## AMP 155 PWR RESIDUAL HEAT REMOVAL HEAT EXCHANGERS (VERSION 2020)

### Programme Description

Residual Heat Removal System (SRH) removes the residual heat from reactor core, sensible heat from the reactor coolant system at a controlled rate. This is an engineered safeguard system, which includes two 100% capacity residual heat removal pumps, two 50 % capacity, vertical, shell-and-U-tube type residual heat removal heat exchangers. Reactor coolant passes on tube side made of stainless steel (SS) while shell side made of carbon steel (CS) carries component cooling water (CCW). SRH heat exchangers are considered critical components as these are designed to remove decay heat and residual heat from the reactor coolant system pressure boundary so that refuelling and primary system servicing can be performed.

The objective of this programme is to manage the ageing of the SRH heat exchangers in PWR nuclear power plants. Heat exchanger (HX) performance monitoring, ageing effects identification, mitigation and corrective actions plan development and its implementation are requirements of this programme which are necessary to ensure that they continue to perform their required function and meet performance objectives throughout the design life and for life extension period.

**Evaluation and Technical Basis**

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

This programme is applicable to the managing of the ageing of shell-and-U-tube type heat exchangers in Residual Heat Removal System in PWR nuclear power plants. The active or potentially active degradation mechanisms in the SRH heat exchangers are Intergranular Stress Corrosion Cracking (IGSSC), Mechanical Fatigue, Wear, Precipitate Fouling, Corrosion, Erosion/Corrosion, moreover Stress Relaxation in supporting parts of HX. Periodic assessment of ageing mechanisms associated with heat exchanger tubes, tube sheets, tube joint welds, shell, nozzles, heads and fasteners is performed.

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

This programme includes preventive actions for addressing degradation. Preventive measures include performance monitoring, condition monitoring and preventive maintenance. The performance testing and maintenance are preferred, monitoring may be used instead if sufficient technical justification can be shown that testing is not feasible.

Boron concentration in primary water is responsible for reactivity control and may lead to precipitate fouling, also known as scaling, from borated compounds on tube side. Chlorides can significantly increase the potential for IGSCC. Alternating wet and dry periods will allow concentration of boron on the heat exchanger tubes and further accelerate IGSCC. Therefore, periodic grab sampling and chemical analysis are performed for verification of the primary water chemistry.

This programme incorporates periodic reviews in which the test or monitoring methods and intervals are evaluated to be the most appropriate for use such that required action limits, are not exceeded. These reviews consider advances in testing and monitoring technologies, operating histories of the heat exchangers, fouling rates, changes in cooling fluid quality, heat load availability, and previous test or monitoring results. If unacceptable indications and deteriorations are found in inspection, expansion of the inspection area and increase in the frequency of inspection and leak testing is considered [1].

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

Inspection and leak detection for SRH HXs are conducted in accordance with national regulations or governing documents. Detection means are [2]:

1. Operation abnormality;
2. In-service inspection;
3. Surveillance testing;
4. Preventive maintenance;
5. Special inspection;
6. Audio-visual alarm;
7. Routine observation.

The degradation of the heat exchangers can be detected by using following non-destructive examinations (NDE) methods (see also AMP 145):

1. Visual — this includes inspection for evidence of erosion, corrosion, fouling, and damaged coatings by methods such as direct visual inspection and inspection using visual aids (e.g., video probe);
2. Dimensional — this includes inspection for determining shell or nozzle wall thickness, using ultrasonic technique;
3. Surface and volumetric — this includes inspection for determining wall thinning and discontinuities by eddy current method, or other methods (such as liquid penetrant, magnetic particle, and ultrasonic).

The following programs may also be considered for additional means of ageing detection:

1. Structural integrity — this includes vibration monitoring by either portable or fixed tools to assess any structural integrity, foundation or component looseness issues.
2. Enhanced Chemical Monitoring Programme — routine chemical analyses programme is enhanced to detect any corrosion products and/or foreign/loose objects and/or tube material.
3. Physical Parameter Monitoring Programme — inlet/outlet temperature and pressure/flow rate monitoring programmes are implemented to detect any increase/decreased temperature and pressure at inlet/outlet.

Degradation of heat exchangers tubes can also be identified through leak testing in accordance with applicable procedures (e.g., Helium Leak Test Procedure), and technical specifications specified by manufacturers of the heat exchangers.

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

Sufficient heat load to permit effective performance testing would be available during cooldown which requires that tests be conducted within a relatively narrow time frame. In that time frame, Thermal Performance Rating is evaluated to determine if thermal capacity of the heat exchangers is degraded. While the frequency of monitoring through the inspections and leak testing is performed during each Refuelling Outage (RFO), and in accordance with national regulations or governing documents.

In case of detection of wall thinning, its significance is assessed by trending with previous measurements.

Inter-fluid leakages could be monitored by chemical and radiolytic analysis and eddy current tube testing.

Abnormal pressure differential and temperature monitoring across exchanger may indicate occurrence of fouling, periodical (each RFO) measurement of the shell side flow rate and the shell side pressure drop is performed to obtain their trends.

Inservice testing or monitoring is performed prior to performing any corrective action that would impact the thermal performance of the heat exchanger (i.e. cleaning) to determine the ‘as-found’ condition of the heat exchanger. This as-found condition is essential for establishing appropriate testing or monitoring intervals. [1]

Intervals are adjusted as part of the programme review, based on fouling rate, type of fouling, operational requirements and heat load availability to guarantee satisfactory performance during the interval. Intervals may not exceed 10 years.

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

The inspection results are evaluated to determine the need for mitigating actions.

If fouling is identified in the shell or on the outside of tubes, deposits and sludge are analyzed and cleaned only on an “as-needed” basis.

If inspection results reveal high/deviated concentrations of chlorides, updating/adjustment of chemistry control programme is considered.

1. ***Acceptance criteria:***
2. Indications detected from NDE that show no detectable change since the previous inspection are considered acceptable.
3. Indications detected from NDE that show material erosion/corrosion losses that do not exceed the limits specified for the design of the components at the end of the next periodic inspection interval, are considered acceptable.
4. Unless otherwise specified, the acceptance criteria in accordance with national regulations or governing documents, such as the ASME BPVC, Section XI, will apply.

Conditions that do not comply with the general acceptance criteria mentioned above may be considered acceptable provided that the fitness-for-service of the component has been demonstrated, to the satisfaction of the regulatory authority, until the end of the next periodic inspection interval (see also AMP 145).

1. ***Corrective actions:***

The inspection results are evaluated in accordance with national regulations or governing documents and approved fitness-for-service guidelines to determine the need for corrective action. If required, a corrective action plan, which includes tube plugging, tube sleeving, repair, replacement, or other mitigating actions, is developed and implemented (see also AMP 145).

Internal leaks are detectable from chemical or activity measurement, and from inspection and tests. In case of observation of abnormality in said measurements, corrective actions, such as identifying where the leak is, are taken based on operating procedures.

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.

Review and evaluation of plant-specific and industry-wide operating experience have shown that current inspection and leak testing programmes for the heat exchangers used in residual heat removal heat exchangers in PWR nuclear power plants are generally effective in managing ageing effects.

A comprehensive review of currently available information regarding heat exchanger used in nuclear power plants is presented in 3], where common characteristics of heat exchanger designs and service applications are examined to establish groupings for ageing mechanism and ageing management programme*/*technique evaluations; all ageing mechanisms for the heat exchanger applications are investigated to determine which are non-significant, and which are significant; and ageing management programmes*/*techniques are examined to determine which are effective for detecting and*/*or mitigating the significant ageing mechanisms.

In addition, EPRI overview and guidelines for heat exchanger maintenance, testing and performance monitoring are documented in References [4-6].

Research and development efforts and an effective experience exchange are important elements for implementing continuous improvement in this programme and in defining adequate corrective actions.

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

1. ***Quality management:***

Site QA procedures, review and approval processes, and administrative controls are implemented in accordance with the different national regulatory requirements (e.g. 10 CFR Part 50, Appendix B [7].

### References

[1] ASME OM Code, Part 21 Inservice Performance Testing of Heat Exchangers in Light-Water Reactor Power Plants, 2012 edition.

[2] US NUCLEAR REGULATORY COMMISSION, Aging of Non-Power-Cycle Heat Exchangers Used in Nuclear Power Plants, NUREG/CR-5779, ORNL, 1992.

[3] SANDIA NATIONAL LABORATORIES, Aging Management Guideline for Commercial Nuclear Power Plants - Heat Exchangers, SAND93-7070, SNL, 1994.

[4] ELECTRIC POWER RESEARCH INSTITUTE, Heat exchangers: Over of Maintenance and Operation, EPRI/NMAC TR-106741, EPRI, Palo Alto, CA, 1997.

[5] ELECTRIC POWER RESEARCH INSTITUTE, Preventive Maintenance Basis, Volume 32: Heat exchangers Condition Assessment Program, BOPHX-01, Rev 1, EPRI, Palo Alto, CA, 1997.

[6] ELECTRIC POWER RESEARCH INSTITUTE, Heat Exchangers Testing Guideline, EPRI-7552, Subsection 4.2, EPRI, Palo Alto, CA, 1997.

[7] UNITED STATES 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.