

# KRB-A: dismantling operations and related techniques

## Techniques for decontamination and packaging

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### 1. The electro-polishing procedure

In order to maximise the recycling an effective decontamination procedure for disassembled steel parts had to be developed.

The features of this technique are:

- quick processing time,
- reliability, and
- less secondary waste.

The decontamination of steel parts with phosphoric acid is a highly efficient decontamination technique especially when used for electro-polishing. This decontamination procedure has been working very successfully at KRB-A since 1983.

The process is done in a basin filled with phosphoric acid and is supported by an electrical current of maximum 6 000 A. The average treatment time is 4 hours per part. Local spots of contamination are removed by mechanical methods if necessary.

Fig. 1 shows the principle of electro-polishing and the surface treatment.

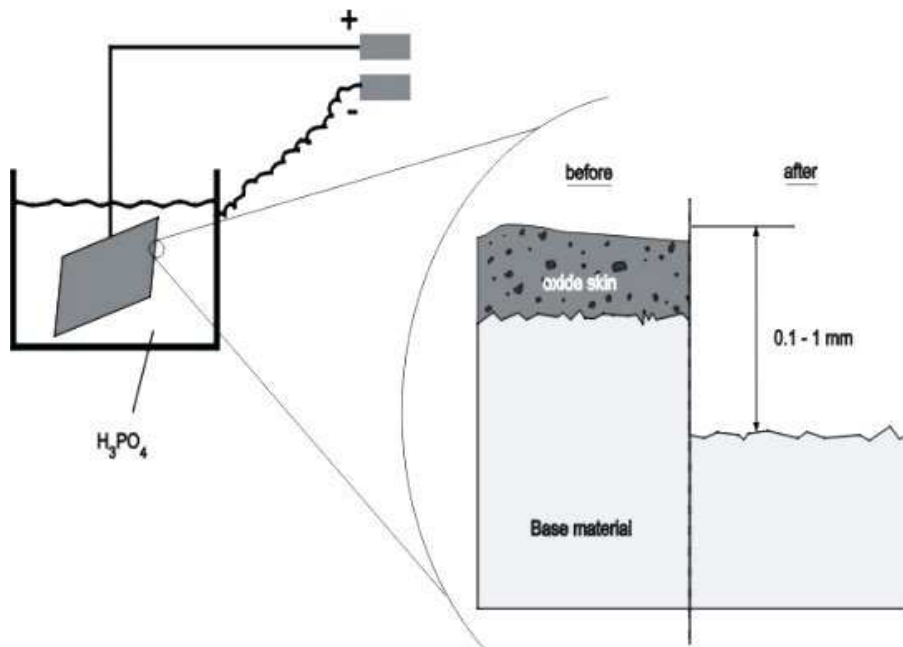


Figure 1. Principle of electro-polishing and surface treatment

The minimisation of secondary waste from decontamination is possible because a special regeneration procedure for phosphoric acid has been developed.

After regeneration, the phosphoric acid is reusable.

## 2. Thermolysis for the treatment of iron-oxalate

In order to minimize the secondary waste the phosphoric acid has to be regenerated after a certain time.

The regeneration process was developed within the framework of the second decommissioning programme of the European Commission (1984 - 1988).

The schematic principle is given in Fig. 2.

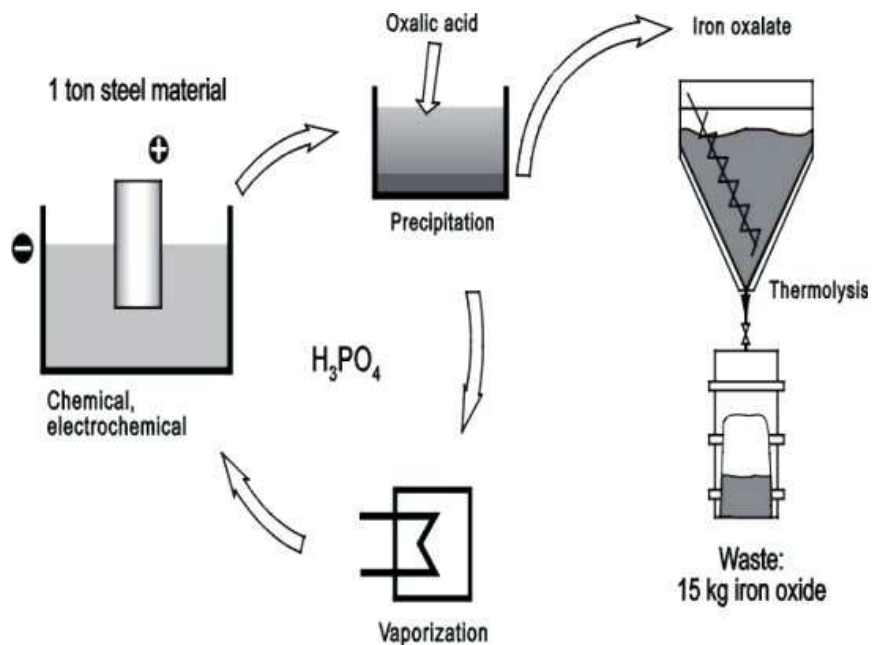


Figure 2. Schematic principle of the regeneration process

It is possible to recycle the phosphoric acid by adding oxalic acid to precipitate the dissolved iron as iron oxalate which contains the  $^{60}\text{Co}$  activity.

The iron oxalate can be thermolysed to obtain iron oxide as an acceptable product for final storage. Until now about 210 Mg of iron oxalate with an activity up to 1 000 Bq/g have been produced.

Different procedures have been tested. The construction of a pilot plant using a heated cone impeller seemed to be an optimal solution and was put into effect.

The facility with the cone impeller and a recleanable filter device will be used for converting the iron oxalate into the stable iron oxide (Fig. 3).

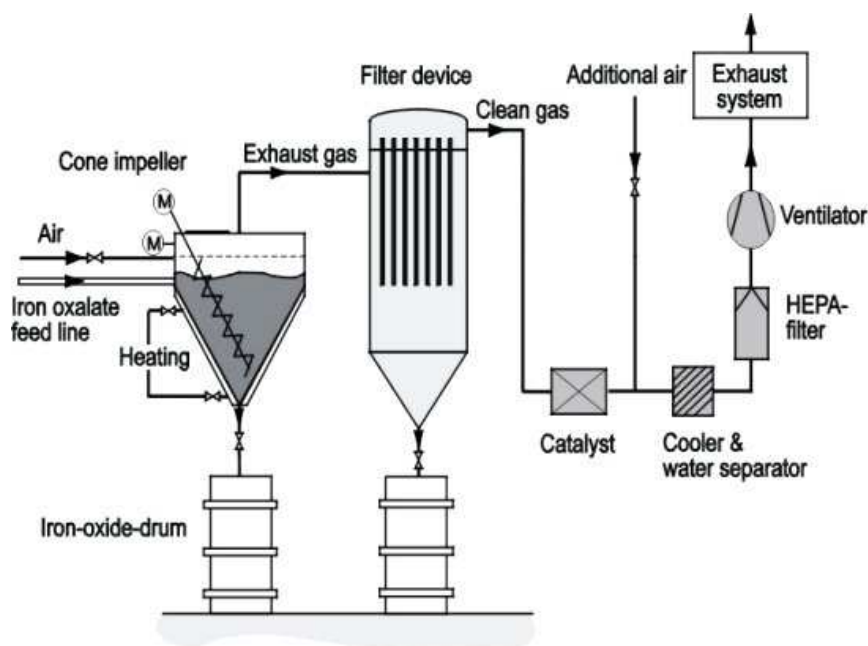


Figure 3. Thermolysis plant for iron oxalate

After inactive tests with the cone impeller the facility was set up in the turbine hall next to the Fe-oxalate store. Around the cone impeller and filter unit a secondary housing with an extra ventilation system was built.

A series of preliminary tests were made in order to prove the practicability of the thermolytic conversion of the iron oxalate. Table 1 shows the technical data of the thermolysis facility.

<b>Charge</b>		100 kg Fe-oxalate
<b>Heating period</b>		
	<b>(h)</b>	8
<b>Process period</b>		
	<b>(h)</b>	7
<b>Fe-oxide</b>		
	<b>(kg)</b>	45
<b>H<sub>2</sub>O</b>		
	<b>(dm<sup>3</sup>)</b>	20
<b>Gas</b>		
	<b>(m<sup>3</sup>)</b>	90
<b>Volume reduction</b>		
		factor 2.5
<b>Mass reduction</b>		
		factor 2.2

Table 1. Technical data of the thermolysis facility

To carry out the test described below, the cone impeller was first filled with 80 kg of primary crushed iron oxalate. Then the temperature of the heat carrier oil was raised up to such a degree that the product was dried but not yet thermolysed. This occurred while stirring apparatus and ventilator were in operation.

With the aid of a flue gas analyzer qualified for the measurement of the concentrations of oxygen, carbon dioxide, and carbon monoxide, whose probe was installed between the filter device and the catalyst, and from whose readings the water vapor content in the exhaust blast could be calculated, the end of the drying process could be determined.

After a further ascent of temperature, when the control point in the lower part of the cone impeller indicated about 200 °C to 230 °C (which corresponds, due to the temperature gradient, to a product temperature of around 150 °C to 170 °C), higher concentrations of carbon monoxide (up to 14 000 ppm) as well as a strong production of dust occurred.

As a reason for that the decay of free oxalic acid can be assumed which is included in the iron oxalate as an impurity.

The decay of the iron oxalate, whose decomposition point amounts to 190 °C, began, when the temperature indicated by the control point in the cone impeller reached about 250 °C.

This could be recognized by the increase of the concentrations of carbon dioxide and carbon monoxide (CO<sub>2</sub>) and the decrease of the concentrations of oxygen. Furthermore, this phase was accompanied by a strong generation of dust. The reaction course quietly and rather steadily. The air supply was always regulated in such a manner that on the one hand the concentration of carbon monoxide was low and the condensation of water between cone impeller and condenser could be prevented, but, on the other hand, no excessive cooling of the iron oxalate took place.

About half an hour after reaching the highest concentration of carbon monoxide during the thermolysis of iron oxalate, the transport of dust into the filter device virtually ended. The reason was the far-reaching conversion of the lighter iron oxalate into the heavy iron oxide.

During the entire process, the concentration of carbon monoxide had to be monitored carefully. Its generation, in relation to the concentration of carbon dioxide measured simultaneously, is remarkable.

It turned out that, except during the presumed decay of oxalic acid, the concentration of carbon dioxide was higher than that of carbon monoxide; this can be attributed to a partial oxidation of carbon monoxide to carbon dioxide before reaching the catalyst.

In order to find out the possibilities of controlling the course of the thermolysis and their secondary reactions, several parameters were varied and examined with respect to their influence on the process. The operation of the stirrer caused a temporary increase of the contents of carbon monoxide and dioxide in the exhaust blast as well as a decrease of the concentration of oxygen. Moreover, an enhanced release of dust into the filter housing took place.

A durable change in the gas concentrations after turning on or out the stirrer, however, could not be detected.

The control of the admission of air into the cone impeller made possible, as already indicated, the dilution of the thermolytic gases, but an influence on the reaction velocity of the thermolysis could not be proved.

The temperature of the heat carrier oil, finally, is suitable to control the velocity of thermolysis. This is important because by this manner an interruption at the end of a working day respectively a termination after virtually complete conversion can be produced. No use had to be made of the possibility to regulate the reaction speed by the oil temperature because of the smooth running of the thermolysis.

The end of the pyrolytic process which is not represented (as well as the phase of drying) in Fig. 4 was initiated by approaching of the concentrations of carbon dioxide and monoxide in the exhaust gas to the value zero and of the oxygen content to 20.9 %.

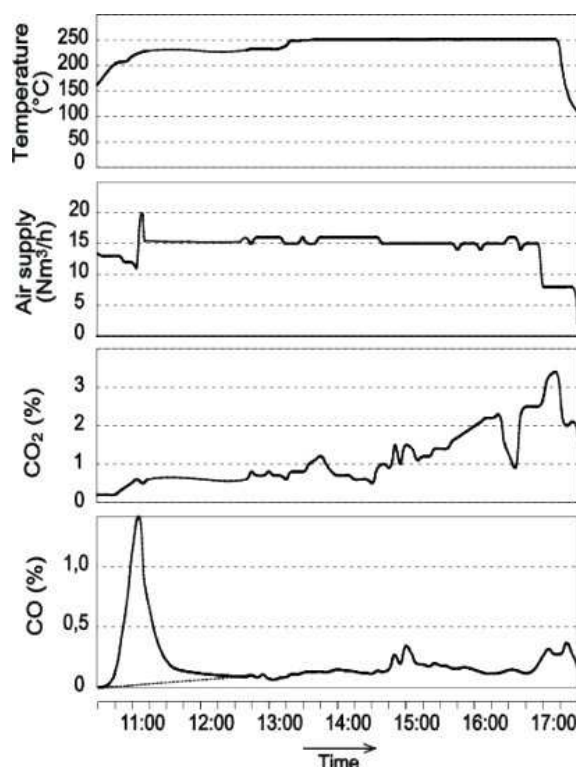


Figure 4. Temperature, air supply, CO<sub>2</sub> and CO during thermolysing

It then could be concluded that nearly the total amount of iron oxalate had been converted into iron oxide. The expelling of the residual pyrolytic gases included in the powdery iron oxalate required additional time.

The entire time consumption for the treatment of 80 kg of iron oxalate was about eight hours. Beside the final product of iron oxide, of which about 34 kg were obtained in the cone impeller, around 3 liters of dust (iron oxalate with iron oxide) yielded in the filter housing.

This dust will at first be collected for subsequent treatment. In the cooler a quantity of less than one liter of water was accumulated.

In order to check the activity balance, samples from the iron oxalate and iron oxide have been taken before and after thermolysing. These samples have been radiologically investigated at the University of Regensburg. As an important result, it could be determined, that the average increase of the specific activity of the iron oxide is about 1.7 to 2.5 times higher than the specific activity of the former iron oxalate.

This results only from the mass reduction (factor 2.2) during the thermolytic process.

Table 2 shows the nuclide compositions of the chemical products before and after thermolysing.

Nuclides	Activity of iron oxalate before thermolysing (Bq/g)	Activity of iron oxide after thermolysing (Bq/g)
<sup>60</sup> Co	41.2	79.0
<sup>63</sup> Ni	124.0	228.0
<sup>55</sup> Fe	18.1	19.0
<sup>241</sup> Am	0.4	0.8
<sup>241</sup> Pu	7.0	6.7

<sup>137</sup>Cs, <sup>238</sup>Pu, <sup>239/240</sup>Pu below 0.2 %

Table 2. Nuclide composition before and after thermolysing

### 3. The onion cast container

Activity calculations on the RPV and its internals pointed out that about 150 Mg of contaminated and activated steel can be recycled for nuclear purpose by controlled melting.

By applying the "onion casting" a minimum number of waste containers will be achievable.

The overall total mass of a waste container is limited to 20 Mg corresponding to the requirements of the Konrad repository. The disadvantage of currently available standard Konrad waste containers is the low filling factor for steel components resulting from the given mass limit of 20 Mg per waste container.

Table 3 gives the dimensions of two standard Konrad waste containers.

		<b>Container Type VI</b>	<b>Mosaik Type II</b>
<b>Dimensions</b>	<b>(mm)</b>	2000 x 1600 x 1700	Ø 1060 x 1500
<b>Wall thickness</b>	<b>(mm)</b>	150	150
<b>Gross volume</b>	<b>(m<sup>3</sup>)</b>	5.4	1.3
<b>Remaining load volume</b>	<b>(m<sup>3</sup>)</b>	3.1	0.5
<b>Dead weight</b>	<b>(Mg)</b>	18.3	6.0
<b>Possible payload</b>	<b>(Mg)</b>	1.7	0.6

Table 3. Standard Konrad waste containers

The idea and the layout for a new waste container was given by the target to realise an optimal volumetric efficiency with a maximum activity inventory. The introduction of the "onion package" fulfils these aims.

Fig. 5 shows the principle layout of an onion cast container for final storage:

- the new container cast out of low contaminated steel < 1 Bq/g,
- high active components (> 200 Bq/g) will be put into, and
- fixed by filling up with molten metal of < 200 Bq/g.

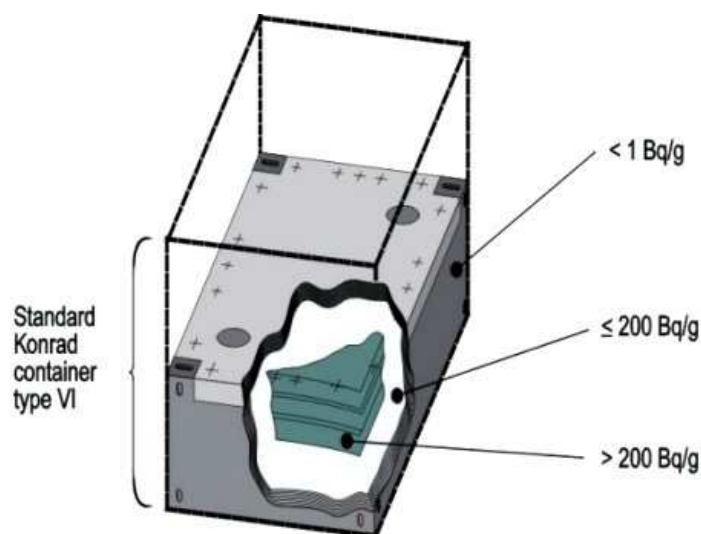


Figure 5. Principle of the "onion package" for final storage

The container layout is based on the Konrad Type VI container with reduction of the height by 50 %.

The outer geometrical dimensions of the new container are 2 000 x 1 600 mm and 850 mm in height.

The wall thickness of the basic design is 150 mm.

The new waste container has a dead weight of 10.8 Mg. In comparison to standard Konrad waste containers, the onion cast containers enables a much higher payload of 8.8 Mg for steel components.

After inserting high activated components in the centre of the container, the free volume of the onion package is poured with low radioactive material. By this, the inserted high radioactive material is fixed. So this new waste container can be considered as a homogeneous radioactive source.

The new waste container had to meet the German rules for transport of radioactive materials (GGVS) and the requirements for the Konrad disposal. The outer package of such waste containers must be non-flammable.

Meanwhile, the licence according to the GGVS has been submitted. Also, the technical conditions of onion cast containers for the Konrad repository are fulfilled. Currently, it is acted upon the final acceptance licence for the Konrad disposal.

Due to the GGVS transport regulations, the <sup>60</sup>Co activity inventory is limited to 3.5·10<sup>13</sup> Bq for the onion package. Thus the following average dose rate limits can be maintained:

- on the package surface: < 2 mSv/h;
- at a distance of 1 m: < 0.1 mSv/h.

The development of the onion cast container has been done in co-operation with the companies GNS, Essen and Siempelkamp, Krefeld.

An inactive prototype package has been manufactured and has successfully passed the following test:

- drop test with a drop height of 0.8 m,

- stack test with an top load of 120 Mg,
- handling test with a container spreader,
- dye-penetration test.

Until now, five containers for onion casting were manufactured. It is foreseen to fill these waste containers with the high radioactive pellets of the SSG tube bundle.

#### 4. Optimised concept for packaging of activated material

To optimise the packaging of the RPV internals, different variants were investigated for economy and technical possibility. The activation and contamination of the components were analysed in view of the possible waste treatment for final storage in Morsleben (ERAM) or Konrad.

Possible is also an interim storage at KRB-A for about 10 years to lower the activity. The segmented internals were investigated for packaging into conventional containers or into monolith cast containers.

The activation of the RPV internals depends on the distance to the core and whether the component was steam affected (less activation) or water affected (higher activation).

Table 4 shows the technical data and the  $^{60}\text{Co}$  activation of the RPV internals.

Component	Maximal dimensions (mm)	Number of parts	Mass (kg)	$^{60}\text{Co}$ activity (Bq/g)
RPV cover bolts	Ø 117 × 1 280	52	5 200	~ 1
Water-steam separator cyclones	Ø 336 × 1 470	69	8 200	$1.0 \times 10^2$
Water-steam separator stand pipes	Ø 168 × 1 715	69	4 500	$2.4 \times 10^5$
Core shroud cover	Ø 3 200 × 538	1	1 600	$2.4 \times 10^5$
Core spray feeding	Ø 103 × 2 150	2	130	$2.4 \times 10^5$
Feedwater sparger	Ø 250 × 4 070	2	300	$3.0 \times 10^{-2}$
Thermal shield	Ø 3 696 × 750	1	400	$1.2 \times 10^5$
Core shroud flange with core spray system	Ø 3 200 × 152	1	1 500	$4.4 \times 10^7$
Top guide	Ø 3 035 × 194	1	1 340	$3.9 \times 10^{14}$
Core shroud	Ø 3 200 × 4 572	1	8 400	$9.8 \times 10^6$
Core support	Ø 2 921 × 495	1	1 410	$8.7 \times 10^7$
Core support seat	Ø 3 200 × 178	1	1 100	$3.3 \times 10^6$
Core shroud support	Ø 3 588 × 620	1	1 300	$3.3 \times 10^5$
Poisoning system	Ø 51 × 7 500	1	100	$3.3 \times 10^5$
Lower core shroud	Ø 2 896 × 1 063	1	1 800	$6.1 \times 10^3$
<b>Total</b>			$\Sigma = 37\,280$	$\Sigma = 7.9 \times 10^{14}$

Table 4. Technical data and  $^{60}\text{Co}$  activity of the PRV internals

All RPV internals consist of stainless steel material X5CrNi 18 9 (ASTM Type 304), except the feedwater sparger which is made of X6CrNiTi18 10 and the core shroud support which is constructed with Inconel-600 material.

For packaging of the activated material, the German restrictions and limits for final storage, interim storage and the radioactive transportation must be respected.

Concerning these limits, there are principally different options for recycling or disposal of RPV internals depending on the mass specific activity.

The activity limits of the four disposal groups, as shown in Table 5, are basing on the waste packaging conditions:

- average payload of a 200 liters drum for the final storage ERAM: 200 kg;
- average payload of a Mosaik-II type Konrad container: 300 kg.

	Group 1	Group 2	Group 3	Group 4
$^{60}\text{Co}$ limit (Bq/g)	< 200	$200 \dots 2 \times 10^6$	$2 \times 10^6 \dots 1 \times 10^7$	$> 1 \times 10^7$
Options for waste disposal (site)	Melting for recycling (restricted reuse)	Packaging into drums (ERAM)	Packaging into Mosaik containers (Konrad)	Mixing high activated with low activated material to enable final storage (ERAM or Konrad)
	<b>or</b>	<b>or</b>	<b>or</b>	<b>or</b>
	Applying for onion cast containers (Konrad)	Applying as inlay material for onion cast containers (Konrad)	Applying as inlay material for onion cast containers (Konrad)	Interim Storage

Table 5. Waste disposal options and waste classification for RPV internals

Two different packaging concepts for the RPV internals have been investigated and compared with special regard on specific waste container need and total costs.

*Variant A* prefers straight transportation and final storage at the disposal site ERAM for all RPV internals which will fulfil the activity requirements of the disposal site.

The remaining material had to be prepared for the Konrad disposal with interim storage on the KRB site or in a Bavarian interim storage.

Actually, the ERAM disposal site is accepting only 200 liters and 400 liters drums with a single mass up to 1 250 kg.

*Variant B* is focused on the application of onion cast containers. This concept will cause interim storage before the disposal site Konrad will be available. Most of the RPV internals will be used for onion cast containers, whereas components with a specific activity of more than  $3.30 \times 10^5$  Bq/g are packed into Mosaik containers for later disposal also in the Konrad site. This variant use an activity overload of the Mosaik containers. Within 10 years of interim storage on site, these containers will reach the transportation limits.

The planned Konrad disposal site will accept rectangular and cylindrical waste containers up to 20 000 kg each.

*Variant A* is shown in Table 6 and *Variant B* is given in Table 7.

Component	Mass	Packaging unit	Numbers	<sup>60</sup> Co activity
	(kg)			(Bq/unit)
RPV cover bolts	5 200	200 l drum	12	$4.33 \times 10^5$
Water-steam separator cyclones	8 200	200 l drum	18	$4.56 \times 10^7$
Water-steam separator stand pipes	6 230	200 l drum with FC100	15	$9.97 \times 10^{10}$
Core shroud cover				
Core spray feeding	300	melting with controlled/free recycling		
Feedwater sparger	400	200 l drum with FC70/100	2	$2.40 \times 10^{10}$
Thermal shield	1 500	Mosaik II-15/90	4	$1.65 \times 10^{13}$
Core shroud flange				
Core spray system	1 340	Mosaik II-15/120	5	$1.05 \times 10^{14}$
Top guide	8 400	Mosaik II-15/65	17	$4.84 \times 10^{12}$
Core shroud	1 410	Mosaik II-15/100	4	$3.07 \times 10^{13}$
Core support	1 100	Mosaik II-15/45	2	$1.82 \times 10^{12}$
Core support seat	1 400	200 l drum with FC100	4	$1.16 \times 10^{11}$
Core shroud support				
Poisoning system	1 800	Concrete container II	2	$5.49 \times 10^9$
Lower core shroud				

FC70/FC100 = reusable containers for transports and handling at the disposal site.

Mosaik II-15/90 = cylindrical Konrad waste container (wall thickness 150 mm and inner lead shielding 90 mm thick).

Table 6. Optimised packaging **Variant A**: Preferences for final storage in ERAM

Components	Mass	Packaging unit	Numbers	<sup>60</sup> Co activity
	(kg)			(Bq/unit)
RPV cover bolts	13 700	Fixing material for onion cast container	-	-
Water-steam separator cyclones				
Feedwater sparger				
Water-steam separator stand pipes	9 830	Inlay material for onion cast container	2	$7.78 \times 10^{11}$
Core shroud cover				
Core spray feeding	1 400	Inlay material for onion cast container	1	$4.70 \times 10^{11}$
Thermal shield				
Lower core shroud	1 500	Mosaik II-15/7	3	$2.20 \times 10^{13}$
Core shroud support	1 340	Mosaik II-15/110	4	$1.31 \times 10^{14}$
Poisoning system	8 400	Mosaik II-15/50	15	$5.49 \times 10^{12}$
Core shroud flange	1 410	Mosaik II-15/80	3	$4.09 \times 10^{13}$
Core Spray system	1 100	Mosaik II-15/30	2	$1.82 \times 10^{12}$
Top guide				
Core shroud				
Core support				
Core support seat				

Table 7. Optimised packaging **Variant B**: Preferences for final storage in ERAM

Also, the costs for both packaging concepts have been investigated. For each packaging option the following cost categories have been calculated:

- container costs,
- transportation costs,
- final/interim storage costs,
- equipment costs,

- treatment costs for melting or waste conditioning.

The container costs and final disposal costs are lower in *Variant A*, because waste container costs for drums are much cheaper than thick-walled and high qualified standard waste containers or onion cast containers for Konrad.

However, in this case the transportation costs to the disposal site are higher because of the higher amount of waste containers.

Comparing *Variant A* and *Variant B*, the total costs for conditioning and disposal of all RPV internals are nearly similar and will be in the range of 5.0 to 5.5 Mio DM.

When following the concept of *Variant A* a lot of waste from the dismantling of RPV internals could be given to the final disposal ERAM. This disposal is open for radioactive waste until mid of 2000.

The concept of *Variant B* includes a political and also a cost risk. In this case, transportation and final storage costs had to be estimated for the time after interim storage. Also from an actual point of view, the future availability of the Konrad disposal is not absolutely sure.