62-150-E, Revision 6, Appendix R Separation Requirements, Containment El. 5'-0"

8. "EQ Design Manual - Calvert Cliffs Nuclear Power Plant, Unit No. 1 and 2," Baltimore Gas and Electric Co.

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

Neither the containment building nor its structural components are exposed to continuously flowing water.

2.2 Potential Aging Mechanism Determination

Attack by abrasion and cavitation is not a potential aging mechanism for the structural components of containment because the CCNPP containment 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 containment is not exposed to continuously flowing water. Therefore, abrasion and cavitation are not a potential aging mechanism for any structural components of the containment.

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 Mechanism Determination

There is no masonry block wall in the containment system. Therefore, this aging mechanism does not apply to the containment.

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 containment.

4.0 RECOMMENDATION

Not applicable.

5.0 REFERENCES

Not applicable.

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 misali‚ ,ment 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 containment at CCNPP is approximately 70 feet below the average ground elevation. The basemat is situated on Miocene soil, which is exceptionally dense and will support heavy foundation loads. The major soil types are sandy silts, silty sands, and slightly clayed sands. The ultimate bearing capacity of the foundation strata is in excess of 80,000 psf, and the allowable bearing capacity is 15,000 psf. However, the design bearing pressure of the basemat is 8,000 psf. The soil bearing pressure was about the same as the overburden removed due to excavation.

2.2 Potential Aging Mechanism Determination

Settlement is a potential aging mechanism for all structural components in the containment structure. Since the concrete basemat is the only structural component directly supported by the soil media, and also for convenience of discussion, only the concrete basemat is identified as the structural component subject to the aging mechanism due to settlement.

- Concrete basemat LR-S-1 through 7

where:

LR-S-1: Provides structural and/or functional support to safety-related equipment.

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

LR-S-3: Serves as a pressure boundary or fission product retention barrier to protect public health and safety in the event of any postulated DBEs.

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

LR-S-5: Provides structural and/or functional support to non-safety-related equipment whose failure could directly prevent satisfactory accomplishment of any of the required safety-related functions.

LR-S-6: Provides flood protection barrier (internal flooding event).

LR-S-7: Provides rated fire barriers to confine or retard a fire from spreading to or from adjacent areas of the plant.

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 component unmitigated for an extended period of time, this aging mechanism could affect intended functions LR-S-1, 3, and 5 of the concrete basemat.

2.4 Design and Construction Considerations

In addition to soil bearing capacity, settlement of the containment basemat was also investigated in the design of the containment. A maximum post-construction settlement of 1/2 inch was predicted in the original containment design[2]. Since the concrete basemat is a rigid foundation and is situated on a exceptionally dense soil, the containment structure tends to uniformly settle as a rigid body. Most of the predicted 1/2 inch settlement is in terms of uniform settlement, which has no adverse effect on the structural components of the containment. A small fraction of the 1/2 inch settlement will be in terms of differential settlement. It is so small that the effect on the structural component is negligible.

The excavation for the containment building was below 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 containment is exceptionally dense, and the design bearing pressure is about the same as that of the removed overburden and is much smaller than the allowable bearing capacity. As discussed in Section 2.4, the predicted 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 containment structural components, no management program is necessary.

3.0 CONCLUSION

CCNPP's containment is situated on Miocene soil, which is exceptionally dense and will support heavy foundation loads. Additionally, the structural load on the containment basemat is about the same as the removed overburden weight. Therefore, the soil bearing stress is well below its ultimate bearing capacity, and the long-term settlement is predicted to be only 1/2 inch.[2] In addition, the settlement rate declined after completion of construction, and the groundwater table is maintained by the dewatering system. 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 containment.

4.0 RECOMMENDATION

Settlement is not a plausible aging mechanism for the concrete basemat of the containment 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. "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 an inadequate drainage system. In containment, structural steel components vulnerable to corrosion are the steel members such as base plates and brackets that are not readily accessible for visual inspection and that can form pockets to harbor liquids.

2.2 Potential Aging Mechanism Determination

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

·	Steel columns	LR functions LR-S-1, 5
·	Steel beams	LR functions LR-S-1, 5
·	Base plates	LR functions LR-S-1, 5
·	Floor framing	LR functions LR-S-1, 5
·	Steel bracing	LR functions LR-S-1, 5
·	Platform hangers	LR functions LR-S-1, 5
·	Decking	LR functions LR-S-1, 5
·	Floor grating	LR functions LR-S-1, 5
·	Checkered plates	LR functions LR-S-1, 5
·	Cast-in-place anchors	LR functions LR-S-1, 5
·	Post-installed anchors	LR function LR-S-1
·	Crane girder	LR function LR-S-5
·	Lubrite plates	LR function LR-S-1, 5

where:

LR-S-1: Provides structural and/or functional support to safety-related equipment.

LR-S-5: Provides structural and/or functional support to non-safety-related equipment whose failure could directly prevent satisfactory accomplishment of any of the required safety-related functions.

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 all structural steel components of the containment, its effects were considered in the original design. As a result, all exposed structural steel surfaces in the containment except grating, checkered plates, and metal decking, which are galvanized steel, were shop-painted or field-painted during the

construction phase in accordance with CCNPP's design specifications No. 6750-C-31[2] and No. 6750-A-24[3].

Maintenance of protective coatings on CCNPP's equipment and structures follows the requirements specified in Calvert Cliffs Procedure MN-3-100[4]. 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. This procedure requires inspection of all painted plant areas inside containment. Application of coatings at CCNPP follows standard procedures specified in the applicable design standard[5]. This standard specifies material based on normal and post-accident environmental conditions and addresses the refurbishment of existing coated surfaces and the need for new coating and recoating.

Galvanic material on steel components is one of the protective coating systems. Maintenance of galvanic coatings is covered under the same maintenance program as paint and other protective coatings.

The post-installed anchors used for the horizontal tie rod anchorages of reactor coolant pump restraints are Wej-It™ concrete anchors. Wej-It anchor bolts are made of cold-rolled, high strength steel having a rust-resistant zinc coating with a final clear acetate coating that exceeds U. S. government specifications and the ASTM B-117 salt spray test.[6]

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

A coating program, MN-3-100[4] is implemented at CCNPP for the exposed surfaces of structural steel components inside the containment. Conditions adverse to quality (such as degraded paint or corrosion) are reported in an Issue Report under QL-2-100[7]. The coatings program 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 are 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

All exposed structural steel surfaces in the containment are covered by a protective coating. All these protective coatings are maintained per Calvert Cliffs Procedure MN-3-100[4]. This procedure requires an inspection at the beginning of each major outage of all coated plant

areas inside containment. In areas accessible for coating inspection, damage to coating can be detected visually well in advance of degradation due to corrosion of the structural steel.

Aging management of degraded coating conditions on accessible structural steel in the Containment Structure is accomplished through the combination of existing plant programs. However, structural steel components not readily accessible require additional aging management.

4.0 RECOMMENDATION

Coatings on structural steel in accessible areas are 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. "Specification for Furnishing, Detailing, Painting, and Delivering Containment and Auxiliary Building Structural Steel," CCNPP's Design Specification No. 6750-C-31, Revision 2, May 1970.

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

4. "Protective Coating and Painting Program," CCNPP's Procedure MN-3-100.

5. "Coating Application Performance Standard," TRD-A-1000, Calvert Cliffs Nuclear Power Plant, Unit No. 1 and 2, Revision 8, August 1991.

6. "Specification and Load Data for Wej-Its," Vendor's product catalog by Wej-It Corp., Brownfield, Colorado.

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

The containment/basemat liners and the refueling pool liner at CCNPP are ASTM A36 carbon steel and SA-240 Type 304 stainless steel, respectively.[3,4] These liners were constructed from a series of individual steel plates welded together. Both the plate material and the welds are subject to the same potential degradation mechanisms. The significance of potential degradation of the liners is considered to apply equally to the plate material and the welds.[1]

Neither the carbon steel liner nor the stainless steel liner has dissimilar metals; therefore, they are not subject to galvanic corrosion.

2.1 Conditions

2.1.1 Containment Wall and Dome Liner

The containment wall and the containment dome are 3'-9" and 3'-3" thick, respectively, and are subject to compressive stress due to dead weight and prestress load under normal plant operating conditions. This configuration minimizes cracks in the concrete that allow penetration of moisture, oxygen, and chlorides, which cause corrosion degradation. Therefore, the containment liner from the concrete side is not exposed to aggressive chemicals from the outside environment, such as acid rain, salt-containing atmospheres, and groundwater. The interior surfaces of the containment wall and dome liners are exposed to the containment internal environment, and corrosion of these surfaces could occur in the presence of moisture and oxygen as a result of electrochemical reactions unless the existing coating is maintained by an effective coating management program.

2.1.2 Basemat Liner

The top surface of the basemat liner is protected from equipment and corrosive agents by an 18-inch-thick concrete cover . The bottom surface of the basemat liner is susceptible to potential contact with underground water. The primary paths of ingress for these fluids are the construction joints in the concrete basemat underneath the liner.

2.1.3 Refueling Pool Liner

SA-240 Type 304 stainless steel used in the refueling pool is resistant to electrochemical corrosion in the refueling/spent fuel pool environments. The corrosion rate of this steel ranges from 0.05 mil in 100 years (virtually no corrosion) to less than 0.01 mil per year in a borated fuel pool water environment.[5] Therefore, the electrochemical corrosion is negligible and is not a potential aging mechanism for the stainless steel liner.

The stainless steel liner in the refueling pool is not a load-bearing structural component. The induced strains in the liner, resulting from conformation to deformation of the concrete wall of the pool, are negligible under normal plant operating conditions. The liner is not exposed

to corrosive environmental conditions under normal operating conditions. Therefore, the conditions for SCC to occur do not exist for the stainless steel liner in the refueling pool.

The heat-affected zones of welds at the stainless steel liner are potential sites for "sensitization." Sensitized Type 304 stainless steel is susceptible to IGSCC in boric acid solution.[1] Degradation of the stainless steel liner due to IGSCC in the pool is typically evidenced by leakage and detected by observation of an increased amount of pool water leakage.

2.2 Potential Aging Mechanism Determination

Corrosion is a potential aging mechanism for the following structural components of containment because conditions exist that are conducive to corrosion of liner plates, as discussed in Section 1.0:

- Containment liner (internal surface) — LR function LR-S-3
- Basemat liner (external surface) — LR function LR-S-3
- Refueling pool (stainless steel liner) — LR function LR-S-3

where:

LR-S-3: Serves as a pressure boundary (including fluid retaining boundary) or fission product retention barrier to protect public health and safety in the event of any postulated DBEs.

2.3 Impact on Intended Functions

If the effects of corrosion of liner 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 the intended function of components listed in Section 2.2.

2.4 Design and Construction Considerations

The containment liner and the basemat liner were not designed as load bearing structural components. Their primary function is to maintain a leaktight barrier to minimize the release of radioactive nuclides to the atmosphere in the event of a postulated DBE inside the containment. They were designed to conform to the deformation of the containment concrete. Under normal operating conditions, the strain imposed on the liner plate is much less than the yield strain of the liner plate. For corrosion protection, the inside face of the containment liner was covered with a protective coating during the construction stage.

The welds for each section of the basemat liner plate were covered with test channels, and a test pipe was provided for each continuous segment of the leak chase channels. The tops of

the pipes are 1 to 1.5 inches above the top of the concrete base slab and are sealed with caps. These pipes were initially used to test the leaktightness of the basemat liner, and they can also be used to detect the leakage of the basemat liner.

The refueling pool liner was not designed to carry any design loads and was designed as a leaktight barrier.[4] Under normal operating conditions, the imposed strain on the liner due to conforming to concrete deformation is very small and is negligible because the stresses in refueling pool concrete components are minimal.

2.5 Plausibility Determination

Based on the discussion in Sections 2.1.1 and 2.3, corrosion is a plausible aging mechanism for the liner of the containment dome and wall.

The inside surface of the basemat liner is covered with an 18-inch-thick concrete slab, and the containment atmosphere is not corrosive. Therefore, corrosion of this surface of the basemat liner is not a plausible aging mechanism. Although the bottom surface of the basemat liner is covered with at least 7 feet of concrete mat, it does have the potential to be exposed to underground water. Since the quality of underground water is unknown, corrosion of the bottom surface of the basemat liner is considered a plausible aging mechanism until it is shown that the groundwater will not degrade the basemat concrete or embedded rebar.

Based on the discussion in Section 2.1.3, corrosion in sensitized zones of the refueling pool liner due to IGSCC is a plausible aging mechanism.

2.6 Existing Programs

The inside surface of the containment liner is covered by a protective coating. Accessible portions of this liner are currently maintained under CCNPP Procedure MN-3-100[6] and QL-2-100[7]. For inaccessible portions, an age-related degradation inspection is needed to manage the effects of corrosion.

Corrosion of the refueling pool liner is managed by a System Summary and Improvement Plan (PEG-19[8]) performance indicator which measures and trends structural leakage from the refueling pool any time the pool is filled.

There are no existing programs at CCNPP that are designed specifically to identify corrosion of the exterior surfaces of the basemat liner.

3.0 CONCLUSION

The exposed surface of the containment liner is susceptible to degradation due to electrochemical corrosion. Therefore, corrosion of the containment liner is a plausible aging mechanism. The exposed surface of the liner is covered by a protective coating that is currently maintained under CCNPP procedure MN-3-100. An age-related degradation inspection will be used to address corrosion of areas of the containment liner that are not normally accessible.

The possibility of corrosion also exists for the bottom surface of the basemat liner due to the potential exposure to underground water leaking through the construction joints/cracks of the concrete basemat underneath the liner. Therefore, corrosion is a plausible aging mechanism for the basemat liner but this aging can be managed by sampling the quality of the ground water and demonstrating that the groundwater will not cause deterioration of the basemat liner should they come into contact.

For the stainless steel liner of the refueling pool, degradation due to IGSCC of heat-affected zones of welds could cause the liner to leak. Therefore, IGSCC of the stainless steel liner is a plausible aging mechanism for the refueling pool liner. Because the liner only serves as a fluid retaining boundary and does not provide a structural integrity function, measuring and trending leakage from the refueling pool (when filled) is an effective aging management technique.

4.0 RECOMMENDATION

Based on the above discussion, the following recommendations are made:

- During initial plant construction, groundwater observation wells were installed to monitor the fluctuation of the groundwater table, and samples were taken for groundwater quality testing. Although the wells are still in place, the monitoring activities have been discontinued. It is recommended that the groundwater water quality be tested using these wells. This data can be used to evaluate the effects of chemical attacks on the below-grade portion of the containment structure due to aggressive groundwater exposure.

- A age-related degradation inspection should be used to verify the condition of the containment liner in areas that are not readily accessible.

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.

3. "Specification for Furnishing, Fabricating, Delivering and Erection of the Containment Structure Liner Plate and Accessory Steel," CCNPP's Design Specification No. 6750-C-16, Revision 8, May 1971.

4. "Specification for Stainless Steel Liner Plate and Spent Fuel Pool Bulkhead Gate," CCNPP's Design Specification No. 6750-C-28, Revision 5, June 1973.

5. "Safety Evaluation Report Related to the Operation of Comanche Peak Steam Electric Station, Units 1 and 2," NUREG-0797, July 1981.

6. "Painting and Other Protective Coatings", CCNPP's Procedure MN-3-100, Revision 2.

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

8 "System Summary and Improvement Plans", Plant Engineering Section Guideline PEG-19, Revision 0

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

The potential for corrosion of tendons was considered in the initial design of the prestressed tendon system of CCNPP's containment structure. Therefore, a petroleum-based grease product VISCONORUST 2090P™ was used in the tendon sheathing to protect the tendon.[2]

Based on 1-, 3-, 5-, and 10-year tendon surveillances of Unit 1 containment, a few minor rust spots on the tendon bearing plates and a pitting spot on one prestressing wire were noted. The rust spots on the tendon bearing plates were evaluated and determined to have no effect on the plates' performance. Grease samples taken during each surveillance were laboratory tested, and all met the acceptance criteria specified in the surveillance procedure. The wire with pitting was removed for laboratory testing which showed that the wire met the original specification requirements.

2.2 **Potential Aging Mechanism Determination**

Corrosion is a potential aging mechanism for the post-tensioning system, including the ¼ inch diameter prestressing wires, the anchor heads, the shims, and the bearing plates, because they could be exposed to corrosive environment as described in Section 1.0.

- Post-tensioning system LR-S-1 through 4

where:

LR-S-1: Provides structural and/or functional support to safety-related equipment.

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

LR-S-3: Serves as a pressure boundary or fission product retention barrier to protect public health and safety in the event of any postulated DBEs.

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

2.3 **Impact on Intended Functions**

If the effects of corrosion are allowed to degrade the above structural component unmitigated for an extended period of time, this aging mechanism could affect intended function LR-S-3 of the post-tensioning system. Intended functions LR-S-1, 2, and 4 will not be affected because these functions will be served by the containment wall.

2.4 **Design and Construction Considerations**

The Calvert Cliffs post-tensioning system is a BBRV system furnished by Prescon Corporation.[2] There are a total of 875 tendons including 204 dome tendons, 467 hoop tendons, and 204 vertical tendons.[3] Each tendon consists of 90 ¼-inch-diameter wires (ASTM A-421-65T), 2 anchor heads, and 2 sets of shims. The tendon sheathing system consists of spirally wound carbon steel tubing connecting to a trumplate (bearing plate and trumpet) at each end. The bearing plates were fabricated from steel plate conforming with ASTM A-6-66 and the trumpets from AISI C1010-C1020 material. VISCONORUST 2090P™ is used in the tendon sheathing to protect the tendon from corrosion.[2]

The tendon system is currently monitored by a surveillance program in accordance with CCNPP's procedures STP-M-663-1/2[4] for meeting the inspection requirements of Regulatory Guide 1.35.

2.5 **Plausibility Determination**

Based on the discussion in Sections 2.1 through 2.4, corrosion is a plausible aging mechanism for the post-tensioning system that includes the ¼-inch-diameter prestressing wires, anchor heads, shims, and bearing plates.

2.6 **Existing Programs**

The tendon system in CCNPP containment is tested and monitored by tendon surveillance program STP-M-663-1/2.[4] The surveillance test was performed in 1, 3, and 5 years after the structural integrity test, and every 5 years thereafter.

3.0 **CONCLUSION**

Corrosion of tendons was considered in the initial design of the prestressed tendon system and is periodically monitored as part of the tendon surveillance program. Corrosion inspection of the tendon system is performed in accordance with CCNPP's procedures STP-M-663-1/2 for meeting the inspection requirements of Regulatory Guide 1.35.

4.0 **RECOMMENDATION**

The surveillance program should be continued throughout the license renewal period to monitor the condition and performance of the tendon system

5.0 **REFERENCES**

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

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

3. "Prestressing Report - Containment Structure, Calvert Cliffs Nuclear Power Plant, Unit 2," Baltimore Gas and Electric Company.

4. "Containment Tendon Surveillance," STP-M-663-1/2, Calvert Cliffs Nuclear Power Plant, Units 1 and 2, Baltimore Gas and Electric Co.

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

With the exception of corrosion-induced wire cross-sectional loss, predictions of prestress losses were calculated during design to ensure the containment can maintain its pressure capacity under postulated DBE inside the containment.

2.0 EVALUATION

2.1 Conditions

The conditions and performance of the Calvert Cliffs tendon system are monitored by lift-off tests in accordance with CCNPP's surveillance test procedures STP-M-663-1/2.[2] The procedures were prepared to meet requirements in Regulatory Guide 1.35.

The prestressed tendons in CCNPP Unit 1 containment have been tested in 1-, 3-, 5-, and 10-year surveillance following the testing procedure and acceptance criteria specified in Test Procedure STP-M-663-1.[2] Based on the test and investigation results, no evidence of prestress loss exceeding the technical specification requirements has been observed.

2.2 Potential Aging Mechanism Determination

Prestress losses are a potential aging mechanism for the post-tensioning system because stress losses with age are a common phenomenon in a typical prestressed tendon.

- Post-tensioning system LR-S-1 through 4

where:

LR-S-1: Provides structural and/or functional support to safety-related equipment.

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

LR-S-3: Serves as a pressure boundary or fission product retention barrier to protect public health and safety in the event of any postulated DBEs.

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

2.3 Impact on Intended Functions

If prestress losses are allowed to degrade the above structural component unmitigated for an extended period of time, this aging mechanism could affect intended function LR-S-3 of the post-tensioning system. Intended functions LR-S-1, 2, and 4 will not be affected because these functions will be served by the containment wall.

2.4 Design and Construction Considerations

The Calvert Cliffs post-tensioning system is a BBRV system furnished by Prescon Corporation. There are a total of 875 tendons including 204 dome tendons, 467 hoop tendons, and 204 vertical tendons.[3] Each tendon consists of 90 ¼-inch-diameter wires (ASTM A-421-65T), 2 anchor heads, and 2 sets of shims. The tendon sheathing system consists of spirally wound carbon steel tubing connecting to a trumplate (bearing plate and trumpet) at each end. The bearing plates were fabricated from steel plate conforming with ASTM A-6-66 and the trumpets from AISI C1010-C1020 material. VISCONORUST 2090P™ is used in the tendon sheathing to protect the tendon from corrosion.[4]

In accordance with Regulatory Guide 1.35, lift-off tests of tendons are performed periodically. Prestress force measurements from the lift-off test are compared with the time-dependent prediction of prestress losses which are calculated and considered in the design of prestressed concrete containments. However, the existing prediction of prestress losses considered a service life of 40 years.[5] Therefore, the prediction must be updated to reflect the proposed term of license renewal and to provide the basis for lift-off test comparisons during the license renewal period.

2.5 Plausibility Determination

Based on the discussion in Sections 2.1 through 2.4, prestress loss is a plausible aging mechanism for the prestressing wires of the post-tensioning system.

2.6 Existing Programs

The tendon system in CCNPP containment is tested and monitored by tendon surveillance program STP-M-663-1/2.[2] The surveillance test was performed in 1, 3, and 5 years after the structural integrity test, and every 5 years thereafter.

3.0 CONCLUSION

Prestress losses in tendons were considered in the initial design of the prestress tendon system and are periodically monitored as part of the tendon surveillance program during the current license period. Prestressing force in tendons is monitored by CCNPP's procedures STP-M-663-1/2[2] for meeting the lift-off force requirements of Regulatory Guide 1.35. The current prestress losses were predicted for 40-year service life. The tendon liftoff forces measured in each of the prior surveillance tests all met the requirements specified in Section 3.6 of the CCNPP Technical Specification.[5]

4.0 RECOMMENDATION

The current prestress losses that were specifically predicted for a service life of 40 years should be updated to reflect the anticipated prestress losses during the license renewal period. Retensioning of tendons, if determined to be necessary based on tendon surveillance data and the updated prestress losses, should be performed.

5.0 REFERENCES

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

2. "Containment Tendon Surveillance," STP-M-663-1/2, Calvert Cliffs Nuclear Power Plant, Units 1 and 2, Baltimore Gas and Electric Co.

3. "Prestressing Report - Containment Structure, Calvert Cliffs Nuclear Power Plant, Unit 2," Baltimore Gas and Electric Co.

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

5. "Calvert Cliffs Nuclear Power Plant, Units 1 and 2, Technical Specification," Baltimore Gas and Electric Co.

APPENDIX O - WEATHERING

1.0 MECHANISM DESCRIPTION

1.1 Concrete

Components and structures that are located in an environment that is exposed to ambient conditions are susceptible to degradation due to weathering. 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, an increase in hardness, and shrinkage.

1.2 Marinite XL Board

The Marinite XL board is fabricated from calcium silicate with inert fillers and reinforcing agents. Weathering of Marinite XL board material may occur due to exposure to temperature and humidity changes.

2.0 EVALUATION

2.1 Conditions

According to Specification ASTM C33-82, "Standard Specification for Concrete Aggregates," [1] 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.

The Marinite XL boards are located in the Containment Structure. The normal environmental conditions (outside the primary shield) are as follows[3]:

Temperature 120°F (average limit)
Humidity 70 % (max.)
Radiation 0.35E6 rads (40 years integrated gamma dose under normal operating conditions)

2.2 Potential Aging Mechanism Determination

Degradation by weathering is a potential aging mechanism for the following Containment Structure architectural components because they are exposed to temperature and humidity fluctuations similar to outdoor conditions:

- protective coating (exterior applications) LR functions LR-S-1, 2, 3, 4, 5, 7
- partitions and ceilings (Marinite XL board) LR function LR-S- 7

where:

LR-S-1: Provides structural and/or functional support to safety-related equipment.

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

LR-S-3: Serves as a pressure boundary or fission product retention barrier to protect public health and safety in the event of any postulated DBEs.

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

LR-S-5: Provides structural and/or functional support to non-safety-related equipment whose failure could directly prevent satisfactory accomplishment of any of the required safety-related functions.

LR-S-7: Provides rated fire barriers to confine or retard a fire from spreading to or from adjacent areas of the plant.

2.3 Impact on Intended Functions

Weathering of the inside-Containment Structure protective coatings could result in a loss of their functions protecting structural components from any corrosive environment inside the Containment Structure. However, coatings inside the Containment Structure are only safety-related because of the potential impact of coating failure on the operation of the emergency sump in the event of a design basis accident inside the Containment Structure. Therefore, degradation due to weathering effects will not prevent these coatings from performing their safety-related functions.

Weathering could impact the intended function of the Marinite XL board if the aging mechanism caused degradation of the material such that it was not capable of performing its' fire barrier function.

2.4 Design and Construction Considerations

Since weathering has no impact on the intended functions of protective coating, no further discussion of CCNPP's design and construction considerations is necessary in regard to protective coating.
The Marinite XL board is used as a fire separation barrier on cable trays within the Containment Structure. The board is designed to meet Appendix R criteria and is required to maintain its integrity during normal environmental conditions within the Containment Structure in order to provide the barrier function. The Marinite XL board is used only on cable trays outside the primary shield in the Containment Structure [5]. The Marinite XL board is fabricated from calcium silicate with inert fillers and reinforcing agents.

As noted in Section 2.1 above, the Marinite XL boards are exposed to a normal average temperature of 120°F and to a normal maximum relative humidity of 70%. The Marinite XL board is not affected by moisture or high humidity in accordance with the manufacturer's literature [4, 6]. The manufacturer has indicated that Marinite XL board has been used in moist-cure ovens with normal temperatures ranging between 200°F and 250°F

and with steam injection to maintain a wet atmosphere. After 10 years of continuous operation, no harmful effects were identified on the Marinite[6].

Since the environment in the Containment Structure is basically ambient conditions for many living and working environments, and are much less severe than a moist-cure oven, no deterioration of the Marinite would be plausible under the conditions occurring in the Containment Structure.

2.5 Plausibility Determination

Based on the discussion in Sections 2.1 and 2.4, weathering is not a plausible aging mechanism for any architectural components in the CCNPP Containment Structure.

2.6 Existing Programs

Since weathering is not a plausible aging mechanism, no program is needed to control this degradation mechanism to maintain the intended functions of the Containment Structure architectural components.

3.0 CONCLUSION

Based on this evaluation, weathering is not a plausible aging mechanism because no intended functions of the Containment Structure architectural components are affected by this aging mechanism.

4.0 RECOMMENDATION

Weathering is not a plausible aging mechanism for the Containment Structure and its architectural components. No further action is required.

5.0 REFERENCES

1. "Standard Specification for Concrete Aggregates," American Society of Testing and Materials, ASTM C33-82.
2. Component Level Scoping Results for the Primary Containment Structure (Sys. 059).
3. "EQ Design Manual - Calvert Cliffs Nuclear Power Plant, Unit No. 1 and 2," Baltimore Gas and Electric Co.
4. Manville Products Catalog IND-336 10-80 (page 3).
5. BGE Drawing 62-150-E, Rev. 6, Appendx R Separation Rqmts, Ctmt. El. 5'-0".
6. Manville Products Catalog R-34 3-87 (pages 2 and 5).

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

Section 5.2.1 of Baltimore Gas and Electric Company's EQ Manual[4] states:

> *Ambient air bulk temperatures inside containment are limited to an average of 120 °F by plant technical specification section 3/4.6.1.5. A 120 °F normal service air ambient temperature is used for evaluating component normal service aging unless otherwise specified. Note that this value <u>does not</u> include process heating or energization temperature rise effect. ... specifies that the maximum normal ambient temperature for the pressurizer house is 140 °F. The primary loop RTDs which are located in the containment pump bays, experience higher temperatures, assumed to be 160 °F based on unverified temperature monitoring . . . .*

In addition, Section 5.1.4.4 of BG&E's UFSAR[5] states:

> *The main high-temperature piping consists of two penetrations for feedwater, two penetrations for main steam, two penetrations for steam generator blowdown, one for the reactor coolant letdown line and one for the reactor coolant sampling line. These have a maximum operating temperature range between 435 °F and 537 °F. Thermal insulation is provided on the outside diameter of each line and separate coolant circulation, with instrumentation suitable for flow monitoring, is provided in the air gap between the insulation and the penetration liner sleeve. The combination of insulation and coolant circulation is designed to restrict the maximum temperature rise in the concrete to 150 °F.*

As stated above, the inside surface of the primary shield wall is subject to sustained internal heat buildup, and the concrete around the eight pipe penetrations (two main steam lines, two feedwater lines, two steam generator blowdown lines, one reactor coolant letdown line, and one reactor coolant sample line) is also subject to extended local heatup.

2.2 Potential Aging Mechanism Determination

Elevated temperature is a potential aging mechanism for the following concrete structural components of containment because they could be exposed to temperatures higher than the degradation threshold of elevated temperature for concrete (150 °F):

- Concrete containment wall — LR functions LR-S-1 through 7
- Primary shield wall — LR functions LR-S-1, 2, 4

where:

LR-S-1: Provides structural and/or functional support to safety-related equipment.

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

LR-S-3 : Serves as a pressure boundary or fission product retention barrier to protect public health and safety in the event of any postulated DBEs.

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

LR-S-5 : Provides structural and/or functional support to non-safety-related equipment whose failure could directly prevent satisfactory accomplishment of any of the required safety-related functions.

LR-S-6 : Provides flood protection barrier (internal flooding event).

LR-S-7 : Provides rated fire barrier to confine or retard a fire from spreading to or from adjacent areas of the plant.

Other structural components are not exposed to temperatures higher than the degradation threshold of elevated temperature for concrete. Therefore, elevated temperature is not a potential aging mechanism for these components.

2.3 Impact on Intended Functions

If the effects of elevated temperature are allowed to degrade the above structural 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

The ambient bulk temperature inside the containment during normal plant operation is limited to 120 °F,[6] and the concrete surface temperature for the design of containment building is limited to 150 °F.[7] The primary shield wall is subjected to sustained internal heat buildup. However, thermal insulation and an air-cooling system are provided at the inner surface of the reactor cavity wall to maintain the concrete temperature at or below 150 °F.[5,8]

The concrete around the eight hot pipe penetrations (two main steam lines, two feedwater lines, two steam generator blowdown lines, one reactor coolant letdown line, and one reactor coolant sample line) is also subject to extended high temperature or local heatup. However, a cooling system combining insulation and coolant circulation was implemented to restrict the maximum temperature in the concrete to 150 °F.[5,9,10]

These temperatures are below the degradation thresholds of elevated temperature for concrete.

A higher temperature of 160 °F noted in Section 2.1 is limited to a localized area of the containment pump bays. Therefore, it will not degrade the concrete in this area.

2.5 Plausibility Determination

Based on the discussion in Sections 2.1 and 2.4, no structural components are exposed to temperatures higher than the degradation threshold of elevated temperature for concrete. Therefore, elevated temperature is not a plausible aging mechanism for any structural components of the CCNPP containment.

2.6 Existing Programs

Although there is no existing program to monitor the temperature profiles for the surfaces of the eight high-temperature containment penetrations listed in Section 2.4 or the surface of the primary shield wall, the original design recognized the potential of elevated temperatures inside the primary shield wall and in the vicinity of the hot piping penetrations in the containment wall. Consequently, insulation and cooling system were installed to maintain their surface temperatures at or below 150 °F as documented in the FSAR and other design documents. Therefore, no program is needed to manage this aging mechanism.

3.0 CONCLUSION

The primary shield wall is subject to sustained internal heat buildup, and the concrete around the eight hot pipe penetrations is also subject to extended local heatup. However, protective measures have been implemented during design and construction stages to mitigate the temperature in these structural components to within 150 °F. No other structural components are exposed to elevated temperature due to a technical specification limit of maintaining the containment bulk temperature at 120 °F.

Therefore, elevated temperature is not a plausible aging mechanism for any structural components of the containment.

4.0 RECOMMENDATION

Elevated temperature is not a plausible aging mechanism for any structural components of the containment. Therefore, no further evaluation or recommendation is necessary.

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. "EQ Design Manual - Calvert Cliffs Nuclear Power Plant, Unit No. 1 and 2," Baltimore Gas and Electric Co.

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

6. Technical Specification Manual, Calvert Cliffs Nuclear Power Plant, Unit 1 a Unit 2.

7. 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.

8. "Reactor Cooling System - Calvert Cliffs Nuclear Power Plant," BG&E's Design Drawings 60-340-E, 60-341-E, and 60-342-E.

9. "Encapsulation Details - Main Steam System, Calvert Cliffs Nuclear Power Plant, Units 1 and 2," BG&E Design Drawings 60-346-E Sheet 2 (Unit 1) and 62-346-E Sheet 2 (Unit 2).

10. "Piping and Instrument Diagram - Component Cooling System, Calvert Cliffs Nuclear Power Plant, Units 1 and 2," BG&E Design Drawings 60-235-E (Unit 1), and 62-235-E (Unit 2).

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 $5x10^{19}$ neutrons/cm^2.

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]

1.4 Maranite XL Board

The Maranite XL board is fabricated from calcium silicate with inert fillers and reinforcing agents.[8] Silicates as a class of material are capable of absorbing up to $1x10^{15}$ Rads before any significant damage occurs.

2.0 EVALUATION

2.1 Conditions

Several in scope structural components are in high radiation areas inside the containment, in particular the primary shield wall which is subject to high neutron dose. Some components receive a higher gamma dose than neutron dose. As noted in Section 1.0, the radiation degradation thresholds for each constituent are:

Concrete	10^{19} neutrons/cm^2
Steel	$> 10^{18}$ neutrons/cm^2
Tendon Wires	$4x10^{16}$ neutrons/cm^2[6]
Tendon Grease	$1x10^{10}$ rad
Maranite XL board	$1x10^{15}$ rad

2.2 Potential Aging Mechanism Determination

Irradiation is a potential aging mechanism for the following structural and architectural components of the containment.

- coating
- concrete basemat
- pr'mary shield wall
- secondary shield wall
- partitions and ceilings (Maranite XL board)

2.3 Impact on Intended Functions

If the effects of irradiation are allowed to degrade the above structural and architectural components unmitigated for an extended period of time, this aging mechanism could affect all their intended functions.

2.4 Design and Construction Consideration

BG&E's EQ Design Manual[7] specifies the following 40-year normal service doses for use in environmental qual: .cation evaluations:

General areas	$0.35x10^6$ rads
Containment pump bays	$3.5x10^6$ rads

Inside primary shield wall	$3.5x10^9$ rads $2.5x10^{18}$ neutron/cm^2

Based on the above, the allowable 60-year service radiation doses are:

General areas	$0.53x10^6$ rads
Containment pump bays	$5.25x10^6$ rads
Inside primary shield wall	$5.25x10^9$ rads $3.75x10^{18}$ neutron/cm^2

As indicated above, the allowable 60-year radiation doses of neutron and gamma radiation incurred by the structural and architectural components are less than the irradiation degradation threshold for each constituent of all structural and architectural components. Therefore, irradiation is not a plausible age-related degradation mechanism for any structural or architectural component of the containment.

2.5 Plausibility Determination

Based on the discussion in Sections 2.1 and 2.4, no structural or architectural components of containment are exposed to radiation higher than their design threshold. Therefore, irradiation is not a plausible aging mechanism for any structural or architectural components of the CCNPP containment.

2.6 Existing Programs

There are no existing programs at CCNPP designed to identify damages to structural or architectural components of the containment due to radiation. However, since this is not a plausible aging mechanism that could degrade these components, no future program is necessary.

3.0 CONCLUSION

All structural and architectural components in the containment are exposed to neutron and gamma radiation. As indicated in Section 2.0 above, the neutron fluence level and the maximum integrated gamma does inside the containment are predicted to be below the degradation threshold for each constituent of all structural and architectural components. Therefore, irradiation is not a plausible age-related degradation mechanism for the structural or architectural components of the containment.

4.0 RECOMMENDATIONS

Irradiation is not a plausible aging mechanism for the concrete structural or architectural components in containment. 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. "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. "Code Requirements for Nuclear Safety Related Concrete Structures," ACI 349-85, American Concrete Institute, Detroit, Michigan

7. "EQ Design Manual - Calvert Cliffs Nuclear Power Plant, Unit No. 1 and 2," Baltimore Gas and Electric Co.

8. Manville Products Catalog IND-336 10-80 (page 3).

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

Some of the internal structural components of containment are subject to high cycle, low-level repeated load, such as equipment vibration load, during normal plant operation. The containment wall and containment dome were designed for abnormal events such as seismic and hurricane 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 containment. Therefore, the fatigue damage of the containment dome and wall is not age-related.

2.2 Potential Aging Mechanism Determination

Fatigue is a potential aging mechanism for the following structural components of the containment because they could experience high frequency of low-level, repeated loads such as equipment vibration load:

· Concrete columns	LR functions LR-S-1, 5
· Concrete beams	LR functions LR-S-1, 5
· Ground slab and equipment pads	LR functions LR-S-1, 5
· Elevated floor slab	LR functions LR-S-1, 5
· Primary shield wall	LR functions LR-S-1, 5
· Secondary shield walls	LR functions LR-S-1, 5
· Steel columns	LR functions LR-S-1, 5
· Steel beams	LR functions LR-S-1, 5
· Crane girder	LR function LR-S-5
· Base plates	LR functions LR-S-1, 5
· Floor framing	LR functions LR-S-1, 5
· Steel bracings	LR functions LR-S-1, 5
· Platform hangers	LR functions LR-S-1, 5
· Decking	LR functions LR-S-1, 5

where:

LR-S-1: Provides structural and/or functional support to safety-related equipment.

LR-S-5: Provides structural and/or functional support to non-safety-related equipment whose failure could directly prevent satisfactory accomplishment of any of the required safety-related functions.

Fatigue is not a potential degradation mechanism for other containment structural components because they are not subject to the high frequency of low level, repeated loads.

2.3 Impact on Intended Functions

If the effects of fatigue 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 intended functions of components listed in Section 2.2.

2.4 Design and Construction Considerations

All internal concrete components of the CCNPP containment were designed in accordance with ACI-318-63.[3,4] The design code[3] limited the maximum permissible design stress level to less than 50 percent of static strength, which is less than the fatigue strength of concrete (55 percent of static strength). In addition, actual concrete stresses induced by cyclic loads during normal plant operation, such as those from machine vibration, are a small portion of the combined stresses resulting from static and dynamic loads. This means that the stress range (magnitude of stress fluctuation) is also small and within the limit that yields extremely long fatigue life ($> 10^7$ cycles, which is equivalent to infinite life), as shown in Figure T-1.

All structural steel components in the containment were designed in accordance with American Institute of Steel Construction (AISC-1963) specification.[4,5] For the design of steel members and connections subject to repeated variation of live load stress, this specification[5] requires that consideration be given to the number of stress cycles, the expected range of stress, and the type and location of a member or detail. For life cycles of more than 2×10^6 loading, the maximum stress may not exceed two-thirds of the basic allowable stress provided in Sections 1.5 and 1.6 of the AISC specification,[5] which is equivalent to 40 percent of the material yield strength.

ASTM A-36 carbon steel is typically used for all structural steel components in the containment.[4] As shown in the fatigue strength curves in Figures T-2 and T-3, the fatigue limit for as-received A-36 steel is about 20 ksi at a life cycle of approximately 2×10^6, which is about 55 percent of the material yield strength. The maximum design stresses of all steel components were limited to 40 percent of material yield strength and are less than the material fatigue limit. Again, the actual steel stresses induced by cyclic loads are small portion of the combined stresses resulting from static and dynamic loads.

2.5 Plausibility Determination

Based on the discussion in Section 2.4, fatigue will not degrade the structural components listed in Section 2.2. Therefore, fatigue 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 the damage to structural steel components due to fatigue. Since fatigue is not a plausible aging mechanism that could degrade the containment structural components, no management program is necessary.

3.0 CONCLUSION

Some concrete components in the containment of CCNPP are subject to high cycles of low-level repeated load. These components were designed in accordance with ACI-318-63[3], which limits the maximum design stress to less than 50 percent of the static stress of the concrete. The concrete fatigue strength is about 55 percent of its static strength at the extremely high cycles (>10^7 cycles) of loading. Therefore, fatigue will not degrade any concrete components in the containment and requires no further evaluation.

Steel components in the containment subject to high-cycle (>10^5 cycles) loading conditions were designed in accordance with the AISC-63 specification.[5] The maximum stress in steel components and connections is smaller than the fatigue limit of steel. Fatigue degradation will have no adverse effects on the continued safety function performance during the license renewal term and requires no further evaluation for all structural steel components in the containment.

4.0 RECOMMENDATION

Fatigue is not a plausible aging mechanism for the structural components in the containment building. Therefore, no further evaluation or recommendation is necessary.

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

4. 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.

5. "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings," American Institute of Steel Construction, 1963.

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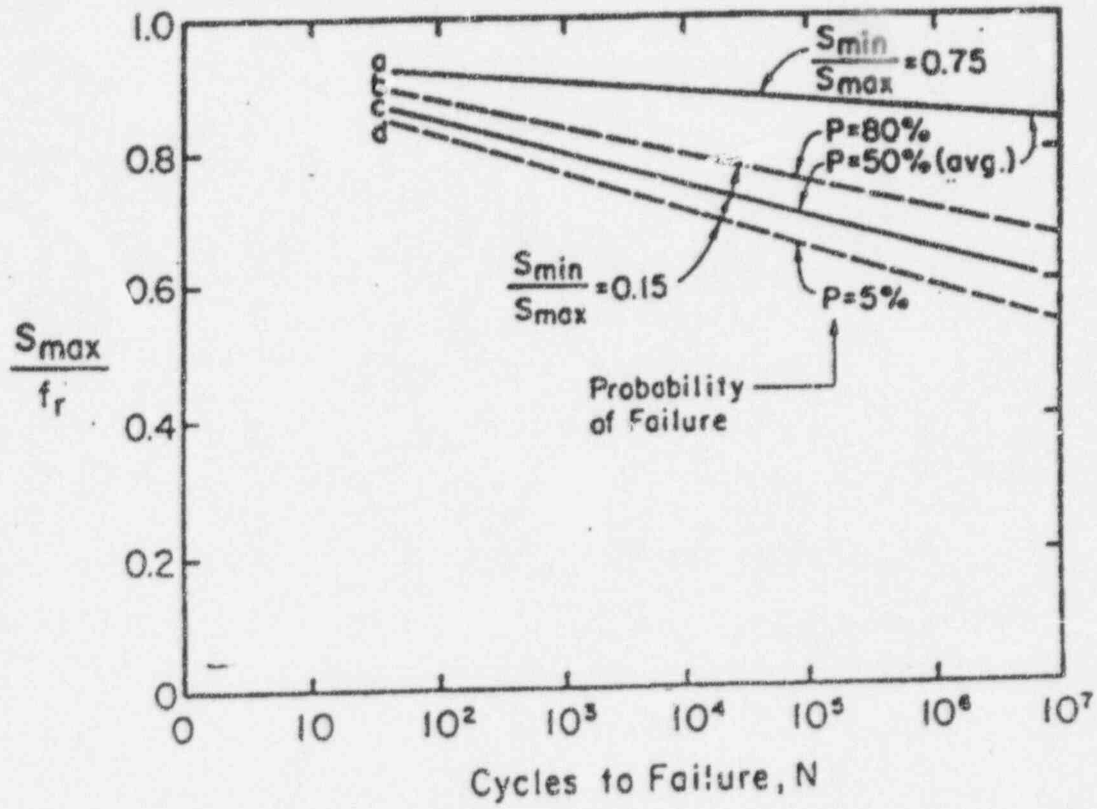
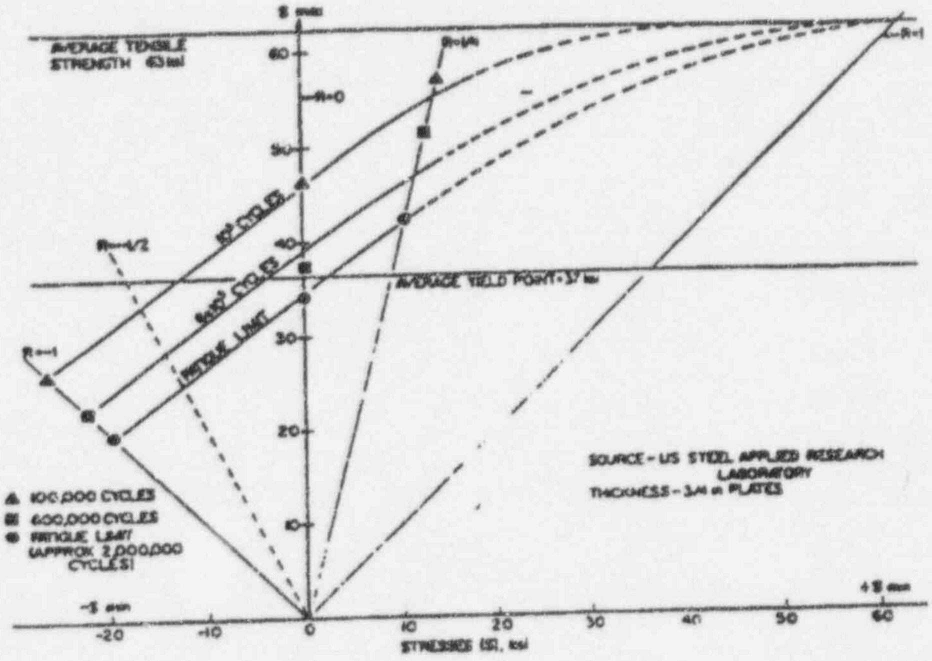
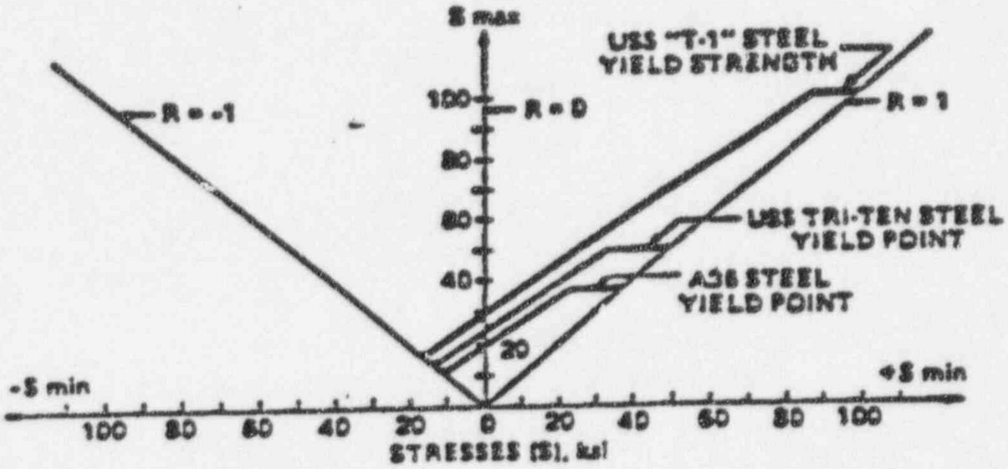


Fatigue Strength of Plain Concrete Beams
(Source: Reference 2)



Fatigue Strength of As-Received A36
Structural Carbon Steel
(Source: Reference 6)



Fatigue Strength of Transversely Groove-Welded Structural Steel Plates at 2X10^6 Stress Cycles (Source: Reference 6)