MANAGING THE FUTURE SWEDISH DECOMMISSIONING WASTE

From dismantling to final dispose

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ABSTRACT (AS PER TITLE)

By Swedish law it is the obligation of the nuclear power utilities to satisfactorily demonstrate how a nuclear power plant can be safely decommissioned and dismantled when it is no longer in service as well as transporting and dispose the waste in a safe way so that the environment will not be affected.

To meet these objectives, detailed plant-specific studies have and are being performed by Westinghouse Electric Sweden AB (WSE) and TLG Services in cooperation with the utilities of Oskarshamn, Forsmark, Ringhals and Barsebäck on behalf of SKB.

The final closure of most of Sweden's NPP is far ahead but anyhow there has been a need for developing a more general decommissioning planning basis. These studies result in estimates of radioactive and conventional waste volumes and radioactivities and will be a major input in designing transport systems and final repositories for the decommissioning waste. The studies will also be used as a base for estimation of the associated decommissioning costs.

The Swedish Nuclear Fuel and Waste Management Co. (SKB) is owned by the Swedish nuclear power utilities and is responsible for managing the nuclear waste by designing, building and operating waste storage and disposal facilities.

The paper will provide detailed data of waste characterization and amounts, as well as of time schedules for the Swedish fleet and show how decommissioning will fit with the existing well-developed waste management system of the country. The standardized waste packages that are planned to be used will be presented as well as managing of the large components, e.g. whole BWR Reactor Pressure Vessels. In order to dispose the radioactive waste the ongoing project to extend SFR (final repository for short-lived LILW) and the planning for the repository for the long-lived waste, e.g. core components will be shown.

1. INTRODUCTION

By Swedish law it is the obligation of the nuclear power utilities to satisfactorily demonstrate how a nuclear power plant can be safely decommissioned and dismantled when it is no longer in service as well as transporting and dispose the waste in a safe way so that the environment will not be affected.

To meet these objectives, detailed plant-specific studies have and are being performed on behalf of The Swedish Nuclear Fuel and Waste Management Company (SKB) in cooperation with the utilities of Oskarshamn, Forsmark, Ringhals and Barsebäck (Figure 1). These studies result in estimates of radioactive and conventional waste volumes and radioactivities and will be a major input in designing transport systems and final repositories for the decommissioning waste. In able to deposit the decommissioning waste the existing final repository for short-lived low- and intermediate level waste, SFR (Figure 1), will be extended and scheduled for operation the year 2020. The studies will also be used as a base for estimation of the associated decommissioning costs for funding.

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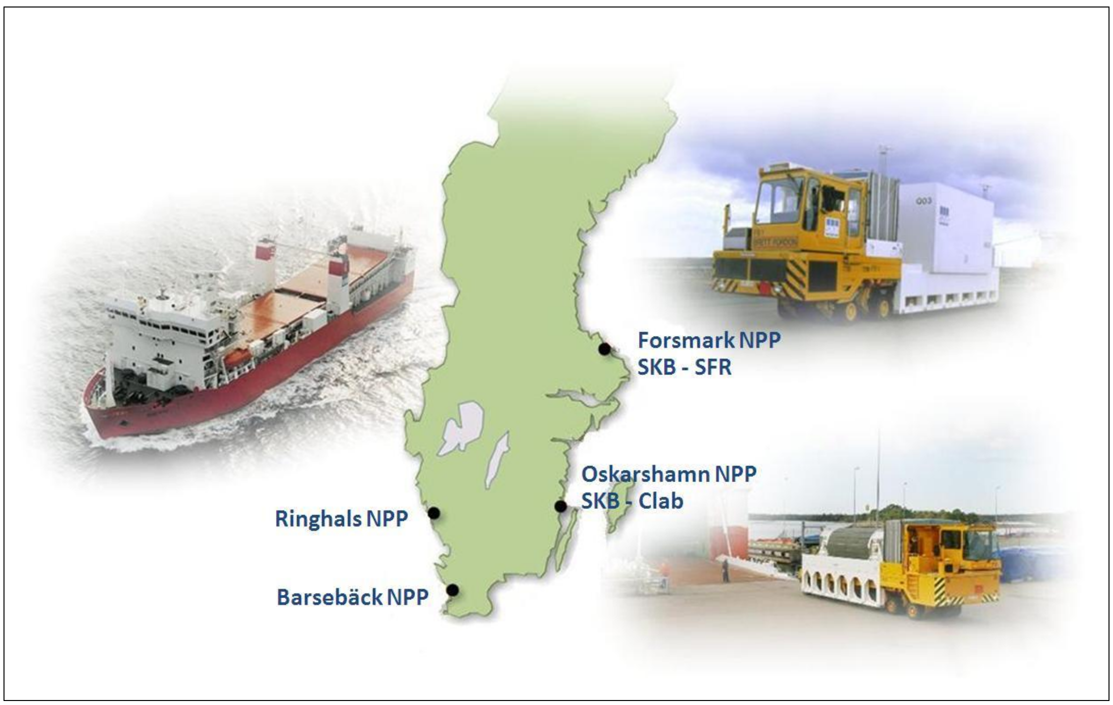

Figure 1. Map of the Swedish nuclear power plants and the SKB facilities.

2. PERFORMED WORK

By contract from SKB Westinghouse performs decommissioning studies for the three BWR units at Oskarshamn and the three BWR units at Forsmark nuclear power plant. For the three PWR units and one BWR unit at Ringhals plant and the two BWR units at Barsebäck plant, the studies are carried out by TLG Services. Westinghouse has previously performed a reference decommissioning study [1] for typical Swedish BWRs, based on Oskarshamn Unit 3. A similar methodology is now being used for individual decommissioning studies of Oskarshamn and Forsmark. The individual decommissioning study of Barsebäck is already developed and was performed in 2006 by TLG [2]. In accordance with [2] TLG is now performing the decommissioning studies of Ringhals.

3. INVENTORY (SYSTEMS, COMPONENTS, STRUCUTRES, RADIOACTIVITY)

For the studies plant inventory lists have been produced out of component databases, drawings, specifications etc. When not available, measurements and estimates have been done when walking around in the station or data from similar ("twin reactors") units have been used.

The nuclear power plants have provided the quantity of materials for the units and ALARA Engineering has performed the radiological calculations in order to give activity contents when the plant is shut down. The reference date of the activity is one year after shut down of the unit.

In order to classify the dismantling waste material in different categories concerning radioactivity content the materials inventory also has to be combined with data on contamination levels for each piece of material. This has been done by using measured data in combination with calculations of activity transfer and deposition throughout the plant systems. By combining the surface contamination with data of exposed area and mass of each component, an average specific activity (Bq/kg) could be calculated.

The dismantling waste has then been classified according to its specific activity in different categories as shown in Table 1.

Thorough system decontamination is assumed to be applied for most of the primary systems. The average decontamination factor has conservatively been set to 10.

Table 1: Activity Categorization.

Waste Category	Specific Activity [Bq/kg]	Description
Red	$> 10^6$	Radioactive material requiring radiation shielding
Yellow	$10^4 – 10^6$	Radioactive material not requiring radiation shielding.
Green	$500 – 10^4$	Potentially free-release material after treatment
Blue	< 500	Non-active material, controlled area
White	0	Non-active material, uncontrolled area

4. DISMANTLING TECHNIQUES

However, it is assumed that no major technical development activities would be needed for dismantling of the studied reactor units. Already today, there is sufficient experience with different techniques required for the dismantling operations. Some of them have been gained from the NPP dismantling plants already performed or currently on-going. In some cases the most appropriate technique for dismantling an item will be the same technique as was used for maintenance when the plant was operational. For example the turbine may be dismantled in this way, taking advantage of installed lifting equipment such as the overhead travelling crane in the Turbine Building, and using a proven dismantling technique familiar to the plant staff and already covered by existing written procedures. Also, during replacement of major components within operational plants, many useful techniques have been developed. An example is the wide variety of mechanical cutting techniques that have been used in the Nordic countries for handling of replaced reactor internal parts.

5. MANAGEMENT OF THE DECOMMISSIONING WASTE ON SITE

When processed on site, the final decommissioning waste will be packaged in containers of similar type as those currently used for operational waste within the Swedish waste handling system. The chosen container types in the studies are as follows:

5.1 BFA-containers

The process equipment waste in the red activity category (> 10^6 Bq/kg) consists of long-lived and short-lived waste. The long-lived waste mainly consists of the PWR reactor pressure vessels and the internals (both BWR and PWR) located close to the core and is assumed to be segmented and placed in 0,1 m thick steel containers with the outer dimensions 3,30×1,30×2,30 m (Figure 2). The inner volume is approx. 7 m^3 and the maximum weight, including 12 ton of waste, is 34 ton. The long-lived waste is assumed to be disposed of in the final repository for long-lived LILW (SFL; not yet built; scheduled for operation the year 2045).

Figure 2. BFA-containers for long-lived LILW.

5.2 Steel Boxes

The short-lived waste in the red activity category (> 10^6 Bq/kg) is assumed to be transported and stored in 5 mm thick steel containers with the outer dimensions 1,2×1,2×1,2 m (Figure 3) currently used for operational waste. An enlarged version is also foreseen to be used for practical reasons with the dimensions 2,4×2,4×1,2 m and the maximum total weight 20 ton. The boxes are transported in shielded transport containers (Figure 4), and disposed of in the final repository for short-lived waste (an extension of the present SFR facility for operational waste).

Figure 3. Swedish standard steel container for short-lived ILW.

Figure 4. SKB shielded transport container containing waste containers.

5.3 ISO-Containers

The largest quantity of the process equipment waste can be found in the less radioactive categories: yellow (10^4 - 10^6 Bq/kg), green (500 - 10^4 Bq/kg), blue (< 500 Bq/kg) and white (0 Bq/kg). The process equipment waste in the yellow and green categories is assumed to be disposed of in the SFR repository whilst the waste in the blue and white category is assumed to be transported to an appropriate disposal site for conventional waste or a recycling facility. The waste containers to be used for this kind of waste are assumed to be standard 20 ft half height ISO-type containers with top opening and outside measurements 6,06×2,5×1,3 m (Figure 5). The inner volume of these containers is approx. 15 m³ and the total weight is limited to 20 ton.

Figure 5. Disposal of half height ISO-type containers (short-lived LLW) in SFR.

5.4 Large components, e.g. whole RPV (BWR)

As an alternative to segmentation of the BWR reactor pressure vessels the studies also presents how the vessels will be managed as a whole peace. For example similar to how it was installed according to Figure 5. There are a total of 9 BWR vessels to be taken care off from the Swedish nuclear fleet. In the extension project of the SFR facility it is planned to deposit whole RPVs without the core components.

Figure 6. Installing one of the two RPVs (BWR) at the Barsebäck site in the 1970s.

5.5 Waste amounts

For packaging of dismantling metal waste, experience data and calculations from previous segmentation projects have been used. A packing degree of 0,4-1,1 ton/m³ is assumed depending on which type of component is being packed.

The biological shield is assumed to be sawed in blocks to be fitted into the waste containers. The fit will not be perfect and the total packing degree of the concrete waste is assumed to be the same as for crushed concrete, i.e. approx. 1,5 ton/m³. This packing degree is assumed for all concrete waste.

When converting the amounts of original radioactive dismantling waste into container volumes, the indicated required repository volumes for the short-lived LILW (SFR) are about 100000 m^3 (including a vault for whole RPVs) and for the long-lived LILW (future SFL facility) about 2000 m^3.

6. DECOMMISSIONING PROGRAM

The decommissioning period starts with a defueling period when the fuel is transported away from the site to the Clab facility (Figure 1) for intermediate storage. For different reasons a period of time might be needed to prepare the plant for dismantling. If this so called shutdown operation period becomes long there might be a need to upgrade certain functions of the plant before the dismantling operation could start. The site restoration phase concludes the decommissioning period.

A model has been developed where the inventory data can be used to calculate work hours for taking care of all the different types of plant components. The working time estimates are then combined, together with general duration data for different activities during plant decommissioning, into a time schedule for the complete program, from initial planning and preparatory activities to non-radioactive building demolition and site restoration.

The expected total duration, from plant shutdown to finalized landscaping, is typically 10 years, while the actual dismantling period is about 5 years.

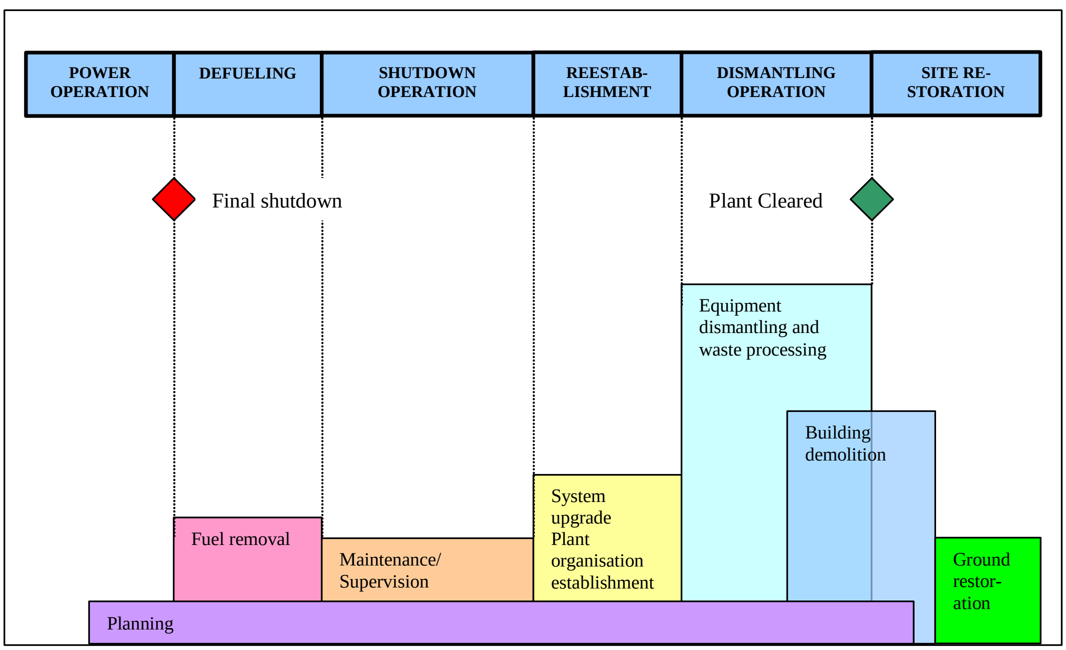

Figure 7. Decommissioning phases.

7. TRANSPORTATIONS AND FINAL DISPOSAL

In order to transport and dispose the waste arising from decommissioning of the NPPs the existing transportation system will be used. It's based on transporting the waste by the sea from the harbours at the NPPs to the harbour at Forsmark with the specially designed ship m/s Sigyn. From the ship transport vehicle will move the waste down in to the SFR facility where it will deposit in the intended storage vaults.

Figure 8. SKB transport vehicle with operational waste and the specially designed ship m/s Sigyn in the background.

In order to deposit the future amounts of decommissioning waste the repository for short-lived LILW (SFR) needs to be extended. The ongoing project is to hand in an application by 2013 so that the extended repository is in operation by 2020. The design of the extended SFR will ensure that large components can be handled such that decommissioning can be optimized with regard to the long term safety.

SFR will also be able to interim store the long-lived LILW until the future repository for long-lived LILW (SFL) will be in operation by 2045.

The coordinated planning of decommissioning activities and design of the repository (and transports) ensures an optimized approach to decommissioning.

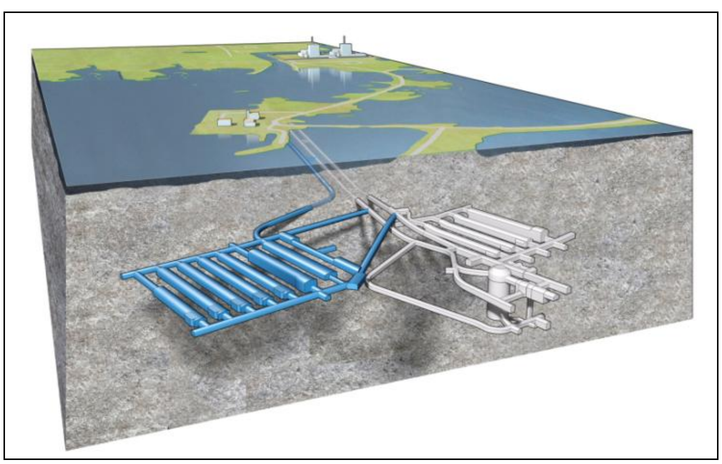

Figure 9: The SFR facility, white-in operation, blue-planned extension.

8. REFERENCES

[1] B. Gustafsson, G. Hedin, H. Johnsson, C. Cassidy, B. Swenson, "Swedish BWR Reference Plant Decommissioning Study", Westinghouse Electric Sweden AB Report SEP 06-055, rev 0, 2006

[2] TLG Services, Inc., "Decommissioning Cost Analysis for Barsebäck Nuclear Station", Document S33-1567-002, Rev. 0, TLG Services, Inc, 2008.