

## **INVENTORY AND CLASSIFICATION OF THE COMPONENTS AND SYSTEMS OF THE GRR-1 FOR DECOMMISSIONING PLANNING**

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### **Abstract**

The Greek Research Reactor (GRR-1) is an open pool type, light water moderated and cooled heterogeneous reactor with thermal power at 5 MW. The reactor has been in extended shut down since July 2004 and the decommissioning planning and costing is now in progress. In the present paper, the inventory as well as the preliminary classification of the reactor components and systems is presented, since this underlies the planning and costing of decommissioning. The strategy of the future decommissioning of the reactor is the removal of all activated and contaminated components and systems without demolition of the biological shielding. Thereupon, the concrete is not included in the inventory presented in this paper.

### **Keywords**

open pool reactor, decommissioning, radioactive waste, inventory, classification, costing

### **1. Introduction**

The Greek Research Reactor (GRR-1) is an open pool type, light water moderated and cooled heterogeneous reactor designed by AMF Atomics. The reactor is located on the Campus of the National Centre for Scientific Research “Demokritos” (NCSR) in Aghia Paraskevi, district of Athens. The NCSR is the operator of the reactor and the possessor of the licenses and permissions. The main experimental facilities installed in the Greek reactor are: six beam tubes, the thermal column, the dry irradiation chamber (it was never used). Also, a pneumatic conveyor, vertical tubes and suitable baskets for irradiations and rotating systems for uniform multiple irradiations were used in the past.

The reactor went critical for first time in June 1961. Since April 1964, the reactor operated at thermal power of 1 MW. In 1971 the reactor was upgraded to 5 MW, giving a maximum neutron flux of  $9 \times 10^{13} \text{ cm}^{-2} \text{ s}^{-1}$  at the core center. Upgrade works included replacement of : (i) the cooling system with a new one, consisting of primary and secondary circuits equipped with three delay tanks, two heat exchangers and cooling towers; (ii) the tile liner of the pool with a stainless steel one; (iii) the power supply systems. Furthermore, the fuel elements were changed from Low Enriched Uranium (LEU) to High Enriched Uranium (HEU). A further Reactor upgrading was decided in 1990 by partial replacement of the water reflector of the Reactor core by Beryllium. The main objectives of this Reactor modification were the increase of the thermal neutron flux at the irradiation facilities positions and the more efficient fuel management. In the time period from 1999 to 2004, gradual replacement of spent HEU fuel elements by fresh LEU elements took place and the reactor operated with a mixed core consisting of both HEU and LEU fuel elements.

In 2004, the reactor was shut-down and the fuel assemblies were removed for safety reasons during the Olympic Games in Athens. Afterwards, inspection of the reactor systems and components was conducted. In 2007, the refurbishment and modernization of the reactor was decided. The refurbishment concerned mainly the replacement of the Primary Cooling System (PCS) as well as the control instrumentation.

Firstly, the pre-dismantling radiological characterization of the PCS [1-4] was carried out as well as neutron calculations [5, 6] for activated parts of the reactor. In December 2009, control rods, beryllium reflector blocks and active core supporting components (grid plate, plenum etc.) were removed from the reactor pool and transferred to the spent fuel storage pool or shielded storage structures at other locations within the facility. The PCS system coolant water was transferred to a storage tank and the reactor pool and piping system were dried. Then the radiological characterization of the PCS was accomplished by the collection and analysis of representative samples from the PCS internal surfaces.

In 2011 the partial decommissioning plan for the PCS was approved by the Greek Atomic Energy Committee [7, 8]. The reactor has been in extended shut down since July 2014.

For the final planning and costing [9] of decommissioning of the GRR-1, the inventory of the components and systems was prepared. The mechanical drawings as well as conventional methods including direct weight or measurement of dimensions of the components were used for estimating the total lengths, area of surfaces and masses.

The classification of the waste which will arise from the decommissioning of GRR-1 was based on the considerations of long term safety, and thus, by implication, the disposal of waste [10]. The results of the previous studies [1-6] concerning the radiological characterization of the components and systems of GRR-1 were considered.

## 2. Facility layout and composition

### 2.1. Premises

GRR-1 facility buildings and structures includes the following buildings: reactor building, external pump house (containing the heat exchangers, the main water purification system and secondary system pumps), a concrete shielded trench at the side of the external pump house (containing the delay tank system), the cooling towers of the Secondary Cooling System (SCS), associated buildings with laboratories and offices and a building housing the electric power units.

The reactor building is of five floor levels and three basement levels. The floor levels include the reactor pool, the spent fuel storage pool, the control room, experimental instrumentation as well as a radioactive waste interim storage, maintenance shops and counting rooms. The building area is  $32.40 \times 18.40 \text{ m}^2$  and its height is 21.17 m (inner dimensions). The upper basement is a  $5.5 \times 7 \text{ m}^2$  room of 2.5 m height containing an ion exchanger which is used mainly for de-mineralization of the spent fuel storage pool water. The floor level of the second basement is 1.3 m below the floor level of the upper basement. At this level (under the pool bottom level) are located: the safety electric valves, the hub for transfer of the pool water to the storage tank, the primary cooling piping and wiring of the pneumatic irradiation facility. This basement is connected via a 17.5 m long tunnel and an airtight door with another underground room containing the two PCS pumps (PCS pump house). This  $13 \times 8.5 \text{ m}$ , 4.2 m high room is at the level of the upper basement.

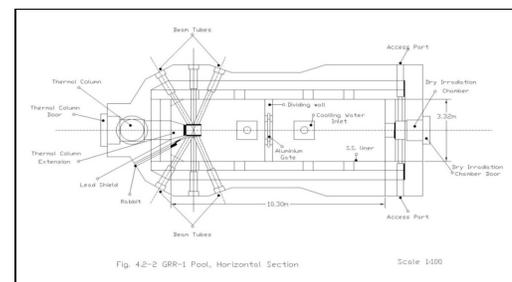


Figure 1. Reactor Pool (horizontal cross-section)

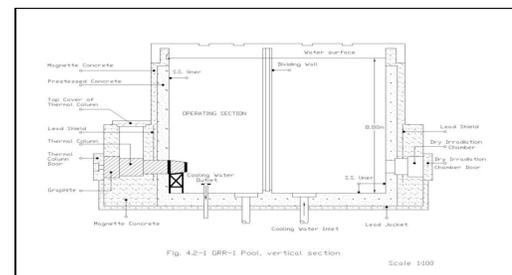


Figure 2. Reactor Pool (vertical cross-section)

### 2.2. Reactor pool

The Reactor pool (Figs. 1 and 2) is a concrete structure with stainless steel liner. The inner dimensions of the pool are 10.30 m in length 3.32 m in width and 8.80 m in height. The pool wall consists of 30 cm thick inner layer of pre-stressed ordinary concrete, followed at the lower part of the pool by a 4 cm thick layer of lead and 110 cm thick external layer of barite

concrete. The thickness of the external layer decreases in steps as the height increases to provide the necessary biological shielding. The liner consists of stainless steel (SS) sheets welded together on SS supports, which are fixed on the concrete walls of the pool. The thickness of the SS sheets varies. The sheets which cover the bottom of the pool and the lower part of the walls, up to a height of 3 meters, have a thickness of 5 mm. The next ones, up to a height of 6 meters, are 4 mm thick, while the sheets that cover the upper part of the walls are 3 mm thick.

The pool is divided into two sections, by means of an aluminum gate: the operating section and the storage one. The gate is a trapezium, made of a 10 mm aluminum sheet, its height is 9.20 m and the two bases are 6.77 and 4.90 m. The gate has also braces and side channels. The usual position of the gate during the reactor operation and shutdown is at its storage place inside the pool.

### 2.2.1. Reactor bridge

The reactor bridge is located on the reactor pool and provides support for the reactor core, ion chambers, control rod drive mechanism etc.

The reactor core is suspended from the bridge by the core support tower. This tower is an aluminum structure suspended vertically from the center of the core support bridge. The grid plate which supports the reactor fuel assemblies is fastened to the lower end of this tower. The reactor bridge will not be decommissioned.

### 2.2.2. Reactor core

The reactor core was fuelled by LEU (19.75% U-235) and HEU (93% U-235), Material Test Reactor type fuel in Al-alloy cladding. Thirty four (34) fuel assemblies (28 standards, 5 controls, 1 special) were supported by an aluminium grid plate (Fig.3) accommodating 6x9 core element positions. Reactor control was performed through five control rods composed of Ag-Cd-In alloy with composition 80%, 5% and 15%, respectively. There are 12 control rods at the GRR-1. The 6 of them were used before 1996 and they are not absolutely, but quite similar to the ones that were used recently. The special rod is made of stainless

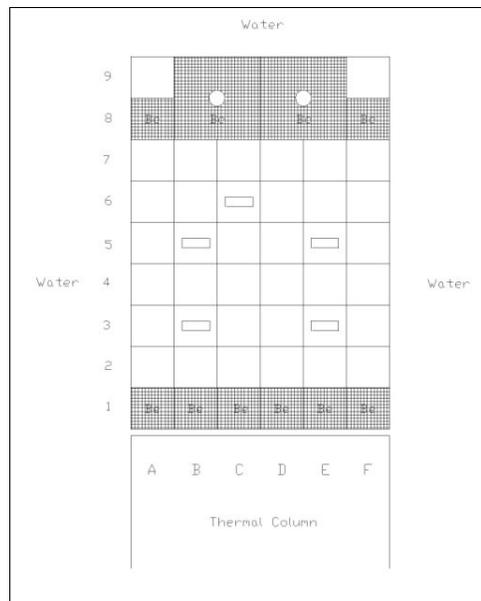
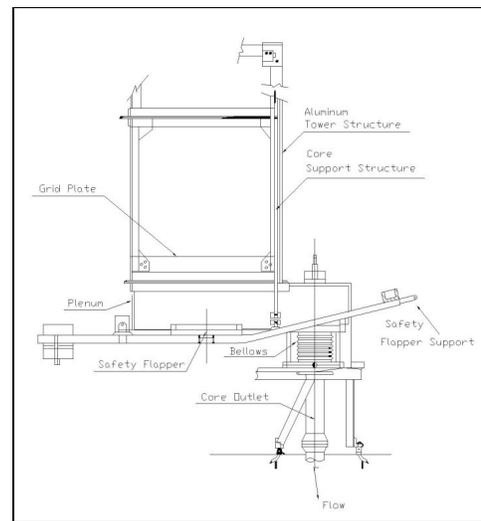


Figure 3. (a) Core grid plate, plenum and flapper configuration; (b) Configuration of the Be blocks at the core

steel and the design is similar to the control rods. Two types of Be blocks were used as reflectors at the two opposite sides of the core (Fig. 3 b): The first type is a solid block of the same dimensions to the ones of the fuel assemblies, occupying one grid plate position. The second type occupies four grid plate positions ( $0.86 \times 0.16 \times 0.16 \text{ m}^3$ ). A cylindrical channel of 6 cm diameter is provided as a neutron flux trap for sample irradiations

### 2.2.3. Experimental tubes

There were 6 experimental tubes made of aluminum for irradiation of samples at the reactor core. In the past 4 of them were cylindrical

and the other two of rectangular cross section. The 5 experimental tubes, two 'rectangular' and 3 cylindrical, were decommissioned and are kept at the interim storage of the reactor building in order to be appropriately managed in the future. For replacement of the decommissioned tubes, 5 new, not irradiated, cylindrical ones were manufactured. The dimensions of the cylindrical tubes, old and new ones, are 2.81-2.97 m in length, 300-550 cm<sup>2</sup> in cross section and their wall thickness is 6.5 mm. The 'rectangular' tubes were 3.12 m in length, 990 to 1300 cm<sup>2</sup> in cross section and their wall thickness was 9.5 mm.

For shielding of the cylindrical tubes, cylinders made of lead were put internally at the rear. There are 24 such cylinders. For shielding of the 'rectangular' tubes, parallelepipeds made of cement were used.

#### 2.2.4. Thermal column

The thermal column is the moderator for slowing down fast neutrons to thermal energies. It consists mainly of a square steel chamber 2.79×1.30×1.35 m<sup>3</sup> (Fig. 1) which encased graphite blocks. It extends, horizontally, at the level of the core, from the inside wall of the operation section of the pool to the outer surface of the biological shielding. The access to the irradiation area is through a square, heavy concrete door. Behind this door, there is a lead shielding (1.52×1.52×0.150 m<sup>3</sup>) with a small matching lead plug which provides access to the irradiation area. The inner surface of the chamber is lined with neutron absorption boron sheet.

A thermal pyramidal column (truncated pyramid) extension is also provided. The extension consists of graphite, encased in aluminum can of volume:  $0.58 \times ((1.29)^2 + (0.66)^2 + 1.29 \times 0.66) / 3$  m<sup>3</sup>. It is located in the operation section of the pool, positioned between the core and the inside end of the square thermal column chamber. In front of the pyramidal column there is a lead block of volume 0.61×0.79×0.13 m<sup>3</sup>.

Furthermore, there is a cylindrical air chamber of volume  $3.14 \times 0.10 \times (1.02)^2 / 4$  m<sup>3</sup>, extending from the top of the shielding

downward to the horizontal chamber which provides vertical access to the thermal column. This opens at the top of the barite shield and is closed by a lead plug of thickness 5.1 cm and a concrete access cover.

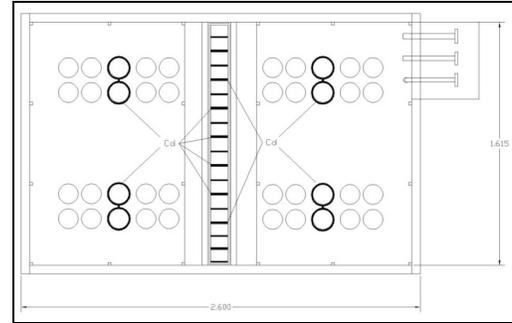


Figure 4. Spent fuel storage pool

### 2.3. Spent fuel storage pool

The spent fuel storage pool (Fig. 4) is a concrete structure with SS liner. The inner dimensions of the pool are 2.60 m in length, 1.62 m in width and 4.00 m in height. The liner consists of SS sheets welded together on SS supports, which are fixed on the concrete walls and the bottom of the pool. The thickness of the SS sheets is 2 mm. Inside the pool, there are: (i) 40 SS tubes of external diameter 0.13 m, 0.50 m in height and their wall thickness is 2 mm; (ii) 17 SS parallelepiped boxes 0.127×0.095 m<sup>2</sup> in cross section, 0.75 m in height and 2 mm wall thickness. The tubes are supported by 4 SS sheets of 1.07×1.62 m<sup>2</sup> and 2mm in thickness, which have 80 holes, two for support of each tube. The boxes are held by 4 hollows of total weight 22 kg. The pool is covered by a 720 kg lid made of galvanized sheet and hollows.

### 2.4. Primary cooling system

A schematic layout of the PCS is shown in Fig. 5. The PCS comprises of aluminum pipes of diameter that changes along the circuit from 6 to 10 inches, three pumps, two heat exchangers, three sequential delay tanks, valves and gauging instruments. The core is cooled by circulating the coolant water through the core. The coolant flows through the core and plenum and then is led to an outlet pipe (Fig. 5). The outlet pipe pass through the pool wall towards the delay tank system. At the outlet of the delay tank system the circuit is divided

into two branches, each with its own pump, flow meter and heat exchanger. Water input is done through the inlet pipes, also penetrating the pool wall. Close to water outlet and inlet two electric valves are installed.

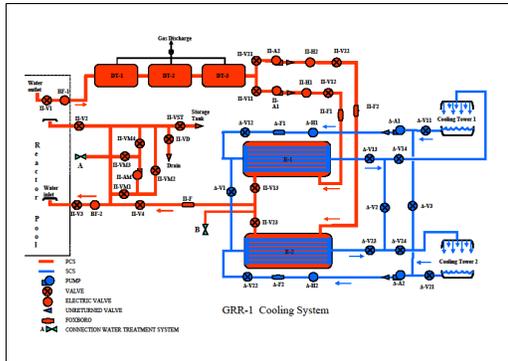


Figure 5. Reactor Primary and Secondary Cooling System

The delay tank system consists of three aluminum tanks of approximately 20 m<sup>3</sup> total capacities, installed in a concrete shielded trench at the side of the external pump house. The tanks introduce a delay of approximately 1.5 min in the water path in order to minimize N-16 activity. A schematic diagram of the delay tank system is shown in Fig. 6.

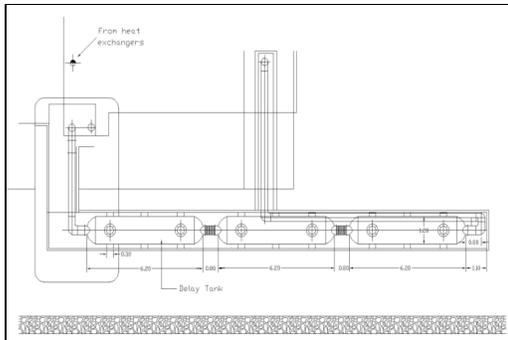


Figure 6. Delay tank system

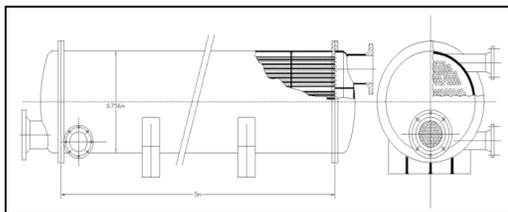


Figure 7. Heat exchanger

The primary cooling pumps are two horizontal, centrifugal, stainless steel pumps of 225 m<sup>3</sup>/h flow rate, installed in the PCS pump room at the basement floor of the reactor building.

The heat-exchangers are two stainless steel, shell and tube type exchangers installed on ground level above the PCS pump room, in the external pump house. Secondary water flows in stainless steel pipes and the coolant water circulates between the piping and the shell of the heat exchangers. A schematic diagram of the heat exchanger is shown in Fig. 7.

### 2.5. Secondary cooling system

The Secondary Cooling System (SCS) transfers heat from the heat exchangers to the cooling towers (Fig. 5). The SCS comprises of carbon steel pipes of diameter that changes along the circuit from 8 to 10 inches, two pumps, valves and gauging instruments.

There are two centrifugal carbon steel pumps, which circulate water from the lower part of the cooling towers to the heat exchangers. Tap water flows through the carbon steel piping, which connects the heat exchangers to the upper part of the cooling towers from where it is flushed down. Air circulates through each cooling tower by means of air blowers. The secondary pumps are located beside the heat exchangers, in the external pump house.

After cooling, the secondary water is pumped back to the heat exchangers. Any loss of secondary water caused by evaporation is automatically replaced.

### 2.6. Water treatment system

For protection of the integrity of aluminum cladding of fuel plates, for minimization of corrosion of the primary coolant system and other reactor components, and for prevention of activation of dissolved materials, the primary demineralized water was maintained in high quality. Therefore the specific resistance was kept higher than 500 kΩ/cm and the pH between 5.0 and 7.0. The purity of water is maintained by means of two ion exchange systems. The first of them installed in the external pump house is composed of two "Mixed Bed" ion exchangers, using resins of regenerative type. These ion exchangers are 0.8 m in diameter, 3.3 m in height and the thickness of the wall is 1 cm. The purified water returns through aluminum piping of 2' back to the pool. The capacity of these ion exchangers is of 9 m<sup>3</sup>/h.

An auxiliary ion exchanger is installed at the upper basement in the reactor building. This unit is mainly used for purification of the water of the spent fuel storage pool. The capacity of this ion exchanger is 4.5 m<sup>3</sup>/h. This one is 0.52 m in diameter, 1.8 m in height and the wall thickness is 1 cm.

An additional ion exchanger with capacity of 4.5 m<sup>3</sup>/h is used for demineralization of tap water which replaces losses of the primary water. This ion exchanger is installed at the 4th floor of the reactor building and is 0.8 m in diameter, 3 m in height and the wall thickness is 1 cm. Each system has a pump of 50 kg.

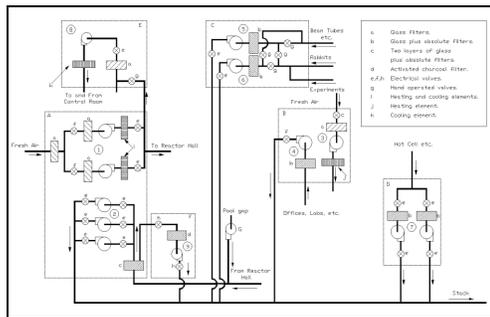


Figure 8. Reactor ventilation system

## 2.7. Ventilation system

A ventilation system is provided for the whole reactor building (Fig. 8). Two input pumps and three output pumps together with filters and associated valves are provided. The input pumps have two levels of operation, the high capacity providing 27000 m<sup>3</sup>/h for each pump and the low capacity providing of 13500 m<sup>3</sup>/h. The output pumps have also two levels of operation. The high capacity provides 32000 m<sup>3</sup>/h for each pump and the low capacity 16000 m<sup>3</sup>/h. Under normal operation conditions, the two input pumps and the two output pumps are operating in the low capacity level, resulting in a negative differential pressure in the reactor hall of approximately 1 cm water column. The input filters are of glass type for filtering the air which is introduced in the reactor hall. The output filters are composed of two layers of glass filters (84 filters of surface 0.6×0.6 m<sup>2</sup>), plus a layer of absolute filters (42 filters of dimensions 0.6×0.6×0.3 m<sup>3</sup>).

## 3. Radiological status of the facility

A radiological survey of the Reactor Pool was performed in July 2009 [3]. The survey con-

sisted of direct measurements in terms of dose equivalent rate, using a submersible gamma dose rate monitor. The maximum contact dose rate for the main components in the reactor pool was: (i) 1.2 Sv/h for the grid plate and associated components; (ii) 18 Sv/h for the reactor control rods; (iii) 0.2 Sv/h for the two big beryllium blocks; (iv) 22 mSv/h at the beam entrance of the experimental tube No. 3; (v) 5.5 mSv/h for the thermal column extension cone and lead shielding. Then the radiological characterization of the GRR-1 components of major radiological concern (the control rods, the grid plate and the beryllium elements) was performed by computational methods [5]. These methods were based on three-dimensional Monte Carlo neutron and photon transport simulations carried out by the MCNP and analytical radionuclide inventory calculations by the use of the FISPACT code. Furthermore, in the case of the grid plate, the cobalt impurity concentration was determined on the basis of best agreement between gamma dose rate calculations and measurements [6]. The results of these studies indicated the dominant radionuclides and their activities in the GRR-1 grid plate, a big beryllium element and a control rod (Table 1).

After removal of the reactor pool internals and drainage of the pool and piping system, a surface decontamination of the liner was performed using pressurized demineralized water. Then a radiological survey of the reactor pool was carried out by collecting representative wipe samples from the liner surface [4]. The gamma spectroscopy analysis of the wipes, revealed the presence of Co-60, Ag-108m, Eu-152, Cs-137, Ag-110m and Eu-154. Co-60 was the dominant radionuclide. The average removable beta activity was: 1.6±0.8 Bq/cm<sup>2</sup> for the floor, 0.4±0.5 Bq/cm<sup>2</sup> for the walls of the first section (section of the core) and 0.13±0.09 Bq/cm<sup>2</sup> for the walls of the second section. No evidence for the presence of fission products or significant concentrations of other pure beta emitters was detected.

Regarding the PCS (Table 3), firstly a dose rate survey was carried out to evaluate the uniformity of activity. The contact dose rate along the piping was about 50 μSv/h. Then the contaminants were preliminarily determined by using the in-situ gamma spectrometry based on NaI(Tl) detector [2]. The results of the in-situ measurements were coupled with Monte

Table 1. Dominant radionuclides and their activities in the GRR-1 components of major radiological concern (year of reference 2009)

Nuclide	$T_{1/2}$ (y)	Activity (GBq)					
		Al Grid [6]	SS Pins [6]	SS Bolts [6]	Al Grid, SS Pins & Bolts [5]	Control Rod (absorber, SS cladding & bottom tip) [5]	Big Beryllium Block [5]
Fe-55	2.74	282 ± 85	1550 ± 1180	339 ± 254	4580	3270	382
Ni-63	100.1	1.5 ± 0.8	50 ± 5	10 ± 8	135	105	12.6
Co-60	5.27	0.46 ± 0.11	35 ± 3	144 ± 14	3.21	5.9	2.2
Mn-54	0.85	0.36 ± 0.05	0.26 ± 0.03	0.17 ± 0.03	1.71		0.8
Zn-65	0.66	1.7 ± 0.3			1.64		
H-3	12.32						1.6E5
Be-10	1.6E6						0.8
Ag-110m	0.67					380	
Ag-108m	127					152	
Cd-109	1.27					97	
Ni-59	7.6E4						0.1

Table 2. Inventory and classification of the components at the Reactor Pool

Component	Material	Mass (kg)	Partitioning (%)		
			VLLW	LLW	ILW
Core (support structure, grid plate, plenum, bellows, flapper)	Al& SS	170			100
12 Control rods (activated and contaminated shaft)	Al, SS, Ag, In, Cd	110	87		13 (mixed)*
2 big blocks Be and 8 small Blocks Be	Be	164			100 (mixed)*
1 Special rod (only the activated part)	SS	8.6			100
Experimental Tubes 1 & 6 (tube, flange and lid)	Al	56		75	25
Experimental Tube 4 (tube, flange and lid)	Al	29		75	25
Experimental Tube 2 & 5 (tube, flange and lid)	Al	221		75	25
Experimental Tube 3 (tube, flange and lid)	Al	340		75	25
24 cylinders for shielding of the experimental tubes (put inside the tubes at the rear)	Pb	1780		100 (mixed)*	
10 ionization chambers		320		100	
Liner (walls, & floor)	SS	14000 (304 m <sup>2</sup> )	100		
Main pool separation gate	Al	700 (13.6 m <sup>2</sup> )	100		
Thermal column (Lead block - back side)	Pb	3940	100 (mixed)*		
Thermal column (Lead slab – on the well)	Pb	660	100 (mixed)*		
Thermal Column (Lead AMF)	Pb	684			
Thermal Column (Old Lead manuf. 1971)	Pb	890			
Thermal column (graphite)	GRT	12608			
Thermal column Lining of the chamber	Boral	248			
Thermal column metal cover of graphite extension pyramid	Al	360			

\* Other danger besides radioactivity is presented

Carlo calculations to quantify the isotopes levels. The characterization of the GRR-1 PCS was accomplished by the collection and analysis of representative smear and metal scratch samples from the PCS internal surfaces. The smear samples were analyzed by gross beta, gross alpha and high resolution gamma spectrometry, while the scratch samples by high resolution gamma spectrometry. Furthermore, representative scratch samples were analyzed by radiochemical techniques for determination of potential alpha and pure beta emitters [1]. The results of the characterization survey indicated that: (i) the activity of a large part of the piping was well below the general clearance level of 100 Bq/kg [11, 12]; (ii) the part of the piping from the heat exchangers back to the pool exhibited Ag-108m activity three times higher than the general clearance level; (iii) the entire volume of the exchangers seemed to be contaminated by Ag-108m of the order of the general clearance level; (iv) the heat exchangers as well as the delay tanks presented spot contamination at the bottom by Co-60 (metal sediments); (v) the presence of alpha or pure beta emitters was minor inside the primary circuit.

Regarding the Water Treatment System, the radiological characterization results of the primary resin waste [13] which was produced during the operation period of the GRR-1 indicated that the activity concentrations are: Ag-108m < 4.70 Bq/g, Cs-137 < 160 Bq/g, Eu-152 < 2 Bq/g, Co-60 < 6 Bq/g. Furthermore, no evidence for the presence of fission products or significant concentrations of other pure beta emitters was detected

#### **4. Inventory and classification of the components and systems of the GRR-1**

The classification of the GRR-1 components and systems was done by considering the final disposal solution [10]. The materials of the GRR-1 were classified in those for: (i) immediate clearance (EW); (ii) interim storage and/or decontamination and clearance (VLLW); (iii) disposal in a near surface facility with provision for release of the sites for general use in 300 years (LLW); (iv) disposal in a geological facility for long term safety (ILW).

The preliminary classifications of the components, at the reactor pool, are presented in Ta-

ble 2. The key radionuclides for classification of the reactor core, control rods and beryllium blocks are the long lived radionuclides Ni-63, Be-10, Ag-108m and Ni-59 (Table 1). The specific activities of these radionuclides in the components of major radiological concern will not be reduced significantly after 300 years. So the materials of these components are classified as ILW. For the SS special rod and the Al experimental tubes, the evaluation was based on the results for the SS pins and Al grid plate presented in the Table 1. The activated part of the special rod is expected to be ILW. For the manipulation of the rods special shafts are used which are expected to present low contamination and classified as VLLW. The experimental tubes can be preliminarily classified as 25 % ILW (up to 1 m from the center of the core) and 75 % as LLW. Also the ionization chambers as well as the cylinders for the shielding of the tubes are expected to be LLW. Based on the wipe tests, the reactor pool liner is classified as VLLW.

At the thermal column only the lead block (back side) and the lead slab (on the well) which are expected to present low contamination can be preliminarily classified as VLLW. The other components of the thermal column cannot be classified. Computational methods should be performed for estimating the extension of thermal column activation. This is necessary, because C-14 ( $T_{1/2}=5740$  y) is produced by neutron activation in graphite, through the C-13(n, $\gamma$ )C-14 reaction and its relevance for clearance even after 300 years is very high. Furthermore, long lived radionuclides can be produced from the impurities in the thermal column lead block as well as in boral [14].

The contamination on the metal components in the spent fuel storage pool is expected not to be higher than the contamination on the liner of the reactor pool. So, all the metal components in the storage pool, of total mass 1300 kg (45 m<sup>2</sup>), can be classified as VLLW. The storage pool cover of 720 kg is expected to EW.

Regarding the PCS, 7000 kg (1000 kg of the piping and 6000 kg the mass of the delay tanks after collecting the metal sediments) are expected to be EW. The other 10000 kg are considered as VLLW.

Table 3. Primary Cooling System components

<i>Component</i>	<i>Mass per length (kg/ m)</i>	<i>Material</i>	<i>Length (m)</i>	<i>Mass (kg)</i>
Pipe 6 inches	10.95	Al	51.4	563
Pipe 8 inches	14.69	Al	52.5	771
Pipe 10 inches	21.18	Al	65.4	1385

<i>Component</i>	<i>Code</i>	<i>Material</i>	<i>Mass per item (kg)</i>	<i>Number</i>	<i>Mass (kg)</i>
Flange 6 inches		Al	2.74	37	101
Flange 8 inches		Al	4.20	32	126
Flange 10 inches		Al	5.64	12	68
Unreturned at П- A1 & П-A2 pumps		SS	70	2	140
Unreturned valve at П-AM pump		Al	25	1	25
Valve 6 inches	П-V1, П-V12, П-V22, П- V13, П-V23, П-V3, П-V2, П-VM1, П-VM2, П-VM3, П-VM4, П-VD, П-VST	Al, SS, Fe	40	13	520
Valve 8 inches	П-V11, П-V21, П-V4	Al, SS, Fe	55	3	165
Electric valve 6 inches	П-H1, П-H2	SS	20	2	40
Electric valve 8 inches	BF-1, BF-2	SS	35	2	70
Pump	П-AM	Al	200	1	200
Pumps	П-A1 & П-A2	SS	400	2	800
Electric flow meter (Foxboro)	П-F1, П-F2,	SS	5	2	10
Air flow meter (Foxboro)	П-F	SS	120	1	120
Delay tank	DT-1, DT-2, DT-3	Al	2000	3	6000
Heat exchanger	E-1, E-2	SS	3000	2	6000
<b>Total weight (kg)</b>					<b>17104</b>

Table 4. Secondary Cooling System components

<i>Component</i>	<i>Mass per length (kg/ m)</i>	<i>Material</i>	<i>Length (m)</i>	<i>Mass (kg)</i>
pipe 8 inches	42.6	Fe	45.5	1938
pipe 10 inches	53.7	Fe	54.8	2941

<i>Component</i>	<i>Code</i>	<i>Material</i>	<i>Mass per item (kg)</i>	<i>Number</i>	<i>Mass (kg)</i>
flange 8 inches		Fe	12.45	26	324
flange 10 inches		Fe	16.71	24	401
unreturned valve 6 inches		Fe	70	2	140
Electric flow meter (Foxboro)		SS	5	2	10
valve 8 inches	Δ-V13, Δ-V23, Δ-V12, Δ- V22, Δ-V1	Fe	150	5	750
valve 10 inches	Δ-V14, Δ-V24, Δ-V2, Δ- V11, Δ-V21, Δ-V3	Fe	200	6	1200
Pump	Δ-A1, Δ-A2	Fe	500	2	1000
electric valve 8 inches	Δ-H1, Δ-H2	SS	20	2	40
Cooling tower		Fe+PVC	6000	2	12000
<b>Total weight (kg)</b>					<b>20744</b>

Based on the results of the resin waste analyses, the water treatment systems are expected to present minimal beta-gamma contamination (at least 2 orders of magnitude lower than the higher specific activities in resin waste). So the three columns and the two pumps which were used for demineralization of the reactor and fuel storage pool water of total mass 1930 kg are considered as VLLW. The fourth column and the pump of total mass 720 kg, which was used for demineralization of tap water for replacement losses of the primary water, is EW.

Since during the operation period of the reactor there isn't any leakage from the PCS to the SCS or any significant incident, the SCS materials (Table 4), of total mass 20700 kg as well as the output filters of the ventilation system, of total mass 700 kg, are not expected to be contaminated and classified as EW.

## 7. Conclusions

For decommissioning planning and costing of the GRR-1, the masses of the materials which will arise from the dismantling, the length of piping as well as the area of the contaminated surfaces were determined. Furthermore, a preliminary classification of the waste which will arise from the dismantling of systems and components was done.

From the decommissioning of the reactor pool and core, PCS and SCS, storage pool, water treatments systems, output filters of the ventilation system, are expected: 29800 kg of EW; 28000 kg of VLLW and 4600 mixed VLLW (lead blocks at the thermal column); 580 kg of LLW and 1780 kg mixed LLW (lead cylinders for shielding of the experimental tubes); 265 kg of ILW and 180 of mixed ILW (beryllium blocks and activated part of the control rods). The partitioning of the thermal column materials of total mass 14800 kg will be done in the future when the extension of activation will be studied by computational methods.

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