Full System Decontamination at the Obrigheim Nuclear Power Plant Prior to Decommissioning

Chr. Topf, Erlangen

Introduction

In May 2005 the German nuclear power plant in Obrigheim was shut down, after 36 years of operation. Final shut down and decommissioning of the NPP had already been an issue for EnBW since 2004 and a full system decontamination (FSD) prior to dismantling was one of the central topics. Based on the long term experience in FSDs worldwide and on the outstanding results achieved at the German NPP in Stade, Areva NP GmbH was contracted for the planning and performance of the FSD application at Obrigheim. Decontamination performance using Areva NP GmbH’s CORD® family decontamination technology in combination with the decontamination equipment AMDA® was scheduled for the beginning of 2007.

CORD (chemical oxidation reduction decontamination) represents the chemical decontamination process while AMDA (automated mobile decontamination appliance) is the synonym for the external decontamination equipment of Areva NP GmbH.

HP/CORD UV Concept

As for all other state of the art processes of the CORD family, the HP/CORD UV process is a multi-cycle process which may be applied not only for decontamination in operating NPPs, but also for decontamination for dismantling. In this context the abbreviation HP stands for permanganic acid, the chemical used for pre-oxidation, and UV represents the in-situ decomposition of the decontamination chemical with an ultraviolet light source. The principle of HP/CORD UV is shown in Fig. 1. Each treatment cycle includes the following steps:

- step 1: pre-oxidation with HP,
- step 2: HP reduction with the decontamination chemical,
Stilllegung und Rückbau

– step 3: decontamination,
– step 4: UV decomposition of the decontamination chemical and solvent clean-up.

Dissolved corrosion products and the activity in solution are deposited on ion exchange resins during the decontamination step 3. After completion of step 3 the decontamination chemical is decomposed to water and carbon dioxide during step 4. The number of treatment cycles is adapted to the decontamination targets based on Areva NP experience and preliminary tests with representative samples.

### References for Full System Decontamination with HP/CORD UV

Areva NP has global experience with FSDs in still operating NPPs (see Table 1) and also with NPPs permanently shut down (see Table 2). The company has performed nearly all FSDs in PWRs and BWRs in Europe. All projects were completed successfully.

<table>
<thead>
<tr>
<th>NPP</th>
<th>Country</th>
<th>Year</th>
<th>Type</th>
<th>Supplier</th>
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<tr>
<td>BR3 Mol</td>
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<td>1991</td>
<td>PWR</td>
<td>Westinghouse</td>
</tr>
<tr>
<td>VAK Kahl</td>
<td>Germany</td>
<td>1992/93</td>
<td>BWR</td>
<td>AEG</td>
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<tr>
<td>MZFR Karlsruhe</td>
<td>Germany</td>
<td>1995</td>
<td>D₂O</td>
<td>Siemens</td>
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<tr>
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<td>Germany</td>
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<td>BWR</td>
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<tr>
<td>Caorso</td>
<td>Italy</td>
<td>2004</td>
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<td>GE</td>
</tr>
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<td>GE/Toshiba</td>
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<td>1 Fukushima 2</td>
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<td>Japan</td>
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<td>BWR</td>
<td>GE/Toshiba</td>
</tr>
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</table>

Tab. 1. Full system decontamination in operating NPPs performed by Areva NP.

Tab. 2. Full system decontamination prior to dismantling.

Decontamination Targets

Decontamination targets are clearly based on the aim to facilitate the dismantling activities of the NPP systems in total.

The targets for decontamination at the Obrigheim plant are summarized below:
– reduction of the activity inventory especially at the steam generators (SG) for additional dismantling measures with regard to dose rate savings and rendering material suitable for free release,
– reduction of the ambient dose rate in working areas,
– no significant shift of the gamma/alpha ratio,
– minimum waste generation.

Therefore an average decontamination factor (DF) of more than 10 was contractually guaranteed by Areva NP, but a maximum dose reduction was of course the main goal of the FSD.

### Technical Description

The project was divided into 3 phases, starting with a feasibility study in which the general framework regarding decontamination area, engineering, efficiency and waste generation of the decontamination was established. The second phase included detailed engineering and compilation of procedures for on-site performance as well as the preparation of documents for authority
approval of the planned decontamination. These tasks were realized in close cooperation between the 
Obrigheim plant project team and the Areva NP project team. Finally the on-site performance (phase 3) 
planned for the first quarter 2007 ended as scheduled.

Due to the optimum team-work between the 2 project teams the overall project was completed within the scheduled time frame and without any problems.

Decontamination System and Area

The NPP Obrigheim is a 357 MW_e PWR with a 2 loop design and was operated from 1969 to 2005. The FSD included the following systems and components:

- reactor pressure vessel (RPV) with internals, no fuel,
- pressurizer,
- primary circuit (two loops) including SGs, as well as parts of:
  - residual heat removal system (RHR),
  - volume control system (CVCS),
  - emergency injection system,
  - mechanical filters of the chemical purification system (CPS).

The decontamination flow path (see Fig. 2) had a total system volume of 160 m³ with a system surface of 8,100 m². Tab. 3 lists the surface areas according to material. The SGs account for about 75% of the total surface area.

Process Engineering

The FSD was performed using mainly plant-internal systems with support of the external decontamination equipment AMDA. Besides the integrated NPP systems described above the following systems were additionally used for support:

- chemical injection system,
- component cooling system,
- coolant storage,
- plant exhaust system,
- building drains,
- spent resin tanks.

As part of the engineering phase a test run of all systems, excluding the external AMDA equipment, was performed successfully at decontamination conditions.

During decontamination the AMDA equipment was in operation for injecting the decontamination chemicals, for by-pass cleanup through ion exchange resins and for UV decomposition of the decontamination chemicals in the UV skids. Exhausted resins from the decontamination process were transferred from the AMDA resin filters into the plant internal spent resin tank. Circulation during decontamination was established with all pumps in operation, the solvent temperature was adjusted by removal of excess thermal energy using the heat exchangers of the RHR system.

Results

A total of 4 HP/CORD UV cycles were performed. The dissolved cations and activity were deposited on 6.7 m³ of ion exchange resins with more than 75% required for the corrosion products.

The results of the decontamination are summarized in Tab. 4. No significant change in the Gamma/Alpha nuclide ratio was detected.
Due to the extremely low dose rates at the SG surface the dose rate measurements after decontamination had to be carried out with a shielded detector. Long time shielded contact dose rate measurements at selected points of the SGs indicate an even lower contact dose rate compared to first measurements.

The dose rates inside the SG channel heads were drastically reduced (see Fig 4) and ensure high man-Sievert savings for upcoming dismantling activities. Visual inspection of the SG channel heads after decontamination showed metallically clean surfaces.

Reduction of the ambient dose rate especially in areas of the residual heat removal (RHR) heat exchangers and the chemical volume control system (CVCS) recuperative heat exchanger, which are located in one single room, was another concern. The ambient dose rate in these regions was able to be reduced by a factor of 10.

Conclusions

After a successful FSD at the German PWR in Stade the FSD in Obrigheim proves once again that the HP/CORD UV process in combination with the AMDA provides excellent results for dose rate reduction in the primary as well as the auxiliary systems. All decontamination targets were met and/or surpassed. Especially the extremely low contact dose rates achieved at the SGs allows easy handling for dismantling and disposal of these components.

These outstanding results could only be obtained because of the close and excellent co-operation between Obrigheim and Areva NP GmbH.

Integration of the primary system and auxiliary systems into the decontamination flow path is very important for subsequent decommissioning activities. A FSD for decommissioning should in any case be performed directly after final shut down of the NPP which ensures that experienced plant personnel with intimate system and operating knowledge is still available and the functionality and usability of all NPP systems is given.

The combination of the HP/CORD UV concept with AMDA technology is not only suitable for decontaminations prior to dismantling but has proven to be also a standard decontamination process for components and systems of operational NPPs whether PWR or BWR. The obtained high DFs as well as the reduction of the ambient dose rate demonstrate clearly the potential of a FSD for operating plants to realize high man-Sievert savings.

The low contact dose rates in the primary circuit and at the heavy components resulting in high DFs for the different systems far exceeded the targets and expectations of the decontamination.

Figure 3 illustrates the excellent results for the dose rate reduction at the 2 SGs. The average dose rate at the SGs after decontamination amounts to 1.6 µSv/h. This gives an average DF at the SGs of higher than 1,400.