**AMP 309 NON-METALLIC LINER (VERSION 2018)**

### Programme Description

This AMP provides guidance for in-service inspection (ISI) of non-metallic liners which are installed to enhance the leak tightness of concrete containment structures (CCSs) in NPPs. This AMP contains the essential attributes of an effective ageing management programme in accordance with the IAEA Safety Guide No. NS-G-2.12 [1] or the national regulatory requirements [2].

The non-metallic liner (e.g., urethane, epoxy coating, elastomeric) is generally applied to the interior surfaces of the CCSs. Material qualification, installation and testing requirements for the non-metallic liner during original construction and subsequent repair and replacement follow, for example, the requirements in accordance with the codes and standards [3-7].

The main function of the non-metallic liner is to reduce the leakage of air from inside the containment structure to the outside environment during operating life of the plant. It also provides a smooth surface which can be easily decontaminated.

During operation phase of the plant, inspection and testing of the non-metallic liner is performed in accordance with approved plant procedures as required by the code [8]. These plants procedures require periodic ISI, testing and repairs if necessary, of the non-metallic liner at a frequency in accordance with the requirements of the code or as agreed upon with the regulatory authority.

### Evaluation and Technical Basis

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

The scope of this AMP covers the non-metallic liners for concrete containment structures of CANDU NPPs. The non-metallic liner is coated on the interior surfaces of the concrete containment structures to enhance the leak tightness of such structures.

ISI of non-metallic liners is required to demonstrate that they function effectively for the whole intended period of operation of the plant to ensure that the CCSs can meet the regulatory leakage rate requirement. The acceptability of 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 liners for concrete containments and their integral attachments are not within the scope of this AMP. The steel liners and their integral attachments are within the scope of AMP 301. The concrete portions of the containment structures are within the scope of AMP 302 and protective coating material is within the scope of AMP 308.

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

This programme is a condition monitoring programme. However, non-metallic liner materials are qualified prior to being used. The effect of radiation, the leakage rate, elasticity, chemical resistance, ease of decontamination, impact resistance, adhesion, fire resistance, abrasion resistance, heat ageing and immersion of the liner material are determined in accordance with the code [3]. Heavy traffic due to equipment and machinery as well as heat source are avoided in the vicinity of the liner area to avoid any potential damage to the material.

1. ***Detection of ageing effects:***

The primary ISI method is the visual inspection which consists of looking for any visible signs of deterioration such as blisters, cracks, tears, cuts, abrasions, burns and other signs of degradation [8]. When the acceptance criteria are exceeded, evaluation of the inspection results is performed by qualified personnel. Recommendation for repair, further evaluation or expansion of inspection scope is provided.

The adhesion loss between the non-metallic liner material and the substrate surface, can occur in the liners. This will result in blisters or bubbles in the liner material and is generally caused by improper preparation of the substrate surface prior to the installation of the liner material. This can also be caused by air trapped behind the liner during the depressurization phase of the leakage rate test of the CCSs.

Mechanical damages can be caused by contact or impact with moving equipment and material, in particular heavy and high traffic areas. Signs of degradation include tears, cuts, cracks, abrasions, gouges, loose or peeling material and discoloration, etc. Damage to the liner can result in loss of leak tightness and difficulty in cleaning the surface of the CCSs and thus resulting in contamination on the surface.

Damage in non-metallic liners can also be caused by irradiation. The mechanical properties of the liner material can be affected which can include reduced elasticity and adhesion. The degree and rate of degradation is in general proportional to the radiation dose. The most vulnerable location will likely be near the steam generators and areas of the containment structures exposed to direct radiation field. Degradation due to irradiation can cause premature local failure of the liner and reduction in the leak tightness.

Damage of the non-metallic liner can also be in the form of burns in the vicinity of equipment and systems of high operating temperature.

With the exception of inaccessible areas, all surfaces are monitored by virtue of the examination requirements on a scheduled basis.

For example, the Canadian Code CSA N287.7-17 “In-service Examination and Testing Requirements for Concrete Containment Structures for Nuclear Power Plants” [8] stipulates that for the inspection and examination of non-metallic liners, the following are required:

* Accessible non-metallic liners, coatings, and joint sealants are examined at a frequency equal to or at minimum that of integrated leakage rate testing (ILRT), and in approximately equal time intervals, within the examination period;
* For inaccessible non-metallic liners, coatings, and joint sealants, the examination is at a frequency agreed upon by the operating organization and the regulatory authority;
* The frequency of examination is increased as specified by the in-service examination lead for non-metallic liner that have exhibited significant deterioration during previous examinations or have known defects or are subjected to degradation mechanisms that could adversely affect the integrity of the structure;
* Prior to station restart, following the occurrence of abnormal/environmental loads that exceeded those specified in the design specification, non-metallic liner is subjected to an examination to evaluate the integrity of the structure.

Visual inspections are performed, by line of sight from available viewing angles from ﬂoors, platforms, walkways, etc. The visual inspections are performed with adequate illumination to detect evidence of degradation and abnormal surface conditions, etc. Location and condition of the inspected area is recorded on the inspection sheets and the required data are filled in noting any observations of damage or degradation.

The leakage rate test for the CCSs also provides an indication on the performance on the leak tightness of the non-metallic liner. The leakage rate test of the CCSs is performed at a frequency in accordance with the code requirements [8] or as agreed upon between the plant and the regulatory authority.

Other methods of testing for the non-metallic liners include in-situ “Pull Test” and physical tests at the laboratory to determine mechanical properties. The “Pull Test” is performed by a qualified inspection organization. To perform this test, the test surface of the liner is cleaned with a suitable degreaser and the surface is properly abraded. Epoxy adhesive to the test area and the underside of the steel disc is applied with excessive adhesive removed. The adhesive is then allowed to cure for 24 hours. The Pull Test Device is threaded to the steel disc adhered to the liner and a maximum tensile load is applied gradually and the results are recorded [3].

Physical test of the liner can also be performed to determine if the liner’s integrity has deteriorated since the last inspection. The physical tests follow industry wide test procedures such as the American Society for Testing and Materials (ASTM) [9-11]. A liner sample can be cut, removed, checked for contamination and provided to a laboratory for physical testing in accordance with the requirements of the station procedure. This can include tests for tensile strength, tensile stress at 100 %, % elongation, tear strength and durometer hardness test. Repairs to the test and affected area are performed to restore the affect area to meet the original design intent.

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

The methods for monitoring, recording, evaluating, and trending the data that result from the programme’s inspections provide for identification of adverse ageing trends such that corrective action can be performed as necessary in a timely manner. The trending of the performance of the liner material can be achieved by comparing the record of visual inspection and other tests with previous results.

1. ***Mitigating ageing effects:***

This AMP is a condition monitoring programme and no mitigating ageing effects are intended.

1. ***Acceptance criteria:***

When the acceptance criteria are exceeded, evaluation of the inspection results is performed by a qualified personnel and recommendation for repair, further evaluation or expansion of inspection scope is provided.

The programme provides examination acceptance criteria for the inspections. The programme contains the following types of examination acceptance criteria:

* For visual inspection, the acceptance criterion is the absence of any visible signs of deterioration such as blisters, cracks, tears, cuts, abrasions, burns and other signs of degradation;
* For pull tests, the minimum acceptable pull-off adhesion value is based on the original installation specification for the type of non-metallic liner. The failure criteria of the liner during the pull test is also defined [3];
* For the physical tests, the acceptance criteria are based on the original installation specification for the type of non-metallic liner. The test follows international standards such as American Society for Testing and Materials (ASTM).

Areas that show signs of deterioration require an engineering evaluation or correction by repair or replacement.

1. ***Corrective actions:***

Repair and/or replacement of the non-metallic liners are performed in accordance with pertinent governing requirements or guidance documents for the plant. Detected conditions that do not satisfy the examination acceptance criteria are required to be dispositioned through the plant corrective action programme, which may require repair, replacement, or analytical evaluation for continued service until the next inspection. The disposition will ensure that design basis functions of the non-metallic liners will continue to be fulfilled for all licensing basis events.

Examples of methodologies that can be used to analytically disposition unacceptable conditions include engineering evaluation methods, as well as supplementary examinations to further characterize the detected condition, or, alternatively, repair and replacement procedures.

Measures are established to assure that conditions adverse to quality, such as failures, malfunctions, deficiencies, deviations, defective material and non-conformances are promptly identified and corrected. In the case of significant conditions adverse to quality, the measures assure that the cause of the condition is determined and corrective action taken to preclude repetition. The identification of the significant condition adverse to quality, the cause of the condition, and the corrective action taken are documented and reported to the plant responsible engineer.

1. ***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 ageing management.

Appropriate sources of external operating experience are Ageing Management of Concrete Structures in Nuclear Power Plants (IAEA Nuclear Energy Series No. NP-T-3.5 (2016) [12].

The current non-metallic liner (Normac) used in the CANDU NPPs was selected as a supplementary to the original epoxy liner (rigid material) which was deemed not satisfying the requirements of a liner because mainly of its rigidity. At one NPP in Canada, since the application of Normac began in 1989, the leakage rate of the CCS has decreased or remained relatively stable with each major application programme. Up-to-date, visual inspection of the Normac liner has revealed no significant problems or concerns regarding the Normac liner on the floor or on the walls of the reactor building. One problem, which occurs during depressurization after the leakage rate test is the delamination or “blistering” of the Normac liner. The blisters are air filled and are likely the result of air trapped in the concrete while the reactor building is pressurized. During depressurization, the entrapped air escapes to the nearest lower pressure boundary by the shortest path possible and gets trapped behind the liner. At the NPP, these blisters are removed and repaired in accordance with the plant procedure. The liners on the floors are typically in good condition, particularly in low traffic areas. Some damage has occurred in high traffic areas and routine repairs have been carried out.

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

1. ***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., CSA N286-12 [13]).

### References:

1. INTERNATIONAL ATOMIC ENERGY AGENCY, Ageing Management for Nuclear Power Plants, IAEA Safety Standards Series, No. NS-G-2.12, IAEA, Vienna (2009).
2. CANADIAN NUCLEAR SAFETY COMMISSION, Fitness for Service: Aging Management, CNSC Regulatory Document 2.6.3, CNSC, Ottawa, Canada (2014).
3. CANADIAN STANDARD ASSOCIATION, Material Requirements for Concrete Containment Structures for Nuclear Power Plants, CSA N287.2-17, CSA, Mississauga, Ontario, Canada (2017).
4. CANADIAN STANDARD ASSOCIATION, Construction, Fabrication, and Installation Requirements for Concrete Containment Structures for CANDU Nuclear Power Plants, CSA N287.4-09, CSA, Mississauga, Ontario, Canada (R2014).
5. CANADIAN STANDARD ASSOCIATION, Examination and Testing Requirements for Concrete Containment Structures for Nuclear Power Plants, CSA N287.5-11, CSA, Mississauga, Ontario, Canada (R2016).
6. CANADIAN STANDARD ASSOCIATION, Pre-operational Proof and Leakage Rate Testing Requirements for Concrete Containment Structures for Nuclear Power Plants, CSA N287.6-11, CSA, Mississauga, Ontario, Canada (R2016).
7. CANADIAN STANDARD ASSOCIATION, Aging management for concrete containment structures for nuclear power plants, CSA N287.8-15, CSA, Mississauga, Ontario, Canada (2015).
8. CANADIAN STANDARD ASSOCIATION, In-service Examination and Testing Requirements for Concrete Containment Structures for Nuclear Power Plants, CSA N287.7-17 CSA, Mississauga, Ontario, Canada (2017).
9. AMERICAN SOCIETY FOR TESTING MATERIALS, ASTM D412-16, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers-Tension, ASTM, West Conshohocken, PA, USA.
10. AMERICAN SOCIETY FOR TESTING MATERIALS, ASTM D624-00, Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers, ASTM, West Conshohocken, PA, USA.
11. AMERICAN SOCIETY FOR TESTING MATERIALS, ASTM D2240-15, Standard Test Method for Rubber Property Durometer Hardness, ASTM, West Conshohocken, PA, USA.
12. INTERNATIONAL ATOMIC ENERGY AGENCY, Ageing Management of Concrete Structures in Nuclear Power Plants (IAEA Nuclear Energy Series No. NP-T-3.5, (2016).
13. CANADIAN STANDARD ASSOCIATION, Management System Requirements for Nuclear Power Plants-Second Edition, CSA N286, CSA, Mississauga, Ontario, Canada (2012).