REVIEW AND DEVELOPMENT OF AGING MANAGEMENT PROGRAMS OF THE MAIN COMPONENTS AT PAKS NPP

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Abstract

According to the License Renewal related Hungarian Atomic Energy Authority's Nuclear Safety Regulations and Guidelines a systematic review and development of the aging management programs of all the safety related equipment has been performed for Paks NPP. The AMP Review methodology is based on US NRC 10 attributes (Scope, Preventive actions, Parameters monitored or inspected, Detection of aging effects, Monitoring and trending, Acceptance criteria, Corrective actions, Confirmation processes, Administrative controls, Operating experience) taking into account the typical VVER-440 constructional, operational, QA and other administrative control features. This paper deals with the AMP review of the main components: RPV, RPV Internals, Steam Generators, Pressurisers, MCPs, Main Gate Valves and the Primary piping. All known and potential degradation mechanism was taken into consideration. All the aging management related programs and activities (ISI, Maintenance, Chemical control, Technical Condition Monitoring, Operational data monitoring, Operational experience monitoring, QA e.g.) together with the related NPP's internal procedures have been identified for the review. The results of the review ascertain the strengths and weaknesses of the previous programs and activities as related to the need to understand and manage the effects of aging of the main components. The methodology and the main results of the review as well as examples of typical recommendations for development of the current programs are reported in the paper.

INTRODUCTION

The owner's intention of WWER-440/213 units in Central Europe is to keep the plants in operation as long as technically feasible and reasonable from business point of view, e.g. to run Paks NPP 20 years behind the planned 30 years of operational lifetime. The preconditions of the long term operation are the safety and good plant condition. The first is ensured by the implemented safety upgrading programs, commitment of operators and proper regulation. The last depends mainly on the past and recent practice of AMP, in-service inspection, maintenance, testing and recording the lifetime relevant data as well as on the knowledge of the design basis of the lifetime limiting structures, systems and components. In the last ten years comprehensive ageing management studies have been performed for the most important safety related SSCs of the WWER-440/213 units in the countries operating this type of units. The AMP studies were performed mainly in the frame of PSR in accordance to the guidelines developed on the basis of IAEA Safety Guide 50-SG-O12. According to the License Renewal related Hungarian Atomic Energy Authority's Nuclear Safety Regulations and Guidelines based on the USNRC 10 attributes, a systematic review of the aging management programs, of all the safety related equipment, SSCs in safety classes 1-3+ has been performed at Paks NPP. AMP review of the main components was performed by VEIKI Co.

SCOPE OF THE AMP REVIEW

The following main components of the VVER units are included in the frame of the AMP review performed by VEIKI Co.:

Table 1: Main components included in the AMP review performed by VEIKI Co.

Reactor vessels	Steam	Primary circuit piping	Primary circuit gate
RPV Internals	Pressurizers	Branch pipes of the primary	Primary circulating

AMP REVIEW STAGES

1. Identification of potential degradation mechanisms

For the first step of the AMP review the potential degradation mechanisms and critical locations of the main components was determined. The base for the determination was the Hungarian authority AMP guideline 1.26. and the available PWR/VVER aging related information. Detailed comparison of the degradation mechanisms/critical locations of the GALL report and VVER findings were performed. Differences were identified and assessed to modify the list of possible degradation mechanisms and potential critical locations.

Table 2: List of potential degradation mechanisms of main VVER components

	Low Cycle Fatigue	Radiation Embrittlement	Thermal Embrittlement	SC Cracking	Stress Corrosion Cracking	Corrosion in Boric Acid Environment	Erosion	Swelling	General Corrosion	High Cycle Fatigue	Change of Properties	Stratification
Reactor vessels	x	x	x	x		x			x		x	
RPV Internals	x	x	x	x	x			x		x	x	
Pressurizers	x		x	x		x	x		x		x	x
Steam generators	x		x	x			x		x	x	x	
Primary circulating pumps	x			x		x	x		x	x		
Primary circuit gate valves	x		x	x		x	x		x		x	
Primary circuit piping	x		x	x		x	x		x			x
Branch pipes of the primary circuit	x		x	x		x	x		x			x

Critical locations
Critical locations of possible degradation processes were identified based on PWR/VVER operational practice and assessment of the construction, operational parameters, flow rates and material susceptibility. Critical locations susceptible to **fatigue** were identified on the base of design calculations. Critical locations of **thermal embrittlement** are places, with

highest operational temperatures and susceptible material. From point of view of **radiation embrittlement** the most susceptible locations are the RPV vessel wall and 5/6 circumferential weld close to the active core. The r**adiation related material behavior** of the RPV internals in the long term operation has to be taken into account as well, so **swelling**, embrittlement and **irradiated assisted stress corrosion cracking** of highly irradiated core basket locations has to be further investigated. **General corrosion and boric acid corrosion** are taken into account at external surfaces and welded attachments, like structural support locations made of ferritic steels. **Boric acid corrosion** can take place at location where the primary coolant can get out, like bolted connections. **High cycle fatigue** cannot be excluded at structures with possible vibration and high flow velocities like some components of the RPV internals and the heat exchanger tube bundle of the stem generators. **Several forms of the stress corrosion cracking** were taken into account for the 08H18N10T austenitic material made components at locations with low flow velocities with possible concentration of corrosive impurities. The steam generator heat exchanger tubes are well known from the VVER operational practice as high susceptible to this degradation mechanism. Some locations of the RPV internals can be susceptible to the SCC as well, especially in period of extended operation. **Stratification** phenomena related thermal fatigue/high cycle fatigue of the piping connected to the primary circuit shall be taken into account in the future AMP activities as well at locations with relatively high possible temperature differences and modes of operation of low flow velocities.

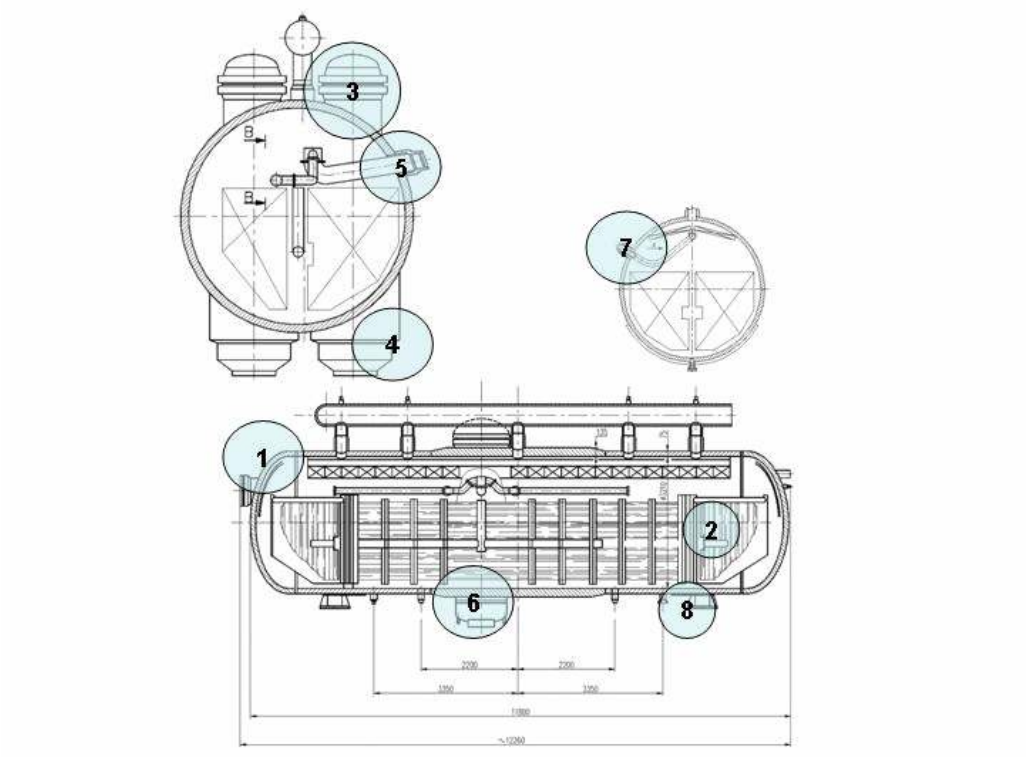

FIG.1. Critical locations of the VVER Steam Generators

2. Identification of preventive or mitigating actions

Selection of construction material not susceptible to certain degradation processes at the foreseen operational environment and in a given construction is the most effective preventive AMP step, but it can rarely be used in the practice of the operational units. However in the case of repair, partial reconstruction it is a possibility. All forms of corrosion of inner surfaces

can be mitigated by means of **properly adjusted primary/secondary circuit water chemistry parameters**. In the case of SG tubes ODSCC complex preventive actions have been used, like copper removal from the secondary circuit, introduction of high pH, low impurities secondary water chemistry, tight austenitic condenser tubes, corrosion resistant high temperature feed water heat exchanger tubes and more effective SG blow down system is foreseen as well. In case of locations with **high fatigue usage factors** strict control of the sudden changes of operational parameters and possible limitations of the actual operational cycles can be used. To mitigate the **RPV wall radiation embrittlement** low leakage core has been introduced resulting at least 40% decreasing neutron flux of the critical locations. To prevent **boric acid corrosion** of outer surfaces the leak detection system (YC) can be used, therefore the YC of the RPV vessel head has been revitalized.

3. Identification of parameters to be controlled

The parameter control is based on the existing or specially developed programs for the component locations declared critical by the preliminary analyses. In the case of **Fatigue and thermal aging:** operational cycles, operational temperature/pressure parameters, as well as temperature changing rates are controlled. On line and periodic control of primary and secondary circuit water system's parameters according to Paks NPP internal procedures and SG blow down's chemical parameters are identified for this AMP step of **Corrosion processes**. In the case of **Radiation embrittlement** parameters connected to the neutron-physical calculations are to be controlled.

4. Detection of specified aging effects

Aging effects were identified taking into account possible degradation mechanisms. **Fatigue, all forms of stress corrosion and several types of local corrosion** can result in crack initiation and crack propagation. Aging effect of **thermal and radiation emrittlement** is characterized by loss of fracture toughness. **Boric acid corrosion, general corrosion, wear and erosion** effect is general or local loss of material. **Swelling** can result in changes of the dimensions.

These aging effects were taken into account at the potential critical locations and a detailed review of all programs of the NPP was performed to identify the possibility of timely detection, before serious consequences, not repairable conditions occur.

These aging effects in the majority of cases were found detectable using following NPP Paks current programs:

- In-service Inspection Programs, Periodic Condition Monitoring Programs, which were reviewed and modified on the base of AMP related 1.26 guideline, and ASME XI
- Visual inspections in the frame of Maintenance Programs, which were reviewed and modified on the base of AMP related 1.26 guideline
- Pressure tests
- RPV material Surveillance program
- Walk down programs of the operational personal

For locations, not covered by above programs special one time inspection programs are foreseen.

5. AMP related Monitoring and Trending

Monitoring of parameters of primary/secondary water chemistry is connected to this step of AMP of all forms of **in surface corrosion**. Monitoring performed by the leak detection system is connected to this step of AMP of outer surface **boric acid corrosion.** Monitoring of the operational parameters and cycles is one step of the adequate AMP for **fatigue and for any type of crack propagation** connected degradation forms. Trending of the size and number of indications found during the ISI is covering this AMP step of all **local effects related degradation forms, like SCC.** In the case of **steam generator ODSCC**, trending of the plugged tubes can be taken into account. Trends in wall thickness thinning are taken into account as an AMP step for all type **degradations with loss of material**. Trending of Neutron fluencies of critical locations of the RPV is one of the most important indirect AMP step for radiation emrittlement.

6. AMP related Acceptance Criteria

Criteria described in the criteria catalog of the ISI programs provide acceptance criteria for **all local forms** of possible degradation of critical locations. Criteria described in the periodic material condition inspection programs and in the maintenance programs are taken into account as AMP step for all type of degradation effects detectable by visual examination. Criteria described in leak detection system procedure is one step of AMP for **all local corrosion forms** connected to the vicinity of the place of detection, like VVER specific Nickel ring bolting connections. Several criteria required by procedures of the primary/secondary water chemistry like allowable chloride content, impurities and pH range are connected to AMP of **all forms of in surface corrosion** mechanisms. For **degradation forms with loss of fracture toughness** the acceptance criteria is to be given by the ongoing TLAA computations.

7. AMP related corrective actions

Degradation related deficiencies not allowable by the connected ISI acceptance criteria shall be repaired. All the repair procedures at the NPP Paks have written documentation and were reviewed, modified on the base of ASME XI and age related PWR/VVER operational practice. In the cases of not fulfilling of other type acceptance criteria like water chemistry, operational parameters and leak rate NPP Paks internal procedures describe actions to recover acceptable conditions.

8. AMP related confirmation process and administrative control

Several internal procedures, like QA system of the Paks NPP assure fulfilling these administrative steps of the Aging Management Programs. In addition to the former procedures a new complex AMP procedure was compiled, taking into account the above 10 attributes and recommendations of the Hungarian AMP related regulatory guides. It has to be mentioned at this stage of the AMP attributes that a new central AMP division was recently organized to coordinate and monitor all AMP related activities at the NPP Paks. The new division plays very important role in facilitating all kind of AMP related activities, like R&D, Strength, TLAA calculations and periodic assessment of adequacy of current programs.

9. AMP related operational experience

In the frame of AMP review of the main components a comprehensive assessment of all available PWR/VVER age related operating experience was performed. Detailed review of the IAEA IRS, WANO and NRC LER database was performed. The information gained was used in the justification and modification of current AMP programs and focusing attention to certain possible critical locations, not foreseen as critical, so fare. Collecting age related operational experience is a permanent task of all AMP related activities and plays very important role in plants with extended life time.

CONCLUSION

The ageing management programs of the main equipment ensures safe and presumable competitive basis for the future strategic plans of the Paks NPP units with the following recommendations:

- The results of the ongoing strengths and TLAA calculations has to be taken into account in the future in the related programs
- The degradation of CRDM nozzle welds needs special AMP attention.
- The 22K material thermal aging could be important, so it needs additional examination.
- Further enhancement of effectiveness of SG's blow down system should be considered.
- In the case of critical locations not covered by current detection programs one time inspection programs have to be performed before the end of the design life of the Units.
- Stratification phenomenon of the primary circuit connected piping has to be investigated by additional temperature monitoring and fatigue calculations.
- Cavity dosimetry is recommended for the additional validation of the computed RPV's wall fluencies taking into account the life extension and power up rate of the Units.

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