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AGING MANAGEMENT OF CONCRETE CONTAINMENT STRUCTURE – STANDARD DEVELOPMENT

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ABSTRACT

The CSA Group formerly known as Canadian Standards Association is scheduled to publish a new standard on aging management of concrete containment structures for nuclear power plants (CSA N287.8). It is being prepared by a technical subcommittee under the jurisdiction of the CSA N287/N291 Technical Committee (TC), including experts from across the nuclear industry, government and regulatory authorities, and service providers, among others.

This standard is to provide aging management requirements to ensure that concrete containment structures satisfy their functional and performance requirements in all different phases of their life-cycle. Moreover, the requirements provided in this standard are to ensure that for new concrete containment structures, aging is addressed during design and construction phases.

The standard is currently under development and is scheduled to be published in Spring 2016. The paper discusses the development of the new standard CSA N287.8 within CSA N287 series of standards.

INTRODUCTION

The development of specific Canadian standards for nuclear power plants came about as a result of concerns raised by utilities and industries for consistent standards and specifications for the design, construction, examination and testing of concrete containment structures for nuclear power plants.

First developed in the late 1970s and revised in the early 1990s, the CSA N287 series of Canadian nuclear standards, define requirements for concrete containment structures of nuclear power plants. This series of standards includes requirements for materials, design, construction, examination and testing during construction; proof pressure and leakage rate testing requirements; and requirements for in-service examination and testing of the concrete containment structures. The standards of this series have recently been updated to incorporate industry experience and lessons learned, as well as addressing challenges posed by aging and plant life extensions of nuclear power plants.

Many Nuclear Power Plants (NPPs) in Canada are nearing the end of their original design life and refurbishment programs are underway at several plants. With aging NPPs, it was determined there was a need for a proactive approach to identify and address degradation of structures before their ability to meet design requirements could be adversely affected. Furthermore, considerable Operating Experience (OPEX) with existing structures provides valuable lessons learned for new concrete construction associated with NPPs concrete structures. To ensure implementation of a consistent approach to aging management for concrete containment structures, development of the standard was initiated.

SEED DOCUMENTS

Aging Management (AM) is a combination of engineering, operations, inspection, and maintenance actions to control, within acceptable limits, the effects of physical aging and obsolescence of a structure and its components.

The standard is intended to identify minimum requirements to ensure adequate aging management of concrete containment structure in accordance with regulatory requirements and international guidelines, with consideration to industry OPEX and other lessons learned. In addition to concrete containment structure, the standard is also intended to provide guidance for aging management of other concrete structures.

While there are many documents describing degradation mechanisms for concrete structures and providing guidelines for inspection, monitoring and repairs, no standard specific for aging management of concrete structures has been identified.

Sources of information used in preparation of CSA N287.8 included the Canadian Nuclear Safety Commission (CNSC) document for fitness for service and aging management [1] that provides requirements for managing aging of Structures, Systems and Components (SSC) of a power reactor facility, as well as IAEA documents that provide guidelines on aging management [2] and [3]. Additional documents including [4] – [27] provide useful information for aging management of concrete containment structure and related components such as post-tensioning system, liners, coatings, etc.

FUNDAMENTAL PRINCIPLES

Concrete can be a very durable construction material under favorable environmental conditions, and its performance as concrete containment structures in nuclear power plants has been good. Experience shows that aging degradation can be a result of exposure to aggressive environments, excessive structural loads, accident conditions, use of unsuitable materials, poor material and construction quality, and inadequate maintenance or inspections.

A major consequence of aging of concrete containment structures can be excessive leakage and/or loss of structural integrity. In worst cases, these issues can impact on the safe and long term operation of the plant. This may require actions ranging from increased monitoring and trending up to and including mitigating measures such as concrete repair or replacement. However, the functional or performance requirements defined by the design basis and safety analysis of the concrete containment structures should not be affected provided the structures are kept in good maintenance by timely detection and mitigation of degradations with an Aging Management (AM) plan.

Understanding the relevant aging mechanisms and their potential impact on concrete containment structures is the key to an AM plan. This includes an understanding of:

- material properties
- methods of construction
- structure models
- aging stressors
- operating conditions
- aging mechanisms
- sites of degradation
- consequences of degradation
- relevant Research and Development (R&D) and OPEX

- maintenance history
- mitigation measures
- current condition of structure.

A PLAN-DO-CHECK-ACT cycle illustrated in Figure 1 can be linked to many programs typically implemented in a nuclear power plant.

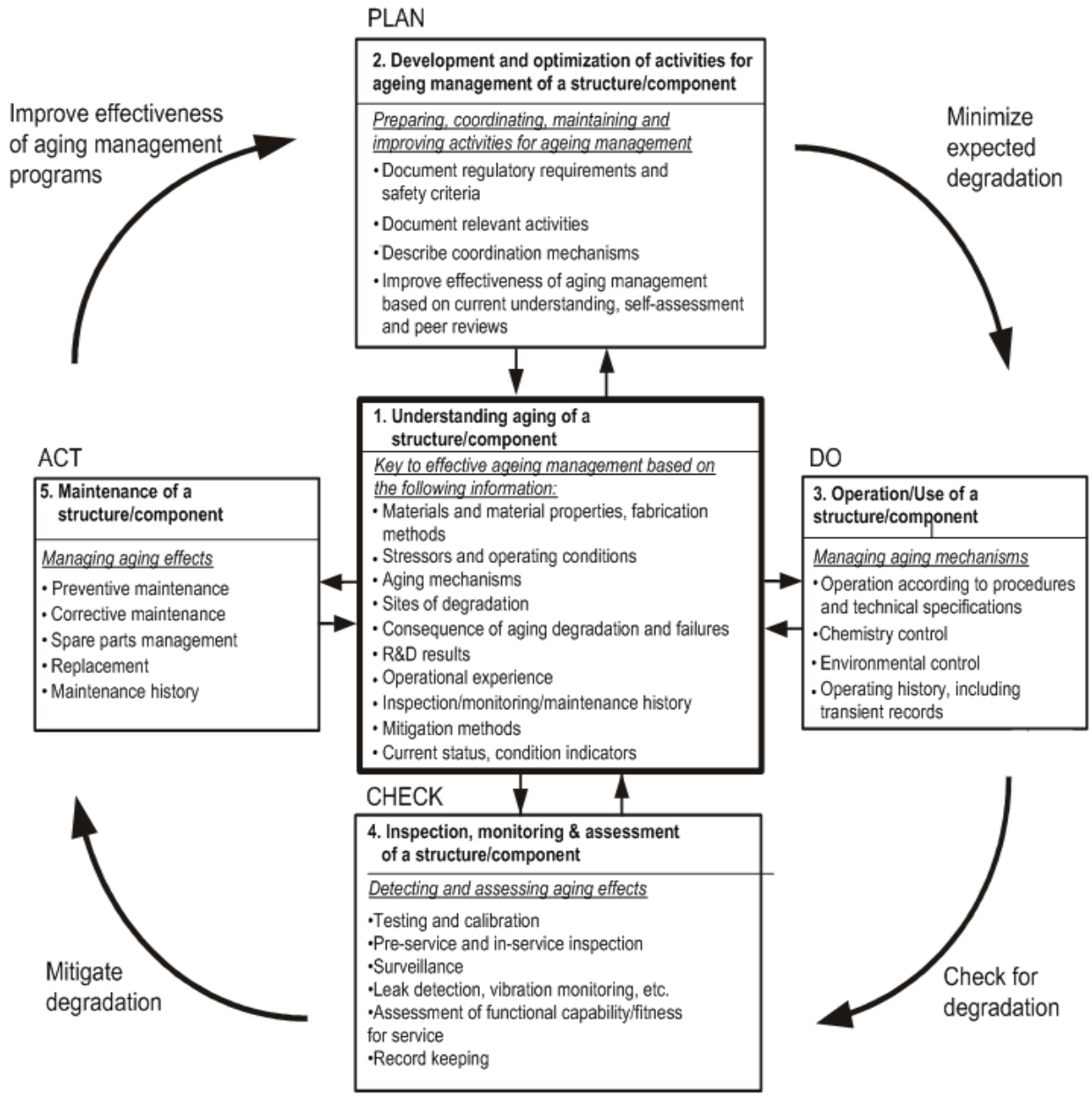

Figure 1 Systematic Approach to Aging Management [2]

The "PLAN" activity in Figure 1 refers to the development, coordination, integration and optimization of the programs and activities related to aging management of a concrete structure and its components. This should include but is not limited to: documenting the regulatory requirements, safety criteria and relevant

activities; describing the coordination mechanism and processes; and improving effectiveness of aging management.

The "DO" activity involves the management of aging mechanisms by minimizing the expected degradation of a concrete structure and its components by operating or using it as per the approved operating procedures and technical specifications. This includes maintaining operating conditions within design limits, establishing proper environmental control, and maintaining operating history including transient records.

The "CHECK" activity includes the inspection, monitoring and assessment of a concrete structure and components to ensure timely detection and evaluation of aging effects. Condition indicators and other data identified in the AM plan should be collected, recorded and evaluated to provide a basis for decisions on the type and timing of necessary mitigative actions.

The "ACT" activity refers to the timely mitigation and correction of structures and components degradation by the implementation of maintenance, repair and replacement activities. It includes preventive and corrective maintenance, spare parts management and replacement, etc. The AM plan for a concrete structure can consist of existing programs such as periodic inspections, maintenance, condition assessments, obsolescence management and system health monitoring, etc, and if necessary, developing new programs.

The essential elements of a systematic approach to managing aging of concrete structures include:
- Organizational arrangements
- Data collection and record keeping
- Screening of structures and components for the purposes of aging management
- Evaluation for aging management
- Condition assessment
- Development of aging management plans
- Management of technological obsolescence
- Interfaces with other supporting programs
- Implementation of aging management plans
- Review and improvement.

AGING MANAGEMENT PLAN DEVELOPMENT

Figure 2 was developed for the standard and illustrates development and optimization of AM plan. Evaluations for aging management and condition assessment are performed prior to establishing a new AM plan and as part of optimization of an existing AM plan. Furthermore, these activities are required to be performed during the life of the plant; e.g., when significant changes in operating conditions, modifications to structures, or failure of a structure to meet design requirements occur. A Time Limited Aging Analysis (TLAA) may also need to be revalidated during the life of the plant; e.g., in preparation for life extensions, or when operating conditions exceed design assumptions.

The objective is to ensure the understanding of aging and to establish current condition of a structure in order to estimate its future performance and determine aging management activities necessary to ensure structure's integrity. The understanding of aging allows the selection of appropriate preventative actions in order to minimize and control aging degradation, as well as to determine the most appropriate methods for detection, monitoring and trending of aging effects and mitigative measures.

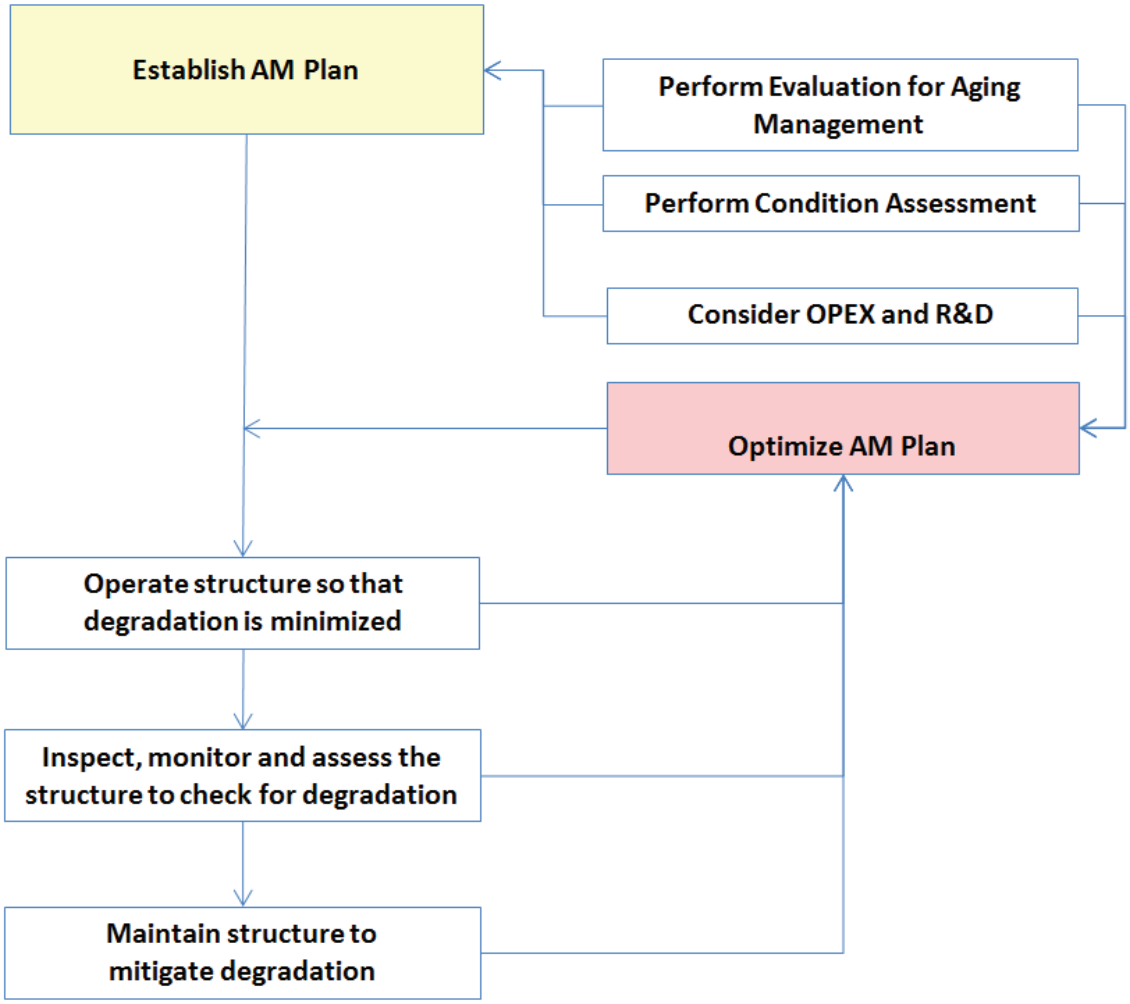

Figure 2 Development and Optimization of Aging Management Plan

NEW DESIGN AND CONSTRUCTION

Industry OPEX has indicated that properly designed and constructed concrete structures of NPPs typically have good field performance well beyond their original design life. Aging related degradation is typically initiated or facilitated by an inadequate design, improper choice for materials, and the lack of attention to details during construction. The first two are often associated with the lack of understanding of aging and operating environment, while the last one can be caused by inadequate technical specifications and quality control during construction.

Understanding aging and operating environment and accounting for it during design, as well as considering the possibilities for inspections and maintenance as applicable, together with the enhanced quality control during construction, would improve the quality of new concrete structures of NPPs.

The importance of an easily retrievable documentation and record keeping system (or database) for aging management cannot be overemphasized. One of the key components of effective aging management is ensuring the validity of assumptions used at the time of design. Thus, design information including any

design changes that took place during construction should be well documented and readily available for the life cycle of the plant. Construction documentation, records of all inspections, tests, monitoring and maintenance activities should be available. Furthermore, the database is intended to support operation, inspection and maintenance (DO-CHECK-ACT) and allow for trending; thus it is important that representatives of operations, maintenance and engineering units are involved in the design of the record keeping system to facilitate obtaining the desired quality and quantity of aging related data. Figure 3 developed for the standard illustrates an example of a documentation hierarchy for aging management of concrete containment structure.

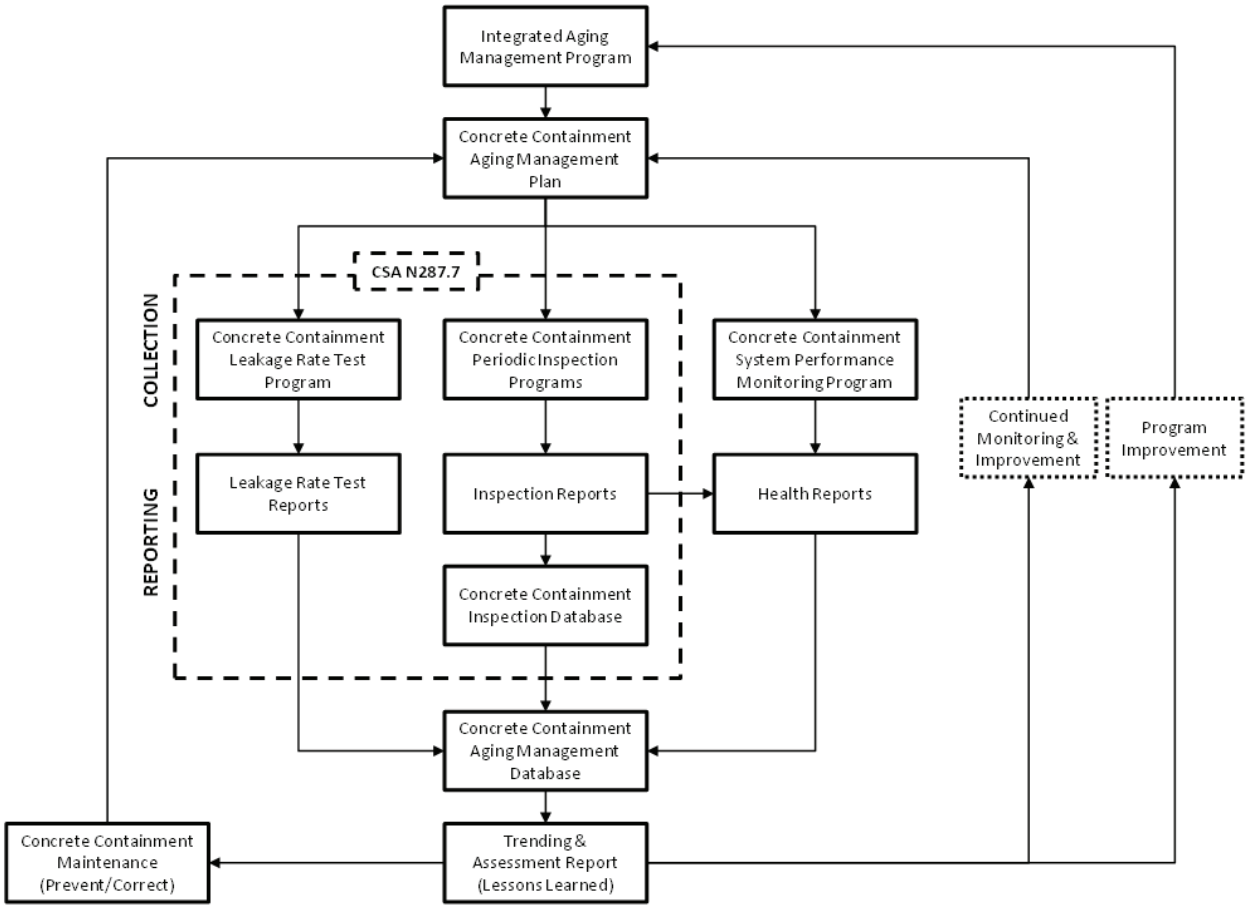

Figure 3 Example of Concrete Containment Aging Management Plan Document Hierarchy

SUMMARY OF SIGNIFICANT FEATURES

This new standard provides aging management requirements for concrete containment structures and their components for nuclear power plants and is directed towards owners/operators, designers, manufacturers, fabricators, and constructors.

The standard provides requirements for aging management of existing concrete containment structures to address emerging challenges and ensure that existing concrete containment structures and their components satisfy their functional and performance requirements in all different phases of their life cycle including design, construction, commissioning, operation, and decommissioning.

The standard also provides requirements for aging management of new concrete containment structures to ensure that:

- aging is addressed during design and construction phases
- containment structures and their components satisfy their functional and performance requirements in all different phases of their life cycle including design, construction, commissioning, operation, and decommissioning.

The standard includes requirements pertaining to:

- aging considerations during design and construction
- development and optimization of aging management including requirements for an aging management plan, organizational arrangement, aging management team, data collection and a record keeping system
- operation (normal and abnormal)
- inspection, monitoring, and assessment
- maintenance (preventive and corrective)
- evaluation for aging management
- condition assessment.

The standard provides background information on typical aging mechanisms, aging effects, potential degradation sites, condition monitoring and mitigation, as well as the consequences of aging degradation for concrete containment structures to enhance understanding of aging, to form a foundation for effective aging management. The standard considers industry OPEX that shall be taken into consideration by NPPs' owners/operators, designers, engineers and specialists in order to ensure integrity of NPP's concrete containment structures during their entire service lives and subsequent decommissioning, and to ensure that aging management is addressed during design and construction of new NPPs.

REFERENCES

[1] CNSC REGDOC 2.6.3, Fitness for Service – Aging Management. March 2014

[2] IAEA NS-G-2.12, Ageing Management for Nuclear Power Plants, IAEA Safety Standards Series Safety Guide, Vienna: IAEA, 2009

[3] IAEA TECDOC-1025, Assessment and Management of Ageing of Major Nuclear Power Plant Components Important to Safety: Concrete Containment Buildings, IAEA, 1998

[4] CSA N287.1-14 General requirements for concrete containment structures for nuclear power plants

[5] CSA N287.2-08 (R2013) Material requirements for concrete containment structures for CANDU nuclear power plants

[6] CSA N287.3-14 Design requirements for concrete containment structures for nuclear power plants

[7] CSA N287.4-09 (R2014) Construction, fabrication, and installation requirements for concrete containment structures for CANDU nuclear power plants

[8] CSA N287.5-11 Examination and testing requirements for concrete containment structures for nuclear power plants

[9] CSA N287.6-11 Pre-operational proof and leakage rate testing requirements for concrete containment structures for nuclear power plants

[10] CSA N287.7-08 (R2013) In-service examination and testing requirements for concrete containment structures for CANDU nuclear power plants

[11] CSA A864-00 (R2005) Guide to the Evaluation and Management of Concrete Structures Affected by Alkali-Aggregate Reaction

[12] EPRI Report 1019157 (2009) Guideline on Nuclear Safety-Related Coatings, Rev.2 (Formerly TR-109937 and 1003102)
[13] EPRI Report 1011224 (2005) Aging Identification and Assessment Checklist: Civil and Structural Components
[14] IAEA Safety Standards Series No. NS-G-2.6 (2002) Maintenance, Surveillance and In-service Inspection in Nuclear Power Plants
[15] IAEA TECDOC-1503 (2006) Nuclear Power Plant Life Management Processes: Guidelines and Practices for Heavy Water Reactors
[16] IAEA TECDOC-1736 (2014) Approaches to Ageing Management for Nuclear Power Plants - International Generic Ageing Lessons Learned (IGALL) Final Report
[17] IAEA Technical Reports Series No. 338 (1992). Methodology for Management of Ageing of Nuclear Power Plant Components Important to Safety
[18] IAEA Safety Report Series No. 15 (1999) Implementation and Review of a Nuclear Power Plant Ageing Management Programme
[19] IAEA Safety Series No. 50-P-3 (1991) Data Collection and Record Keeping for the Management of Nuclear Power Plant Ageing
[20] IAEA Safety Report Series No. 57 (2008) Safe Long Term Operation of Nuclear Power Plants
[21] NIST ANSI Codes and Standards for the Repair of Nuclear Power Plant Concrete Structures: Recommendations for Future Development. 2013
[22] US NRC NUREG-1611, September 1997 Aging Management of Nuclear Power Plant Containments for License Renewal
[23] US NRC NUREG-1801 Rev. 2 (2010) Generic Aging Lessons Learned (GALL) Report, Final Report
[24] US NRC NUREG/CR-7111. NRC, Washington, DC (2012). A Summary of Aging Effects and Their Management in Reactor Spent Fuel Pools, Refueling Cavities, Tori, and Safety-Related Concrete Structure
[25] US NRC Regulatory Guide 1.35.1(1990) Determining Prestressing Forces for Inspection of Prestressed Concrete Containments
[26] US NRC Regulatory Guide 1.35 (1990) In-service Inspection of Un-grouted Tendons in Pre-stressed Concrete Containments
[27] US NRC Regulatory Guide 1.90 (2012) In-service Inspection of Prestressed Concrete Containment Structures with Grouted Tendons

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