## AMP 313 Containment Prestressing System (VERSION 2018)

### Programme Description

This AMP provides reasonable assurance of the adequacy of pre-stressing forces in pre-stressed concrete containment tendons for intended period of operation. It focuses on loss of pre-stressing forces due to ageing phenomena of materials (creep and shrinkage of concrete, relaxation or corrosion of steel). The programme consists of an assessment of inspections performed in accordance with AMP 302. The assessment related to the adequacy of the pre-stressing force needs to establish acceptance criteria and trend lines in accordance with national codes or guidelines [1-4].

This AMP is an acceptable option to manage containment tendon prestress forces with reference to its acceptable band [5]. However, it is recommended that operating experience related to the containment tendon pre-stress force is adequately evaluated. Guidance related to the adequacy of pre-stressing force for containments with grouted tendons in some Member States is also included in this AMP.

### Evaluation and Technical Basis

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

The programme addresses the assessment in regard to tendon pre-stressing force of unbounded pre-stressed concrete containments measured in accordance with AMP 302. For bonded pre-stressed systems in concrete containments, specific guidelines for assessment of tendon pre-stressing force from some Member States such as Canada and USA are also described herein.

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

Maintaining the pre-stressing force above the minimum required value (MRV), as described in the acceptance criteria (attribute 6), ensures that the structural and functional adequacy of the containment are maintained. The said requirement is essential to be maintained during the service life of containment as per frequency of ISI mentioned in AMP 302.

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

The maintenance of the tension in the tendon is checked by adequate monitoring and recording throughout the life of the containment and during periodic tests (mechanical and air leakage). For this programme, the loss of containment tendon pre-stressing forces due to creep, elevated temperature, relaxation or shrinkage is detected by analyzing and trending the data obtained as part of AMP 302. For containments with unbonded tendons, the data includes the pre-stress force in selected sample tendons using lift-off tests. In case of containments with bonded tendons, the data for loss of pre-stress is obtained from:

1. Lift-off or equivalent test and flexural tests on test beams;
2. Lift-off tests or equivalent test on the few unbonded tendons installed in the containment with bonded tendons;
3. Measurement of strains and stresses in the bonded tendons recorded by instrumentation described in AMP 311;
4. Displacements of the containment structure measured during periodic containment pressure tests.

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

The parameters monitored are the containment tendon pre-stressing forces in accordance with AMP 302. The effective pre-stressing force measured during the service life of containment at a specific location and time differs from the initial pre-stressing force due to the time dependent pre-stressing losses. The estimated and measured pre-stressing forces are plotted against time and the predicted lower limit (PLL), MRV, and trending lines are developed for intended period of operation. For example, US NRC RG 1.35.1 [1] provides guidance for calculating PLL and MRV based on the expected variation in the systemic time dependent losses in pre-stressing forces. The trend line represents the trend of pre-stressing forces based on the actual measured forces. For example, US NRC IN 99-10 [6] provides guidance for constructing the trend line.

Force measurement is properly documented by individual reports for each tendon measurement and full history of measured forces is also maintained in database. The comparison of these forces with acceptance criteria is required to be reported in final report of ISI of concrete containment as per specified frequency mentioned in AMP 302.

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

This AMP is a condition monitoring programme and does not include actions to mitigate ageing effects.

***6. Acceptance criteria:***

The acceptance criteria normally consist of PLL and MRV. The pre-stressing force trend lines indicate that existing pre-stressing forces in the containment tendon would not be below the MRVs prior to the next scheduled inspection. The goal is to keep the trend line above the PLL because, as a result of any inspection performed in accordance with AMP 302, if the trend line crosses the PLL, the existing pre-stress in the containment tendon could go below the MRV soon after the inspection or any time within the intended period of operation of the containment structure. Further, the cause is determined, documented, evaluated, and corrected.

When test beams are used to evaluate the bonded pre-stressing system [7], the test beam that exhibit the greatest deterioration in appearance is selected for examination. The bonded test beam is flexurally tested to 95 % of the designed cracking moment and the flexural tests are considered acceptable if the test beams do not show sign of concrete cracking. The test beam is subsequently tested by chipping the concrete cover. The tendon is then taken out and examined and its condition evaluated. The condition of the tendon of the test beam is considered acceptable if no deterioration is present. In addition, a lift-off test or other equivalent test is performed on all unbonded test beams to determine the pre-stressing force. The lift off tests is considered acceptable if:

1. The pre-stressing forces are greater than the design value. The design value is calculated based on the factored material resistance, including long-term pre-stressing losses that are due to (i) shrinkage and creep of the concrete; and (ii) relaxation of the tendon;
2. There is no unusual trend indicating that the pre-stressing force could fall below the design value at any time within the service life of the containment structure.

Periodic containment pressure tests are used to evaluate the elastic response of bonded pre-stressing system. Reference [8] provides guidance and acceptance criteria for this type of tests.

***7. Corrective actions:***

If acceptance criteria are not met, then either systematic re-tensioning of tendons or a reanalysis of the containment is warranted to ensure the design adequacy of the containment.

***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 enclosure 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 ageing management.

Appropriate sources of external operating experience are references [9] as well as [5].

The applicable portions of the experience with pre-stressing systems described in US NRC IN 99-10 [7] could be useful. Additional industry operating experience has been documented in some publications [6, 10-12]. However, tendon operating experience may be different at plants with prestressed concrete containments. The difference could be due to the pre-stressing system design (e.g., button-headed, wedge, or swaged anchorages), type of steel (e.g. normal or low relaxation steel), environment (e.g. ambient temperature, humidity), and type of reactor (i.e., pressurized water reactor, boiling water reactor and heavy water reactor). Thus, the plant-specific operating experience is further evaluated for the intended period of operation.

Furthermore, reference [13] describes that in one of the pre-stressed concrete containment, unbonded test tendons were grouted due to leakage of grease and alternative inspection scheme was proposed as an alternative way to monitor the pre-stress levels in concrete. This inspection scheme included visual inspection, strain and temperature measurement on the concrete surface, overall deformation and dynamic characteristic measurements. This new inspection scheme may be validated before implementation in any other containment and any R&D is recommended.

At the time when this AMP was produced, no relevant R & D was identified.

***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 [14]).

### References

1. UNITED STATES NUCLEAR REGULATORY COMMISSION, Determining Prestressing Forces for Inspection of Prestressed Concrete Containments, NRC Regulatory Guide 1.35.1, USNRC, 1990.
2. UNITED STATES NUCLEAR REGULATORY COMMISSION, Generic Aging Lessons Learned (GALL) Report, NUREG 1801, USNRC, 2010.
3. AFCEN, RCC-CW Rules for Design and Construction of PWR Nuclear Civil Works; 2015 Edition.
4. ARCHITECTURAL INSTITUTE OF JAPAN, Guidelines for Maintenance and Management of Structures in Nuclear Facilities, AIJ, Tokyo, Japan, 2015 (in Japanese).
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. UNITED STATES NUCLEAR REGULATORY COMMISSION, Degradation of Prestressing Tendon Systems in Prestressed Concrete Containment, Information Notice 99-10, Revision 1, USNRC, 1999.
7. 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.
8. UNITED STATES NUCLEAR REGULATORY COMMISSION, Inservice Inspection of Prestressed Concrete, NRC Regulatory Guide 1.90, USNRC, 2012.
9. INTERNATIONAL ATOMIC ENERGY AGENCY, Ageing Nuclear Energy Series Management of Concrete Structures in Nuclear Power Plants, No. NP-T-3.5, 2016.
10. D. J. Naus, Concrete Component Aging and its Significance to Life Extension of Nuclear Power Plants, NUREG/CR-4652, Oak Ridge National Laboratory, 1986.
11. H. Ashar, and D.J. Naus, Prestressing in Nuclear Power Plants, Concrete International, American Concrete Institute, Detroit, Michigan, 1994.
12. UNITED STATES NUCLEAR REGULATORY COMMISSION, A Summary of Aging Effects and Their Management in Reactor Spent Fuel Pools, Refueling Cavities, Tori, and Safety-Related Concrete Structure, NUREG/CR-7111, USNRC, 2012.
13. Z. Sun, S. Lin and Y. Xie, Strength monitoring of a prestressed concrete containment tendons, Nuclear Engineering and design, p. 213-220, 2002.
14. 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.