### AMP 149 CANDU/PHWR Heavy Water Management (VERSION 2020)

### Programme Description

The objective of the programme is to minimize heavy water leakages and losses and maintaining the minimum system inventories of heavy water for the primary heat transport and moderator systems. Heavy water is systematically managed in such processes as classification, storage, transfer, recovery, and inventory management of heavy water in use through the operation of the heavy water handling management procedure. Focus of heavy water management is given on preventing heavy water leakage accident, prompt recovery of downgraded heavy water to increase economic effects and reducing radiation exposure caused by diffusion. For this, taking into consideration the design and fabrication characteristics and operation experience, the existence of related procedures and their effectiveness are reviewed to confirm whether the existing programmes could remain valid during the intended period of operation [1]. Major considerations include (a) assuring that the components comprising the systems related with heavy water management will perform stable operation for the intended period of operation, and (b) confirming that the performance tests and maintenance and management programmes are implemented for the components associated with heavy water management.

The main sources of heavy water leakage during normal operations are related to fuel handling, system sampling and maintenance activities (i.e. fuel channel closure plugs, graylocs, valve packing, gasket leaks, pump seals, equipment draining for maintenance, minor leaks from heat exchanger tubes, swagelocks, failed welds, etc.). Therefore, other ageing management programmes that are relevant and integral to this programme include AMP 103, AMP 142, AMP 143, AMP 144, and AMP 145.

### Evaluation and Technical Basis

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

This programme covers the systems related to the supply, inventory management, consumption, and recovery of heavy water. The systems within the scope include the D2O collection system, D2O supply system, D2O vapour and liquid recovery systems, D2O clean-up system, and D2O upgrading system. The D2O supply system plays the role of central storage and supply of heavy water. It is designed to store newly introduced heavy water and supply it to the primary heat transport and moderator systems when needed. The D2O vapour and liquid recovery systems assists in preventing tritium contamination by recovering leaked vapour or liquid heavy water during reactor operation, shutdown or maintenance periods. The D2O clean-up system removes organic particles and dissolved ionic impurities from the heavy water recovered during plant operation and supplies it to D2O upgrading system. The D2O upgrading system distils the water in which heavy and light water are mixed to produce heavy water having reactor-class purity.

The primary ageing degradation in these systems is corrosion induced loss of material, that can occur at the connection points of components, such as tanks and pumps. Other sources of heavy water leakages can be from wear and tear / usage of valves, gaskets and connections, fittings [2-4].

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

The prevention and mitigation of heavy water loss are conducted by through plant walkdown inspections and preventive operations and maintenance, such as controlling water chemistry, following approved procedures for opening and closing connections, maintaining protective coatings and cathodic protection systems. The plant operating procedures require regular/periodic monitoring of the locations where leakages are likely to occur.

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

This ageing management programme utilizes on-line tritium monitoring and chemistry monitoring, periodic plant system inspections and walk-downs to monitor for material degradation and leakage in the heavy water management systems.

It is necessary to continuously monitor for the presence of tritium in the air inside the building to detect any leakage of heavy water, as well as through visual inspection of the locations where system leakages are likely to occur. As operation years increase, the concentration of tritium in the moderator heavy water rises (unless a tritium removal facility / programme is available). The plant implements leakage management of the primary heat transport and moderator systems to preserve heavy water inventory and detect any heavy water leakage. This includes chemistry monitoring and sampling of the heavy and light water systems for indications of leakage or contamination.

In accordance with the plant operating procedures for heavy water consumption/recovery measurement and management, the following are measured: the amount of heavy water consumed as a gaseous and liquid status by the primary heat transport system; the amount of heavy water recovered by vapour recovery system; and the amount of heavy water recovered as a liquid status. As to the consumption of heavy water, the following are measured and monitored: daily consumption of small amount of heavy water occurring without special heavy water leakage accident; consumption of heavy water that exceeds the scope of normal consumption; and consumption of heavy water supposed to have occurred or be proceeding due to leakage.

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

The ageing of the heavy water management systems is routinely assessed and monitored through a combination of in-service inspections, leakage monitoring and testing, and / or performance & condition monitoring programmes.

To measure and manage the amount of heavy water consumption and recovery that occurs during the operation of the plant, a plant specific procedure is implemented. The consumption of heavy water is measured and managed every day. There are two methods to measure heavy water consumption: direct method using heavy water concentration and indirect method using tritium concentration. The indirect method is applied when measuring heavy water consumption by the direct method is impossible, when the analyzed values are not reliable due to such causes as the contamination of samples, or in other inevitable cases.

The parameter monitored or inspected for heavy water management programme is the loss of material caused by corrosion that can occur on system components. To preserve heavy water inventory, it is monitored, through the heavy water leakage monitoring equipment, whether the intended functions of components are lost due to material deterioration caused by such ageing effects as corrosion.

The equipment for leakage detection is operated to monitor the leakage of light water. It is also used for monitoring leakage of small amount of coolant to control unnecessary consumption of heavy water in accordance with relevant operating procedures.

A procedure is also prepared to confirm that heavy water upgrader maintains proper performance and to establish measures for enhancing performance, if needed, considering the trend of changes in the performance of heavy water upgrader.

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

The main objective of this programme is to mitigate the loss of material due to corrosion in system components through the leakage management. 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 adjusting preventive maintenance and parts replacements, carrying out repairs or overhauling components, or design changes to improve materials, protective coatings, connector types, etc.

1. ***Acceptance criteria:***

Acceptance criteria include design standards, operating limits, procedural requirements, current licensing basis, industry codes or standards, and engineering fitness-for-service evaluation. The consumption of heavy water is measured and managed every day in accordance with relevant plant operating procedures. The annual consumption of heavy water is continuously managed. As to the annual consumption of heavy water, sufficient margin is secured as its amount of recent annual consumption is within 1 % (one tenth of design prediction) of the total system water during normal operation.

1. ***Corrective actions:***

The focus of heavy water stock management is given to the consumption of heavy water to a degree exceeding the acceptance criteria or the occurrence of unexpected heavy water leakage. When the area of leakage and corroded location are identified, appropriate actions including repair and replacement are taken to prevent recurrence of deterioration in accordance with relevant procedures. Such actions include (a) reducing the probability of heavy water leakage which can be caused by corrosion degradation and (b) changing current plant design and operation process including the usage of valves/pumps that can prevent leakage, the welding of piping for repair, and the usage of material with high corrosion resistance.

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 the ageing management.

Ageing degradation of components and sub-components resulting in the heavy water leakage has been generally reported. So, plants make effort to reduce the heavy water leakage through the facility improvement and the compliance of a maintenance procedure. Therefore, the management of the heavy water is effectively conducted to reuse the withdrawn heavy water through D2O upgrade process by withdrawing the leaked heavy water.

The OPEX at Embalse NPP, related to Heavy Water Management can be summarized as follows. At the start of the refurbishment outage (after defueling), the heavy water inside the Primary Circuit was completely drained and stored in a tank, previously reconditioned and adapted, outside the reactor building. New piping and pumps were installed for this purpose. All the necessary measurements were put in place to detect and avoid any minimal and potential leakage. After the refurbishment outage finished, the heavy water was pumped back to their circuit using the same piping and pumps. An alternative back-up storage tank was also prepared to store the heavy water in case the first choice had developed a leak. At the end of all these maneuvers, the amount of heavy water pumped backed to the Primary Circuit was measured to be the same as what was originally removed. This represented a successful case of heavy water management at Embalse NPP.

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

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

1. ***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 [5]).

### References

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Safety Standard Series No. SSG-48, Ageing Management and Development of a Programme for Long Term Operation of Nuclear Power Plants, Specific Safety Guide, IAEA, Vienna, 2018.

[2] AMERICAN NATIONAL STANDARDS INSTITUTE, Power Piping, ANSI B31.1

[3] AMERICAN NATIONAL STANDARDS INSTITUTE, Steel Measurement and Control Technology, ANSI B16.5.

[4] AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Pressure Vessels, The ASME Boiler and Pressure Vessel Code, Section VIII.

[5] CANADIAN STANDARDS ASSOCIATION, Management System Requirements for Nuclear Facilities, CSA N286, CSA, Toronto, Canada.