Full System Decontamination of the PWR Stade prior to Decommissioning

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1 Introduction

E.ON, the owner of the Nuclear Power Plant Stade (NPP), began very early with planning for decommissioning of the NPP after final shut down period was decided. Full System Decontamination (FSD) prior to start decommissioning activities was one of the central topics. During a decontamination workshop in 2003, held at Stade, all decontamination technologies available on the world market were compared with regard to technology, efficiency, references and waste generation. The Framatome ANP CORD® Family (<u>C</u>hemical <u>O</u>xidation <u>R</u>eduction <u>D</u>econtamination technology in combination with decontamination equipment AMDA® (<u>A</u>utomated <u>M</u>obile <u>D</u>econtamination <u>A</u>ppliance) was selected as the best possible solution. Decontamination performance was scheduled short time after the plant final shutdown activities prior to commencement of dismantlement.

2 Why FSD prior to Decommissioning with CORD Family Decontamination Concept?

Reduce dose levels at components and for ambient dose

=> Minimization of man Sievert exposure during further planning and decommissioning activities

=> Activity inventory and at the end surface contamination minimized

=> No sophisticated dismantling techniques required

Waste Minimization by metallically clean surfaces

=> Waste generation during following disassembling / treatment (e.g. blasting) minimized

=> Material volume for free release of heavy components is maximized

High Cost Benefit Ratio for Customer

=> High planning safety for decommissioning schedule

=> Cost savings by shortened approval process for decommissioning activities

=> Cost Savings by waste minimization during the decommissioning process

=> Cost savings due to easier dismantling techniques and lower regulations for transport (e.g. Type A packing can be avoided) and storage

=> Cost savings due to shortening further treatment (e.g. blasting) and minimization of additional waste

=> Cost savings due to the shorter schedule

=> Money back by free release material

3 Framatome FSD Concept as applied at NPP Stade

3.1 Decontamination Target

The PWR Stade is of 4-loop design and was operated until permanent shutdown for 31 years (1972 – 2003). The decontamination (FSD) was scheduled during a post-operation phase, after defueling, and short time before decommissioning activities.

The FSD concept of Framatome was tailored to the decontamination targets, as defined by NPP Stade:

- Maximum reduction of the activity inventory and at the end the dose levels
- Maximum reduction of ambient dose rates in work areas
- Maximum volume of materials for free release process (key objects here SGs)
- Minimum waste generation
- No significant shift of the gamma / alpha ratio

3.2 Decontamination Concept

The project was performed in 3 phases, starting with a feasibility study, followed by compilation of procedures and finalized by the onsite performance. All FSD tasks were planned and realized in close cooperation between the project teams of KKS and Framatome ANP. The successful performance was ensured by this optimum teamwork.

The decon circuit for the FSD incorporated the whole primary circuit with defueled RPV, the RHR systems, the VCS (including degasifier), the RWCU and partly emergency injection system. This decon circuit had a total volume of 310 m^3 with a surface of 17000 m^2 with SG tube area as majority surface. The FSD was performed mainly with plant internal systems and the AMDA, connected at RHR and VCS tie-ins. The decontamination was supported by auxiliary systems of the plant (chemical injection system, component cooling systems, coolant storage, plant exhaust system, building drains, spent resin tank). AMDA was in operation mainly for bypass cleanup through ion exchange resins, for mechanical filtering of crud particles and for UV decomposition. Exhausted resins from the decontamination process were transferred from the AMDA resin filters into the plant internal spent resin tank.

As decontamination process, the well known HP/CORD UV process was chosen from the CORD Family (HP = Permanganic acid and UV for ultraviolet induced decomposition of chemicals).

4 HP/CORD® UV Concept

HP/CORD UV in combination with AMDA is not only applied for decontamination in operating NPP but also for decontamination for dismantlement. Typical applications are decontaminations of components, system sections or entire systems as well as FSD. HP/CORD UV process is applied as a multi-cycle process as all other state-of-the-art-processes of the CORD Family. The big advantage is that the decontamination process can be tailored in accordance to the decontamination targets. Each HP/CORD UV cycle includes four steps (Preoxidation with HP, reduction of HP with the decontamination chemical, Decontamination and UV decomposition of the decontamination chemical and solvent cleanup). Dissolved corrosion products and the activity in solution are fixed on ion exchange resins during the decontamination step. The decontamination chemical is decomposed to water and carbon dioxide after completion of the decontamination step. The CORD Family decontamination approach ensures low dose rates at NPPs systems/components, metallically clean surfaces, low waste volumes, no resin waste containing chelates and a unchanged water quality in the decon circuit.

5 References for Full System Decontamination with HP/CORD UV

Framatome ANP has global experience with FSDs of still operating NPPs (6 FSDs in Sweden - BWR, Finland-VVER and Japan - BWR) and also with NPPs that are permanently shut down (see Table 1). All projects were wholly successful and high DFs were achieved for all reactor types and water chemistries.

NPP	Country	Year	Type	OEM
BR3 Mol	Belgium	1991	PWR	Westinghouse
VAK Kahl	Germany	1992/93	BWR	GE/AEG
MZFR	Germany	1995	D2O	Siemens
Wuergassen	Germany	1997/98	BWR	GE/AEG
Haddam Neck	USA	1998	PWR	Westinghouse
Lingen	Germany	2001	BWR	GE/AEG
Caorso	Italy	2004	BWR	GE
Trino	Italy	2004	PWR	Westinghouse
Stade	Germany	2004/05	PWR	Siemens

Table 1: Full System Decontaminations prior to decommissioning

6 Results

A total of 4 HP/CORD UV cycles were performed. In total 609 kg of corrosion products were removed and a total activity of 2.7 E13 Bq, approx. 730 Ci, with > 90% of Co-60. The corrosion products and activity were fixed on ion exchange resins. In total 15.4 m^3 were necessary and meets the planning value of 16 m^3. More then 70% was need for the corrosion products and activity. A comparison of waste volumes of NP processes, means oxidation with potassium permanganate and nitric acid and no UV decomposition will have ended up with a waste volume > 60 m^3. This demonstrates again clearly the huge advantage of the HP/CORD UV process.

The overall personnel exposure for the FSD related performance was 96.5 mSv and met also the planning value of 90 mSv. Additional activities increased the total exposure by 56 mSv, but exposure stayed much below the planning of 137 mSv, thanks to the already achieved excellent decontamination results.

Excellent results for Decontamination factors (DF) and outstanding results for the ambient dose rate reduction (DRF), no other decontamination came even close, were achieved (see Table 2). Final dose rate measurements were done with an unshielded detector. Thus the actual decontamination factors (DFs) are much higher. No significant change on the Gamma/Alpha nuclide ratio was detected.

DF	Actual
DF (overall)	> 58*)
DF primary system	> 74*)
DF SG tubing	> 160*)
DF auxiliary systems	> 38*)
DRF (overall)	> 75*)
Gamma / ALPHA nuclide ratio	No significant change

*) DF and DRF base on unshielded dose rate measurements – real DF much higher

Table 2: FSD results of the NPP Stade

Figure 1 (left side SG 1, 2 and 4; right side SG3) and Figure 2 demonstrate the excellent steam generator results. DFs >> 100 were achieved for all SGs with 2% plugged tubed. For SG 3 DFs >> 30 though 16% plugged tubes were reached. The SG tubes are so clean that the positions of plugged tubes can be detected by means of dose rate measurements (Figure 2). The visual inspections of the steam generators after the decontamination showed metallically clean surfaces (see Figure 3). Contamination level was examined with smear tests at SG water box. Contamination level was found as minimum much lower then 50 Bq/cm² for Co-60 and stay much below the limit value given by German rule StrlSchV § 44 (Co-60 100 Bq/cm²). Overwhelming DRF results in excess of 75 were obtained without interference from adjoining components, i.e. instrumentation lines. Interference as shown on the right of Figure 4 can be attributed to instrumentation lines that were not part of the decontamination flow path. These lines will be removed first after commencement of the dismantling activities so that the low dose rates as shown on the left part of Figure 4 can be reached.

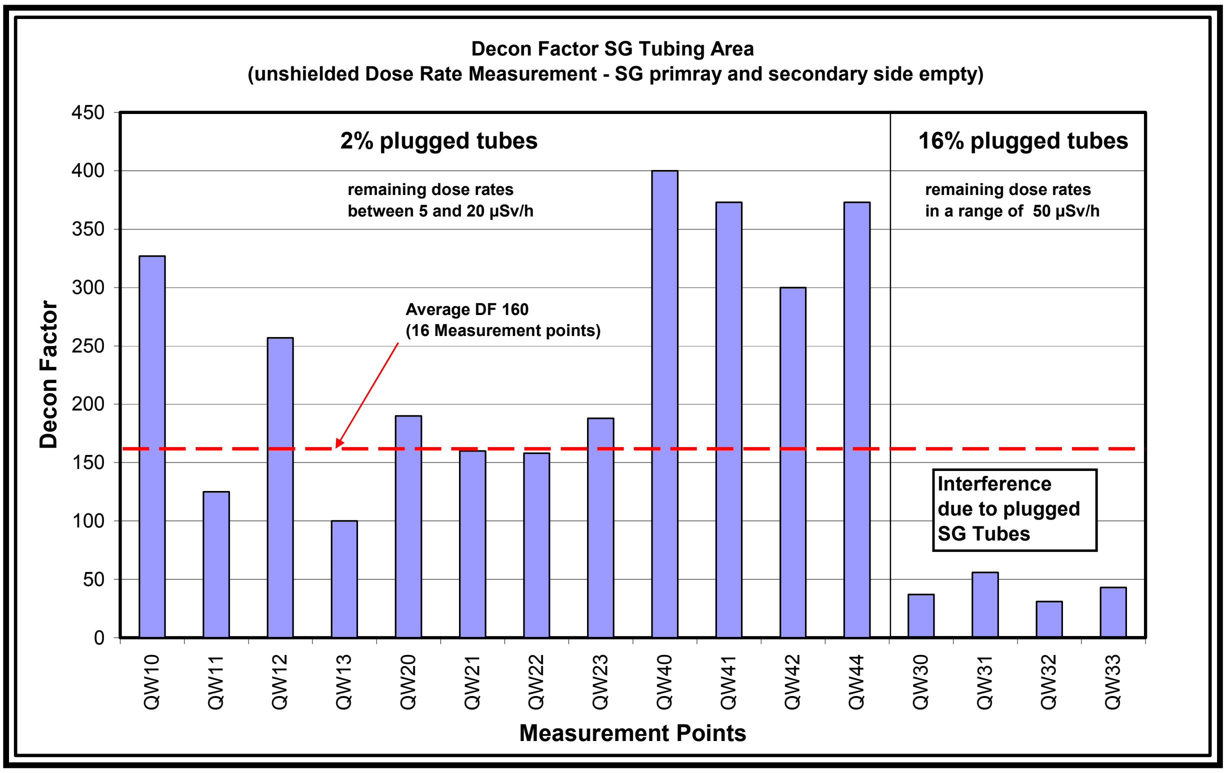

Figure 1: Steam generator decontamination factors for SGs 1 – 4

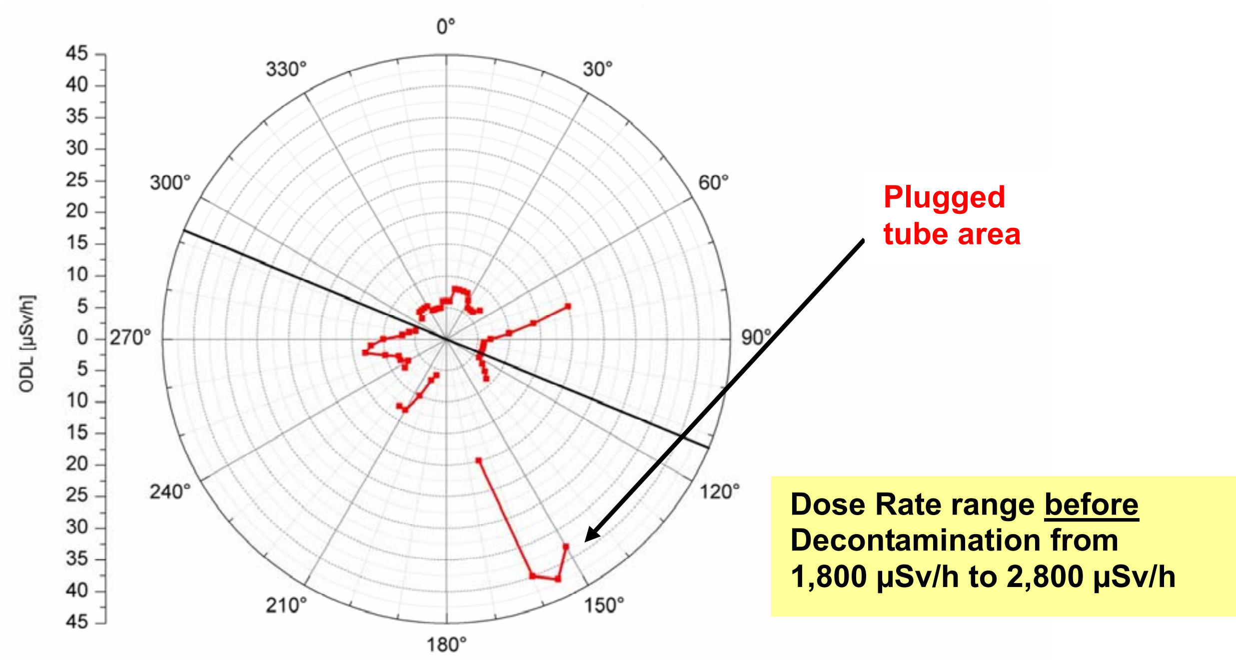

Figure 2: Contact dose rate of drained SG 4 after decontamination

Figure 3: SG channel head surfaces with tube sheet after decontamination

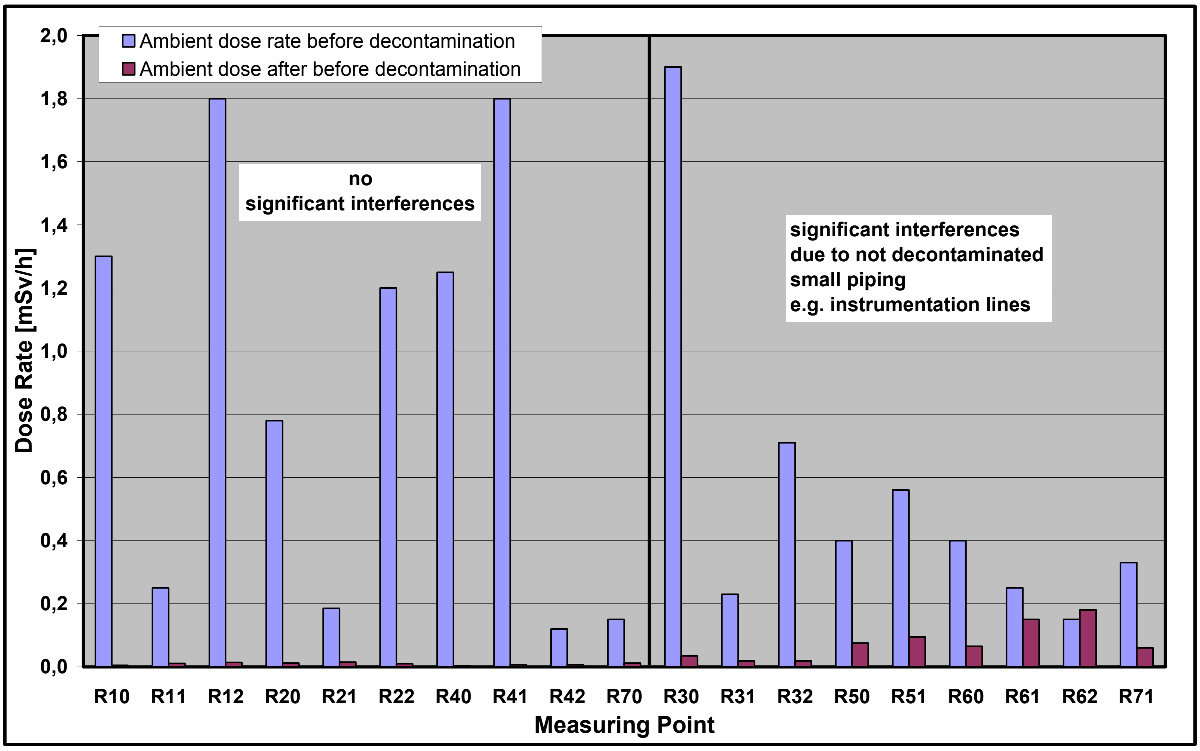

Figure 4: Ambient dose rates before and after decontamination (non-shielded measurements)

7 Conclusions

The FSD at Stade demonstrated again that the HP/CORD UV process produces excellent results in primary and auxiliary systems. All decontamination targets were surpassed or met. During the whole project a close and excellent teamwork and cooperation between Stade and Framatome ANP took place. The FSD at Stade, performed close after final shut down, showed again, that this is the best approach. This ensures that experienced plant personnel with intimate system and operating knowledge are still available and that functionality and usability of all NPP systems is given.

Particular emphasis must be given to the outstanding DRF of >>75 even though it was influenced by non-decontaminated areas, e.g. instrumentation lines. Other decontaminations not even came close. Due to the obtained low dose rates and use of non-shielded measurement devices, many measurements were influenced by radiation sources not in the decontamination flow path. Thus all given actual DFs are even higher. The achieved very low dose rates will ensure a high amount of man Sievert savings for the upcoming planning and decommissioning activities, facilitate and speed up the decommissioning and the metallically clean surfaces ensure a high material volume for the free release process. At the end NPP Stade will have a high cost benefit from this FSD.

The HP/CORD UV process, at applied for the FSD at Stade, it is also a proven standard decontamination process for operational NPPs either PWR or BWR. The obtained DFs and DRF demonstrate clearly the potential of a FSD for operating NPPs. Thus, high man-Sievert savings can be realized.