**AMP 142 CANDU/PHWR FUEL HANDLING (VERSION 2017)**

**Programme Description**

The main objective of this programme is timely detection and mitigation of ageing degradation of mechanical components/assemblies of the fuel handling systems of CANDU and CANDU/PHWR in conformance with the guidelines, codes and standards applicable by the Member States, to ensure their integrity and functional capability through plant service life. Ageing management guidelines for nuclear power plants are also given in safety guide [1].

The on-power fueling operations are carried out by two remotely controlled fueling machines, operating at each end of a fuel channel. While new fuel bundles, from one-fueling machine are inserted into a fuel channel, irradiated fuel bundles from that channel are received into another fueling machine clamped at another end. Either machine can load or receive fuel. The fueling machines receive new fuel while connected to the new fuel port and discharge irradiated fuel while connected to the discharge port. The entire fuel handling operation is automated. The irradiated fuel is transported to the Spent Fuel Storage Bay for interim-term storage, and subsequently transferred to dry fuel storage for long-term storage of the fuel.

The fuel handling system comprises of fueling machine head, fueling machine (including columns, bridge and carriages), ball and screw assembly, ram assembly, fuel transfer port, etc. A complex system of mechanical, hydraulic and computer based controls ensures accurate positioning and the required operating forces for the fuel handling devices during the oft-repeated operations involved in connecting/disconnecting to the fuel channels and primary heat transport system of the reactor. The system design and operating procedures ensure safety during refueling operations.

The mechanical components of the fuel handling system work in a high radiation environment and there is relative motion between the parts of the assemblies. Under these conditions, the materials/components undergo degradation due to mechanisms such as general wear and tear, erosion, corrosion, irradiation damage, vibration, etc. Over a period of time, the effects of these degradation mechanisms may hinder the relative movement of parts or can affect the functioning of the overall component or assembly, such that they need to be replaced. Therefore, effective ageing management of these degradation mechanisms require a comprehensive programme for maintenance, inspection, and replacement of these parts / components at appropriate time intervals to ensure fitness for service of the components/assemblies of the fuel handling system. This programme manages the effects of ageing primarily through a combination of visual inspections and condition monitoring/measurement for evidence of loss of material due to wear and tear, erosion, corrosion, cracking and change in material properties.

Technological obsolescence, which can be an issue for critical spare replacement parts of the fuel handling system (e.g. mechanical shaft encoders, port valves and other system control valves, flow meters, mechanical cables, as well as electrical, and instrument and control equipment, etc.) is managed in accordance with TOP 401.

**Evaluation and Technical Basis**

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

The programme includes assessments that ensure the fitness for service and continued reliable operation of the fuel handling system in CANDU/PHWR to show that: (1) ageing effects due to wear and tear, erosion and corrosion do not hinder the relative movement of the components in the assemblies, carriages, bridge and columns (using data primarily obtained by periodic measurements); and (2) that components prone to irradiation and thermal ageing damage are replaced at regular intervals.

The objective of formulating the life management programme for the components/assemblies of the fuel handling system has been to address the various degradation mechanisms and their mitigation through research and development in the fields of design, manufacture, operational experience, and in-service inspection. Ageing degradation mechanisms of included in this programme are:

* General wear and tear;
* Erosion and corrosion;
* Vibration;
* Irradiation damage;
* Thermal damage.

The programme may also be credited with managing loss of material of metallic components and with loss of material, cracking, and change in material properties of elastomers, for given material and environment combinations. This programme manages the effects of ageing of polymer materials in all environments to which these materials are exposed. The degradation mechanisms on polymers include surface cracking, discoloration, crazing, scuffing, hardening of material and dimensional changes.

The programme consists of periodic visual inspection [2-3] of metallic and elastomeric components. The programme also includes procedures or administrative controls to assure that the structural integrity of the fuel handling system containing radioactive material is maintained.

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

The reactor fuel handling systems are call for very high reliability of operation and integrity throughout the reactor life span. Hence the critical components of these systems are designed, constructed, and environmentally qualified to high quality and engineering standards as stipulated in national requirements and codes such as [4-6].

This is primarily a condition monitoring programme that includespreventive maintenance and inspections of all the critical components/assemblies of the fuel handling system on a timely basis in a planned manner to address normal wear and tear of metallic components, cracking and loss of strength of the elastomeric components in order to prevent failures.

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

This ageing management programme utilizes periodic plant system inspections and walk-downs to monitor for material degradation and leakage. This programme inspects components such as fuelling machine components, fuelling machine heavy water cooling system, fuel transfer system components, shuttle transport system components, catenaries, hoses, bearing pads and other metallic and elastomeric components.

For metallic components, the detection of ageing effects is primarily by visual inspection. Examples of inspection parameters for metallic components include:

* Wear, tear, erosion/corrosion and material wastage (loss of material);
* Leakage from or onto external surfaces (loss of material);
* Worn, flaking, or hardened surfaces (loss of material);
* Corrosion stains on thermal insulation (loss of material);
* Protective coating degradation (cracking, flaking, and blistering);
* Leakage for detection of cracks on the external surfaces of stainless steel.

For metallic components, deterioration of the protective coating can be an indicator of possible underlying degradation such as corrosion, or leakage.

The ageing effects for flexible polymeric components may be monitored through a combination of visual inspection and manual or physical manipulation of the material. “Manual or physical manipulation of the material” means touching, pressing on, flexing, bending, or otherwise manually interacting with the material. The purpose of the manual manipulation is to reveal or detect changes in material properties, such as hardening, and it can also help make the visual examination process more effective in identifying ageing effects such as cracking. Examples of inspection parameters for polymers include:

* Surface cracking, crazing, scuffing, and dimensional change (e.g., “ballooning” and “necking”);
* Discoloration;
* Exposure of internal reinforcement for reinforced elastomers;
* Hardening of the material as determined by a loss of suppleness.

Visual inspection will identify indirect indicators of flexible polymer hardening or loss of strength and include the presence of surface cracking, crazing, discoloration, and, for elastomers with internal reinforcement, the exposure of reinforcing fibers, mesh, or underlying metal. Visual inspection is 100 % of accessible components. Manual or physical manipulation can be used to augment visual inspection to confirm the absence of hardening or loss of strength for flexible polymeric materials (e.g., reinforced EPR) where appropriate. The sample size for manipulation is at least 10 percent of available surface area. Hardening or loss of strength and loss of material due to wear for flexible polymeric materials are expected to be detectable before any loss of intended function.

When required by national regulations or governing documents [2-3], inspections are conducted in accordance with the applicable code requirements. In the absence of applicable requirements, plant-specific visual inspections are performed of metallic and polymeric component surfaces using plant-specific procedures implemented by qualified inspectors [7-8]. The inspections are capable of detecting age-related degradation and are performed at a frequency not to exceed duration given in the operating plant’s procedure for inspection. This frequency accommodates inspections of components that may be in locations that are normally only accessible during outages. Surfaces that are not readily accessible during plant operations are inspected when they are made accessible and at such intervals that would ensure the components’ intended functions are maintained. Surfaces that are insulated may be inspected when the external surface is exposed (i.e., during maintenance) at such intervals that would ensure that the components’ intended functions are maintained. The intervals of inspections may be adjusted, as necessary, based on plant-specific inspection results and industry operating experience.

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

The programme uses standardized monitoring and trending activities to track degradation. Inspections, testing and preventive maintenance are performed as per the extent and schedule given in attributes 2 and 3. The results of these activities are monitored and trended for ageing effects which degrade the performance and functioning of the fuel handling systems. Deficiencies are documented using approved processes and procedures, such that results can be trended.

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

Inspections, testing and preventive maintenance are performed as per the extent and schedule given in attributes 2 and 3. The results of these activities are evaluated to determine the need for mitigating actions. The mitigating actions may include removal of surface indications, adjusting preventive maintenance and parts replacements, carrying out repairs or overhauling components, or design changes such as to improve the geometry, materials, stress levels, protective coatings, connector types.

***6. Acceptance criteria:***

For each component/ageing effect combination, the acceptance criteria are defined to ensure that the need for corrective actions will be identified before loss of intended functions.

* For metallic surfaces, any indications of relevant degradation detected are evaluated. For stainless steel surfaces, a clean, shiny surface is expected. The appearance of discoloration may indicate the loss of material on the stainless steel surface;
* For flexible polymers, a uniform surface texture and uniform color with no unanticipated dimensional change is expected. Any abnormal surface condition may be an indication of an ageing effect for metals and for polymers;
* For flexible materials, changes in physical properties (e.g., the hardness, flexibility, physical dimensions, and color of the material are unchanged from when the material was new) are evaluated for continued service in the corrective action programme. Cracks are absent within the material;
* For rigid polymers, surface changes affecting performance, such as erosion, cracking, crazing, checking, and chalking, are subject to further investigation.
* Acceptance criteria include design standards, procedural requirements, current licensing basis, industry codes or standards, and engineering fitness-for-service evaluation.

***7. Corrective actions:***

The inspection results for indications are evaluated based on the acceptance criteria in Attribute 6 to determine the need for corrective action. If required, a corrective action plan, which includes repair, replacement, operation with restrictions, or other mitigating actions, is developed and implemented. Modifications, repairs or replacements are performed as per the codes and standards, site quality assurance procedures, review and approval processes, and the requirements of operating plants procedure manual in the member states.

***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.

KANUPP-1 fuelling machines have been in service since its commissioning in the early 1970’s and, as of 2017, has fuelled over 17,000 channels involving over 25,000 fuel bundles till now. Before re-licensing in 2001, these machines were required to remain in-service beyond their original intended design life. Therefore, these machines were assessed by an IAEA expert under ISFoK Safety Case#3 in March 2001 to improve the safety features of KANUPP fuelling machines and related system. A number of recommendations were made by the expert and most of these were implemented [9]. Since then, more than twelve years have been passed and to assure continued safety, it was suggested by the regulatory authorityto re-assess/evaluate the present condition of critical components of fuel handling system once more. Therefore internal efforts were made by the plant fuel handling section to assess the critical components (from mechanical point of view) of the fuelling machines and prepared this report with same idea. The assessment performed was based on the maintenance records and performance of these components and then compared with the design specifications available within the Fuel Handling Section.

Sources of research and development activities relevant to this AMP include the Candu Owners Group (COG), Canadian Nuclear Laboratories (CNL) and CANDU Energy Inc. in Canada, as well as Korea Institute of Nuclear Safety (KINS) and Bhabha Atomic Research Centre (BARC) in India.

***9. Quality management:***

Administrative controls, quality assurance procedures, review and approval processes, are implemented in accordance with the different national regulatory requirements (e.g., CSA N286-05 [10]).

**References**

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