Full System Decontamination for Decommissioning: Experiences at NPP Barsebäck Units 1 and 2 applying the AREVA NP GmbH HP CORD® UV / AMDA® Technology

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Summary

In November 2007 and January 2008 a Full System Decontamination on the entire primary system was performed on Unit 2 and Unit 1.The overriding goal for this project was to find a way to minimize personal radiation exposure during the shut down and dismantling period. One important step to reach this is a Full System Decontamination (FSD) as the first and most effective step.

Barsebäck NPP chose to use the AREVA NP proprietary chemical decontamination process HP/CORD® UV. The RPV internals were removed and the lower part of the reactor vessel was included in the recirculation path. The decontamination was performed by operating the NPP systems such as the 4 loop recirculation pumps and RHR pumps and RWCU system IX-Columns. The external decontamination equipment AMDA® (Automated Mobile Decontamination Appliance), supplied by OKG and AREVA NP GmbH, was used for all chemical injection, decomposition of the decon chemicals, additional clean up through IX-Resin, filtration at the bottom of the reactor vessel and additional heat up capacity. The total system volume was calculated to be approximately 200 m³ with a surface area of 1800 m² for both applications.

3 HP/CORD UV cycles were performed at Barsebäck Unit 2, removing a total of 2.14 E12 Bq and a total mass of 64 kg of metal ions as corrosion products. This was collected on 3 m³ of cationic and 1 m³ of anionic resin. The dose rates for 101 measuring points, distributed over the main system piping and components, was monitored online (40) and by hand measurements (61). The overall average decon factor achieved was 93. The decon factor of the RECIRC system was 134, that of the auxiliary systems such as RHR and RWCU were 74 and 64 respectively.

At Barsebäck Unit 1 also 3 HP/CORD UV were performed removing a total of 1.29 E12 Bq and a total mass of 118 kg metal ions as corrosion products. This was collected on 4 m³ of cationic and 1 m³ of anionic resins. The overall average decon factor achieved for 101 measuring points, distributed over all the systems identical to Unit 2, was 298. The decon

factor of the RECIRC system was 493, that of the auxiliary systems such as RHR system and RWCU system were 130 and 100 respectively.

The estimated collective dose for decommissioning activities after 2017 and the motivation for performance of a Full System Decontamination was based on the achievement of an average decon factor of greater than 50 on all the primary systems. The initial estimate for total dose savings for decommissioning activities lies in the range of 6600 mSv for both units. This estimation is only to be seen as a planning tool, not to be judged as the BKAB “official” dose estimation for the total decommissioning and dismantling of the plants.

1 Introduction

Minimizing personal radiation exposure during shut down and dismantling activities is the highest priority for the decommissioning of a NPP. One important step to reach this is a Full System Decontamination (FSD) as the first and most effective step.

This paper gives an overview of the experiences and results of the FSD at the nuclear power plants Barsebäck Kraft AB and outlines the effects of the decontamination results in dose rate reductions and for the minimization of personal radiation exposure for the remaining service operation time and for coming decommissioning activities which commence after 2017.

The two 600 MW_e ABB-Atom designed BWR Units at the Barsebäck site went in operation 1977 and 1979 respectively. Due to political decisions unit 1 was shut down in 1999 and unit 2 was shut down in 2005. Decommissioning activities for both units are now in a planning phase, for a dismantling earliest in 2017. The dismantling time is linked to the aviability of a final storage. During the last years the plants were operated with hydrogen water chemistry and zinc injection.

2 Project Organisation

Based on the good experiences and results from the PRIM system decontamination project, performed by AREVA NP GmbH (then Framatome ANP GmbH) in 2002 at the NPP Barsebäck Unit 2, and the FSD experience at NPP Oskarshamn Unit 1, AREVA NP GmbH was contracted for the planning and performance of the FSD application at Barsebäck.

The project was performed in co-operation as a team under a 3-Party Agreement between NPP Barsebäck, OKG AB and AREVA NP GmbH. NPP Barsebäck was responsible for the maintenance and operation of all plant systems and support functions such as mechanical, electrical, chemistry and waste handling activities. OKG AB supplied part of the decontamination equipment AMDA® and provided manpower for installation and operation of the decontamination equipment. AREVA NP GmbH was responsible to lead the engineering and perform the chemistry oversight during the application of their proprietary decontamination process HP/CORD UV.

3 Decontamination Flowpath and Process Engineering

The decontamination flow path included all major plant systems and components such as the lower part of the reactor vessel, the four recirculation loops as well as the RHR system, and the RWCU system. The RPV internals were removed and the reactor tank filled to a level of -3m below the core in order to allow operation of all the 4 recirculation pumps. The total system volume was estimated at 200 m^3 with a surface area of approximately 1800 m^2.

System recirculation as well as heat up to the required process temperature (90-95°C) was done primarily with the recirculation pumps. The process temperature was stabilized using the heat exchangers of the RHR system. In addition, the RHR pumps were also in operation to facilitate circulation in the auxiliary systems and clean up the decontamination solution through the RWCU Ion exchange columns.

AREVA NP GmbH's and OKG´s external decontamination equipment AMDA was deployed for all chemical injection, decomposition of the decontamination solvent, filtration at the bottom of the reactor vessel, additional heat up capacity and bypass cleanup using external AMDA ion exchange resin columns (see Fig 1).

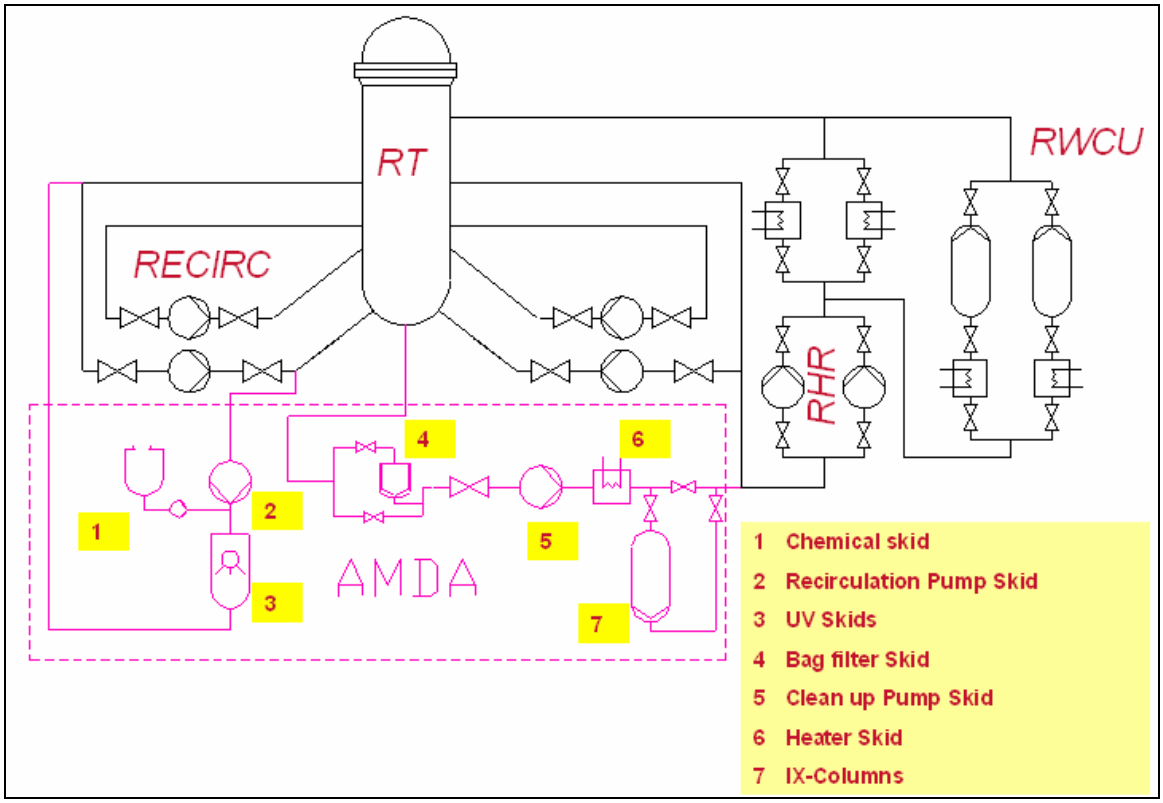

Figure 1: Principle Flowpath

Exhausted resins were transferred from the AMDA resin columns to the plant's own spent resin tank for waste treatment via existing plant procedures.

4 The CORD® Concept

The HP/CORD UV process selected for this decontamination campaign is part of the CORD (chemical-oxidation-reduction-decontamination) Family Concept developed by AREVA NP GmbH. The CORD Family Concept is designed to cover all decontamination needs worldwide by generating high decontamination factors and low waste volumes while causing no undue corrosive attack to the base material. Because CORD is a regenerative process, the entire decontamination work is performed with one fill of water. After completion of each process cycle, the oxidation and decontamination chemicals are decomposed by means of AREVA NP GmbH's patented photo-catalytic decomposition process (UV), while dissolved corrosion products and activity are placed on ion exchange resins.

The HP/CORD UV process – like all other state-of-the-art processes in the CORD Family – is applied as a multi-cycle process. Each treatment cycle includes the following steps:

Step 1: Preoxidation with HP (permanganic acid)
Step 2: HP reduction with the decontamination chemical
Step 3: Decontamination
Step 4: UV decomposition of the decontamination chemical and solvent cleanup

Dissolved corrosion products and the activity in solution are placed on ion exchange resins during the decontamination step. The decontamination chemical is decomposed to water and carbon dioxide after completion of the decontamination step.

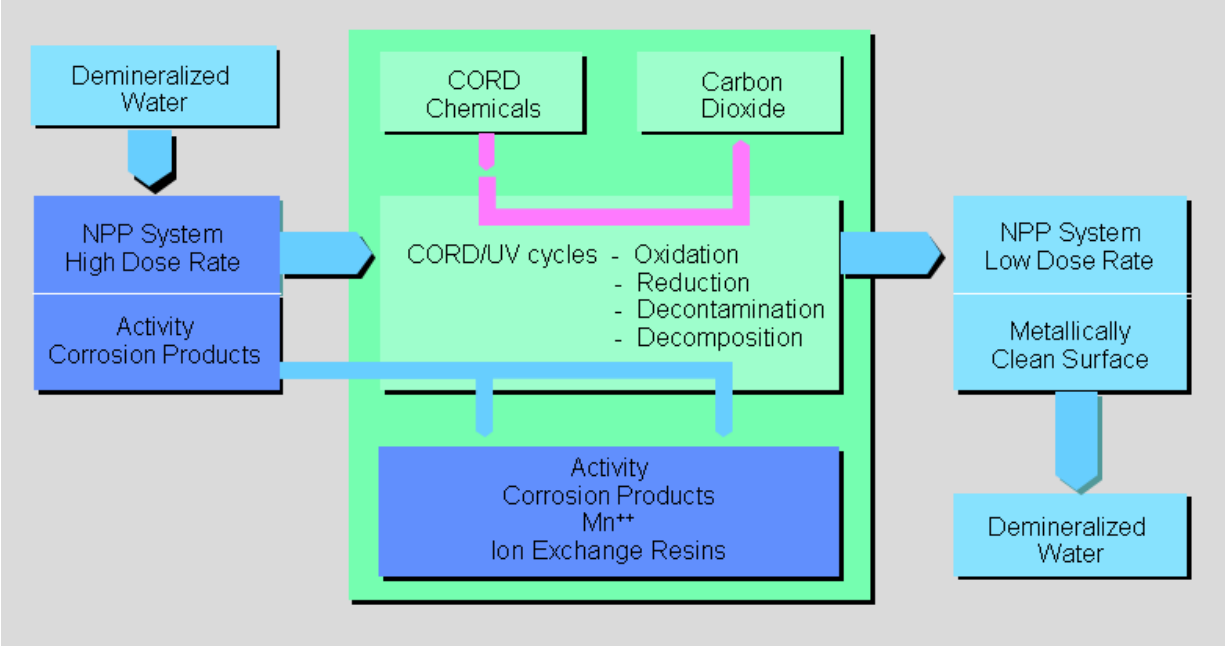

Figure 2: Principle of the HP/CORD UV Concept

5 Results

The decontamination in Unit 2 was performed first in November 2007. The total chemical application took approx. 11 days including heat up to process application temperature of 90 – 95°C with the heat generated by operating all the 4 recirculation pumps.. 3 HP/CORD UV cycles were performed at Barsebäck 2 in which a total of 2.14 E12 Bq (57 Ci) and a total of 64 kg metal ions as corrosion products were removed and placed on totally 3 m³ of cationic and 1 m³ of anionic resins.

The decontamination at Barsebäck Unit 1 was performed in January 2008. Heat up time in Unit 1 was longer with the actual chemical application also being approx. 11 days. As in Unit 2 also 3 HP/CORD UV were performed and a total of 1.29 E12 Bq (Ci) and a total of 118 kg metal ions as corrosion products were removed and placed on totally 4 m³ of cationic and 1 m³ of anionic resins.

The activity removed in each of the cycles for each unit is shown in the following diagrams.

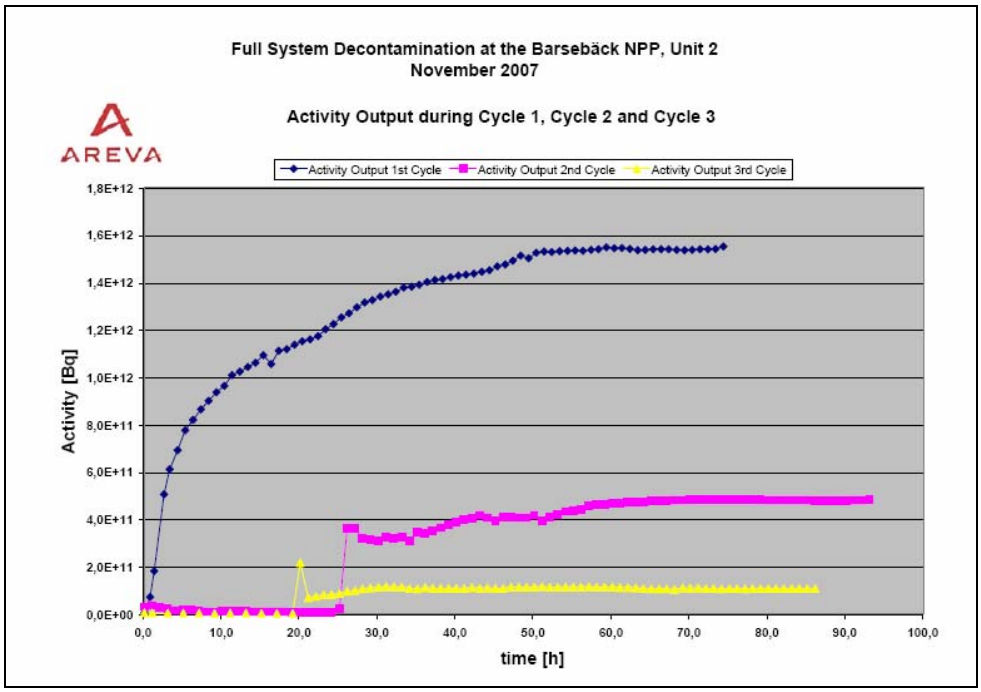

Figure 3: Activity output per cycle in Unit 2

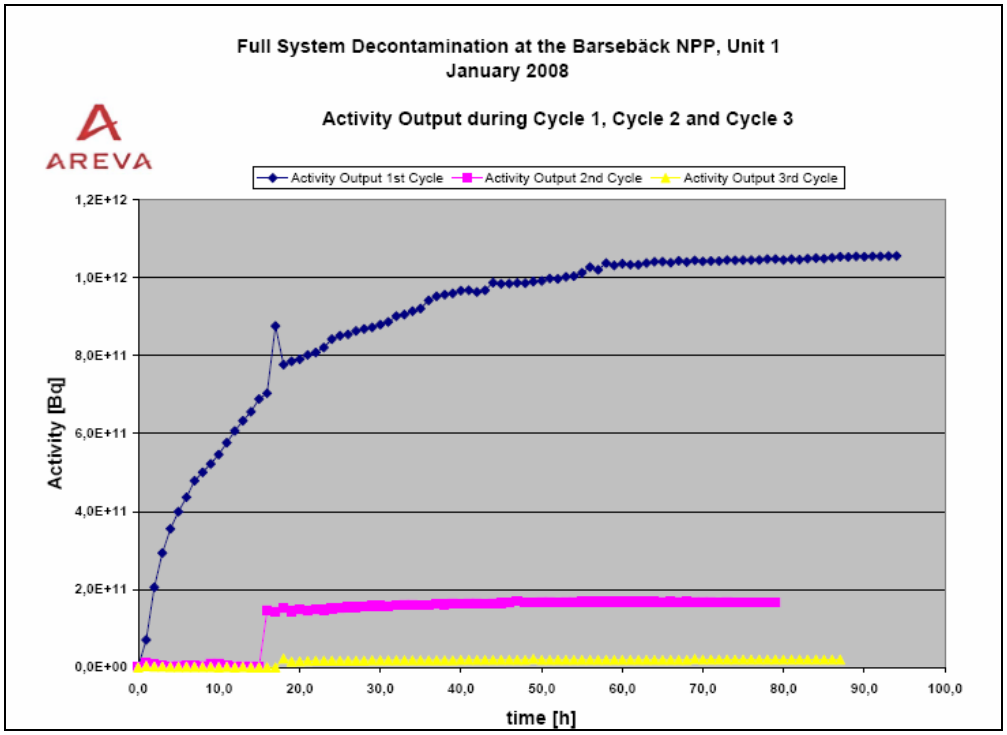

Figure 4: Activity output per cycle in Unit 1

The dose rates for 101 measuring points distributed over the main system piping and components was monitored by online measuring equipment for 40 points and by hand measurements for the rest. Figure 5 shows the decreasing dose rates for the online

measuring points during the 3 decontamination cycles for the main recirculation system (313) at Unit 2. Similar tendencies were seen in the dose rate progression in the decontamination at Unit 1.

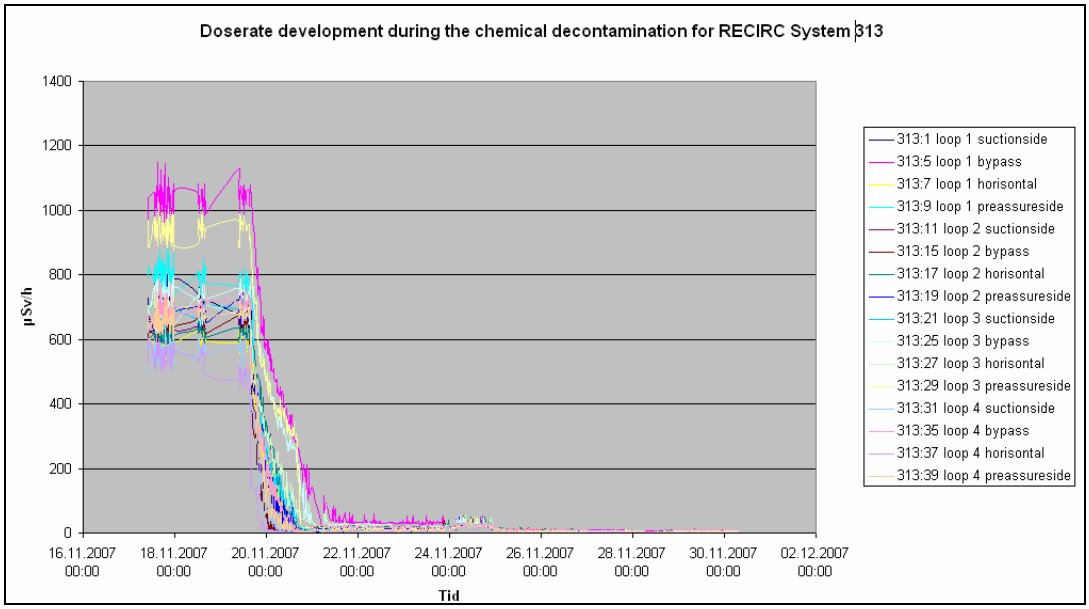

Figure 5: Doserate changes during the decontamination for the Recirculation System in Unit 2

The dose rates before and after the decontamination for the Recirculation System for all the doses rate measuring points for units 2 and 1 are shown in figure 6 and 7 respectively.

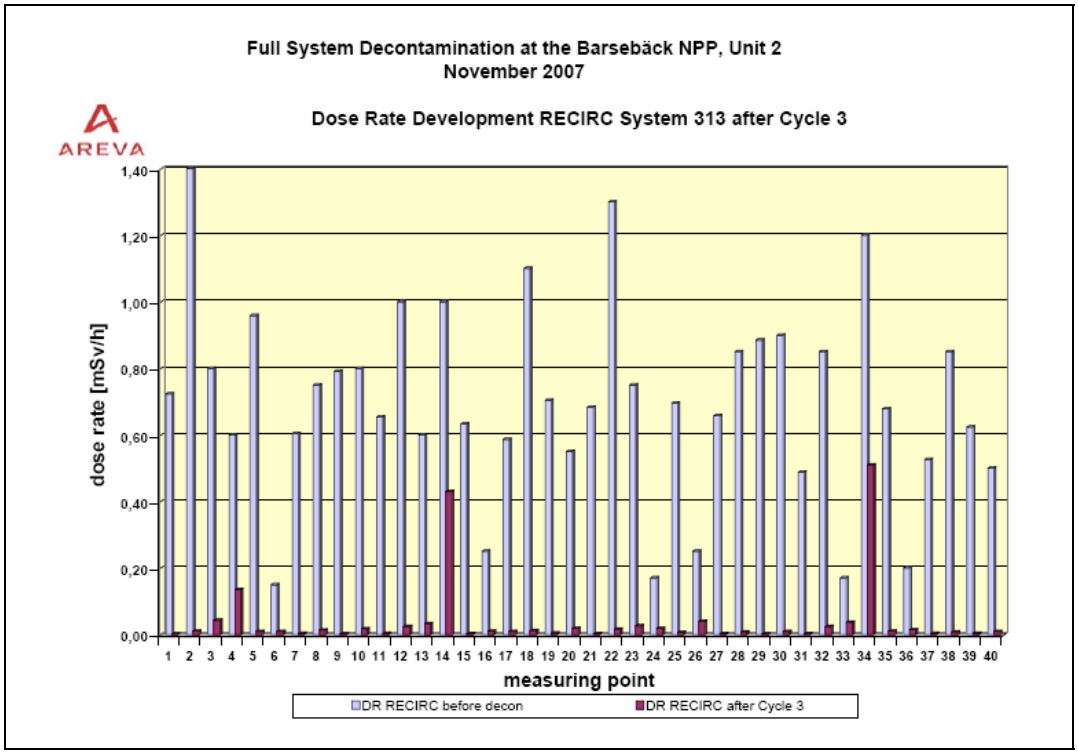

Figure 6: Dose rates of the Recirculation System in Unit 2 before and after the decontamination

The average overall decon factor achieved in Unit 2 was 93. The average decon factor of the RECIRC system was 134, those of the RHR system and RWCU were 74 and 64 respectively.

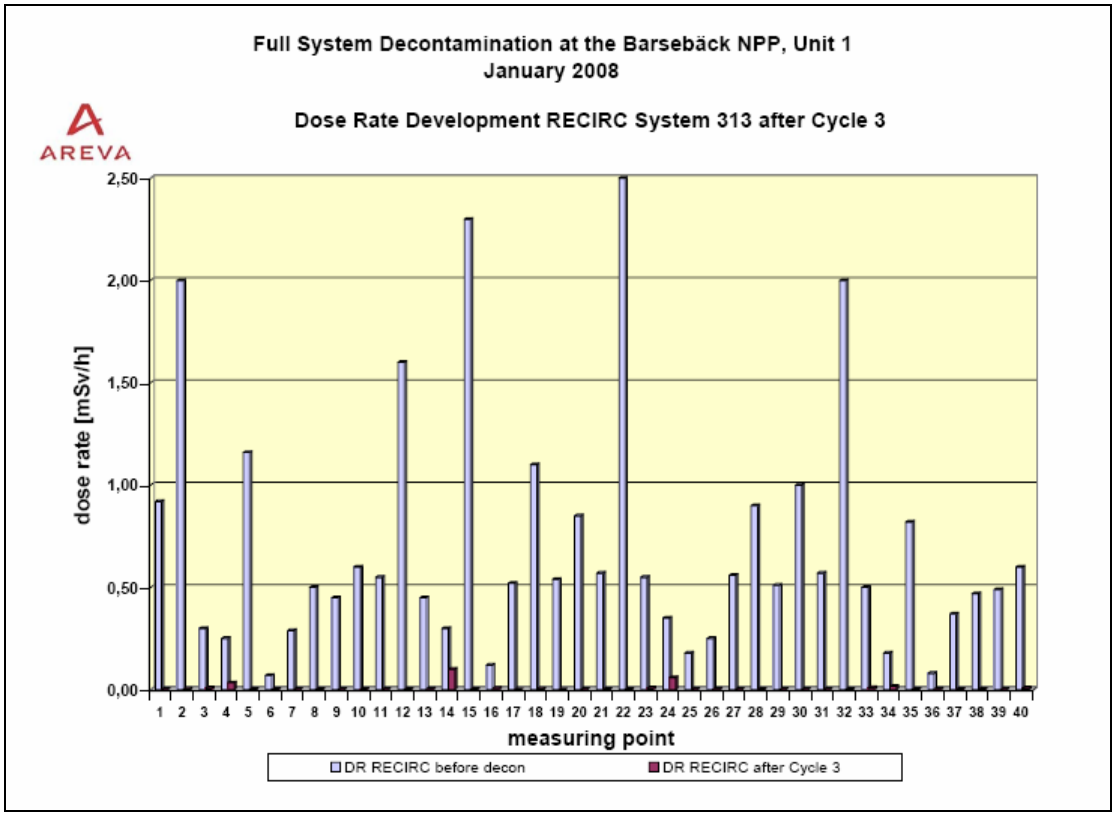

Figure 7: Dose rates of the Recirculation System in Unit 1 before and after the decontamination

The average overall decon factor achieved in Unit 1 was 298 (identical location of measuring points as in Unit 2). The average decon factor of the RECIRC system was 493, those of the RHR system and RWCU were 130 and 100 respectively.

The total Collective Radiation Exposure (CRE) for the preparation and performance work at both units at NPP Barsbäck was 138.3 mSv, only slightly above the estimated dose budget of 129.5 mSv. Details are shown in the following diagram. A relatively high amount of radiation exposure collected was by the mechanical and operations departments for maintenance and modification work during the preparation phase for the decontamination in both units.

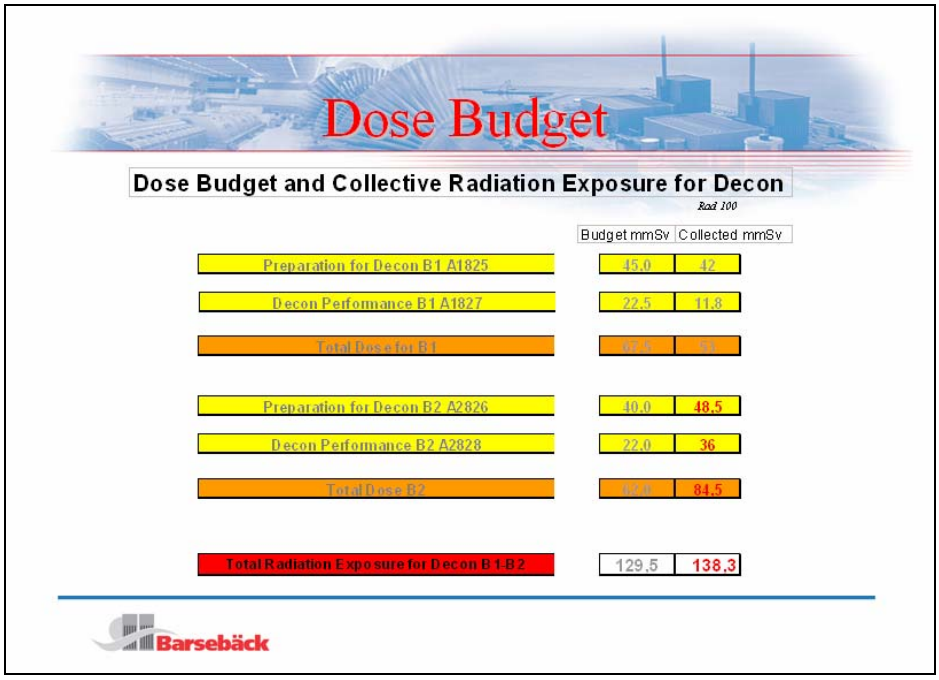

Figure 8: Dose Budget and Collective Dose for the FSD at NPP Barsebäck

6 The decontamination results impact on the future decommissioning and dismantling activities on site

The estimated collective dose for decommissioning activities after 2017 and the motivation for performance of a Full System Decontamination was based on the achievement of an average decon factor of greater 50 on all the primary systems. All these decontamination targets were met and/or surpassed. The average dose rates at both the units 1 and 2 were reduced from 0.7 and 0.8 mSv/h before the decontamination to an average of 0.03 mSv/h.

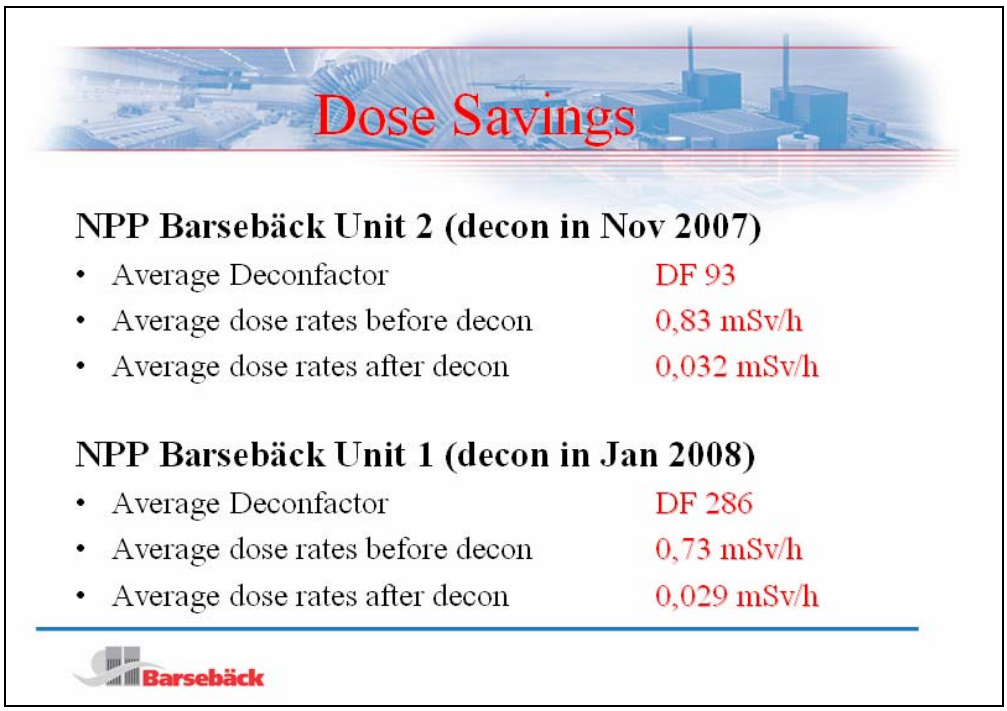

Figure 9: Overall DF results and dose rate reduction at NPP Barsebäck

The overall change in dose rates (featured as different colored zones) for each unit is summarized in the following pie charts and demonstrates the excellent result at both units.

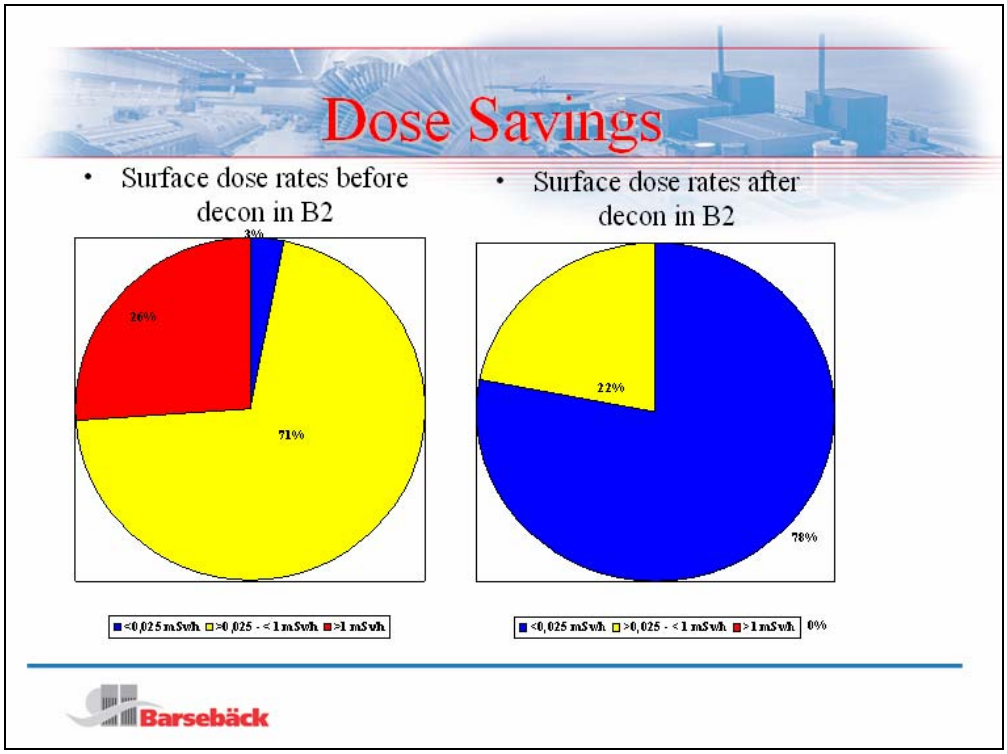

Figure 10: Changes in dose rates before and after the decontamination in Unit 2

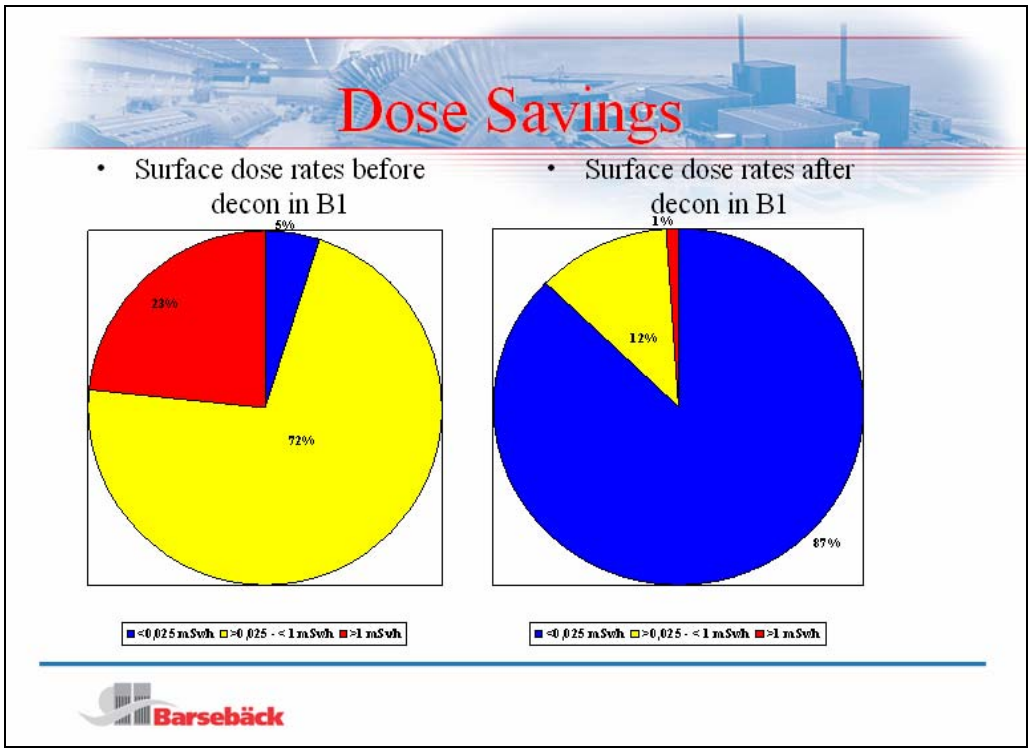

Figure 11: Changes in dose rates before and after the decontamination in Unit 1

7 Waste

A total of 7 m³ of cationic exchange resin and 2 m³ anionic exchange resin waste was generated during the chemical decontamination of both the Barsebäck units. Additionally a total of 12 filter bags were generated as additional waste, containing crud and insoluble particles, mobilized during the decontamination application.

8 Conclusions

The FSD in both units at Barsebäck will give a significant reduction of the collective doses during the service operation and the dismantling phase. The initial dose savings estimated for decommissioning and dismantling activities, based on the achieved decontamination results, lies in the range of 6600 mSv for both units. The collective dose exposure for the preparation and performance of the decontamination in both units was 138.3 mSv, which was only slightly above the dose budget estimated.

All the decontamination targets were met and/or surpassed. These excellent results could only be obtained because of the close co-operation between Barsebäck, OKG AB and AREVA NP GmbH.

The decontamination application also demonstrates that a FSD for decommissioning should be performed when experienced plant personnel with intimate system and operating knowledge still are available and the functionality and usability of all NPP systems is given. This gives a limited time to do this after the final shut down