CONCEPTUAL DESIGNS FOR THE CONDITIONING AND PACKAGING OF EXCHANGEABLE NON-FUEL CORE COMPONENTS FOR FINAL DISPOSAL IN SWITZERLAND

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ABSTRACT

Concepts for the conditioning and packaging of non-fuel reactor core components from the Swiss Nuclear Power Plants have been developed for the Swiss National Cooperative for the Storage of Radioactive Waste (NAGRA). These wastes include control rods, flow restriction rods, burnable poison rod assemblies, part length control assemblies, and primary and secondary neutron sources. Based on waste materials and available or planned container characteristics, optimization of the internal configuration of selected containers has been performed. Large concrete waste containers about 2m x 2m x 4.5m, i.e. 20m^3, foreseen for decommissioning waste could accommodate entire BWR and PWR control rods and burnable poison rods. Existing thick walled iron containers are considered for flow restriction rods and part length control assemblies. The volume of packaged waste amounts to about 1,600m^3 from the 1,600 PWR MWe and the 1,300 BWR MWe with a plant lifetime of 40 years.

INTRODUCTION

The nuclear power plant (NPP) non-fuel reactor core components considered in this study are those wastes which are exchanged within the reactor core from time to time. These wastes are more active and of a lesser volume than the other operational wastes and are spread throughout the NPPs. The conditioning and packaging of these wastes for final disposal has not been extensively investigated as have the other operational wastes.

A preliminary study has been performed for the Swiss National Cooperative for the Storage of Radioactive Waste (NAGRA), to investigate how the conditioning and packaging of these special wastes could be performed in view of their final disposal. Preliminary studies of the packaging and disposal of decommissioning wastes in Switzerland have shown that a large waste container would be most suitable for large waste items (1). It is therefore planned to use a large concrete container, about 2m x 2m x 4.5m (20m^3), which could also be considered for the non-fuel core components if necessary.

OBJECTIVES AND PARAMETERS

The main objective of this study was to design and model waste containers which would not only meet shielding, heat, structural and weight requirements, but would be large enough to accommodate the entire length of a control rod. Material handling and conditioning exposure could be greatly reduced if items such as control rods could be disposed of without having to be cut into smaller pieces. The Tritium release associated with exposing the B_4C within a control would create a substantial radiological hazard and should be avoided if at all possible. However, the large assembly-type waste items, composed entirely of solid steel, would presumably present a much lesser hazard if cut into small pieces before packaging. The basic parameters of the design included an overall weight limit for each waste container (including waste) of 60 metric tons, a maximum dose rate at each container surface and at a distance of 1 meter from the surface of not more than 200 and 10 millirem/hour respectively, and that no voids could be present within the filled waste containers for structural integrity during transportation and repository placement. In addition to these limitations, it was decided to rule out the use of lead as a shielding material in the large containers due to its toxicity. These considerations set the task of balancing the volume of waste allocated to each container with the internal configuration and thickness of the shielding materials required to stay below the maximum permissible gamma and neutron dose rate levels and the overall weight constraint.

DESCRIPTION OF WASTES

The waste materials considered in the design models originated from the following NPPs now existing in Switzerland:

- 3 Pressurized Water Reactors(PWRs): 350MW,350MW,and 920MW (electric)
- 2 Boiling Water Reactors(BWRs): 320MW and 990MW (electric)

The dimensions of the waste types considered (burnable poison rod assemblies and control rods) consist of overall lengths ranging from 3.80m to 4.20m and widths ranging from 16x16cm to 25x25cm respectively. The actual numbers of the discrete waste items allocated to each large container were dependent on optimization factors such as the maximum allowable dose rate, overall weight, shielding material requirements, etc. Calculated activities ranging up to 3,400 curies per item were associated with these wastes, largely due to the presence of ^{60}Co in the steel materials. The activation time associated with the waste materials ranges from 1 to 20 years, depending on the actual plant lifetime of the particular waste item. The cooling time used in the waste activity calculation was commonly 5 years. The realistic elapsed time period for the conditioning of these wastes will most probably be longer than 5 years, therefore all values resulting from the modeling study are assumed to be conservative.

CONTAINER DESCRIPTION

As a first estimation, it was decided that the elongated rod-type waste items, such as control rods or neutron source rods, should be conditioned and packaged in large rectangular waste containers, while the large assembly-type wastes could be cut into small pieces and placed into thick walled iron drum containers. With this in mind, three different streams of waste types and disposal containers were examined and are summarized in Table I.

An illustration of the large container dimensions as applied for a particular modeling case can be seen in Fig. 1.

Waste types which could not be placed into the large containers due to their overall size, burnable poison rod assemblies for instance, would be cut into small pieces and placed within an existing thick walled iron drum-type container design shown in Fig. 2. This type of container is presently in use in Switzerland and Germany for interim storage and is suitable for final disposal.

MODEL DESIGNS AND CALCULATIONS

The waste conditioning and packaging study was performed in three stages. The first stage was the design and modeling of waste containers which could accommodate all but the neutron emitting waste items and the very large assembly-type wastes. The second stage was to design and model a waste container which would contain both primary and secondary neutron sources and source rods requiring a hydrogen rich shielding material. The third and final stage was the modeling of the drum-type container previously mentioned which could accommodate the large rod assemblies, once these materials had been cut into small pieces.

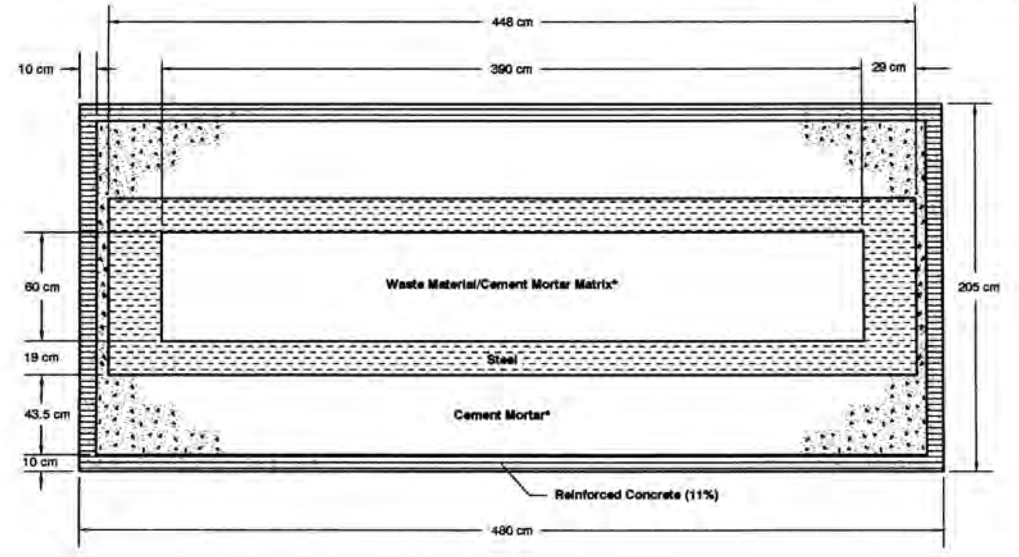
The first stage began with the use of a PC version of the QAD-CGGP computer code from Oak Ridge National Laboratories (2). QAD-CGGP is a combinational geometry point kernel code system for gamma-ray shielding calculations. A large rectangular waste container was then modeled. The outer portion of the large containers were composed of 10 cm thick reinforced concrete, while the internal configuration of cement mortar and steel shielding material was varied according to the shielding requirements of the specific waste materials. Figure 1 shows the basic configuration of shielding materials within the extended large container design including the overall dimensions for a particular case.

Radiation detection points were modeled on the surfaces and at one meter distances from the container surfaces . The calculated dose rates proved to be at a maximum value at the container ends due to the construction of the rod-type waste items. The main contribution to the gamma radiation was from the ^{60}Co within the stainless steel material of the wastes. For the placement of the rod-type wastes within the containers, a thick inner steel box was modeled (see Fig. 1) which would contain the optimal number of waste items and then filled to capacity with cement mortar. It was assumed that all materials (waste and mortar) within the inner steel box were a homogeneous mixture. To account for the non-uniform radiation distribution of the waste items, weighting factors were applied to the material densities in incremental regions along the width and length of the waste location in the container geometry. Due to the 4.50 - 4.80 meter length restriction of the overall waste container, the steel thickness of the inner box was varied to provide adequate shielding while allocating as many rods as possible within each box. The maximum number of rods per container was determined by the activity associated with each type of rod and

TABLE I

Waste Stream And Disposal Container Summary

Basic Lg. Containes		Extended Lg. Containers	Drums
Length:	4.50m	4.80m	0.9m
Height:	2.05m	2.05m	1.15m
Width:	2.05m	2.05m	0.9m
Wall Thickness:	0.1m	0.1m	0.25m
Volume:	$18.9m^3$	$20.2m^3$	$0.73m^3$
		(Predicted Allocation)	
Control Rods	(3.80m)	Longer Control Rods	Fuel Rod Assy.
		Neutron Source Rods	Burnable Poison Rod Assemblies.
			Flow Restriction Rods.
			Shim Rod Assy.



* Borated Silicone Rubber Replaces Cement Mortar in Neutron Source Rod Containers

Fig. 1. Large-Container.

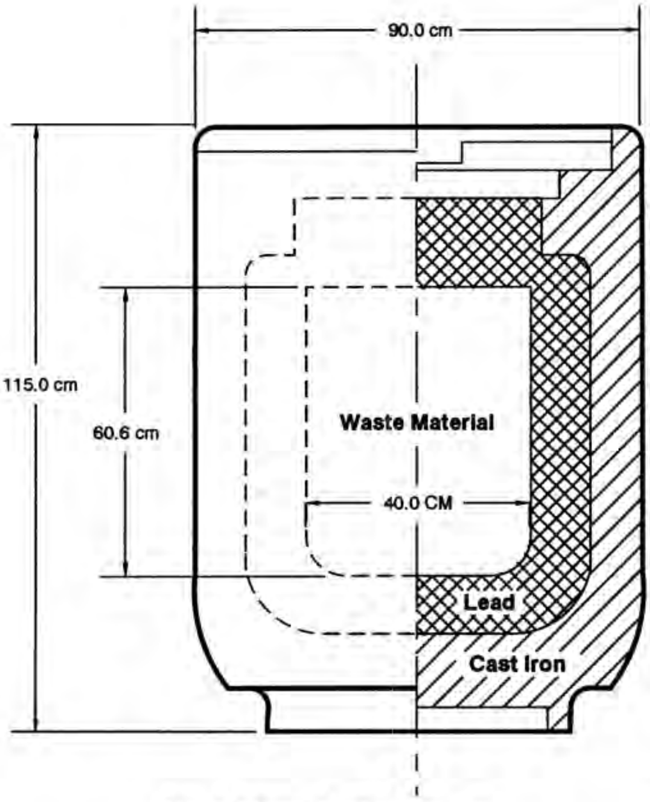


Fig. 2. Drum-Type Container.

the calculated dose rate outside the container. The final limitation was the overall weight of the filled container. The optimization of steel thickness and the number of rods within each container was carried out for each type of waste item.

The second stage of the modeling study was performed using the Oak Ridge National Laboratory RSIC Computer Code called ANISN-PC (3). ANISN-PC is a multigroup one-dimensional discrete ordinate neutron code system with anisotropic scattering. The code was used to calculate neutron dose rates outside the waste containers at a position where the least amount of shielding material would be encountered. To deal with the one-dimensional geometry constraint of the ANISN code, the source region of the container which housed the waste material was modeled as a fully reflected planar source at the midpoint of the large container. The gamma ray dose rate calculations for the neutron source rods were performed using QAD-GP because this code proved more effective in handling the gamma contribution. The activity produced by ^{60}Co within the steel rods again greatly overshadowed that of the neutron sources and their associated secondary gamma emission.

The shielding materials used for large containers which would contain neutron sources and source rods consisted of borated silicone rubber and borated steel used to construct the inner container box. Advantages of the borated silicone rubber are its richness in hydrogen, its high density, and its heat resistance. The configuration of the large containers used to package neutron sources was much like that shown in Fig. 1, replacing the cement mortar with borated silicone rubber which could be "poured" into each container to surround the waste items.

It was determined through calculation that the entire inventory consisting of 4 ^{252}Cf primary and 88 Sb-Be secondary neutron sources and source rods could be effectively placed in one large container. The only limitation would be that the ^{60}Co activity associated with these sources could not exceed a total of 1,200 curies.

In the third and final stage of the modeling study, waste types which could not be placed into large containers due to their size, rod assemblies for instance, were modeled using an existing drum-type thick walled iron container design (Fig. 2). The rod assembly waste types were assumed to have been cut into small pieces and embedded in cement with additional non-activated scrap steel to improve internal shielding. This matrix was modeled within the drum containers with a filling factor of about 30 percent. Drum-type container dose rate calculations were performed using the QAD-GP computer code with a cylindrical geometry input.

RESULTS

The results of this design study for the conditioning and packaging of the exchangeable non-fuel core component wastes arising from 40 years of operation of the Swiss nuclear plants are summarized in Table II. Under the conservative assumption of the applied cooling time, the volume of the packaged waste would be about 200m^3 from the PWR 1,600 MWe and 1,400m^3 from the BWR 1,300 MWe.

CONCLUSIONS

The investigation made for the conditioning and packaging of exchangeable non-fuel reactor core components has raised the following points:

- The preliminary characteristics of a representative waste container for a particular waste type can be defined upon the specification of the average waste to be packaged, the emplacement position, and the weight of the shielding, structural and waste materials.
- The waste items investigated could be packaged in already existing thick walled iron containers, and in large containers of about 20m^3, and 4.5m to 4.8m long foreseen for decommissioning wastes. The volume of the packaged waste is about 125m^3 per 1000 MWe for the Swiss PWRs and 1000m^3 per 1000 MWe for the BWRs. Not included in the BWR figures are the fuel assembly boxes.
- The specification of the waste containers for the studied wastes was for a reference time of five years. This oversimplified assumption for purposes of preliminary design and planning is unrealistic and leads to designs which require large amounts of shielding for the waste containers if one is to meet the prescribed dose criteria.
- Further studies to ensure the fullfillment of the transportation regulation of the large containers must be performed to define the detailed design of the filled containers.

REFERENCES

1. J.C. Alder, "Preliminary Studies of Packaging and Disposal of Decommissioning Waste in Switzerland" Nuclear Technology, Vol.86, August, 1989, p.197.
2. QAD-CGGP, RSIC Computer Code Collection,CCC-49, Oak Ridge National Laboratory.
3. ANISN-PC, RSIC Computer Code Collection,CCC-255, Oak Ridge National Laboratory.

TABLE II
Allocation of Wastes

POWER PLANT ORIGIN	WASTE TYPE	TOTAL AMOUNT	ITEMS PER CONTAINER	CONTAINER TYPE	DOSE RATE @1m (mrem/hr.)	TOT. VOL. (m^3)
PWRs 350MW	Control Rods	150	64	LG.CONT.	7.36	57.330
	Pt.Lgth.Ctl.Assy.	8	6	DRUM	9.99	1.464
	Sec.Neut.Srcs.(*)	38	38	LG.CONT.*	7.82	20.019
	Prim.Neut.Srcs.(*)	2	2	LG.CONT.*		
	Burn.Pois.Rd.Ass.	88	7	DRUM	5.66	9.516
	Flow Restr.Rods	240	30	DRUM	5.66	5.856
BWR 320MW	Control Rods	165	9	LG.CONT.	8.35	383.230
	Sec.Neut.Srcs.(*)	3	3	LG.CONT.*		
PWR 920MW	Control Rods	144	36	LG.CONT.	5.60	76.440
	Sec.Neut.Srcs.(*)	32	32	LG.CONT.*		
	Prim.Neut.Srcs.(*)	2	2	LG.CONT.*		
	Pt.Lgth.Ctl.Rods	76	15	DRUM	8.23	7.944
	Flow Restr.Rods	150	10	DRUM	5.56	10.980
BWR 990MW	Control Rods	447	9	LG.CONT.	4.70	1008.500
	Sec.Neut.Srcs.(*)	6	6	LG.CONT.*		
						========= 1581.429

(*): The primary and secondary neutron sources may be placed within the same large container provided that the Co-60 activity associated with these sources does not exceed 1,200 Ci.