**AMP 150 CANDU/PHWR ANNULUS GAS SYSTEM (VERSION 2021)**

**Programme Description**

The objective of the programme is to ensure the integrity of annulus gas system (AGS) by managing the effects of ageing on the system during the intended period of operation, taking into consideration the design, fabrication characteristics, and operating experience. This includes (a) deriving the ageing phenomena that can occur on the components of the annulus gas system, and (b) establishing the measures to manage the effects of ageing on the components of the annulus gas system.

**Evaluation and Technical Basis**

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

The AGS circulates dry carbon dioxide (CO2) through the annular space between fuel channel pressure tube and calandria tube for the purposes of detecting leakage from pressure tubes or calandria tubes, and for preventing the corrosion of fuel channel components by protecting the oxide film on the outer wall of pressure tube. Major components of the AGS are the tubing/piping, valves, circulation pump, flowmeters, compressors and heat exchangers, which are constructed in accordance with applicable national codes and standards such as [1-2]. The relevant ageing effects include loss of material due to corrosion or wear, loss of sealing function due to hardening, and cracking due to fatigue. The programme manages the ageing effects on these components caused by such phenomena.

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

Preventive actions to minimize and control ageing degradation due to corrosion of the AGS components include implementation of appropriate operating procedures, with monitoring and control of the annulus gas humidity and chemistry during normal operation, regular system purging, and preventive maintenance actions. A stable supply of carbon dioxide (CO2) to the annulus gas system is secured by periodically alternating the usage of gas cylinder banks or bulk CO2. Appropriate chemistry management is implemented and periodic examinations and tests are performed to satisfy the acceptance criteria for the functions of the annulus gas system during normal operation. Additionally, all O-rings are periodically replaced to prevent leakage caused by O-ring hardening.

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

Methods to detect ageing effects of the AGS include:

* The major components comprising the system are periodically maintained and inspected for damage by corrosion, wear or cracking, and replaced or overhauled.
* Flow by each group of channels: The flow of each group of channels is monitored online. When the outlet filter flow alarms on low flow, relevant procedures are followed to take measures needed to restore normal condition. Changes in AGS flow may indicate corrosion or leakage of the AGS subcomponents.
* Dew point temperature: The increase in moisture within the annulus gas system requires close monitoring as it can mean heavy water leakage from a pressure tube or a calandria tube. The moisture within the annulus gas system is managed not to exceed the limits. The moisture increases in the annulus gas system is monitored online at the main control room through the input signals from dew point detectors and a leakage detector.
* Concentrations of deuterium, oxygen, and nitrogen: Concentrations of deuterium, oxygen, and nitrogen in the annulus gas system are measured and monitored through periodic tests which may indicate degradation or malfunction of parts of the AGS, though the primary aim of these chemistry controls is for protection of fuel channel components. The management of deuterium aims at minimizing the inflow of hydrogen into pressure tubes which are made of Zirconium alloy. The management of oxygen is implemented to maintain the stability of protective oxide film that controls hydrogen inflow into calandria tubes and pressure tubes. Nitrogen concentration is included in the management items to control the increase in radiation level of annulus gas, but it is managed to maintain a level less than the acceptance criteria as nitrogen can cause corrosion on fuel channel bellows. For these, examinations are implemented in accordance with plant operating procedures.

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

The chemistry parameters of the AGS are periodically monitored and trended for changes which may indicate ageing effects on the AGS (see attribute 3). The system is systematically managed taking into consideration changes in chemistry conditions of the system following the operational conditions including start up, shutdown, special operation, and abnormal operation.

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

Ageing effects are mitigated primarily by maintaining AGS chemistry / purity and by maintenance of system components, pumps and valves. When the effects of ageing degradation or monitored parameters exceed the acceptance criteria, actions are taken in accordance with operating and maintenance procedures to correct or mitigate the ageing effect.

1. ***Acceptance criteria:***

The dew point temperature and concentrations of deuterium, oxygen, and nitrogen in the annulus gas system are tightly controlled within the plant specific acceptance criteria. Fitness for service or acceptance criteria for AGS components are given in the design and operating performance specifications, maintenance manuals and applicable codes for the AGS components.

1. ***Corrective actions:***

The ageing degradation of the annulus gas system could cause the deterioration of its intended safety function (leak detection and corrosion protection of pressure tubes). Appropriate corrective actions are to be taken when the parameters monitored for the management of ageing effects on the annulus gas system exceed the acceptance criteria, or when components of the system. Corrective actions are implemented per plant specific procedures including AGS chemistry management, plant inspection and maintenance procedures, and corrective action programme.

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.

Annulus gas leakage was frequently experienced due to hardening of the O-rings inside the AGS flowmeters which monitor the flow of carbon dioxide inside the annular spaces. Therefore, all O-rings were replaced and defective parts were repaired during overhaul. To improve the reliability, the operating and chemistry control procedures were also revised based on the results of regular inspections and overhauls.

Sources of operating experience include CANDU Owners Group (COG) database which includes operating experience of all CANDU reactors, and International Reporting System for Operating Experience (IRS).

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

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 N286-05 [3]).

**References**

[1] AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Nuclear Power Plant Components, The ASME Boiler and Pressure Vessel Code, Section III.

[2] CANADIAN STANDARDS ASSOCIATION, General Requirements for Pressure Retaining System and Components, CSA N285.0, CSA Toronto, Canada.

[3] CANADIAN STANDARDS ASSOCIATION, CSA N286-05, Management system requirements for nuclear power plants, CSA, Toronto, Canada.