## AMP 302 In-Service Inspection FOR CONCRETE CONTAINMENT (VERSION 2021)

### Programme Description

This AMP provides specific guidance for in service inspection (ISI) for managing ageing of containment reinforced concrete, and bonded and unbonded post-tensioning systems. The references [1–6] describe practices and techniques for the inspection, mitigation of ageing degradation, corrective action including repair methods, and operating experience for concrete containments. This AMP in conjunction with AMP 318 provides general guidance for developing an effective AMP for concrete containments.

The primary ISI method for concrete containments is visual examination, supplemented by testing. For unbonded prestressed concrete containments, detailed visual examination of the concrete surfaces surrounding anchorages of tendons are performed. In addition, in the ASME Code [7], for unbonded post-tensioning system, tendon wires are tested for yield strength, ultimate tensile strength, and elongation. Samples of tendon corrosion protection medium is analyzed for alkalinity, water content, and soluble ion concentrations [7, 8]. The quantity of free water contained in the anchorage end cap and any free water that drains from tendons during the examination is documented. Samples of free water are analyzed for pH. Prestressing forces are measured in selected unbonded sample tendons (by lift off tests or other equivalent tests). For bonded post-tensioning system, strain and deformation measurements are used to ensure that stresses are within prescribed limit during the pressure and leakage rate tests and to confirm the integrity of the post-tensioning system. Behavior of the structure during normal operation can be monitored using instrumentation installed for this purpose allow for evaluation of time-dependent changes. In structures, where a few tendons were left ungrouted for monitoring purposes, direct measurements of the prestressing force can be performed. In some cases, a series of test beams, are cast at the time of construction, and are used for evaluating bonded prestressing systems. These test beams are tested periodically to confirm that potential material degradation and time-dependent pre-stressing losses do not result in pre-stressing forces that are below design values; and to confirm that the time-dependent pre-stressing losses due to shrinkage and creep of the concrete and due to the relaxation of the tendon, are within expected values.

References [7, 9-14] provide detailed requirements for ISI of concrete containments.

The ageing management of steel elements (accessible area): liner, liner anchor, integral attachment connected to the concrete containment and acts as leak tight membrane is addressed in AMP 301, while AMP 309 provides guidance for ageing management of non-metallic liner which functions as a leak tight barrier. Ageing management of structural concrete is provided in AMP 306.

When post-tensioning system repair/replacement activities are performed, augmented examination requirements following the activities are required. This AMP does not address any augmented examination following repair or replacement activities. ASME Code [7] or CSA Code [9] provides guidance for augmented inspection following a repair/replacement activity.

### Evaluation and Technical Basis

***1. Scope of the ageing management programme based on understanding ageing:***

This AMP covers the concrete containments for PWR (including WWER), BWR, and CANDU Reactors. The components within the scope are reinforced concrete containment, prestressed concrete containments including prestressing systems with both bonded and unbonded of tendons. This AMP and AMP 306 is also applicable to the concrete portion of the steel containments (for example, base mat) that perform a pressure retaining function. The programme also includes testing of the tendon corrosion protection medium and the pH of free water.

Examination of the concrete containment areas that are inaccessible (e.g., concrete covered by steel elements (inaccessible area): liner, liner anchor, integral attachment, foundation material, or backfill or obstructed by adjacent structures or other components) are exempted. Instead, the acceptability of concrete in inaccessible areas is evaluated when conditions exist in accessible areas that could indicate the presence of or result in degradation to such inaccessible areas. Steel elements (accessible area): liner, liner anchor and integral attachment for concrete containments are not within the scope of this AMP. These are within the scope of AMP 301. Non-metallic liners are within the scope of AMP 309.

***2. Preventive actions to minimize and control ageing degradation:***

This is a condition monitoring programme. However, the programme includes actions:

* To prevent or minimize corrosion of the unbonded prestressing tendons by maintaining corrosion protection medium chemistry within acceptable limits;
* To minimize deterioration of the concrete and post-tensioning system by ensuring that the operating and environmental conditions are within the values accounted for in design;
* To ensure that tendon prestress forces do not fall below design values.

***3. Detection of ageing effects:***

The examination items (condition indicators) are determined and method and frequency of the examinations are specified to ensure that ageing effects would be detected before they would compromise the design-basis requirements. This examination can be based on a global monitoring system as described in reference [10]. In this case, measurements are compared and evaluated against the design values. For sites with multiple plants, the examination requirements may be modified if the containments utilize the same unbonded prestressing system and are essentially identical in design. For example, in ASME Code [7] in-service inspections of concrete and unbonded post-tensioning systems are required at 1, 3, and 5 years following the initial structural integrity test. Thereafter, inspections are performed at 5-year intervals. If the site has multiple plants constructed under the same conditions within same 2 years period of time, inspections of the unbonded prestressing system of each plant can be performed at 10-year intervals. Concrete inspection frequency remains at 5 years interval. In the case of tendons, only a sample of the prestressing tendons of each tendon type requires examination during each inspection.

In containments without pre-stressing system such as WWER 440, it is useful to measure deformations of containment structure during the pressure and leakage rate tests in critical profiles. For containments without any embedded instrumentation for strain measurements it is possible to use additional deformation measurement methods such as geodetic methods or deformeters connected to invar wire.

The primary inspection method for concrete surfaces is visual examination, and concrete surfaces are examined for evidence of damage or degradation, such as concrete cracks and conditions indicative of degradation. For prestressed concrete containments, additional examinations may be required to verify the structural integrity of post-tensioning systems.

The areas which are inaccessible are evaluated for existing or potential concrete degradation mechanisms, for example based on requirement of ASME code, subsection IWL [7]. These degradations may be caused by chemical and physio-chemical processes in the concrete and deterioration due to environmental conditions including, but not limited to, aggressive chemical attack, erosion and cavitation, corrosion of embedded steel, freeze-thaw, leaching of calcium hydroxide, reaction with aggregates (more details are provided in AMP312), increase in permeability or porosity, and combined effects.

All accessible concrete surfaces require general visual examination to detect degradation due to ageing. ACI 201.1R [15] and ACI 349.3R [16] provide guidance on visual examination. In most chemical and physical processes influencing concrete durability, the main factors include transport mechanisms within pores, cracks, and the presence of water [17]. Table A.l of CSA N287.8 [17], presents a general review of some of the stressors, ageing mechanisms, aging effect and degradation sites, which could be evaluated for concrete containment structures and components. In case of prestressed concrete containments, selected areas, such as those that indicate suspect conditions and concrete surface areas surrounding tendon anchorages of unbonded post-tensioning systems require more rigorous detailed visual examination. The acceptability of inaccessible areas is evaluated when conditions are found in accessible areas that could indicate the presence of, or could result in, flaws or degradation in such inaccessible areas.

For concrete containments, the embedded reinforcing steel especially the outer layer of steel rebar where joints, cracks, or local defects are present, are susceptible to corrosion. The resultant cracking, loss of bond and loss of material (spalling, scaling) are visual inspected as per ASME code, subsection IWL [7] and CSA N287.8 [17]. Further, due to elevated temperature, concrete strength and modulus of elasticity can be reduced.

For prestressed concrete containments, examinations required to identify the structural integrity of unbonded and bonded post-tensioning systems are as follows:

* **Unbonded post-tensioning systems**

A percentage of all tendons or number of selected sample tendons for each inspection is determined based on requirements contained in the national codes and standards. The tendons to be examined during an inspection are randomly selected from each type of tendon that have not been examined during earlier inspections. ASME Code [7] provides one acceptable basis for selection of tendons. The examinations are performed to detect the loss of prestress of tendons and the loss of material due to corrosion of tendon wires or strands.

In some plants pre-stressing forces are measured in selected sample tendons by conducting lift-off tests or equivalent tests. Hydraulic shim-type load cell [18, 19] has also been used experimentally at some other plants. In some countries, hydraulic shim-type cell has been implemented experimentally. In addition, to verify that the tendons are free of corrosion and mechanical damage, one sample tendon of each type is detensioned, and the tendon wires or strands are tested for yield strength, ultimate tensile strength, and elongation. Tendon wires or strands are also visually examined for cracks, corrosion, and mechanical damage.

The accumulation of water during transportation, storage or service life of the structure is one of the root causes of corrosion. The unbonded tendons are protected from corrosion by means of grease, wax or inert gas.

To determine effectiveness of the corrosion protection medium, sample of the medium from each tendon that is selected for lift-off and detensioning are analyzed for alkalinity, water content, and soluble ion concentrations. The quantity of free water contained in the anchorage end cap and any free water that drains from tendons during the examination is documented. Samples of free water are analyzed for pH. The amount of corrosion protection medium removed from each tendon anchorage is measured and compared to amount replaced. These values are recorded and compared to verify any loss of protection medium of tendons.

* **Bonded post-tensioning system**

Pre-stressing forces in containments with bonded systems cannot be measured directly by lift-off tests or detensioning a sample tendon. Therefore, the structural integrity of post-tensioning system is monitored at some plants by the strain gages, stress meters, vibrating wires, and strain meters embedded in the concrete or attached to the tendon wires or strands.

The monitoring of the structural behavior of containment structures with grouted tendons can follow the requirements of [10]. The ageing management of these instruments is described in AMP 311. Other approaches to ageing management of bonded prestressed concrete containments include containment pressure tests [20–22], and monitoring prestressing tendons for loss of prestress and corrosion using test beams with representative sample of pre-stressing tendons, with concrete exposed to similar environment [9].

Bonded tendons are protected by grout and concrete surrounding the tendons. Recent studies on both bonded and unbonded systems can be found in [5, 23].

If a dewatering system is relied upon to control settlement, further evaluation is recommended to verify the continued functionality of the dewatering system during the subsequent period of extended operation.

***4. Monitoring and trending of ageing effects:***

All concrete surfaces are to be monitored at a minimum by visual examination. The evaluation methods, frequency of inspection and acceptance criteria for reinforced concrete structures are described in AMP 306. The trending of reinforced concrete is possible by comparing the record of (e.g., quantitative data, qualitative information, photographs) with previous examination results.

In unbonded post-tensioning systems, prestressing force in all tendons randomly selected for inspection is measured by lift-off test or equivalent test. In addition, one tendon of each type is selected from the first-year inspection sample and designated as a common tendon which is then examined during each inspection. This procedure provides monitoring and trending information of prestressing forces over the life of the plant. The liftoff force in the selected tendons is compared with acceptance criteria based on the predicted force for that tendon over its life in accordance with AMP 313. The lift off force for the common tendon is compared with the lift off force recorded during previous inspections and is used to establish a trend in the loss in prestress over time. Corrosion protection medium chemistry and free water pH are also monitored for each examined tendon, and is compared to acceptance criteria as well as to establish a trend. Samples of the grease are taken at both ends of the tendons and analyzed for free water content, alkalinity, and presence of aggressive ions (i.e., chloride, sulfide, and nitrate ions).

For some plants with bonded post-tensioning system, strains in the tendons, reinforcement, and concrete are monitored by containment monitoring system described in AMP 311. However, at other plants, periodic containment pressure tests are performed and deformations in the accessible areas of the concrete containment are monitored and trended.

For PWR, CANDU/PHWR and BWR concrete containments located in moderate to severe weathering conditions, further monitoring and evaluation are performed for loss of material (scaling, spalling) and cracking due to freeze-thaw.

***5.***  ***Mitigating ageing effects:***

This AMP is a condition monitoring programme and does not include actions to mitigate ageing effects. However, if protective coatings that are applied to the containment surface is credited to mitigate ageing effects and are degraded or removed as a result of the ISI, the affected area is recoated. For exposed parts of concrete, minimizing exposure to moisture by repairing the cracks and waterproofing the concrete surface can reduce the corrosion of tendons, embedded steel and cracking & spalling due to freeze thaw and alkali-aggregate reactions. Expansion and irregular cracking due to sulfate attack can be reduced by minimizing contact of sulphates to the structure by diversion of the ground water by improving drainage and/or waterproofing the concrete structure. Also, effective implementation of ISI programmes and regulatory oversight may reduce the ageing effects which would provide the timely detection and mitigation of ageing degradation to ensure the required safety margins.

***6. Acceptance criteria:***

Guidance for establishing both qualitative and quantitative inspection criteria of concrete surfaces, tendon anchorage, and prestressing wire or strand are provided in a number of national and international codes and standards. Guidance for the acceptance criteria are provided in some references (e.g., Refs [7, 9, 15, 16, 24–26]) for identification of concrete degradation. Inspection and evaluation is performed by qualified engineer, meeting the qualification requirements of the appropriate member state regulatory authority.

The acceptance standards for the unbonded post-tensioning system are quantitative in nature. For the post-tensioning system, quantitative acceptance criteria are established for tendon force and elongation, tendon wire or strand samples, and corrosion protection medium Specific acceptance criteria may be referred in the ASME Code [7] and RCC-CW [10]. Free water in the tendon anchorage areas is not acceptable. The measured tendon lift-off forces may be compared with predicted tendon pre-stressing forces in accordance with AMP 313. The method for calculating the predicted tendon prestressing forces are defined in several codes or guides (e.g., Refs. [27, 28]), which may be used as an acceptable methodology for ageing management.

In order to quantify performance of the containment structure, condition indicators are used that characterize the condition of the structure and can be monitored and trended to infer or directly indicate whether a structure has the ability to function within acceptance criteria. Thus, specified bounds on the value of the condition indicator are established forming the acceptance criteria. Refer to [17, 29] for further guidance.

The acceptance criteria of AMP 306 can be applied for the concrete part of containment structures by keeping in view the difference in design codes, philosophy, ISI techniques as well as exposure conditions of containment from those of other reinforced concrete structures.

Furthermore, if degradation of concrete containment is detected that exceeds the acceptance criteria, plant specific actions can be identified based on detailed monitoring and trending, and structural evaluation to mitigate the root cause or source of degradation.

***7. Corrective actions:***

Items for which examination results do not meet the acceptance standards are to be evaluated to determine whether the concrete containment is acceptable without repair of the item. If repair is required, it is needed to determine the extent, method, and completion date of the repair or replacement. The cause of the condition and the extent, nature, and frequency of additional examinations is also identified by the evaluation. Procedures for the concrete repair, repair of reinforcing steel, and repair of the post-tensioning system and requirements for the examinations after repair are specified in ASME code [7]. Other codes and standards may be referred as per national practice and configuration of prestressing system.

For reduction of strength and modulus of concrete due to elevated temperatures in PWR, CANDU/PHWR and BWR concrete containments, evaluation or plant specific AMP is performed if temperature limits are exceeded (e.g. [7]).

***8. Operating experience feedback and feedback of research and development results:***

This AMP addresses the industry-wide generic experience. Relevant plant-specific operating experience is considered in the development of the plant AMP to ensure the AMP is adequate for the plant. The plant implements a feedback process to periodically evaluate plant and industry-wide operating experience and research and development (R&D) results, and, as necessary, either modifies the plant AMP or takes additional actions (e.g., develop a new plant-specific AMP) to ensure the continued effectiveness of the ageing management.

The following instances of operating experience regarding concrete containment have been reported:

* Cracked, spalled, and degraded concrete for reinforced concrete of some containments [30];
* Cracked anchor heads for the prestressing tendons for unbonded pre-stressed concrete containments [30];
* Degradation in pre-stressing systems [31];
* Containment Concrete Surface Condition Examination Frequency and Acceptance Criteria [32];
* Breakage of a Prestressing tendons Cable in the Cylindrical Part of the Reactor Containment Shell [33];
* Failures of containment tendon field anchor heads due to Hydrogen stress cracking [34];
* ACI 423.4R-2014 [35], NUREG/CR-7208 [23] and OECD/NEA report [5] identified various potential issues related to both bonded and unbonded tendons;
* Delamination of Crystal River 3 containment structures. The facility was permanently shut down on February 20, 2013 [36];
* Appropriate source(s) of external operating experience is Ageing Management of Concrete Structures in Nuclear Power Plants (IAEA Nuclear Energy Series No. NP-T-3.5 [29].

It is necessary to consider the above documents and any other related operating experience identified in the future.

Nearly 30 years of operational experience of WWER-440/V213 plants shows that the contact of borated water with reinforced concrete structures of containment could not be avoided. These contacts are minimized by appropriate operational and maintenance practice and the cases of the leakage of borated water are inspected and mapped. Focused investigations have been made regarding chemical degradation of the concrete due to borated water including sampling and laboratory tests. The observed degradation effects are limited and acceptable. Nevertheless, the issue is part of relevant ageing management programme. The preventive measures are of great importance.

The only German NPP with concrete containment is NPP Gundremmingen (KRB-II), which is twin unit plant with BWR (Boiling Water Reactor). The prestressing system of KRB consists of bonded tendons (grouted) lined with a steel liner. The visual inspections of concrete are periodic. Some one-time (non-periodic) tests on prestressed concrete were performed, which includes the strain measurements by means of strain gauges and Nondestructive tests on tendons (remnant magnetism method) to check the wire breaks. Based on this test, the operator reported that no damages were found.

Related to this AMP, it is reported that measurements with the load cells during the post-tensioning indicated that the tendon force measurements with hydraulic jacks tend to overestimate the tendon forces in the horizontal tendons by approximately 5 %. For the vertical tendon, the measurement with the hydraulic jack was in relatively good agreement with the results from the load cells [37].

During the plant operation and refueling stage, failure of tendons or strands have been heard by the workers and operators as indicated in operating experience feedback [33, 34]. For tendon failure detection, reference [35] recommends the installation of sensors mounted on various locations of the break to measure the sound effect. The information retrieved from the sensor is further analyzed for exact location of break. It is also proposed that provision for indication of these sensors may be made in main control room. The applicability of these sensors in prestressed concrete containments has not been confirmed yet in any member state and further R&D is required to explore the possibilities.

The research project at Lund University, in collaboration with Vattenfall (Swedish nuclear power plant owner) and Energiforsk, has verified the moisture content in the reactor containments. This was performed by the use of moisture sensors inserted into the concrete by drilling. The conclusion is that the desiccation has been slower than originally assumed in theoretical models applied [38].

In Sweden, during decommissioning at Oskarshamn unit 2 BWR plant; cutting for openings for transportation of material has been carried out. The openings are located at the areas of both dry-well and wet-well. The opening is cut through the containment wall and it consists of concrete with both prestressed and non prestressed reinforcement. The liner is grouted inside the containment wall. Pictures were taken of the non-prestressed reinforcement and it shows that no corrosion or other defects are found in the opening area [40].

***9. Quality management:***

Site quality assurance procedures, review and approval processes, and administrative controls are implemented in accordance with the different national regulatory requirements (e.g., 10 CFR 50, Appendix B, [39]).

**References:**

[1] Government Office of Nuclear Safety: Ageing Management of Nuclear Power Equipment. Safety guide JB-2.1. Czech Republic, January 2010 (in Czech language).

[2] HUNGARIAN ATOMIC ENERGY AUTHORITY, Guidelines 4.12 On ageing management during operation (in Hungarian), HAEA(2016, version 3), 2016.

[3] NUCLEAR REGULATORY AUTHORITY OF THE SLOVAK REPUBLIC, Ageing management of Nuclear power plants -- requirements, BNS I.9.2/2014, UJD SR, Bratislava, 2014.

[4] NUCLEAR REGULATORY AUTHORITY OF THE SLOVAK REPUBLIC, Regulation No. 33/2012 Coll., on the regular, comprehensive and systematic evaluation of the nuclear safety of nuclear equipment. UJD SR, Bratislava, 2016.

[5] ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD/NEA), Bonded or Unbonded Technologies for Nuclear Reactor Pre-stressed Concrete Containments, Nuclear Safety NEA/ CSNI/R (2015)5, June 2015.

[6] CHINA NATIONAL ENERGY ADMINISTRATION, Ageing Management Guideline of Prestressed Concrete Containment in Nuclear Power Plants, NB/T 20153-2012, 2015.

[7] AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Rules for In Service Inspection of Nuclear Power Plant Components, Subsection IWL, Requirements for Class CC Concrete Components of Light-Water Cooled Power Plants, The ASME Boiler and Pressure Vessel Code, 2019 Edition and 2008 Addenda as Approved in 10 CFR 50.55a Edition, 2015.

[8] AMERICAN CONCRETE INSTITUTE, Corrosion of Prestressing Steels, ACI 222.2R-14, ACI, October 2014.

[9] CANADIAN STANDARDS ASSOCIATION, In-service Examination and Testing Requirements for Concrete Containment Structures for CANDU Nuclear Power Plants, N287.7-08, CSA, Mississauga, Ontario, Canada, 2008.

[10] RCC-CW Rules for Design and Construction of PWR Nuclear Civil Works AFCEN; Edition. 2019

[11] Normative Technical Documentation of Association of Mechanical Engineers (N.T.D. ASI) Section IV. Residual Lifetime Assessment of Nuclear Power Plant Equipment and Pipelines type VVER, 2013 (in Czech language).

[12] Technical Standard of Czech Energetical Companies (ČEZ,a.s.) Lifetime management of Power Plants Equipment in ČEZ, ČEZ\_ST\_0006. April 2012 (in Czech language).

[13] Guide of Czech Energetical Companies (ČEZ,a.s.) Assets evidence, efficiency, condition and lifetime assessment. ČEZ\_PP\_0330. September, 2012 (in Czech language).

[14] HUNGARIAN ATOMIC ENERGY AUTHORITY Guidelines A4.21 Programme for the Maintenance, Testing and Surveillance in Nuclear Power Plants Version 1 (in Hungarian), HAEA, 2016.

[15] AMERICAN CONCRETE INSTITUTE, Guide for Making a Condition Survey of Concrete in Service, ACI Standard 201.1R,ACI, Detroit, MI, 2008.

[16] AMERICAN CONCRETE INSTITUTE, Evaluation of Existing Nuclear Safety-Related Concrete Structures, ACI Standard 349.3R-18, ACI, January 2018.

[17] CANADIAN STANDARDS ASSOCIATION, Ageing Management for Concrete Containment Structures for Nuclear Power Plants, N287.8-15, CSA, Mississauga, Ontario, Canada, 2015.

[18] Ozaki et al.,NEW PRESTRESSING FORCE MEASUREMENT SYSTEM FOR PRESTRESSEDCONCRETE CONTAINMENT VESSELS, Proceedings of the 1st fib Congress, Osaka, Japan, 2002.

[19] Kawai et al., MONITORING METHOD OF THE STRUCTURAL INTEGRITY AT TSURUGA UNIT 2 AND GENKAI UNIT 3 & 4, Proceedings of the 1st fib Congress, Osaka, Japan, 2002.

[20] The Japan Society of Mechanical Engineers, Codes for Nuclear Power Generation Facilities--Rules on Containment Vessels for Nuclear Power Plants-, JSME S NE1-2014, JSME , Tokyo, Japan, 2014.

[21] UNITED STATES NUCLEAR REGULATORY COMMISSION, Inservice Inspection of Prestressed Concrete Containment Structures with Grouted Tendons, Regulatory Guide 1.90, USNRC, Washington DC, 2012.

[22] CHINA NATIONAL ENERGY ADMINISTRATION, Structural Integrity Test of Containments for Pressurized Water Reactor Power Plants, NB/T 20017-2010, (2001).

[23] UNITED STATES NUCLEAR REGULATORY COMMISSION, NUREG/CR-7208, Study of Post Tensioning Methods, USNRC, November 2015.

[24] JAPAN CONCRETE INSTITUTE, Concrete Diagnosis and Maintenance Techniques ’16[Basis], JCI, Tokyo, Japan, 2012 (in Japanese).

[25] JAPAN CONCRETE INSTITUTE, Practical Guideline for Investigation, Repair and Strengthening of Concrete Structures-2013, JCI, Tokyo, Japan, 2013.

[26] ARCHITECTURAL INSTITUTE OF JAPAN, Guidelines for Maintenance and Management of Structures in Nuclear Facilities, AIJ, Tokyo, Japan, 2015. (in Japanese).

[27] UNITED STATES NUCLEAR REGULATORY COMMISSION, Determining Prestressing Forces for Inspection of Prestressed Concrete Containments, NRC Regulatory Guide 1.35.1, USNRC, 1990.

[28] JAPAN SOCIETY OF CIVIL ENGINEERS, Standard Specifications for Concrete Structures 2012, Design, JSCE, Tokyo, Japan, 2012 (in Japanese).

[29] IAEA NUCLEAR ENERGY SERIES, NP-T-3.5, Ageing Management of Concrete Structures in Nuclear Power Plants, 2016.

[30] H. Ashar, G. Bagchi, Assessment of Inservice Condition of Safety-Related Nuclear Power Plant Structures, NUREG-1522, Division of Engineering, Office of Nuclear Reactor Regulation, USNRC, 1995.

[31] UNITED STATES NUCLEAR REGULATORY COMMISSION, Degradation of Prestressing Tendon Systems in Prestressed Concrete Containment, Information Notice 99-10, Revision 1, USNRC, 1999.

[32] UNITED STATES NUCLEAR REGULATORY COMMISSION, Containment Concrete Surface Condition Examination Frequency and Acceptance Criteria, Information Notice 2010-14, USNRC, 2010.

[33] INTERNATIONAL ATOMIC ENERGY AGENCY, Break of a Prestressing System Cable in the Cylindrical Part of the Reactor Containment Shell., International Reporting System For Operating Experience (IRS),IRS Number: 7501,2002., (2002).

[34] INTERNATIONAL ATOMIC ENERGY AGENCY, Failures of containment tendon field anchor heads due to Hydrogen stress, International Reporting System For Operating Experience(IRS),IRS Number: 562, 1985.

[35] AMERICAN CONCRETE INSTITUTE, Corrosion and Repair of Unbonded Single Strand Tendons, ACI Standard 423.4R-14, ACI, November 2014.

[36] UNITED STATES NUCLEAR REGULATORY COMMISSION, NRC Inspection Report, Crystal River Nuclear Plant -- Special Inspection Report 05000302/2009007, October 12, 2010 (ADAMS Accession No. ML102861026), 2009.

[37] ENERGIFORSK 2016, Instrumentation of tendons in Forsmark 2, ISBN 978-91-7673-243-4, 2016.

[38] CLIMATIC CONDITIONS INSIDE NUCLEAR REACTOR CONTAINMENTS, by Mikael Oxfall, doctoral thesis, report TVBM-1035, Division of Building Materials, Faculty of Engineering, Lund University, Lund, 2016.

[39] UNITED STATES NUCLEAR REGULATORY COMMISSION, 10 CFR Part 50, Appendix B, Quality Assurance criteria for Nuclear Power plants, Office of the Federal, Register, National Archives and Records Administration, USNRC, Latest Edition.

[40] Oskarshamn unit 2, Reactor Containment, Experience from Inspection at Cutting openings to Drywell and Wetwell, Registration No 2021-01206E.