RPV In-Situ Segmentation Combined with Off-Site Treatment for Volume Reduction and Recycling – 14286

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ABSTRACT

Decommissioning of NPPs generates large volumes of radioactive or potentially radioactive waste. The proper management of the large components and the dismantling waste are key success factors in a decommissioning project.

A large component of major interest is, due to its size and its span in radioactivity content, the RPV which can be disposed of as is or be segmented, treated, partially free released for recycling and conditioned for disposal in licensed packages.

To a certain extent the decommissioning program has to be led by the waste management process. Long execution times and delays due to problems with on-site waste management processes are major cost drivers for decommissioning projects. This involves also the RPV.

In Sweden, the extension of the repository for short-lived LLW and ILW (SFR), plans for a potential disposal of whole RPVs. Disposal of whole RPVs is currently the main alternative but other options are considered. Real data from existing BWR RPVs was used for this study aiming for free release for recycling of a substantial amount of the material, and volume efficient conditioning of the remaining parts. Proven segmentation methods are intended to be used for the in situ segmentation followed by proven methods for packaging, transportation, treatment, recycling and conditioning for disposal. The expected volume reduction for disposal can be about 90% compared to whole RPV disposal.

In this respect the in-situ segmentation of the RPVs to large pieces followed by off-site treatment is an interesting alternative that fits very well with the objective.

INTRODUCTION

There is need for development of the decommissioning process in order to minimize the economic consequences for facility owners and the community. A smooth and environmental friendly decommissioning process is also important to prove that nuclear energy is a sustainable energy source i.e. a platform for nuclear new build.

Discussions are on-going to find the optimal solution for handling of the BWR RPVs, four alternatives could be identified:

1. Dismantling and disposal of whole RPV with or without interim storage waiting for disposal facility to be ready.
2. Dismantling of whole RPV, transportation to Studsvik for treatment with the intension of free release of the majority of the material and volume reduction of the remains.
3. Segmentation of the RPV in-situ at the NPP. Packing in containers for transportation to Studsvik for treatment and free release of the majority of the material.
4. Segmentation of the RPV in-situ at the NPP. Packing in containers for transportation to the

disposal facility without any further treatment or free release of the material.

Alternative 3 has been studied by ndcon. Besides the potential for free release of a large part of the material directly or after decay, the NPP do not need to handle question related to dismantling of whole RPV from the NPP, nor special transport of the RPV, interim storage and costs related to conditioning and disposal at the Swedish extension of the repository for short-lived LLV and ILW (SFR).

THE ndcon WASTE MANAGEMENT CONCEPT

Based on the previous experience, the existing regulatory framework, disposal requirements, and the NPP owners' expectation for safe, fast, and cost effective decommissioning, the ndcon waste management concept has been developed. The waste management concept is described in Fig. 1. Variants may be applied to consider local conditions. A first analysis is proposed to be performed in an early phase indicating the logistics and treatment alternatives for the waste streams, see Fig. 2. This analysis can be rather complex and could benefit from the use of a simulation tool.

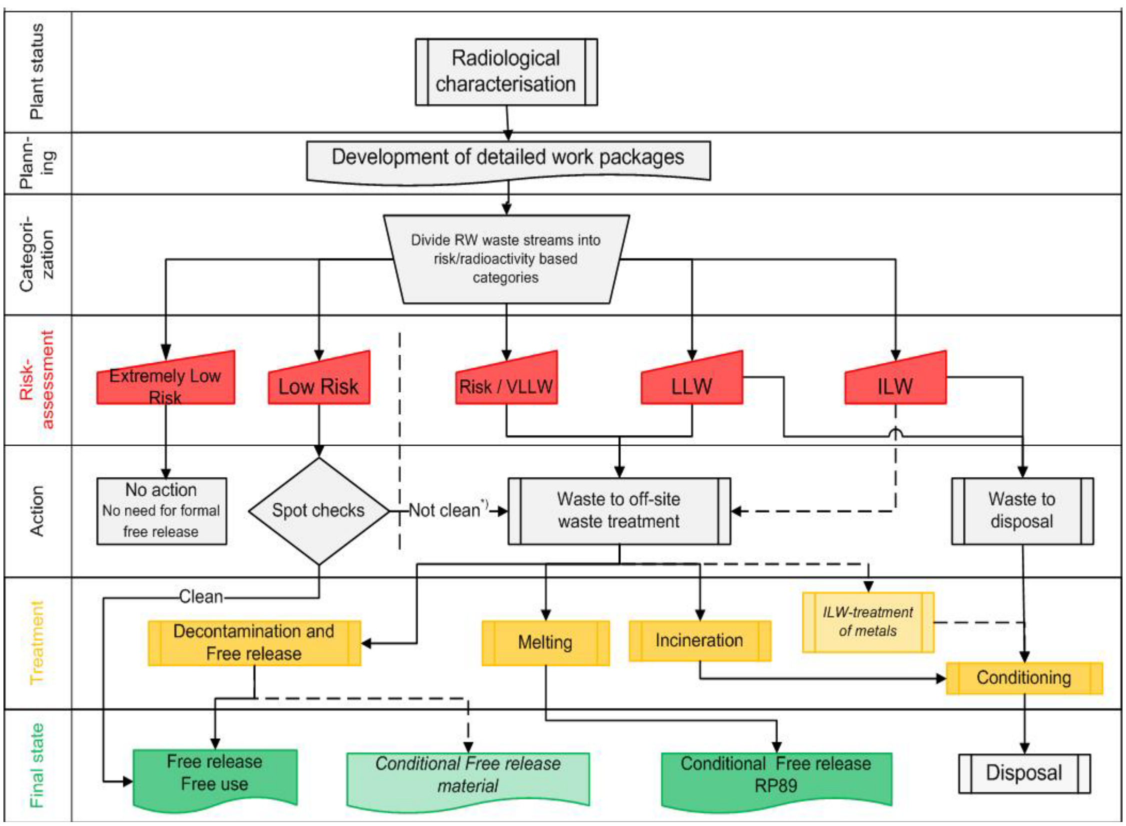

Fig. 1. Risk-based concept for waste management during decommissioning [1].

The waste management is using a concept based on risk for contamination and activity level class to optimize the treatment. For the lowest categories (extremely low risk, and low risk) the actions needed can take place on-site. For the remaining categories (risk / very-LLW, LLW, and ILW), the actions needed (waste treatment) are in most cases proposed to be handled off-site. For the off-site waste treatment, different facilities are used depending on the waste streams. The Decontamination and Free Release facility can be used for waste streams not suited for melting, such as cables, galvanized steel, motors, and electronics. Melting is proposed for carbon and stainless steel, copper, aluminium, nickel base alloys, brass, and lead. Incineration is used for burnable waste and will result in a stable end product suitable for disposal. The simulation tool is also used to identify bottle necks and to optimise the needed space and equipment.

The need for ILW-treatment of metals depends on local national disposal conditions, off site treatment can shorten the on-site decommissioning time and increase packing efficiency and optimize the disposal by separation between short-lived and long-lived waste.

The disposal volume for a typical BWR can, according to performed studies, with the ndcon waste management concept be reduced by up to 2/3, leading to substantial potential savings for the NPP owner.

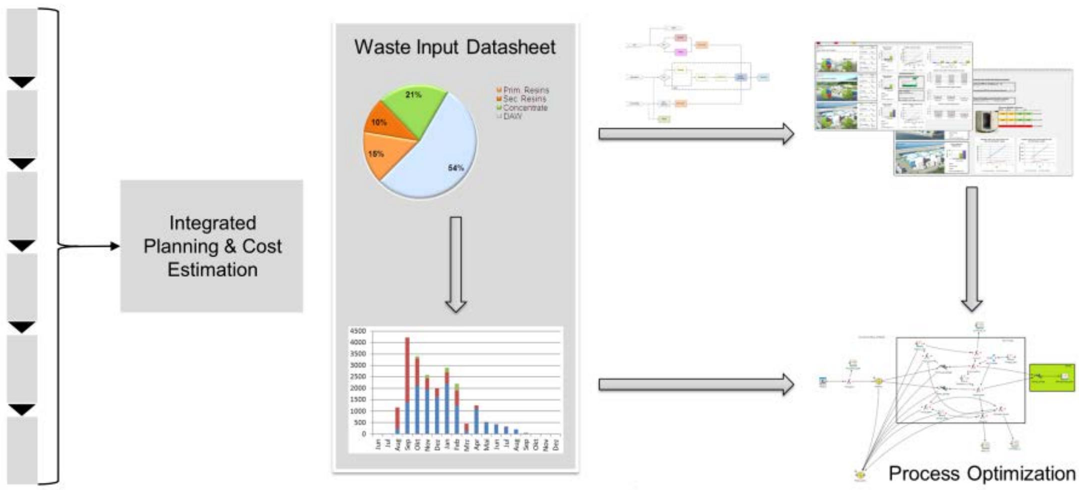

Fig. 2. The simulation tool is used to analyse waste streams, identify bottle necks and to optimise the needed space and equipment for the D&D project [2].

To summarize, by using the ndcon waste management concept different waste categories can be handled differently to achieve an environmentally sound decommissioning with minimum volumes for disposal.

ASSUMPTIONS FOR THE HANDLING OF BWR RPVS

The assumptions for the study are:

- Higher nuclide content in the RPV of Unit 2 compared with Unit 1
- The material for potential free release has been grouped (categorised) as follows:
  - Direct free release after melting
  - Free release within ten years after melting
  - Free release within 10-25 years after melting
  - Material for disposal at SFR
- The RPV heads are packed in boxes and shipped in one-piece for treatment
- Segmentation is performed in large pieces (rings), and the rings are further segmented in a pool to pieces weighing 10-20 tons.

- Loading in industrial package type 2 (IP-2) containers. Transportation to Studsvik. Short turnaround time
- The RPV isolation is assumed to be removed and is not part of this study.

RPV IN-SITU SEGMENTATION

The assumed handling of the Swedish BWR RPVs has been to dispose them as whole packages at the repository facility SFR, which require a separate tunnel and vault. The disposal of the RPV cannot take place until the repository is ready, which may cause delays in a decommissioning project if it must wait for the repository to be finalized. Delays are cost driving and are the starting point for the investigation if alternative methods can be applied to avoid the requirement of having to wait for the repository to open.

The alternative method chosen for the investigation is in-situ segmentation of the RPV. A reference reactor with the following data has been chosen to represents a typical BWR:

Inner length :	20 m
Inner diameter:	5,2 m
RPV thickness:	14 cm
RPV head thickness:	7 cm
Total weight incl insulation:	530 ton
RPV head weight:	90 ton

There are different methods that can be used in order to segment the RPV into suitable sized pieces, one is presented hereafter. Westinghouse has a vast experience in RVI segmentation which does not differ much from RPV segmentation. Similar dimensions have been cut many times before and are therefore not considered as a hindrance [3, 4].

The RPV is water filled as soon as the primary piping has been cut and plugged, this in order to minimize unnecessary dose exposure for the personnel. The RPV is then cut with a Plasma Arc Cutting system (PAC) into rings that are lifted and placed in a water filled pool next to the reactor pool. Once the rings are placed in the pool, they are further segmented into suitable sized pieces for transportation. Mechanical cutting tools are used for this activity. The sizes of the different rings that are anticipated are shown in figure 3 below. The principle is to cut a ring out, cut it further in the pool, transport the pieces for further treatment and then continue with the next ring until the whole RPV is cut.

A HEPA ventilation system needs to be installed to handle the airborne contamination that follows the PAC cutting activities. The water level in the RPV is also adjusted so that the water surface is just below the cutting kerf at all time. As an alternative to PAC, mechanical cutting techniques can also be used to cut out the rings. It will however take longer time and as the radiation level is relatively low PAC is the preferred alternative.

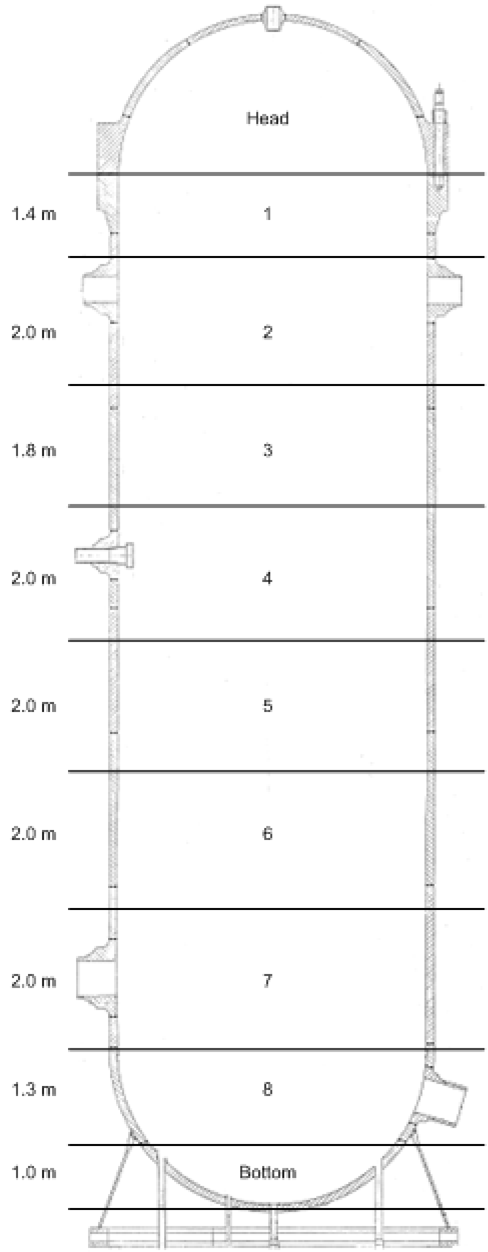

Fig. 3. Proposed cutting of the rings of the RPV.

CALCULATION OF RPV ACTIVATION

Tables I and II summarize the calculation of the NPP RPVs, and indicated the heights relative to the core bottom in cm of the cladding and the base material relative to the need for decay. The need for decay is divided into the categories Direct free release, 10 years decay, respectively 25 years decay. The remaining height between the decay zones indicate the material needs to be deposited in SFR.

TABLE I. Division in height (cm) of NPP Unit 1 cladding and base material relative to the need of decay.

Measurements in cm	Unit 1 cladding		Unit 1 base material	
	Below core bottom	Above core bottom	Below core bottom	Above core bottom
Direct free release	-	+755-top	-	+755-top
10 years decay	bottom - (-200)	+600-+755	bottom - (-200)	+610-+755
25 years decay	-200 - (-100)	+540-+600	-200 - (-60)	+500 - +610

TABLE II. Division in height (cm) of Unit 2 cladding and base material relative to the need of decay.

Measurements in cm	Unit 2 cladding		Unit 2 base material	
	Below core bottom	Above core bottom	Below core bottom	Above core bottom
Direct free release	-	+790-top	-	+790-top
10 years decay	bottom - (-335)	+735-+790	bottom - (-260)	+680-+790
25 years decay	-335 - (-130)	+555-+735	-260 - (-90)	+525 - +680

The calculations are also shown in Table III where the needs for decay at different heights of the RPVs are shown in a colour coded manner.

TABLE III. Unit 1 and Unit 2 cladding and base material relative to the need of decay. Results sectioned from RPV top to bottom.

		Unit 1			Unit 2	
	Between cm	Cladding	Base material		Cladding	Base material
1150	top	0	0		0	0
1100	1150	0	0		0	0
1050	1100	0	0		0	0
1000	1050	0	0		0	0
950	1000	0	0		0	0
900	950	0	0		0	0
850	900	0	0		0	0
800	850	0	0		0	0
750	800	0	0		10	10
700	750	10	10		25	10
650	700	10	10		25	25
600	650	10	10		25	25
550	600	25	25		25	25

500	550	SFR	25	SFR	SFR
450	500	SFR	SFR	SFR	SFR
400	450	SFR	SFR	SFR	SFR
350	400	SFR	SFR	SFR	SFR
300	350	SFR	SFR	SFR	SFR
250	300	SFR	SFR	SFR	SFR
200	250	SFR	SFR	SFR	SFR
150	200	SFR	SFR	SFR	SFR
100	150	SFR	SFR	SFR	SFR
50	100	SFR	SFR	SFR	SFR
0	50	SFR	SFR	SFR	SFR
-50	0	SFR	SFR	SFR	SFR
-100	-50	SFR	25	SFR	SFR
-150	-100	25	25	SFR	25
-200	-150	25	25	25	25
-250	-200	10	10	25	25
-300	-250	10	10	25	10
-350	-300	10	10	25	10
bottom	-350	10	10	10	10
RPV Head		0	0	0	0

OFF-SITE TREATMENT

The RPV in-situ segmentation needs to be combined with off-site treatment in order to optimize the volume needed for the repository. The treatment will be performed at Studsvik, using proven methods and experience from similar RPV projects. Based on the previous projects, it can be concluded that:

- The time for segmentation is short, and the Rip and Ship concept can be used.
- The transportation costs will be low (<0.1 Euro/kg)
- No additional transportation cover or shell will be needed.

VOLUME REDUCTION AND RECYCLING

The results from the study (see Table IV) indicate that the degree of free release of material is high (>70%) when taking account for up to 25 years of decay. The volume for disposal per RPV can be reduced from 600 m^3 to 35-50 m^3, a reduction of >90%. The result is divided into categories in Table IV.

TABLE IV. NPP RPV tonnage divided in different categories.

	Unit 1 (ton)	**Unit 2 (ton)**
Direct free release	189	178
Free release after 10 years decay	168	146
Free release after 25 years	55	66

decay		
Disposal at SFR	121	143
Secondary waste incl. isolation (4%)	21	21
Degree of free release	74%	70%

OPTIMIZING CONTAINERS FOR DECOMMISSIONING WASTE

There is great uncertainty regarding containers to be used for decommissioning waste. The ndcon judgement is that there is a great potential for cost savings. Studsvik has performed comprehensive or with type descriptions for operating waste. The proposed containers in series 12, 23, and 24, are judged to be applicable for operating waste as well as for decommissioning waste. When container type 24 is approved, complementing variants can be developed. Initial studies regarding e.g., two-position mould have been performed with good results.

CONCLUSIONS

By combining proven methods for RPV in-situ segmentation and off-site treatment more than 70% of the RPV material for the studied NPP may be subject for clearance and recycling. The volume for the repository can be reduced with more than 90% to 35-50 m^3/RPV.

By the proposed method there is no need to wait with the RPV handling until the extension of the repository SFR is ready for receiving decommissioning waste, nor any need for whole RPV removal from the NPP or whole RPV disposal at SFR.

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