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Review of Planned Graphite Usage for the PBMR Demonstration Power Plant

Executive summary

This report is a summary of information about graphite in Pebble Bed Modular Reactor (PBMR) fuel and structural materials with respect to its post-irradiation management. The report was prepared as part of PBMR's participation in the CARBOWASTE Project, a Euratom Project under Framework 7 of the European Commission. Content of the report was prescribed by the Project leaders and includes country-specific legislative and regulatory frameworks, policy objectives of decommissioning, a comparison with international guidelines, the expected pre- and post-irradiation properties and quantities of the PBMR graphite, and plans for handling, treatment and disposal.

All other countries participating in this Project are members of the European Union. The European nations possess various quantities of irradiated graphite from reactors past and present. As such, the primary interest for these countries is strategies for managing the material they have or expect in the near term. South Africa offers a different perspective to the Project because of the relatively early stage of the PBMR. The South African objective for Project participation is to share knowledge about its graphite waste minimization research and to benefit by the research of participating countries. In particular, South Africa will offer the results of experiments performed to prove the concept of microbial treatment of irradiated graphite to remove radionuclides, especially ^{14}C.

Revisions

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List of Abbreviations

This list contains the abbreviations used in this document.

Abbreviation or Acronym	Definition
AMSL	Above Mean Sea Level
AVR	*Arbeitsgemeinschaft Versuchsreaktor* (German for Jointly-operated Prototype Reactor)
ANS	American Nuclear Society
BISO	Bistructural Isotropic Particle
BOL	Beginning of Life
BOP	Balance of Plant
CFRC	Carbon Fibre Reinforced Composites
CSC	Core Structure Ceramics
CTE	Coefficient of Thermal Expansion
CW	Cooling Water
DME	Department of Minerals and Energy
DPP	Demonstration Power Plant
ECP	Engineering Change Proposal
EOL	End of Life
EWC	Equivalent Waste Content
FHSS	Fuel Handling and Storage System
GCR	Gas Cooled Reactor
HICS	Helium Inventory Control System
HLW	High Level Waste
HTGR	High Temperature Gas-cooled Reactor
HTR	High Temperature Reactor
IAEA	International Atomic Energy Agency
ID	Inner Diameter
i-Graphite	Irradiated-Graphite
KNPS	Koeberg Nuclear Power Station
LEU	Low Enriched Uranium
LILW/LL	Low-and Intermediate-Level Waste/Long Lived
LILW/SL	Low Intermediate Level Waste/Short Lived
MCR	Maximum Continuous Rating
MCRI	Maximum Continuous Rating Inventory
MHSS	Main Heat Sink System

Abbreviation or Acronym	Definition
MPS	Main Power System
n/a	not applicable
NORM-E	Naturally Occurring Radioactive Material-Enhanced activity
NORM-L	Naturally Occurring Radioactive Material-Low Activity
NRWDI	National Radioactive Waste Disposal Institute
OD	Outer Diameter
PB	Pressure Boundary
PBMR	Pebble Bed Modular Reactor
PBMR (Pty) Ltd	Pebble Bed Modular Reactor (Proprietary) Limited
PCU	Power Conversion Unit
PGA	Peak Ground Acceleration
PyC	Pyrolytic Carbon
RCCS	Reactor Cavity Cooling System
RPV	Reactor Pressure Vessel
RSS	Reserve Shutdown System
RWMP&S	Waste Management Policy and Strategy
SAS	Small Absorber Spheres
SNF	Spent Nuclear Fuel
SSS	Sphere Storage System
TBD	To be Determined
THTR	Thorium High Temperature Reactor
TRISO	Triple Coated Isotropic Particle
VLLW	Very Low-level Waste
VSOP	Very Superior Old Program
XPS	X-ray Photon Spectroscopy

1. INTRODUCTION

1.1 Purpose

The report was prepared as part of the participation of Pebble Bed Modular Reactor (Proprietary) Limited (PBMR (Pty) Ltd) in the CARBOWASTE Project, a Euratom Project under Framework 7 of the European Commission. Work Package 1 of the Project requires each participating country to assemble and submit information pertinent to its graphite waste. This information will be compiled with that from other countries to create an overall Work Package 1 report, which will serve as reference to all participants and will guide the plan for additional research.

1.2 Scope

Content of the report includes:

a. A discussion of the South African legislative and regulatory frameworks for graphite waste management.

b. The policy objectives for decommissioning the PBMR.

c. A comparison of South African radioactive waste guidelines with international guidelines.

d. The expected chemical and physical properties of the irradiated PBMR fuel matrix and structural graphite and the quantities of both types.

e. Plans for handling both during and after plant operation, for post-irradiation/pre-disposal treatment and for final disposal.

2. THE LEGISLATIVE AND REGULATORY FRAMEWORK

Section 45 of the South African Nuclear Energy Act of 1999 (Act no. 46) states that the authority over management of radioactive waste and storage of irradiated nuclear fuel vests in the Minister of the Department of Minerals and Energy (DME). The Minister, in consultation with the Minister of Environmental Affairs and Tourism and the Minister of Water Affairs and Forestry, may make regulations prescribing the manner of management, storage and discarding of radioactive waste and irradiated nuclear fuel.

Approved by Cabinet in 2005, the Radioactive Waste Management Policy and Strategy (RWMP&S) provides the framework for future management of all radioactive wastes and spent nuclear fuel. Currently, a National Radioactive Waste Disposal Institute (NRWDI) is being created to implement and enforce the management principles defined in the RWMP&S. The Institute will have the following functions, which are aimed at optimizing radioactive waste management and disposal at a national level:

- Design and implementation of disposal solutions for all classes of radioactive waste.
- Conduct research to develop plans for the long-term management of radioactive waste storage and disposal.
- Develop waste acceptance and disposal criteria, assess and inspect radioactive waste for compliance with such criteria and issue disposal certificates.
- Manage, operate and monitor operational radioactive waste disposal facilities, and manage and monitor closed disposal facilities.
- Investigate the need for new disposal facilities, and site, design and construct such facilities as required.
- Manage the disposal of ownerless waste, including the development of waste management plans for such waste, and assist generators of small quantities of waste in technical aspects related to the disposal of such waste.

The scope of the National Nuclear Regulator's jurisdiction is described in the South African National Nuclear Regulator Act of 1999 (Act no. 47) Section 5, where it is stated that:

> The responsibility of the National Nuclear Regulator is to provide for the protection of persons, property and environment against nuclear damage through the establishment of safety standards and regulatory practices and to exercise regulatory control related to safety over the siting, design, construction, operation, manufacture of component parts and decontamination, decommissioning and closure of nuclear installations and other actions to which this Act applies. These would include radioactive waste management facilities associated with nuclear power stations, nuclear fuel cycle facilities that mine and process radioactive ores and minerals [1].

Other national legislation applicable to the possession and handling of radioactive materials are [2]:

- Hazardous Substances Act, 1973 (Act No. 15 of 1973).
- National Environmental Management Act, 1998 (Act No. 107 of 1998).
- National Water Act, 1998 (Act No. 36 of 1998).

- Dumping at Sea Control Act, 1980 (Act No. 73 of 1980).
- Mine Health and Safety Act, 1996 (Act No. 29 of 1996).
- Mineral and Petroleum Resources Development Act (Act No. 28 of 2002).

Table 1 summarizes the South African regulations on radioactive waste classification, treatment requirements and disposal options. The classes encompass all radioactive waste except operational radioactive liquid and gaseous effluent (waste discharges), for which controlled environmental release is permitted routinely under the authority of the relevant regulators.

Table 1: National Radioactive Waste Classification Scheme [1]

Waste Class	Generic Waste Treatment/ Conditioning Requirements	Disposal/Management Options
1. HLW	Waste packaging suitable for handling, transport and storage (storage period on the order of 100 years).	Regulated deep disposal (100s of metres). Reprocessing, conditioning and recycling.
2. LILW-LL	Waste packaging suitable for handling, transport and storage (storage period on the order of 50 years).	Regulated medium depth disposal (10s of metres).
3. LILW-SL	Waste packaging suitable for handling, transport and storage (storage period on the order of 10 years).	Regulated medium depth disposal (<10 of metres).
4. VLLW	Waste stream specific requirements and conditions.	Authorized disposal discharge or reuse.
5. NORM-L (low activity)	Unpacked waste in a miscible form.	Re-use as underground backfill material in an underground area. Extraction of any economically recoverable minerals, followed by disposal in any mine tailings dam or other sufficiently confined surface impoundment. Authorized disposal.
6. NORM-E (enhanced activity)	Packaged or unpackaged waste in a miscible or solid form with additional characteristics for a specific repository.	Dilute and reuse as underground backfill material in an identified underground area. Extraction of any economically recoverable minerals, followed by dilution and disposal in an identified mine tailings dam or other sufficiently confined surface impoundment. Regulated deep or medium disposal.

3. POLICY OBJECTIVE OF DECOMMISSIONING ([1] AND [3])

It has been a key objective in the design of the Pebble Bed Modular Reactor (PBMR) to consider issues related to the decommissioning of the plant at a relative early stage, at least before the detail design baseline is frozen. The schemes employed in the decommissioning of Gas Cooled Reactor (GCR) facilities worldwide were evaluated for consideration in the decommissioning strategy for the PBMR. Although the facilities generally differ substantially in their designs, a certain commonality does exist in all the approaches that have been followed.

3.1 Decommissioning Options

The decommissioning scheme to be adopted for the PBMR is determined by the South African national nuclear strategy regarding the back-end of the fuel cycle and waste disposal method at the time of decommissioning. Presented below are general descriptions of the two options considered.

3.1.1 Early Plant Dismantlement

- The fuel is removed from the reactor and the spent fuel stored in a storage installation.
- Immediately following the fuel removal operation, the radioactive components are removed from the Reactor Pressure Vessel (RPV). The facility, including the support buildings, is then decontaminated to meet final release criteria.

3.1.2 Safe Enclosure

- The fuel is removed from the reactor and the spent fuel stored in a storage facility.
- The fuel removal operation is then followed by a period of care and maintenance where the facility is put in a state of Safe Enclosure.
- Further dismantlement is then done stepwise at later stages in order to obtain the benefits of radioactive decay.
- In order to fulfil the requirements of a state of Safe Enclosure, parts of the facility may need modification to compensate for the loss of certain critical functions as a result of the stepwise dismantlement.
- The safe enclosure option is in keeping with the South African Radioactive Waste Management Policy and Strategy [1].

3.2 Decommissioning Approach for PBMR – Waste Handling and Treatment

Both decommissioning schemes described above perform early fuel unloading, which is followed by dismantlement of the rest of the facility at some stage, either immediately following fuel unloading, or after some time depending on policy and economics related to the waiting time to obtain benefits from radioactive decay. The approach to be followed for the PBMR will, at this stage, not give preference to any one of the schemes but will focus generically on a scheme of fuel unloading followed by dismantlement of the rest of the facility.

It is envisaged that the steps to be followed for the PBMR will therefore be the following:

- Fuel unloading followed by a time of decay, whereafter it is shipped to a High Level Waste (HLW) storage facility.
- Sectioning of the three manifold pipes where they penetrate the biological shield around the reactor cavity, and sealing the reactor vessel as well as the Power Conversion Unit (PCU) side of the manifold pipes completely watertight.
- Removal of the major PCU components from the pressure boundary.
- Decontaminating the PCU pressure boundary to remove the settled dust and other possible contaminants.
- Decontamination of the Helium Inventory Control System (HICS) tanks and sectioning of the complete system.
- Decontamination of the Fuel Handling and Storage System (FHSS) and sectioning and removal of the components outside of the RPV.
- Cutting up of the PCU pressure boundary into smaller sections.
- Dismantling the core structures.
- Dismantling of the RPV by sectioning.
- Dismantling of the Reactor Cavity Cooling System (RCCS) by sectioning.
- Removal of other equipment from the reactor cavity.
- Removal of the grossly activated inside concrete surface of the reactor cavity.
- Removal of the auxiliary systems, which do not provide a service, which is required for the Safe Enclosure concept.

A very important feature in the disposal process is the monitoring of materials to determine and confirm radioactivity levels, particularly where material is to be exempted from regulatory control. Detailed procedures will have to be developed, agreed with the appropriate Authorities and Regulator, implemented and demonstrated. These will include detailed monitoring of individual components and bulk monitoring, and confirmatory checks using gamma spectroscopy equipment and detailed radiochemical analysis.

The removal of activated components and equipment is followed by a decontamination operation throughout the building. The decontamination of the buildings will progress from the higher contaminated areas to the lower contaminated ones, from the top to the bottom, and from the farthest location to the central parts. The decontamination normally is followed by a decision measurement and a controlling measurement by the Authorities. Decontaminated rooms will be sealed in order to avoid recontamination.

After disposal of the decontamination devices (abrasion tools for concrete, washing facilities) and contaminated equipment (mobile filtering stations, vacuum cleaning equipment, ventilation system components, decontamination fluid collection facilities etc.), the plant should be free of artificial radioactive nuclides generated during the former plant operation. This will then be assessed by measurement, documented and confirmed by the Authorities. After the plant is released, the demolition of the buildings and the disposal of recyclable materials can take place.

4. COMPLIANCE WITH INTERNATIONAL GUIDELINES AND REGULATIONS

The Radioactive Waste Management Policy and Strategy for Republic of South Africa [1] establishes a set of national radioactive waste management principles which are explicitly linked to basic International Atomic Energy Agency (IAEA) principles [4].

The IAEA principles are used to derive the following South African principles [1]:

- **Polluter pays principle:** The financial burden for the management of radioactive waste shall be borne by the generator of that waste.
- **Transparency in all aspects of radioactive waste management:** All radioactive waste management activities shall be conducted in an open and transparent manner and the public shall have access to information regarding waste management where this does not infringe on the security of radioactive material.
- **Sound decision-making:** Decision-making shall be based on proven scientific information and recommendation of competent national and international institutions dealing with radioactive waste management.
- **Precautionary principle:** Where there are threats of serious irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.
- **No import or export of radioactive waste:** In principle South Africa will neither import nor export radioactive waste.
- **Cooperative governance and efficient national cooperation:** Due to their crosscutting nature, all activities involving radioactive waste management shall be managed in a manner that prevents duplication of effort and maximizes coordination.
- **International cooperation:** The government recognizes that it shares a responsibility with other countries for global and regional radioactive waste management issues. Its actions shall follow the principles in this policy and in relevant regional and international agreements.
- **Public participation:** Radioactive waste management shall take into account the interests and concerns of all interested and affected, when decisions are being made.
- **Capacity building and education:** The government shall create opportunities to develop people's understanding, skills and general capacity concerning radioactive waste management.

These national principles are not directly derived from the international principles, but rather include extensions of IAEA principles for the management of radioactive waste to the South African national context. In particular, the principles: No import or export of radioactive waste, International cooperation and Capacity Building and Education are not found in the international principles but can be considered implicitly considered in the IAEA principles.

[1] defines roles and responsibilities relative to radioactive waste management for various organizations, in keeping with international practice. In addition, it establishes policies on the interpretation of South African basic principles for radioactive waste management. These policies are clearly in agreement with international concept and approaches for HLW

management. The South African waste classification system appears to be derived directly from the IAEA system of classification.

Options for disposition of HLW and spent fuel are also present in the national policy document (DME) [1]. In only one scenario is there a modification of waste, or delay of the decision on final disposition. Consistent with international thinking, the policy and strategy recognize that the storage of spent fuel is finite and not sustainable indefinitely.

5. DECOMMISSIONING OF THE NUCLEAR REACTOR- CURRENT SITUATION

5.1 PBMR

South African company PBMR (Pty) Ltd has, as its major objective, the design, licensing and construction of the Pebble Bed Modular Reactor Demonstration Power Plant (DPP). At the time of this report, the company is in the design and licensing phases. In addition, various contracts are in place to support the start of on-site construction in 2010, including structural graphite manufacture (SGL Carbon) and engineering, procurement and project and construction management services (Murray & Roberts SNC-Lavalin Nuclear (Pty) Ltd [5]). Completion of the construction phase is scheduled for 2014. Eskom Holdings Limited (Eskom) will own, operate and decommission the PBMR DPP at Koeberg Nuclear Power Station (KNPS) site in the Western Cape Province of South Africa [4]).

5.1.1 The Plant

The PBMR module consists of a graphite-moderated, helium-cooled reactor in which the gas is heated by energy of the nuclear fission process, and a direct cycle power conversion unit in which the heat is converted into electrical energy by means of a turbine-driven generator (refer to Figure 1).

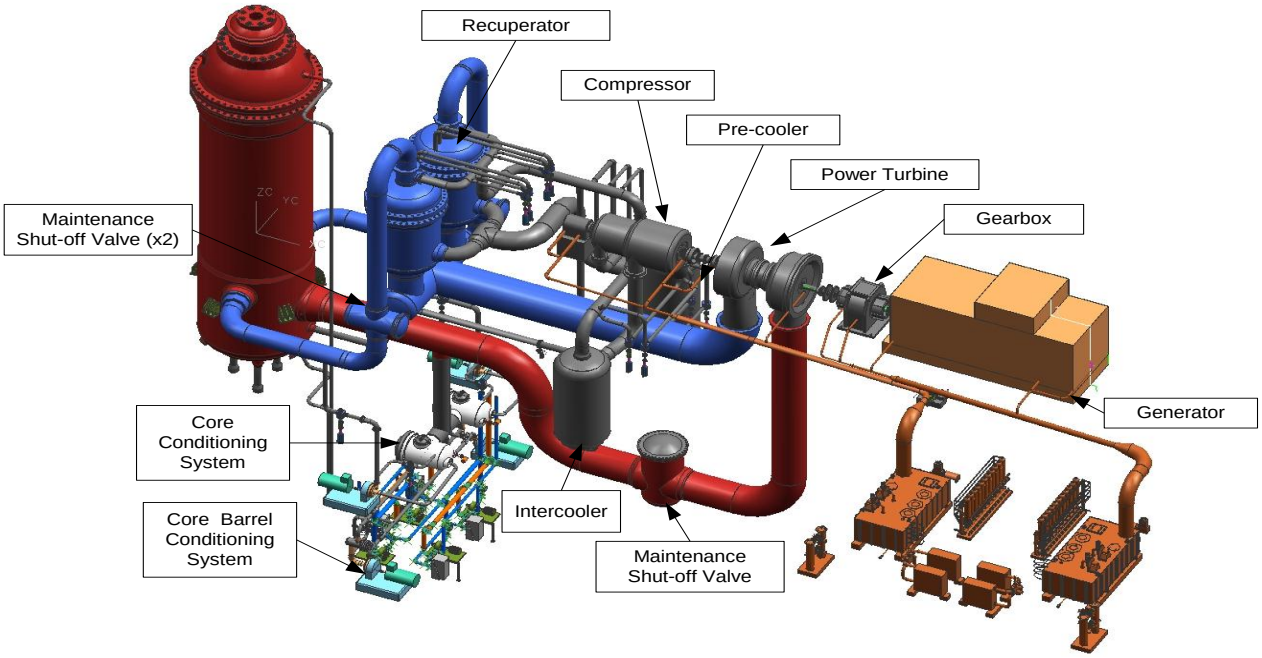

Figure 1: Pebble Bed Modular Reactor [6]

The PBMR reactor core is based on High Temperature Gas-cooled Reactor (HTGR) technology that was originally developed in Germany. This includes the use of spherical fuel elements, referred to as pebbles, which are in size and physical characteristics the same as the fuel that was developed for the German High Temperature Reactor (HTR) programmes. Specifications for the PBMR, coated fuel particles are the same as those tested for Low-enriched Uranium (LEU) in the German Arbeitsgemeinschaft Versuchsreaktor (AVR) reactor

and produced as test fuel for the HTR-Modular design of Interatom. Many of the technical features of the DPP are direct copies of the designs produced for Germany's Thorium High Temperature Reactor (THTR), in particular the components of the FHSS [7].

The plant design envelope is a set of enveloping values that design parameters assume or are bounded by, and which define the scope of what is possible or allowed for the plant design. The parameters listed in Table 2 define the plant design envelope. Select parameters are discussed in more detail following the table.

Table 2: Plant Parameters Defining the Design Envelope [7]

Design Parameters	Enveloping Value(s)			Comment
Plant Location				
Location	On Koeberg site			
Site parameters	Seismic, meteorological, hydrological, geological			
Emergency planning zone	None, falls inside Koeberg zone			
Construction				
Reactor Building	Robust protective enclosure with controllable radionuclide retention function			Designed to protect the reactor and maintain core geometry, not to retain pressure. Instead, designed to vent internal pressure and re-close.
Safe Shutdown Earthquake	0.3 g PGA horizontal for MPS design 0.27 g PGA horizontal for Balance of Plant (BOP)			
Main Vessels – Size, Mass				
	ID Top and Bottom (m)	Overall Height (m)	Total Mass (t)	
Reactor vessel	6.2	30.4	1 016	All dimensions are indication only, since vessels are composite bodies with stepped diameters, welded nozzles, end shells, flanges, etc.
Power				
Total neutronic power (Pn)	400 MWt			MCR is dependent on cooling water temperatures and plant efficiency.
Maximum Continuous Rating (MCR)	175 MWe (max.)			
Continuous stable power range	40% to 100% of MCR			Only during Mode 5(b) normal power operation.
	20% to 100% of MCR, < 40% MCRI => ROT < 800 °C			Possible steady-state operation.

Design Parameters	Enveloping Value(s)	Comment
Ramp rate 100 –55– 100%	10% of MCR per minute	
Load rejection without reactor trip	100% of MCR	
Power Conversion		
Power conversion	Single-shaft Brayton cycle with helium as coolant	Shaft is horizontal, connected to turbine through a 2:1 gearbox
Generator placement	In conventional island	
Core		
Core shape	Annular cylinder around near-solid central graphite reflector	
Core annulus x average height	3.7 OD x 2.0 ID x 11 m	
Fuel		
Fuel type	TRISO coated with UO_2 particle	
Fuel enrichment - Start up core - Normal operation	 4.5% 9.6%	
Fuel configuration	Coated particles in 60 mm diameter graphite spheres	
Uranium content per sphere	9 g U per sphere	
Fuel spheres (steady state)	Approx. 450 000	
Fuel burn-up	Approx. 92 000 MWd/t at 9.6% enrichment	
Pebble centre temperature - Normal operation	1 067 °C with 1 106 ºC max.	At full power
Fuel loading	Continuous, six passes (average)	
Fuel entry	Three loading points from Fuel Handling and Storage System (FHSS)	
Reactivity Control		
Shutdown margin at cold (100 °C)	≥ 1%Δk	
Standby Power		
Alternative power supply	132 kV, 15 MW	
11 kV Main Diesel Generators	2 x 5 MW, 11 kV (=2 x 100%)	
400 V Diesel Generators	2 x 100 kW, 400 V (=2 x 100%)	
Primary Circuit – MPS Pressure Boundary (MPS-PB)		
Maximum operating pressure at 100% MCR	9.0 MPa	

Design Parameters	Enveloping Value(s)	Comment
Design leak rate of MPS	0.1%/day of MPS inventory	
Secondary Circuit – Closed Loop Cooling		
Coolant	Demineralized water	Closed circuit
Tertiary Circuit – Main Heat Sink System (MHSS)		
Coolant	Seawater	
Nominal flow rate	~4 000 kg/s	
Inlet temperature	< 25 °C	Shares Koeberg Cooling Water (CW) inlet wells.
Heat exchange capacity	> 230 MW	
Outlet temperature	< 45 °C	
Maximum temperature rise in outlet channel	< 1.5 °C	Shares Koeberg outlet channel
Staff		
During construction	Estimated maximum 800	
Normal operation	Estimated 105	
During outage	Estimated 250	
Operation and Maintenance		
Plant operating lifetime	~ 40 calendar years	~ 36 years at full power
Availability target	≥ 95% for follow-up reactors	
General overhauls	30 to 50 days scheduled per 6 years	

The PBMR Nuclear Island is located 428 m south and 458 m east of the Koeberg Nuclear Power Station (KNPS) Nuclear Island in Western Cape Province, South Africa. These distances are measured between the centre of the Nuclear Island and the centre line of the RPV in the Reactor Building. The ground floor of the Reactor Building is at an elevation of +13.700 m Above Mean Sea Level (AMSL), while the elevation of the natural ground level at the centre line of the RPV is at an elevation +11.35 m AMSL. The underside of the Reactor Building is founded at a depth of 25.5 m below the ground floor at an elevation of -11.800 m AMSL. The elevation of the terrace is at level +13.50 m AMSL, and is sloped away from the Reactor Building to prevent any flood waters from entering the Reactor Building [6].

5.1.2 The Fuel and Core Structures

Fuel ([7]and[8])

Both present day and planned High Temperature Reactors (HTR) use low-enriched UO_2 Triple Coated Isotropic (TRISO) fuel particles. The design of these particles is based on the development of HTR fuel for the OECD Dragon Reactor Project, from 1960 to 1975 in Britain, and constitute a second generation of fuel after the German Bistructural Isotropic Particle (BISO) fuel particle. The BISO particle consisted of a $(Th,U)O_2$ kernel coated with a porous

pyrocarbon layer and a dense pyrocarbon coating layer. This fuel was used in the AVR and THTR reactors in Germany, and in the Peach Bottom and Fort St Vrain reactors in the USA.

The TRISO particle includes an extra silicon carbide layer in between two dense pyrocarbon layers. This design provides efficient containment of internal fission gases and greatly enhances retention of fission products. During normal operation this retention is effective for burn-ups up to 100 GWd/tHM in the 1 000-1 200 °C temperature range. Under accident conditions, keeping particles intact and retentive is realized up to 1 600 °C, which is the temperature limit in small modular HTRs. At such high temperatures, the HTR may be suitable for power generation with a steam turbine. When the coolant (reactor) exit temperature is lower (~950 °C), a gas turbine and process heat or hydrogen generation system is more efficient.

The composition of a typical fuel sphere as planned for use in the PBMR is shown in Figure 2. Each fuel sphere contains ~15 000 individual coated fuel particles with each kernel being 0.5 mm in diameter. The coatings of the particles form the effective barriers against radionuclide release. The failure of a single particle due to manufacturing defects will have negligible effect on the contamination of the coolant gas. Of the 6 billion particles in the reactor, on average about 120 000 are expected to have defects that may lead to fission product releases when the fuel is heated to high temperatures.

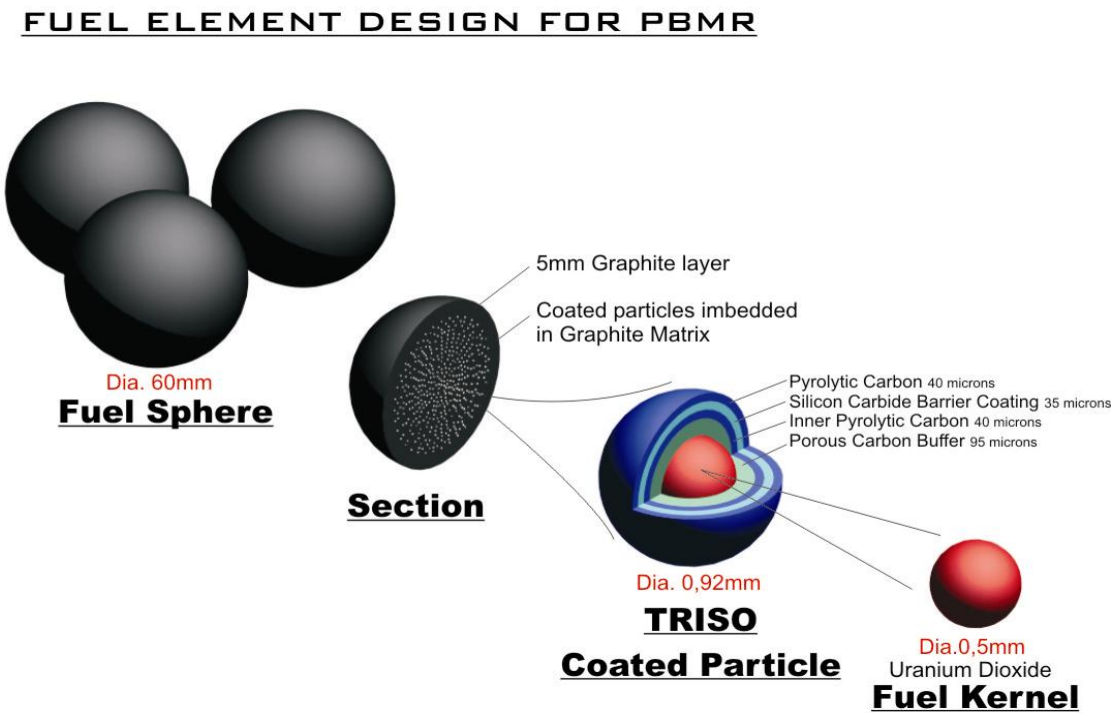

Figure 2: PBMR Fuel Sphere Design [6]

PBMR intends to use fuel enriched to 9.6% (burn-up 92 000 GWd/t), with the possibility of going to higher enrichments < 20% to increase fuel economy. However, this increase will have to wait until a fuel qualification programme has proven such fuel burn-up still maintains the accepted and verified high retention of radionuclides [7].

During reactor operation, fuel pebbles cycle through the reactor, entering at the top of the annular core and exiting at the bottom. To achieve design burn-up, the average fuel pebble effectively passes through the reactor six times at full power, 400 MWth. Each pebble is assessed on exiting the reactor to determine its burn-up level. If the pebble has reached target burn-up, this spent fuel pebble is transferred for storage in large criticality-safe containers at the lower level of the reactor building. The plant design includes sufficient storage container volume to accommodate spent fuel pebbles during the 40-year design lifetime of the PBMR [9].

Other irradiated carbonaceous materials associated with the spent fuel spheres are broken fuel spheres and spheres composed completely of matrix graphite. These materials are accounted for in the storage plans for the spent fuel spheres [10].

Core Structure

Inside the reactor vessel, graphite reflector structures create the fuel bed and provide neutron moderation. Figure 3 and Figure 4 show cross-sectional diagrams of the reactor core, including the graphite reflector structural components and fuel channel.

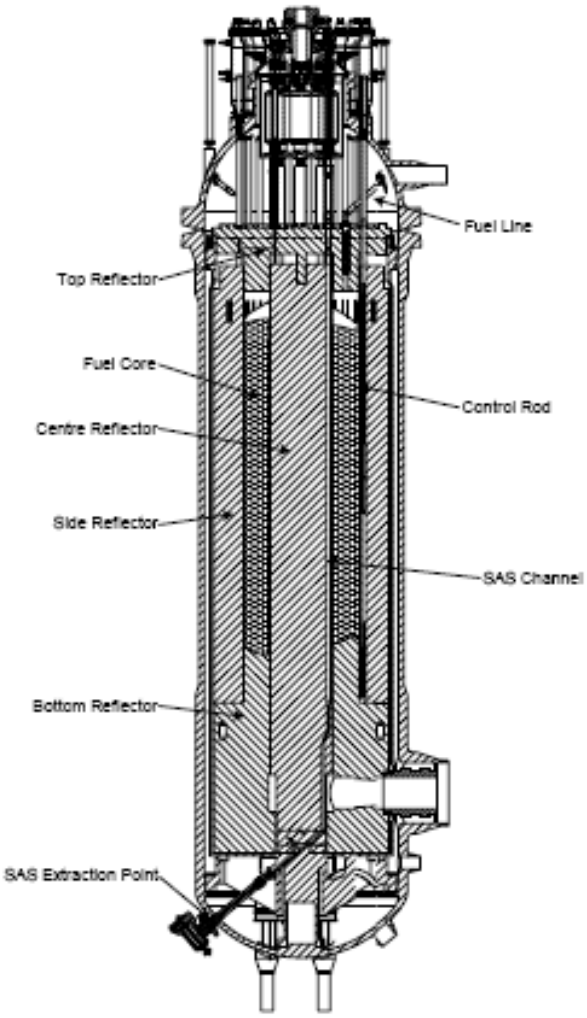

Figure 3: Vertical Cross Section Schematic of the PBMR Reactor Unit [11]

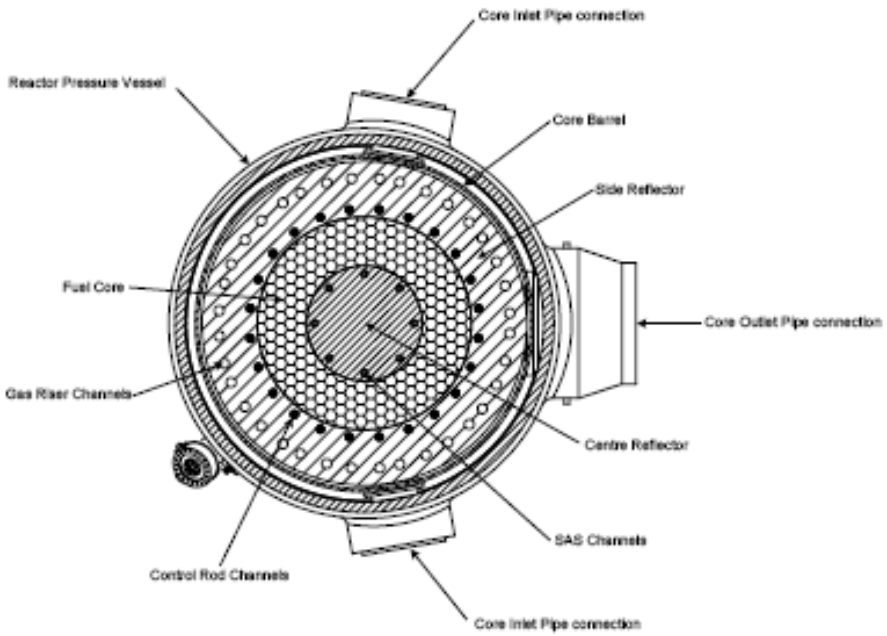

Figure 4: Horizontal Cross Section Schematic of the PBMR Reactor Unit [11]

PBMR maintenance procedures include replacement of the central reflector column and the inner top, bottom and side reflectors after approximately 24 years, or mid-life of the reactor. After reactor shutdown, 60 days are planned for core cool-down and unloading of pebbles before reflector graphite can be replaced. The PBMR would operate for nominally another 16 years (reactor life 40 years) after core structure replacement. Decommissioning and final disposal of the core structures is planned for 40 years or more after final reactor shutdown [12] and [9].

A detailed inventory of the Core Structural Ceramics (CSC) is given in Table 3 to Table 7. The values in these tables represent the CSC in the reactor core at any one time.

Table 3: Centre Reflector Inventory [13]

Centre Reflector	Units	Graphite	CFRC	Metal	Insulation	Total
Number of parts		2 151	0	0	1	2 152
Volume	m^3	50			0.643	50
Density	kg/m^3	1 850			1 800	
Mass	kg	91 625	0	0	1 157	92 782

Table 4: Side Reflectors Inventory [13]

Side Reflectors	Units	Graphite	CFRC	Metal	Insulation	Total
Number of parts		8 106	1 044	1 566	0	10 716
Volume	m^3	159.470	1.276	3.209		164
Density	kg/m^3	1 850	1 500	8 000		
Mass	kg	295 019	1 915	25 674	0	322 608

Table 5: Bottom Reflector Inventory [13]

Bottom Reflector	Units	Graphite	CFRC	Metal	Insulation	Total
Number of parts		1 142	172	162	58	1 534
Volume	m^3	79.126	0.329	0.271	5.093	85
Density	kg/m^3	1 850	1 500	8 000	1 800	
Mass	kg	146 382	493	2 172	9 167	158 213

Table 6: Top Reflector Inventory [13]

Top Reflector	Units	Graphite	CFRC	Metal	Insulation	Total
Number of parts		473	212	304	59	1 048
Volume	m^3	13.435	0.174	0.124	5.352	19
Density	kg/m^3	1 850	1 500	8 000	1 800	
Mass	kg	24 855	261	993	9 633	35 742

Table 7: Total Number of Parts and Mass for Core Structural Ceramics [13]

	Units	Graphite	CFRC	Metal	Insulation	Total
Number of parts		11 872	1 428	2 032	118	15 450
Total mass	kg	557 881	2 669	28 839	19 957	609 345

6. GRAPHITE CHARACTERISTICS

As the PBMR is a future reactor, there currently is no inventory of irradiated graphite. Significant study is devoted to the design of the reactor as PBMR (Pty) Ltd pursues reactor licensing and construction. Part of the design efforts includes choice of graphite vendor and composition, with associated properties. Irradiation analyses for the expected graphite compositions have been performed and used to predict some post-irradiation properties.

6.1 Matrix Graphite

6.1.1 Origin and Manufacture

The PBMR fuel matrix A3-3 graphite is composed of three materials ([14] and [15]):

- Natural graphite powder (manufactured by German company Graphiet Kropfmühl with raw material from a Madagascan mine) - 64%
- Electro graphite powder (made from new coke source by German SGL Group) - 16%
- Phenolic resin (manufactured by German company Hexion, formerly known as Bakelite) - 20%

6.1.2 Pre-irradiation Physical and Mechanical Properties

This paragraph provides tables of the physical properties of the virgin A3-3 graphite.

Table 8: Physical Properties of A3-3 Graphite [15]

Property	Units	20 °C	100	200	300	400	500	600	700	800	900	1 000
Bulk Density	$kg.m^{-3}$	±1 740										
Electrical Resistivity	µohm.m											
Coefficient of Thermal Expansion (CTE) (20°C – T)	$10^{-6}K^{-1}$	n/a										
Isotropy Ratio	-											
Thermal Conductivity* Heat treated at 1 800 °C	$W.m^{-1}.K^{-1}$	0.564	0.496	0.441	0.404	0.373	0.349	0.328	0.310	0.294	0.280	0.267
Heat treated at 1 950 °C	$W.m^{-1}.K^{-1}$	0.720	0.626	0.552	0.500	0.459	0.462	0.397	0.373	0.351	0.332	0.315
Specific Heat**	$J.kg^{-1}.K^{-1}$	727	925	1 133	1 306	1 450	1 569	1 668	1 750	1 818	1 875	1 923
		20°C	**300**	**500**	**700**	**900**	**1 100**	**1 300**	**1 500**	**1 700**	**1 900**	
Emissivity	-	n/a	0.70	0.78	0.85	0.88	0.88	0.90	0.89	0.89	0.88	

*Equations were derived from literature data for the thermal conductivity for fuel matrix graphite heat treated at 1 800 °C (equation (1) and 1 950 °C (equation (2).

**Equation (3) is recommended for specific heat for fuel matrix graphite.

$$\lambda_{1800°C}(T_m) = 0.47\left(1 - 0.01\left(-156.48 + 28.5 \times \ln\left(T_m + 100\right)\right)\right) \quad (1)$$

$$\lambda_{1950°C}(T_m) = 1.5955 - 0.1829 \times \ln\left(T_m + 1\right) \quad (2)$$

Where

$\lambda_{1800°C}$ = thermal conductivity in $W.cm^{-1}.°C^{-1}$ for heat treatment temperature of 1 800 °C

$\lambda_{1950°C}$ = thermal conductivity in $W.cm^{-1}.°C^{-1}$ for heat treatment temperature of 1 950 °C

T_m = measured temperature in °C

$$Cp(T_m) = a_1\left(T_m + a_2\right) + a_3\left(1 - e^{a_4(T_m + a_2)}\right) \quad (3)$$

Where

$Cp(T_m)$ = specific heat capacity in $J.kg^{-1}.K^{-1}$

$a_1 = 34.57 \cdot 10^{-3}$

$a_2 = 200.1$

$a_3 = 2\ 092$

$a_4 = -1.916 \cdot 10^{-3}$

No qualification measurements have been done on PBMR fuel matrix graphite. The properties listed in Table 9 are from the manufacturing specification and literature data [15].

Table 9: Mechanical Properties of A3-3 Graphite [15]

Property	Units	20 °C	100	200	300	400	600	800	1 000
Compressive Strength*	kN	≥ 18							
Dynamic Elastic Modulus	GPa								
Static Elastic Modulus	GPa	3.72							
Shear Modulus	GPa	11.0							
Poisson's Ratio	-	0.3							
Fracture Toughness (K_{IC})	$MPa.m^{1/2}$								
Friction Coefficient (in helium) Graphite-Graphite	-	n/d	0.620	0.620	0.617	0.610	0.581	0.449	0.343

*Note that this compressive strength value relates to the sphere itself – it is not the same as the material property.

6.1.3 Chemical Properties

The chemical composition of the matrix graphite is discussed beginning in Table 10.

Table 10: Specified Impurity Content of Matrix Graphite

Characteristic	Unit	Value
Nitrogen content	$mg.kg^{-1}$	BOL: ≤ 80[1] EOL: ≤ 40[2]
Equivalent boron content	$mg.kg^{-1}$	≤ 1.3
Ash content	$mg.kg^{-1}$	≤ 300
Lithium content	$mg.kg^{-1}$	≤ 0.05

1 BOL: Beginning of Life

2 EOL: End of Life

Table 11: Actual Impurity Content of Matrix Graphite [15]

Element	mg.kg^{-1}	Element	mg.kg^{-1}
Ag	0.010	Li	0.060
Al	18.00	Mg	1.067
B	0.030	Mn	0.881
Ca	11.03	Mo	0.808
Cd	0.005	Na	28.89
Cl	7.180	Ni	2.420
Co	0.241	S	11.18
Cr	9.361	Si	18.58
Cu	0.962	Sm	0.005
Dy	0.005	Sn	1.135
Eu	0.005	Th	0.009
Fe	23.80	Ti	0.402
Gd	0.049	U	0.018
In	0.500	V	0.057
K	2.360	Zn	1.000

6.1.4 Predicted Irradiation History and Post-irradiation Properties

The list of impurities used for the matrix graphite irradiation calculations is given in Table 12. It should be noted that nitrogen was not included as an impurity in this neutron activation analysis, because a precise value for nitrogen concentration was not available. In addition, the importance of this impurity to the purpose of the study (fuel neutronic properties) is minimal. Therefore, the major source of ^{14}C (namely, the ^{14}N conversion to ^{14}C via (n,p) reaction) is not accounted for.

Table 12: Fuel Matrix Graphite Impurities Values Used in Neutron Activation Analysis [16]

Expected Impurities	Quantity (g/kg C in Pebble)	Expected Impurities	Quantity (g/kg C in Pebble)
Ag	1.35E-07	Mg	1.05E-06
B	1.01E-07	Mn	4.26E-07
Ba	5.00E-06	Mo	6.69E-07
Ca	9.28E-06	Na	3.98E-06
Cd	1.03E-07	Ni	1.03E-06
Cl	6.54E-06	Sm	1.10E-08
Co	1.30E-07	Sn	1.13E-06
Cr	1.81E-06	Sr	1.00E-06
Cu	1.19E-07	Th 232	2.00E-07
Dy	1.00E-08	Ti	4.97E-07
Eu	1.00E-08	U 234	2.75E-13
Fe	2.95E-06	U 235	3.60E-11
Gd	1.00E-08	U 238	4.96E-09
K	3.88E-06	V	4.33E-07
Li	1.00E-06	Zn	1.00E-06

Matrix graphite post-irradiation predicted composition (and associated activity) was calculated with the ORIGEN-S code. For the purpose of this exercise, values given in Table 12 were used as the pre-irradiation impurity composition of the matrix graphite. The pre-irradiation composition of the bulk matrix graphite used for the irradiation calculations is assumed to be di-isotopic carbon, as shown in Table 13 [16].

Table 13: Carbon Isotopic Composition of Pre-Irradiation Fuel Matrix Graphite [16]

Isotope	Percent in Matrix Graphite
^{12}C	98.80
^{13}C	1.20
^{14}C	0.00
^{15}C	0.00

Table 14 shows the axial flux profile seen by the average pebble as it travels through the reactor from top to bottom. Each pebble nominally passes through this flux six times before being permanently removed from circulation.

Table 14: Neutron Flux per Axial Location in Reactor as Seen by Fuel Matrix Graphite [16]

Location	Step	Time Interval (Days)	VSOP Flux (<1.86 eV) ($n.cm^{-2}.s^{-1}$)	ORIGIN Flux (<0.5 eV) (n.cm-2.s-1)
Core	1	7.71154	3.59E+13	3.01E+13
	2	7.71154	5.60E+13	4.69E+13
	3	7.71154	8.28E+13	6.94E+13
	4	7.71154	1.22.1E+14	1.03E+14
	5	7.71154	1.34E+14	1.12E+14
	6	7.71154	1.42E+14	1.19E+14
	7	7.71154	1.39E+14	1.17E+14
	8	7.71154	1.32E+14	1.11E+14
	9	7.71154	1.20E+14	1.00E+14
	10	7.71154	1.04E+14	8.75E+13
	11	7.71154	9.36E+13	7.85E+13
	12	7.71154	7.88E+13	6.61E+13
	13	7.71154	6.62E+13	5.55E+13
	14	7.71154	5.75E+13	4.82E+13
	15	7.71154	4.59E+13	3.85E+13
	16	7.71154	3.84E+13	3.22E+13
	17	7.71154	3.28E+13	2.75E+13
	18	7.71154	2.47E+13	2.08E+13
	19	7.71154	2.05E+13	1.72E+13
	20	7.71154	1.66E+13	1.39E+13
	A	20 h	-	1.00E+12
Defuel Chute	B	20 h	-	1.00E+10
	C	20 h	-	1.00E+08
	D	20 h	-	1.00E+06

It is important to note that the post-irradiation composition of the graphite matrix material is based exclusively on interaction of the starting material under full power conditions. No allowance is made for fuel particle failure and resulting migration of fission products, coating materials and/or fuel isotopes into the matrix material. Table 15 lists the predicted composition of the spent fuel matrix graphite at 0 decay time.

Table 15: Predicted Composition of Fuel Matrix Graphite 0 Days after Irradiation Equivalent to 6 Passes through the Equilibrium Reactor Core (400 MWth) (values less than 10^{-10} Curies are not included) [16]

Isotope	Activity (Curies per Fuel Sphere)	Isotope	Activity (Curies per Fuel Sphere)	Isotope	Activity (Curies per Fuel Sphere)	Isotope	Activity (Curies per Fuel Sphere)
H 3	2.82E-04	Y 95	9.23E-08	Pd 116	1.63E-10	I 139	3.51E-09
Be 10	7.46E-10	Zr 95	3.29E-07	Ag 116	1.97E-10	Xe 139	4.79E-08
C 14*	1.61E-07	Nb 95	3.92E-07	In 116m	1.04E-10	Cs 139	9.02E-08
P 32	8.54E-08	Nb 95m	3.81E-09	Cd117	1.53E-10	Ba139	9.83E-08
S 35	3.03E-05	Rb 96	7.51E-10	In 117	1.19E-10	I 140	3.69E-10
Cl36	1.70E-08	Sr 96	3.42E-08	In 117m	1.42E-10	Xe 140	2.41E-08
Ar 37	4.59E-07	Y 96	7.56E-08	Cd 118	1.98E-10	Cs 140	7.29E-08
Ar 39	6.64E-09	Nb 96	1.52E-10	In 118	1.98E-10	Ba 140	1.63E-07
K 42	1.21E-06	Rb 97	1.09E-10	Ag 119	1.06E-10	La 140	1.74E-07
Ca 41	8.01E-10	Sr 97	1.15E-08	Cd 119	1.30E-10	Xe 141	5.76E-09
Ca 45	2.33E-06	Y 97	5.49E-08	In 119m	1.18E-10	Cs 141	5.02E-08
Sc 46	9.37E-08	Zr 97	8.23E-08	Sn 119m	1.49E-06	Ba 141	9.85E-08
Cr 51	7.18E-06	Nb 97	8.34E-08	Cd 120	2.11E-10	La 141	9.89E-08
Mn 54	4.71E-08	Nb 97m	7.82E-08	In 120	2.17E-10	Ce 141	2.83E-07
Fe 55	1.71E-06	Sr 98	2.71E-09	Cd 121	2.06E-10	Xe 142	1.51E-09
Fe 59	7.95E-08	Y 98	2.73E-08	In 121m	2.12E-10	Cs 142	2.25E-08
Co 58	1.62E-07	Zr 98	7.76E-08	Sn 121	1.51E-07	Ba 142	9.47E-08
Co 60	1.48E-05	Nb 98	7.91E-08	Sn 121m	1.58E-10	La 142	1.03E-07
Ni 59	5.81E-10	Nb 98m	1.51E-09	Cd 122	1.80E-10	Pr 142	1.98E-09
Ni 63	7.87E-08	Sr 99	4.49E-10	In 122	2.08E-10	Cs 143	6.65E-09
Zn 65	3.38E-06	Y 99	1.27E-08	Cd 123	1.45E-10	Ba 143	6.80E-08
Ga 75	1.22E-10	Zr 99	6.74E-08	In 123	2.30E-10	La 143	9.00E-08
Ge 75	1.24E-10	Nb 99	4.40E-08	Sn 123	5.88E-08	Ce 143	9.13E-08
Zn 76	1.12E-10	Nb 99m	3.21E-08	Sn 123m	2.91E-10	Pr 143	1.60E-07
Ga 76	2.04E-10	Mo 99	7.94E-08	Te 123m	4.57E-10	Cs 144	1.55E-09
Ga 77	2.95E-10	Tc 99m	7.02E-08	Cd 124	1.47E-10	Ba 144	4.11E-08
Ge 77	1.50E-10	Y 100	3.53E-09	In 124	3.38E-10	La 144	6.71E-08
Ge 77m	3.08E-10	Zr 100	5.00E-08	Sb 124	3.05E-09	Ce 144	2.14E-07
As 77	3.98E-10	Nb 100	5.92E-08	Cd 125	2.78E-10	Pr 144	2.14E-07
Ga 78	3.58E-10	Nb 100m	9.21E-09	In 125	6.54E-10	Pr 144m	3.00E-09
Ge 78	8.18E-10	Tc 100	7.22E-09	In 125m	5.43E-10	Cs 145	1.93E-10

Isotope	Activity (Curies per Fuel Sphere)	Isotope	Activity (Curies per Fuel Sphere)	Isotope	Activity (Curies per Fuel Sphere)	Isotope	Activity (Curies per Fuel Sphere)
As 78	8.38E-10	Y 101	7.87E-10	Sn 125	6.13E-10	Ba 145	1.22E-08
Ga 79	4.54E-10	Zr 101	2.21E-08	Sn 125m	1.27E-09	La 145	4.09E-08
Ge 79	2.01E-09	Nb 101	4.69E-08	Sb 125	2.03E-07	Ce 145	5.26E-08
As 79	2.25E-09	Mo 101	5.18E-08	Te 125m	4.46E-08	Pr 145	5.26E-08
Se 79m	2.23E-09	Tc 101	5.19E-08	Cd 126	2.32E-10	Sm 145	5.61E-10
Ga 80	2.20E-10	Y 102	1.40E-10	In 126	1.43E-09	Ba 146	2.76E-09
Ge 80	2.73E-09	Zr 102	8.48E-09	Cd 127	1.29E-10	La 146	1.81E-08
As 80	3.58E-09	Nb 102	2.83E-08	In 127	1.17E-09	Ce 146	3.88E-08
Ge 81	1.93E-09	Mo 102	3.98E-08	In 127m	1.17E-09	Pr 146	3.96E-08
As 81	4.03E-09	Tc 102	3.99E-08	Sn 127	4.14E-09	Ba 147	2.51E-10
Se 81	4.42E-09	Zr 103	1.77E-09	Sn 127m	3.80E-09	La 147	5.79E-09
Se 81m	4.51E-10	Nb 103	1.37E-08	Sb 127	9.24E-09	Ce 147	2.46E-08
Ge 82	1.68E-09	Mo 103	2.76E-08	Te 127	1.31E-08	Pr 147	2.74E-08
As 82	3.78E-09	Tc 103	2.83E-08	Te 127m	5.54E-09	Nd 147	4.13E-08
As 82m	2.10E-09	Ru 103	8.63E-08	In 128	1.20E-09	Pm 147	2.85E-08
Br 82	1.11E-10	Rh 103m	8.61E-08	Sn 128	9.56E-09	La 148	1.19E-09
Ge 83	7.77E-10	Zr 104	2.97E-10	Sb 128	1.43E-09	Ce 148	1.48E-08
As 83	7.54E-09	Nb 104	4.27E-09	Sb 128m	1.05E-08	Pr 148	1.97E-08
Se 83	6.53E-09	Mo 104	1.69E-08	I 128	5.04E-10	Pm 148	6.16E-09
Se 83m	8.41E-09	Tc 104	1.82E-08	In 129	9.44E-10	Pm148m	2.40E-09
Br 83	1.53E-08	Rh 104	1.06E-08	Sn 129	7.91E-09	La 149	1.85E-10
Kr 83m	1.54E-08	Rh 104m	7.75E-10	Sn 129m	7.20E-09	Ce 149	5.26E-09
Ge 84	1.90E-10	Nb 105	9.83E-10	Sb 129	2.39E-08	Pr 149	1.12E-08
As 84	4.33E-09	Mo 105	7.47E-09	Te 129	2.92E-08	Nd 149	1.26E-08
Se 84	2.42E-08	Tc 105	9.58E-09	Te 129m	1.41E-08	Pm 149	1.66E-08
Br 4	2.55E-08	Ru 105	9.64E-09	In 130	2.65E-10	Ce 150	1.52E-09
Br 84m	1.27E-09	Rh 105	9.55E-09	Sn 130	1.21E-08	Pr 150	5.48E-09
As 85	2.03E-09	Rh 105m	2.74E-09	Sb 130	6.35E-09	Ce 151	2.45E-10
Se 85	1.14E-08	Nb 106	1.51E-10	Sb 130m	1.97E-08	Pr 151	2.24E-09
Se 85m	1.07E-08	Mo 106	3.20E-09	Sn 131	7.64E-09	Nd 151	5.04E-09
Br 85	3.17E-08	Tc 106	5.43E-09	Sb 131	3.26E-08	Pm 151	5.18E-09
Kr 85	3.03E-09	Ru 106	1.64E-08	Te 131	4.14E-08	Sm 151	1.06E-09
Kr 85m	3.17E-08	Rh 106	1.66E-08	Te 131m	1.78E-08	Pr 152	6.20E-10
Sr 85	7.17E-08	Mo 107	8.57E-10	I 131	7.37E-08	Nd 152	3.15E-09

Isotope	Activity (Curies per Fuel Sphere)	Isotope	Activity (Curies per Fuel Sphere)	Isotope	Activity (Curies per Fuel Sphere)	Isotope	Activity (Curies per Fuel Sphere)
As 86	4.81E-10	Tc 107	2.61E-09	Xe 131m	1.33E-09	Pm 152	3.32E-09
Se 86	1.87E-08	Ru 107	3.33E-09	Sn 132	2.22E-09	Pm152m	1.75E-10
Br 86	2.83E-08	Rh 107	3.35E-09	Sb 132	1.29E-08	Eu 152	2.87E-09
Br 86m	9.59E-09	Mo 108	1.02E-10	Sb 132m	1.01E-08	Gd 152	1.94E-07
As 87	1.19E-10	Tc 108	7.59E-10	Te 132	7.59E-08	Pr 153	1.27E-10
Se 87	1.14E-08	Ru 108	1.95E-09	I 132	8.07E-08	Nd 153	1.26E-09
Br 87	3.28E-08	Ra 108	1.99E-09	Sn 133	3.41E-10	Pm 153	1.74E-09
Kr 87	6.04E-08	Ag 108	3.10E-06	Sb 133	1.33E-08	Sm 153	7.61E-09
Se 88	2.81E-09	Ag 108m	1.86E-08	Te 133	4.04E-08	Gd 153	7.86E-08
Br 88	2.34E-08	Tc 109	2.36E-10	Te 133m	4.65E-08	Nd 154	4.12E-10
Kr 88	8.10E-08	Ru 109	1.22E-09	I 133	9.22E-08	Pm 154	5.87E-10
Rb 88	8.37E-08	Ra 109	1.46E-09	I 133m	1.03E-08	Pm154m	1.75E-10
Se 89	3.58E-10	Ra 109m	7.28E-10	Xe 133	1.11E-07	Eu 154	2.22E-10
Br 89	1.36E-08	Pd 109	1.63E-09	Xe 133m	3.47E-09	Pm 155	3.11E-10
Kr 89	8.23E-08	Ag 109m	3.42E-08	Ba 133	2.40E-08	Sm 155	4.19E-10
Rb 89	9.56E-08	Ag 110	8.74E-06	Sb 134	1.26E-09	Eu 155	7.31E-07
Sr 89	3.73E-07	Ag 110m	2.60E-06	Sb 134m	1.21E-09	Pm 156	1.18E-10
Br 90	6.89E-09	Cd 109	1.73E-08	Te 134	5.70E-08	Sm 156	2.22E-10
Kr 90	6.85E-08	Ru 110	4.82E-10	I 134	9.27E-08	Eu 156	4.53E-09
Rb 90	6.75E-08	Ra 110m	5.82E-10	I 134m	1.44E-08	Nd 157	4.12E-12
Rb 90m	3.41E-08	Ag 110	5.69E-10	Xe 134m	4.52E-09	Sm 157	1.25E-10
Sr 90	1.75E-08	Ru 111	1.84E-10	Cs 134	1.17E-08	Eu 157	1.32E-10
Y 90	1.77E-08	Ra 111	3.99E-10	Cs 134m	8.21E-10	Dy 159	3.32E-08
Br 91	8.79E-10	Pd 111	4.38E-10	Sb 135	3.83E-10	Tb 160	1.69E-09
Kr 91	3.32E-08	Ag 111	5.64E-10	Te 135	2.25E-08	Ho 166m	1.03E-10
Rb 91	8.59E-08	Ag 111m	4.42E-10	I 135	7.73E-08	Tm 170	1.09E-10
Sr 91	9.98E-08	Ra 112	2.06E-10	Xe 135	5.53E-08	Th 231	4.35E-10
Y 91	3.46E-07	Pd 112	2.83E-10	Xe 135m	2.51E-08	Th 233	1.97E-06
Y 91m	5.91E-08	Ag 112	2.83E-10	Cs 135m	5.87E-10	Th 234	3.85E-10
Kr 92	1.25E-08	Rah 113	1.29E-10	Te 136	7.18E-09	Pa 232	2.29E-10
Rb 92	6.11E-08	Pd 113	2.38E-10	I 136	3.36E-08	Pa 233	5.25E-06
Sr 92	1.00E-07	Ag 113	2.33E-10	I 136m	2.01E-08	Pa 234m	1.07E-08
Y 92	1.01E-07	Cd 113m	1.75E-08	Cs 136	3.96E-09	Pa 234	9.95E-09
Br 93	1.16E-10	In 113m	2.80E-07	Ba 136m	4.44E-10	U 237	3.64E-10

Isotope	Activity (Curies per Fuel Sphere)	Isotope	Activity (Curies per Fuel Sphere)	Isotope	Activity (Curies per Fuel Sphere)	Isotope	Activity (Curies per Fuel Sphere)
Kr 93	2.44E-09	Pd 114	2.13E-10	Te 137	1.33E-09	U 239	4.45E-08
Rb 93	3.47E-08	Ag 114	2.24E-10	I 137	2.65E-08	Np 239	4.56E-08
Sr 93	1.03E-07	Sn 113	2.80E-07	Xe 137	9.46E-08	Up 241	1.42E-09
Y 93	7.16E-08	In 114	2.30E-08	Cs 137	1.67E-08	Up 243	1.14E-09
Kr 94	5.07E-10	In 114m	2.05E-08	Ba 137m	2.12E-08	Am 242	2.44E-10
Rb 94	1.42E-08	Pd 115	1.66E-10	Te 138	1.95E-10	Am 244	2.93E-10
Sr 94	9.09E-08	Ag 115	1.38E-10	I 138	9.67E-09	Cm 242	5.59E-10
Y 94	1.04E-07	Cd 115	1.98E-10	Xe 138	7.30E-08		
Rb 95	2.18E-09	Cd 115m	6.72E-08	Cs 138	8.92E-08		
Sr 95	5.54E-08	In 115m	1.99E-10	Cs 138m	8.93E-09		

* This value does not include ^{14}C produced from neutron activation of ^{14}N, which is a major contributor to the ^{14}C inventory in irradiated graphite.

The total estimated activity of matrix graphite per fuel sphere (at 0 decay time) is 3.8×10^{-4} Curies. Again, it should be noted that nitrogen was not included as an impurity in the neutron activation calculations, and, as such, the total predicted activity is lower than expected in practice. In addition, the predicted concentration of tritium in the irradiated graphite does not include the absorption/desorption of tritium produced in the helium coolant. It is estimated that a significant portion of the total amount of hydrogen in graphite arises from this source [17].

6.2 Structural graphite

6.2.1 Origin and Manufacture

The PBMR structural NBG-18 graphite is manufactured from a pitch coke filler and coal tar pitch binder by the German SGL Carbon Group [14].

6.2.2 Pre-irradiation Physical and Mechanical Properties

Physical and mechanical properties of the pre-irradiation structural graphite are given, beginning in Table 16.

Table 16: Physical Properties of NBG-18 Graphite [18]

Property	Units	Orientation	20 °C	200 °C	400 °C	600 °C	800 °C	1 000 °C
Bulk Density	$kg.m^{-3}$	-	1 866 ± 15	1 866	1 866	1 866	1 866	1 866
Electrical Resistively	µΩ.m	With grain	9.4 ± 0.4	not required				
		Against grain	9.6 ± 0.5	not required				
		Combined	9.5 ± 0.5	not required				
Coefficient of Thermal Expansion (CTE) (20°C – T)*	$10^{-6}K^{-1}$ or	With grain	not applicable	4.49 ± 0.10	4.82	5.10	5.35	5.57
	$\mu m.m^{-1}.K^{-1}$	Against grain	not applicable	4.62 ± 0.11	4.94	5.23	5.48	5.70
		Combined	not applicable	4.56 ± 0.13	4.88	5.17	5.41	5.62
Isotropy Ratio	-	-	1.04	not applicable				
Thermal Conductivity **	$W.m^{-1}.K^{-1}$	With grain	144.9± 7.5	110.3	85.2	69.4	59.3	53.0
		Against grain	140.5± 7.0	106.8	82.5	67.2	57.5	51.3
		Combined	142.7± 7.6					
Specific Heat***	$J.kg^{-1}.K^{-1}$	-	727	1 134	1 450	1 668	1 819	1 924
Emissivity	-	-	not applicable	0.78 ± 0.02	0.78 ± 0.02	0.78 ± 0.02	0.78 ± 0.02	TBD

*CTE at elevated temperatures is calculated using equation (4) with CTE_{200} being the mean CTE measured in the temperature range 20-200 °C.

Note: temperature (T) is in °C. This equation is only valid for temperatures up to and including 1 600 °C.

** Thermal conductivity (*ThC*) at elevated temperatures is calculated using equation (4) with temperature (T) in °C. This equation is only valid for temperatures up to and including 1 650 °C.

*** The specific heat is calculated using equation (4) with temperature (T) in °C.

$$\frac{CTE}{CTE_{200}} = a \cdot T^2 + b \cdot T + c \qquad (4)$$

Table 17: Parameters for the CTE Equation (4)

Parameter	With Grain	Against Grain	Combined
a	$-9.67\ 10^{-8}$	$-9.20\ 10^{-8}$	$-9.83\ 10^{-8}$
b	$4.081\ 10^{-4}$	$4.135\ 10^{-4}$	$3.997\ 10^{-4}$
c	0.923	0.925	0.9234

$$ThC(T) = ThC(20°C) \cdot \left[A + (1 - A) \cdot e^{k \cdot (T-20)} \right] \quad (5)$$

Table 18: Parameters for the Thermal Conductivity equation (5)

Parameter	Value
A	0.328
k	$-2.20\ 10^{-3}$

$$Cp(T) = a_1 (T + a_2) + a_3 \left(1 - e^{a_4 (T + a_2)}\right) \quad (6)$$

Table 19: Parameters for the Specific Heat Capacity Equation (6)

Parameter	Value
a_1	$34.57\ 10^{-3}$
a_2	200.1
a_3	2 092
a_4	$-1.916\ 10^{-3}$

Table 20: Mechanical Properties of NBG18 Graphite [18]

Property	Units	Orientation	20 °C	200 °C	400 °C	600 °C	800 °C	1 000 °C
Tensile Strength	MPa	With grain	20.8 ± 2.5	20.8				
		Against grain	20.4 ± 2.4	20.4				
		Combined	20.6 ± 2.5	20.6				
Compressive Strength	MPa	With grain	77.4 ± 9.2	77.4				
		Against grain	78.5 ± 8.8	78.5				
		Combined	78.0 ± 9.0	78.0				
Bending Strength (4-point)	MPa	With grain	31.1 ± 3.9	31.1				
		Against grain	29.7 ± 3.3	29.7				
		Combined	30.4 ± 3.7	30.4				
Dynamic Elastic Modulus	GPa	With grain	11.9 ± 0.6	11.9				
		Against grain	11.6 ± 0.5	11.6				
		Combined	11.8 ± 0.6	11.8				
Static Elastic Modulus Non-irradiated	GPa	With grain	7.1	7.1				
		Against grain	7.0	7.0				
Static Elastic Modulus Irradiated	GPa	With grain	9.5					
		Against grain	9.3					
Poisson's Ratio	-	-	0.20	not determined				
Fracture Toughness (K_{IC})	$MPa.m^{1/2}$	-	1.48 ± 0.06	1.48				
Friction Coefficient (in Helium)	-	Graphite-Graphite	not determined	0.62	Friction Coefficient (in Helium)	-	Graphite-Graphite	not determined
		Graphite-Stainless Steel	not determined	0.44			Graphite-Stainless Steel	not determined
Vibration Moulded Block Size	mm	Rectangular: 670 x 450x (<2 300)						
		Rectangular: 670 x 450x (<2 000)						
		Cylindrical: diameter – 1 600, height – 470						

6.2.3 Pre-irradiation Chemical Properties

The chemical composition of the PBMR structural graphite is described in Table 21 to Table 22.

Table 21: Ash Content of the NBG18 Graphite [18]

	Mean	Minimum	Maximum
Ash content (ppm)	182.6	30.0	380.0

Table 22: Chemical Analysis (ppm) NBG18 Graphite [18]

Element	Mean	Min	Max	Element	Mean	Min	Max
Ag	0.014	0.0	0.10	Na	2.443	0.0	8.0
Al	4.971	0.0	26.0	Nb	0.50	0.50	0.50
As	0.0	0.0	0.0	Nd	0.02	0.02	0.02
Au	0.031	0.013	0.09	Ni	1.436	0.05	2.20
B	0.958	0.30	1.30	P	0.5132	0.0	4.30
Ba	0.465	0.0	1.20	Pb	0.1354	0.0	0.30
Be	0.005	0.0	0.03	Pr	0.10	0.10	0.10
Bi	0.50	0.50	0.50	Re	0.1057	0.006	0.50
Ca	13.30	0.0	55.0	Rb	-	-	-
Cd	0.0115	0.0	0.10	Rh	0.0561	0.014	0.20
Ce	0.05	0.05	0.05	Ru	0.08	0.08	0.08
Cl	4.665	3.0	10.0	S	5.33	3.0	10.0
Co	0.0875	0.0	0.30	Sb	0.025	0.0	0.10
Cr	0.331	0.0	0.70	Sc	0.10	0.10	0.10
Cu	0.0556	0.0	0.20	Se	0.0248	0.0	0.1
Dy	0.0723	0.0	0.40	Si	6.912	0.0	25.0
Eu	0.0274	0.0	0.10	Sm	0.0428	0.0	0.10
Fe	14.64	0.60	40	Sn	0.0213	0.0	0.20
Ga	0.05	0.05	0.05	Sr	0.0211	0.0	0.10
Gd	0.1382	0.0	0.70	Ta	0.07	0.07	0.07
Ge	0.01	0.01	0.01	Tb	0.0107	0.009	0.01
Hf	0.05	0.05	0.05	Te	0.02	0.02	0.02
Hg	0.10	0.10	0.10	Th	0.0688	0.01	0.60
In	0.1312	0.01	0.10	Ti	3.460	0.50	9.0
K	0.885	0.04	1.90	Tl	0.03	0.03	0.03
La	0.50	0.50	0.50	U	0.0585	0.0	0.20
Li	0.065	0.0	0.20	V	1.9068	0.10	6.0
Mg	1.317	0.0	14.0	W	0.1841	0.0	3.0
Mn	0.0847	0.0	0.50	Y	0.05	0.05	0.05
Mo	0.0882	0.0	0.30	Zn	0.2609	0.0	2.5

6.2.4 Predicted Irradiation History and Post-irradiation Properties

Table 23 lists the impurities used for the neutron activation analysis of the NBG18 structural graphite.

Table 23: Structural Graphite Impurities Values Used in Neutronic Analysis [19] and [20]

Element	Average Quantity (ppm)	Element	Average Quantity (ppm)	Element	Average Quantity (ppm)
Ag	0.015	Hg	0.1	Rh	0.2
Al	4.971	Ho*	0.08	Ru	0.08
As	0	In	0.046	S	3.208
Au	0.09	Ir*	0.2	Sb	0.025
B	0.951	K	0.885	Sc	0.1
Ba	0.435	La	0.5	Se	0.027
Be	0.004	Li	0.065	Si	6.912
Bi	0.5	Mg	1.317	Sm	0.043
Ca	13.302	Mn	0.085	Sn	0.021
Cd	0.015	Mo	0.09	Sr	0.21
Ce	0.05	N~	10	Ta	0.07
Cl	4.255	Na	12.443	Tb	0.01
Co	0.085	Nb	0.5	Te	0.02
Cr	0.331	Nd	0.02	Th	0.075
Cs*~	0.3	Ni	1.022	Ti	3.449
Cu	0.056	Os*	0.2	Tl	0.03
Dy	0.079	P	0.513	U	0.068
Eu	0.03	Pb	0.135	V	1.733
Fe	14.061	Pd*	0.05	W	0.184
Ga	0.05	Pr	0.1	Y	0.05
Gd	0.163	Rb*	0.5	Zn	0.301
Ge	0.01	Re	0.5		
Hf	0.05	Re	0.5		

*Estimated from period and group

~Estimated from literature

The approximate concentration of nitrogen listed in Table 23 is significantly lower than expected, especially because there is no specification limit on concentration of nitrogen in the NBG-18 graphite. As a point of reference, the specified values for nitrogen concentrations in matrix graphite before and after irradiation are 80 and 40 ppm, respectively [15].

Irradiation expected for the core structural graphite components is represented by exposures calculated for the reactor central column reflector and side reflector, shown in Table 24. Neutron flux values are listed according to neutron energy and location in the reflector component. For the central column, a peak average (radial average at the axial peak height) and full average (axial and radial average) are given. As a conservative measure, inner (peak and average) reflector flux values are given for the side reflector. The portions of the side, top and bottom reflectors (all represented by the side reflector) innermost to the core are exposed to more radiation than the outer portions [21].

Table 24: Predicted Neutron Flux According to Energy Group for Central Column and Side Structural Graphite Reflectors [21]

Neutron Energy (MeV)	Neutron Flux (n/cm^2/s)			
	Central Column		Side Reflector	
	Peak Average	Full Average	Inner-Peak	Inner-Average
3.0000E-09	1.16448E+11	6.60809E+10	8.83977E+10	4.17935E+10
5.0000E-09	2.57333E+11	1.43668E+11	1.71978E+11	8.31382E+10
6.9000E-09	5.60256E+11	3.14956E+11	3.96845E+11	1.90766E+11
1.0000E-08	6.76594E+11	3.75607E+11	4.44421E+11	2.14373E+11
1.5000E-08	1.84812E+12	1.04428E+12	1.30721E+12	6.24993E+11
2.0000E-08	2.79756E+12	1.55762E+12	1.87649E+12	9.02094E+11
2.5000E-08	3.18924E+12	1.76921E+12	2.09174E+12	1.00877E+12
3.0000E-08	3.57174E+12	1.98744E+12	2.37598E+12	1.14322E+12
3.5000E-08	4.22152E+12	2.34396E+12	2.76578E+12	1.33486E+12
4.2000E-08	6.40338E+12	3.55211E+12	4.14336E+12	2.00385E+12
5.0000E-08	8.11373E+12	4.47646E+12	5.13082E+12	2.48845E+12
5.8000E-08	8.67250E+12	4.77415E+12	5.38894E+12	2.62100E+12
6.7000E-08	1.01537E+13	5.57667E+12	6.20991E+12	3.02769E+12
7.7000E-08	1.16844E+13	6.40184E+12	7.02418E+12	3.43293E+12
8.0000E-08	3.56670E+12	1.94699E+12	2.09835E+12	1.03034E+12
9.5000E-08	1.78359E+13	9.72157E+12	1.03346E+13	5.08347E+12
1.0000E-07	5.93362E+12	3.22709E+12	3.37189E+12	1.66324E+12
1.1500E-07	1.73137E+13	9.40365E+12	9.66184E+12	4.78494E+12
1.3400E-07	2.11062E+13	1.13952E+13	1.13199E+13	5.64308E+12
1.4000E-07	6.33026E+12	3.40803E+12	3.26724E+12	1.64059E+12
1.6000E-07	1.98142E+13	1.06702E+13	1.01374E+13	5.10222E+12
1.8000E-07	1.78994E+13	9.60861E+12	8.74874E+12	4.44444E+12
1.8900E-07	7.32908E+12	3.91953E+12	3.44693E+12	1.76425E+12
2.2000E-07	2.24855E+13	1.20318E+13	1.03444E+13	5.32345E+12
2.4800E-07	1.65803E+13	8.85490E+12	7.18772E+12	3.75017E+12

Neutron Energy (MeV)	Neutron Flux (n/cm^2/s)			
	Central Column		Side Reflector	
	Peak Average	Full Average	Inner-Peak	Inner-Average
2.8000E-07	1.51586E+13	8.11096E+12	6.24595E+12	3.30522E+12
3.0000E-07	7.76201E+12	4.15018E+12	3.05073E+12	1.63415E+12
3.1450E-07	4.91769E+12	2.62784E+12	1.87232E+12	1.01169E+12
3.2000E-07	1.71956E+12	9.19461E+11	6.44141E+11	3.49692E+11
3.5000E-07	8.10721E+12	4.35713E+12	2.97256E+12	1.62800E+12
3.9100E-07	8.23430E+12	4.45100E+12	2.90172E+12	1.61521E+12
4.0000E-07	1.47001E+12	7.95704E+11	5.00914E+11	2.82131E+11
4.3300E-07	4.49510E+12	2.44567E+12	1.51408E+12	8.58720E+11
4.8500E-07	4.94870E+12	2.71974E+12	1.63274E+12	9.40279E+11
5.0000E-07	1.06187E+12	5.89539E+11	3.50529E+11	2.03560E+11
5.4000E-07	2.25095E+12	1.25847E+12	7.51510E+11	4.38098E+11
6.2500E-07	2.91114E+12	1.65111E+12	1.03444E+12	6.02434E+11
7.0500E-07	1.46388E+12	8.42926E+11	6.10764E+11	3.48541E+11
7.8000E-07	8.34049E+11	4.82032E+11	4.20161E+11	2.32486E+11
7.9000E-07	8.78751E+10	5.05723E+10	4.87901E+10	2.66145E+10
8.5000E-07	4.50436E+11	2.57838E+11	2.69174E+11	1.45201E+11
8.6000E-07	6.49235E+10	3.68850E+10	4.16761E+10	2.22112E+10
9.1000E-07	2.92796E+11	1.65322E+11	1.95711E+11	1.03424E+11
9.3000E-07	1.05052E+11	5.89481E+10	7.28607E+10	3.85003E+10
9.5000E-07	9.97959E+10	5.53690E+10	7.08550E+10	3.71263E+10
9.7200E-07	1.03640E+11	5.75514E+10	7.56778E+10	3.94130E+10
9.8600E-07	6.31361E+10	3.50061E+10	4.71142E+10	2.43970E+10
9.9600E-07	4.39562E+10	2.43179E+10	3.30343E+10	1.71171E+10
1.0200E-06	1.02619E+11	5.61058E+10	7.68609E+10	3.99946E+10
1.0350E-06	6.16662E+10	3.36200E+10	4.69138E+10	2.42943E+10
1.0450E-06	4.02089E+10	2.18383E+10	3.07161E+10	1.58268E+10
1.0710E-06	1.01319E+11	5.50485E+10	7.82701E+10	4.03148E+10
1.0970E-06	9.74425E+10	5.26916E+10	7.59556E+10	3.90967E+10
1.1100E-06	4.74026E+10	2.55182E+10	3.70267E+10	1.90597E+10
1.1230E-06	4.60551E+10	2.51065E+10	3.65754E+10	1.88443E+10
1.1500E-06	9.36994E+10	5.04868E+10	7.44212E+10	3.81840E+10
1.1700E-06	6.75759E+10	3.61386E+10	5.31633E+10	2.74904E+10
1.2350E-06	2.09481E+11	1.11808E+11	1.67571E+11	8.57102E+10
1.3000E-06	1.95343E+11	1.03728E+11	1.56559E+11	8.01404E+10

Neutron Energy (MeV)	Neutron Flux (n/cm^2/s)			
	Central Column		Side Reflector	
	Peak Average	Full Average	Inner-Peak	Inner-Average
1.3380E-06	1.08750E+11	5.75147E+10	8.75657E+10	4.47122E+10
1.3700E-06	8.83356E+10	4.67473E+10	7.12459E+10	3.64396E+10
1.4400E-06	1.85154E+11	9.78442E+10	1.49764E+11	7.63943E+10
1.4750E-06	8.80087E+10	4.67685E+10	7.16044E+10	3.65023E+10
1.5000E-06	6.11991E+10	3.25213E+10	4.98611E+10	2.55132E+10
1.5900E-06	2.12245E+11	1.12011E+11	1.73027E+11	8.80006E+10
1.6700E-06	1.76279E+11	9.32146E+10	1.44037E+11	7.34711E+10
1.7550E-06	1.78527E+11	9.37173E+10	1.44789E+11	7.37567E+10
1.8400E-06	1.68708E+11	8.86682E+10	1.37016E+11	6.98964E+10
1.9300E-06	1.68681E+11	8.89334E+10	1.37486E+11	7.03078E+10
2.0200E-06	1.59901E+11	8.43505E+10	1.30341E+11	6.67019E+10
2.1000E-06	1.35298E+11	7.15119E+10	1.10585E+11	5.64804E+10
2.1300E-06	4.91039E+10	2.60023E+10	4.05687E+10	2.06677E+10
2.3600E-06	3.54742E+11	1.87000E+11	2.90810E+11	1.47964E+11
2.5500E-06	2.65992E+11	1.40003E+11	2.17287E+11	1.10882E+11
2.6000E-06	6.62191E+10	3.48168E+10	5.43626E+10	2.76891E+10
2.7200E-06	1.53648E+11	8.08897E+10	1.26365E+11	6.41894E+10
2.7680E-06	5.90647E+10	3.11134E+10	4.86840E+10	2.47539E+10
3.3000E-06	5.87838E+11	3.09219E+11	4.81586E+11	2.45709E+11
3.3810E-06	8.24514E+10	4.33219E+10	6.73827E+10	3.42892E+10
4.0000E-06	5.91162E+11	3.10813E+11	4.82867E+11	2.46052E+11
4.1290E-06	1.11850E+11	5.88404E+10	9.09926E+10	4.63912E+10
5.0430E-06	6.60592E+11	3.47734E+11	5.44562E+11	2.76798E+11
5.3460E-06	1.85059E+11	9.69505E+10	1.52763E+11	7.77399E+10
6.1600E-06	4.49008E+11	2.35948E+11	3.72179E+11	1.89101E+11
7.5240E-06	6.32058E+11	3.31472E+11	5.21947E+11	2.65309E+11
8.3150E-06	3.21673E+11	1.68877E+11	2.66427E+11	1.35727E+11
9.1900E-06	3.21439E+11	1.68489E+11	2.65322E+11	1.34975E+11
9.9060E-06	2.38975E+11	1.25374E+11	1.97611E+11	1.00725E+11
1.1220E-05	3.92439E+11	2.05922E+11	3.24313E+11	1.65335E+11
1.3710E-05	6.31017E+11	3.30433E+11	5.20778E+11	2.65280E+11
1.5930E-05	4.70105E+11	2.46974E+11	3.90431E+11	1.98367E+11
1.9450E-05	6.25764E+11	3.28296E+11	5.17452E+11	2.63537E+11
2.2600E-05	4.69904E+11	2.46408E+11	3.89048E+11	1.97949E+11

Neutron Energy (MeV)	Neutron Flux (n/cm^2/s)			
	Central Column		Side Reflector	
	Peak Average	Full Average	Inner-Peak	Inner-Average
2.4980E-05	3.13538E+11	1.64318E+11	2.59300E+11	1.32064E+11
2.7610E-05	3.14032E+11	1.64087E+11	2.59843E+11	1.31928E+11
3.0510E-05	3.12643E+11	1.63620E+11	2.57543E+11	1.31306E+11
3.3720E-05	3.11766E+11	1.63553E+11	2.58001E+11	1.31378E+11
3.7270E-05	3.11208E+11	1.63119E+11	2.57461E+11	1.31220E+11
4.0170E-05	2.33067E+11	1.22293E+11	1.94075E+11	9.82809E+10
4.5520E-05	3.88461E+11	2.03564E+11	3.22137E+11	1.63707E+11
4.8250E-05	1.81153E+11	9.48286E+10	1.49827E+11	7.62297E+10
5.1580E-05	2.06528E+11	1.08357E+11	1.71545E+11	8.71356E+10
5.5600E-05	2.31485E+11	1.21689E+11	1.92140E+11	9.78600E+10
6.7900E-05	6.16745E+11	3.23204E+11	5.10911E+11	2.60216E+11
7.5670E-05	3.31806E+11	1.74527E+11	2.76388E+11	1.40564E+11
9.1660E-05	5.87949E+11	3.08130E+11	4.86652E+11	2.48182E+11
1.3670E-04	1.21570E+12	6.38027E+11	1.01276E+12	5.15533E+11
1.4860E-04	2.52304E+11	1.32423E+11	2.09976E+11	1.06892E+11
2.0400E-04	9.53233E+11	5.00155E+11	7.93279E+11	4.03803E+11
3.0430E-04	1.19188E+12	6.25195E+11	9.93029E+11	5.05596E+11
3.7170E-04	5.91025E+11	3.10087E+11	4.91208E+11	2.50473E+11
4.5400E-04	5.87852E+11	3.07843E+11	4.88745E+11	2.49040E+11
6.7730E-04	1.16413E+12	6.10475E+11	9.68884E+11	4.94072E+11
7.4850E-04	2.88026E+11	1.51308E+11	2.39985E+11	1.22353E+11
9.1420E-04	5.74828E+11	3.01329E+11	4.76553E+11	2.43311E+11
1.0104E-03	2.86468E+11	1.50193E+11	2.37524E+11	1.21145E+11
1.2341E-03	5.68974E+11	2.98137E+11	4.72815E+11	2.41091E+11
1.4338E-03	4.24004E+11	2.22378E+11	3.52328E+11	1.79654E+11
1.5073E-03	1.40373E+11	7.37019E+10	1.17076E+11	5.98070E+10
2.0347E-03	8.40736E+11	4.40345E+11	6.98580E+11	3.56196E+11
2.2487E-03	2.78910E+11	1.45686E+11	2.30982E+11	1.17845E+11
3.3546E-03	1.09897E+12	5.77108E+11	9.18417E+11	4.68359E+11
3.5266E-03	1.35902E+11	7.14431E+10	1.13746E+11	5.79363E+10
5.0045E-03	9.45873E+11	4.96777E+11	7.89259E+11	4.02686E+11
5.5308E-03	2.68293E+11	1.40680E+11	2.23570E+11	1.13819E+11
7.4659E-03	7.97569E+11	4.18811E+11	6.66805E+11	3.39093E+11
9.1188E-03	5.26957E+11	2.76353E+11	4.39290E+11	2.23469E+11

Neutron Energy (MeV)	Neutron Flux (n/cm^2/s)			
	Central Column		Side Reflector	
	Peak Average	Full Average	Inner-Peak	Inner-Average
1.1138E-02	5.21574E+11	2.73759E+11	4.35936E+11	2.21665E+11
1.5034E-02	7.75237E+11	4.06287E+11	6.46187E+11	3.29153E+11
1.6616E-02	2.57118E+11	1.34581E+11	2.14436E+11	1.08699E+11
2.4788E-02	1.01648E+12	5.31970E+11	8.49056E+11	4.32044E+11
2.7394E-02	2.52394E+11	1.31718E+11	2.09465E+11	1.06544E+11
2.9283E-02	1.67244E+11	8.76197E+10	1.39116E+11	7.08042E+10
3.6979E-02	5.80365E+11	3.04356E+11	4.84476E+11	2.46609E+11
4.0868E-02	2.47232E+11	1.29580E+11	2.06206E+11	1.05111E+11
5.5166E-02	7.38811E+11	3.87067E+11	6.17542E+11	3.13982E+11
6.7379E-02	4.88257E+11	2.55834E+11	4.07907E+11	2.07510E+11
8.2297E-02	4.86681E+11	2.54630E+11	4.06182E+11	2.06622E+11
1.1109E-01	7.26638E+11	3.80371E+11	6.08220E+11	3.08973E+11
1.2277E-01	2.41010E+11	1.26513E+11	2.01599E+11	1.02653E+11
1.8316E-01	9.64061E+11	5.04466E+11	8.10543E+11	4.11798E+11
2.4724E-01	7.32613E+11	3.83136E+11	6.15306E+11	3.12699E+11
2.7324E-01	2.45537E+11	1.28589E+11	2.06775E+11	1.04975E+11
3.0197E-01	2.47106E+11	1.29322E+11	2.08742E+11	1.05760E+11
4.0762E-01	7.49715E+11	3.92056E+11	6.33953E+11	3.21458E+11
4.5049E-01	2.52141E+11	1.32471E+11	2.13797E+11	1.08487E+11
4.9787E-01	2.55256E+11	1.33598E+11	2.16004E+11	1.09598E+11
5.5023E-01	2.56163E+11	1.34300E+11	2.17831E+11	1.10516E+11
6.0810E-01	2.58629E+11	1.35393E+11	2.19184E+11	1.11410E+11
8.2085E-01	7.85907E+11	4.11639E+11	6.72383E+11	3.41034E+11
9.0718E-01	2.65003E+11	1.38442E+11	2.26402E+11	1.14946E+11
1.0026E+00	2.65714E+11	1.38894E+11	2.27633E+11	1.15229E+11
1.1080E+00	2.65560E+11	1.38715E+11	2.28074E+11	1.15452E+11
1.2246E+00	2.62919E+11	1.37779E+11	2.27855E+11	1.15322E+11
1.3534E+00	2.60305E+11	1.36192E+11	2.24714E+11	1.13666E+11
1.6530E+00	5.02709E+11	2.62992E+11	4.37869E+11	2.21937E+11
2.0190E+00	4.43312E+11	2.32055E+11	3.89239E+11	1.96905E+11
2.2313E+00	1.77063E+11	9.29433E+10	1.56221E+11	7.91360E+10
2.4660E+00	1.60193E+11	8.38689E+10	1.40665E+11	7.09328E+10
3.0119E+00	2.17417E+11	1.13740E+11	1.93488E+11	9.76182E+10
3.6788E+00	1.33413E+11	6.99438E+10	1.17143E+11	5.92172E+10

Neutron Energy (MeV)	Neutron Flux (n/cm^2/s)			
	Central Column		Side Reflector	
	Peak Average	Full Average	Inner-Peak	Inner-Average
4.4933E+00	1.22083E+11	6.39516E+10	1.08961E+11	5.51931E+10
5.4881E+00	1.09674E+11	5.74026E+10	9.96307E+10	5.08601E+10
6.0653E+00	3.37670E+10	1.78696E+10	3.08228E+10	1.57619E+10
6.7032E+00	2.28186E+10	1.19323E+10	1.92860E+10	9.83758E+09
8.1873E+00	2.58661E+10	1.34599E+10	2.17375E+10	1.11593E+10
1.0000E+01	6.43770E+09	3.48371E+09	6.15081E+09	3.15736E+09
1.1618E+01	1.66001E+09	8.74917E+08	1.65690E+09	8.12196E+08
1.3840E+01	4.73063E+08	2.45841E+08	4.59223E+08	2.30596E+08
1.4918E+01	3.18901E+07	3.07410E+07	6.96334E+07	3.24976E+07
1.7332E+01	4.41248E+07	2.47001E+07	3.87448E+07	2.08132E+07
1.9640E+01	5.71748E+06	2.62327E+06	3.06396E+06	3.10534E+06
Total	3.27617E+14	1.77024E+14	1.80127E+14	9.12867E+13

Key structural components of the reactor will be replaced at reactor mid-life (approximately 24 years). These components include the central column, inner side, top and bottom graphite reflectors. Neutron activation analyses were performed for the representative central column and side reflectors. Appendices B and C provide tables with the predicted post-irradiation composition of each reflector based on the list of impurities and the flux profile given above. The assumed time for radiation exposure for the components is 24 full power years [16].

It should be noted that the quantities of ^{14}C and ^{3}H predicted in the neutron activation calculations do not represent the expected quantities of these isotopes in post-irradiation structural graphite. As previously discussed, the pre-irradiation concentration of ^{14}N in the structural graphite is expected to be significantly higher than the value used for this study, 10 ppm. Therefore, the ^{14}C concentration is underestimated.

Tritium concentration will be affected by the absorption and desorption of tritium produced in the reactor coolant gas. Petr [17] incorporates this phenomenon and conservatively predicts the specific activity of tritium in the side reflector graphite at 24 years of irradiation (i.e. estimated time of replacement) to reach a maximum at approximately 200 MBq/g graphite. The neutron activation study predicts tritium activity of side reflector graphite at 24 years to be on the order of 800 kBq/g (0.020495 Ci/kg). Therefore, the tritium concentration is underestimated in Appendix A and Appendix B.

7. I-GRAPHITE/CARBONACEOUS WASTE RETRIEVAL OPTIONS

7.1 Fuel Matrix Graphite

7.1.1 Handling

During reactor operation, pebbles that have reached target burn-up are discharged to a Sphere Storage System (SSS), which is equipped with 12 storage vessels submerged in a water pool. Spent fuel pebbles are stored for approximately nine years in the water-cooled tanks before being transferred to dry storage vessels. Dry storage is modular and will be built one cell at a time as the need arises. Each cell will contain 6 tanks – eventually there will be four dry cells. At the end of plant life there will be a total of 36 tanks. At nine years after decommissioning, the pools will be converted into dry storage (natural convection). The total capacity of the system is more than 6 million spheres (on the order of 800 m^3 of pebbles and 1 300 m^3 of storage at 0.6 packing fraction), accommodating the life of the plant. This storage system also serves as interim storage facility after plant operational life ([9] and [7]).

The SSS has three primary functions in the PBMR plant. In addition to spent fuel storage capacity and ability to return used fuel to the reactor, the system transfers the contents of storage vessels from one to the other. This function will serve to move spent fuel spheres from water cooled to air-cooled vessels during operation and from air-cooled vessels to transport/disposal casks for treatment or final disposal phase [7].

Broken fuel spheres are collected mainly at the core unloading device and placed in canisters. The canisters are shielded for transport to in-plant storage with other high-level waste. There are no provisions for making these canisters retrievable prior to decommissioning [10].

7.1.2 Properties and Considerations

Spent fuel will be stored safely on the plant site for a 40-year cooling period. After this time, the fuel will generate about 160 W/m^3 of heat energy, compared to generating greater than 2 kW/m^3 when removed from the reactor. Spent fuel activity also will be significantly less after 40 years. The average fuel sphere activity at the time of removal from the core is on the order of 320 Curies per sphere and after 40 years is approximately 4 Ci/sphere. The retrieval of spent fuel for transport to treatment or disposal conditioning will be facilitated by decreased requirements for cooling and shielding. Graphite dust created from sphere handling must be controlled to limit the inhalation dose (mostly ^{14}C) to the workers. Because the final fate of PBMR fuel spheres is undecided, design of the transport cask should accommodate both further processing of the spheres and repository disposal [10].

It is from this interim storage that pebbles would be removed for further processing such as the separation of the TRISO fuel particles from the matrix graphite. If separation is chosen as the management option, matrix graphite will be treated in a manner similar to structural graphite. Without separation, matrix graphite is a component of Spent Nuclear Fuel (SNF), not a separate waste to be treated.

7.2 Core Structural Graphite

7.2.1 Handling

The initial core structure installation and commissioning process is in a 'clean' (non-nuclear) environment, and personnel access is not a significant limitation. The core structure assembly tools then will be modified for use in a radiologically contaminated environment to perform the core structure refit. Lessons learned during the initial installation activities will guide tool modification and facilitate evaluation of the midlife replacement concept. At reactor midlife (~24 years) the most highly irradiated core structural elements will be replaced, or refit. Refit entails dismantling the top end of the reactor (such as removing the Reserve Shutdown System (RSS) assemblies) and removing the centre column. The transport and storage of the core structure used graphite blocks at midlife are accommodated within the site infrastructure. At the time of decommissioning all of the graphite components (those in the core at final shutdown and those removed at midlife) will be transported for treatment or conditioned for final repository disposal. Masses and volumes of these components are provided in Section 6 (Slabber, 2004 [22]).

7.2.2 Properties and Considerations

At the time of reactor shutdown (at mid-life, for example), activities of the reflectors are on the order of 1.3 Curies per kg of central reflector graphite and 0.8 Ci/kg of side reflector graphite. It is estimated that more than 30 mm steel plus 300 mm concrete would be required for initial shielding of the core components. After the 40-year cooling period, less than 30 mm would be required. However, as with the pebble matrix graphite, the presence of ^{14}C requires control of graphite dust generated from handling and processing of graphite. Design of the graphite storage containers will accommodate the fate of the irradiated graphite, which currently is undecided ([19] and [10]).

8. Treatment and Disposal of Irradiated PBMR Graphite

8.1 Waste Classification and Disposal Implications

8.1.1 Matrix Graphite

PBMR is considering two options for spent pebble fuel waste management. The first option is on-site storage, followed later by final disposal of fuel spheres. Spent fuel spheres are stored in on-site fuel tanks for the operating life of the reactor, and an additional appropriate time (presently 40 years) to obtain fission product decay advantage. The low heat generation of this waste makes it possible to store the spent fuel compactly [22].

After the 40-year cool-down, the intact pebbles will be disposed of as HLW, according to the South African national waste classification policy. The policy also states the generic requirements for conditioning of HLW waste, namely a pebble waste package that is suitable for handling, transport and storage on the order of 100 years. In creating the waste package, void space between packed pebbles likely would be filled with a material chosen for its ability to immobilize radionuclides that may leach from the fuel [9].

The second option under consideration for PBMR spent fuel is deconsolidation of spent fuel spheres, reclamation of matrix graphite and storage of coated particles. In this option, the spent fuel will be directed to an on-site facility where matrix and outer pyrolytic graphite of the coated particles are removed from the fuel particles. In addition, the separated graphite may be cleaned, the ^{14}C isotope removed, stored, and made available for other applications. The waste generated in the graphite cleaning process is then solidified as HLW. Cleaned graphite may be amenable to reuse in fresh fuel production operations or for other applications (Slabber, 2006 [6]).

8.1.2 Core Structural Graphite

Two basic options are also under consideration for management of irradiated structural graphite. In both options, the reflector blocks will be stored for a cool-down period of at least 40 years. After this interim storage, the blocks will be disposed as Low-and Intermediate-Level Waste/Long Lived (LILW-LL) or will be treated for removal of ^{14}C and recycled. In the case of direct disposal, a waste package suitable for handling, transport, and 50-year storage will be created and sent to the appropriate disposal facility. As with the fuel spheres, space around and between the reflector components in the disposal container would be filled with a material to stabilize the package and make it more leach resistant. Currently, there is no facility for HLW or LILW-LL waste in South Africa. In the case of recycling, the process would be as described above for matrix graphite.

The South African waste classification policy is summarized in Table 25.

Table 25: DME Policy Summary for HLW and LILW-LL [1]

Waste Class	Waste Description	Waste type / Origin	Waste Criteria	Generic waste treatment / conditioning requirements (1)	Disposal / Management Options
1 HLW	Heat generating radioactive waste with high long and short-lived radionuclide concentrations.	1 Spent fuel declared as waste or spent fuel recycling products 2 Sealed sources	1 Thermal power > 2 kW/m³. OR 2 Long-lived alpha, beta and gamma emitting radionuclides at activity concentration levels > levels specified for LILW-LL 3 OR Long-lived alpha, beta and gamma emitting radionuclides at activity concentration levels that could result in inherent intrusion dose (the intrusion dose assuming the radioactive waste is spread on the surface) above 100 mSv per annum	Waste package suitable for handling, transport and storage (storage period in the order of 100 years). The waste form shall be solid with additional characteristics as prescribed for a specific repository.	1 (a) Regulated deep disposal (100's of metres). (b) Reprocessing, Conditioning and Recycling (c) Long Term Above Ground Storage
2 LILW-LL	Radioactive waste with low or intermediate short-lived radionuclide and intermediate long-lived radionuclide concentrations.	1 Irradiated uranium (isotope production). 2 Un-irradiated uranium (nuclear fuel production). 3 Fission and activation products (nuclear power generation and isotope production) 4 Sealed sources.	1 Thermal power (mainly due to short-lived radio nuclides (T ½ < 31 y) < 2 kW/m³) AND 2 Long-lived radio nuclides (T ½ > 31 y) concentrations. ❖ Alpha: < 4000 Bq/g ❖ Beta and gamma: < 40000 Bq/g (Maximum per waste package up to 10x the concentration levels specified above). OR 3 Long-lived alpha, beta and gamma emitting radionuclides at activity concentration levels that could result in inherent intrusion dose (the intrusion dose assuming the radioactive waste is spread on the surface) between 10 and 100 mSv per annum	Waste package suitable for handling, transport and storage (storage period in the order of 50 years). The waste form shall be solid with additional characteristics as for a specific repository.	1 Regulated medium depth disposal (10's of metres). 2 Managed as NORM-E waste (un-irradiated uranium)

8.2 Graphite treatment

8.2.1 Project Theory

PBMR (Pty) Ltd has established a policy of waste minimization in the design of plant operations. Irradiated graphite is of special interest for waste minimization because the HLW volume of the PBMR per unit electric power generated is estimated to be at least ten times larger than competitor light water reactor HLW. The principle reason for this difference is graphite [22].

The objective of PBMR's waste minimization project is to establish efficient and practical methods to clean irradiated graphite of ^{14}C. Both chemical and biological methods will be considered. In the first phase of waste minimization research, microbial treatment of waste graphite is being pursued. The research currently is at the lab scale, or proof-of-concept phase. Experiments are underway to systematically identify microbial species adaptable to the chemical and radiation environment of the system. Process design requirements include biological processing such that the ^{14}C is incorporated into the bacterial cell structure, as opposed to the production of a water-soluble metabolite or gaseous by-product, such as CO_2. This cellular isolation of the ^{14}C will facilitate removal of the radionuclide from the graphite treatment system. A list of radiation-resistant bacteria used in earlier experimentation has been identified, and these are being tested for viability in the chemically inert graphite system.

A particular challenge for the project is choice of a chemical surrogate for the ^{14}C in graphite. It is expected that a large majority of ^{14}C in the PBMR irradiated graphite, both matrix and structural material, will arise from neutron activation of ^{14}N in surface pores. ^{14}C produced in other parts of the graphite are relatively inaccessible for treatment purposes. These reactions include neutron activation of impurities ^{17}O in water, ^{13}C in the graphite matrix, and ^{14}N in

closed pores. As such, emphasis is placed on the graphite pore ^{14}C and its particular chemical form. Bonding of the ^{14}C with some combination of N, O and H is expected [23][20]. X-ray Photon Spectroscopy (XPS) characterization of irradiated graphite samples is underway to learn more of the pore/surface elemental composition and bonding.

8.2.2 Project Organization [24]

The experimental work described above is the initial phase of a far-reaching project plan. The project currently is focusing on proof of concept activities (Phase 1) with further activities to follow (Phases 2 and 3).

Phase 1 has two sub-phases: 1.1 and 1.2, the objectives of which are:

- Phase 1.1: Prove the concept of using micro-organisms to remove ^{14}C from irradiated graphite waste using low-activity, or non-active, commercially available materials.
- Phase 1.2: Prove the concept of using micro-organisms to remove ^{14}C from irradiated graphite waste using irradiated graphite waste sourced from European reactors.

At the end of Phase 1.1, a decision will be made as to whether Phase 1.2 will proceed. This decision is dependent on the successful outcome of Phase 1.1.

On viable (successful and economically feasible) outcome of the Proof of Concept (Phase 1), Phase 2 will be executed:

- Establishment of a local South African bio-farm for the production of micro-organisms.
- Deconsolidation technique studies on graphite structures and PBMR fuel.
- Construction and operation of a waste minimization demonstration (pilot) plant.

Phase 3 of the project will be full-scale commercialization of the graphite waste minimization technology for application to PBMR graphite and other appropriate materials.

9. APPENDICES

9.1 Appendix A

Table 26: Average Composition and Radioactivity Properties Predicted for Post-Irradiation (24 Full Power Years) PBMR Central Column Reflector (Quantities for 1 kg graphite; cut-off activity 10-1 Ci) [19]

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
H 3	0.020603	2.14E-06	6.97E-10	0.00E+00	0.00E+00	0.00E+00	3.20E-02	1.98E-01
He 6	6.57E-05	2.83E-17	6.08E-10	0.00E+00	2.20E-12	2.52E-06	8.02E-08	1.12E-07
Li 8	0.001427	8.50E-16	5.25E-08	2.64E-08	2.79E-10	4.85E-04	5.28E-06	3.27E-06
Li 9	1.91E-09	2.73E-22	6.46E-14	0.00E+00	3.39E-16	5.76E-10	1.49E-13	9.20E-14
Be 10	2.05E-08	9.19E-07	3.07E-14	0.00E+00	0.00E+00	0.00E+00	8.35E-07	2.66E-05
Be 11	1.18E-07	1.60E-18	3.26E-12	2.54E-14	9.94E-13	2.14E-06	1.31E-09	1.14E-09
B 12	0.000749	1.61E-17	2.80E-08	2.95E-11	4.02E-10	5.65E-04	1.05E-07	5.27E-08
B 13	4.39E-05	8.77E-19	1.63E-09	3.38E-12	8.15E-11	1.56E-04	5.52E-09	2.76E-09
C 14*	0.008851	1.99E-03	2.60E-09	0.00E+00	0.00E+00	0.00E+00	1.90E-01	1.90E+00
C 15	2.55E-07	8.32E-19	4.32E-12	0.00E+00	5.48E-12	1.28E-05	2.08E-09	1.61E-09
N 13	9.81E-09	6.76E-18	2.85E-14	0.00E+00	5.94E-14	7.24E-08	4.72E-09	3.45E-09
N 16	1.68E-07	1.70E-18	2.67E-12	2.96E-17	4.61E-12	1.08E-05	4.55E-09	3.43E-09
F 20	4.07E-06	7.96E-17	5.96E-11	0.00E+00	3.97E-11	7.08E-05	4.07E-08	4.97E-08
Ne 23	1.56E-05	1.18E-15	1.74E-10	0.00E+00	1.59E-11	1.98E-05	1.15E-06	1.61E-06
Na 24	0.270081	3.09E-08	8.86E-07	0.00E+00	6.60E-06	1.28E+01	4.30E+00	2.70E+00
Na 24m	0.192054	8.25E-15	1.57E-08	0.00E+00	5.35E-07	6.53E-01	1.28E-06	7.82E-07
Na 25	2.91E-07	3.84E-17	2.58E-12	0.00E+00	7.52E-13	1.13E-06	2.15E-09	1.29E-09
Na 26	9.95E-10	2.48E-21	1.96E-14	0.00E+00	1.29E-14	2.43E-08	4.05E-13	2.36E-13
Mg 27	0.000293	3.98E-13	1.22E-09	0.00E+00	1.56E-09	2.43E-03	1.95E-04	9.99E-05
Al 26m	3.38E-10	4.93E-21	2.87E-15	0.00E+00	2.05E-15	2.49E-09	4.37E-12	3.12E-12
Al 28	0.051405	1.71E-11	3.77E-07	0.00E+00	5.43E-07	1.03E+00	1.75E-02	1.26E-02
Al 29	8.21E-07	8.30E-16	4.74E-12	0.00E+00	6.72E-12	1.18E-05	6.38E-07	4.56E-07
Al 30	2.62E-09	2.54E-20	3.56E-14	0.00E+00	5.46E-14	1.09E-07	4.66E-11	3.30E-11
Si 31	0.001148	2.97E-11	4.04E-09	0.00E+00	1.48E-11	1.04E-05	6.80E-03	3.36E-03
Si 32	2.07E-09	6.12E-11	7.95E-16	0.00E+00	0.00E+00	0.00E+00	4.30E-08	8.44E-06
P 30	3.2E-10	1.28E-19	2.73E-15	0.00E+00	1.94E-15	2.37E-09	9.01E-11	2.25E-10
P 32	0.00343	1.20E-08	1.41E-08	0.00E+00	3.48E-11	3.55E-05	3.05E-01	4.31E-01
P 33	0.0067	4.30E-08	3.04E-09	0.00E+00	0.00E+00	0.00E+00	5.95E-02	3.72E-01
P 34	4.86E-07	1.81E-17	6.58E-12	0.00E+00	1.00E-12	1.93E-06	1.20E-08	3.06E-08

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
S 35	0.006786	1.59E-07	1.97E-09	0.00E+00	0.00E+00	0.00E+00	1.93E-01	4.77E-01
S 37	3.11E-05	3.05E-14	1.46E-10	0.00E+00	5.41E-10	1.16E-03	1.72E-05	1.49E-05
Cl 34	1.28E-10	5.89E-22	1.55E-15	0.00E+00	7.82E-16	9.46E-10	3.98E-13	1.47E-13
Cl 36	6.61E-05	2.04E-03	9.65E-11	0.00E+00	1.07E-14	1.86E-08	2.28E-03	1.79E-02
Cl 38	0.030595	2.30E-10	2.76E-07	0.00E+00	2.71E-07	5.15E-01	1.36E-01	5.09E-02
Cl 38m	0.003641	8.76E-15	9.27E-12	0.00E+00	1.45E-08	2.02E-02	6.33E-06	2.43E-06
Ar 37	0.091405	9.07E-07	1.28E-09	0.00E+00	1.75E-10	8.98E-04	9.47E-02	1.01E+00
Ar 39	8.94E-07	2.62E-08	1.16E-12	0.00E+00	0.00E+00	0.00E+00	7.94E-05	7.94E-03
Ar 41	0.000146	3.50E-12	4.03E-10	0.00E+00	1.12E-09	1.92E-03	1.63E-03	2.28E-03
K 38	3.89E-10	5.98E-19	2.77E-15	0.00E+00	7.36E-15	1.27E-08	4.75E-10	1.14E-10
K 40	2.89E-10	4.14E-05	8.95E-16	0.00E+00	2.70E-16	4.82E-10	6.64E-08	2.25E-08
K 42	0.004559	7.55E-10	3.83E-08	0.00E+00	8.01E-09	1.41E-02	7.26E-02	2.03E-02
K 43	6.1E-08	1.86E-14	1.12E-13	0.00E+00	3.49E-13	4.34E-07	5.64E-07	3.16E-07
K 44	8.13E-09	4.21E-17	6.92E-14	0.00E+00	1.15E-13	2.12E-07	2.53E-08	6.01E-09
Ca 39	5.7E-10	1.69E-21	8.65E-15	0.00E+00	3.45E-15	4.21E-09	3.37E-12	7.59E-12
Ca 41	2.25E-05	2.65E-04	3.78E-13	0.00E+00	5.82E-14	4.04E-07	1.58E-04	1.50E-04
Ca 45	0.007043	3.95E-07	3.22E-09	0.00E+00	4.87E-16	3.57E-09	1.85E-01	9.64E-01
Ca 47	1.79E-05	2.92E-11	3.65E-11	0.00E+00	1.12E-10	1.91E-04	1.06E-03	1.39E-03
Ca 49	0.000772	1.75E-12	3.98E-09	0.00E+00	1.45E-08	3.12E-02	3.72E-03	8.29E-03
Sc 44	3.92E-10	2.16E-17	1.39E-15	0.00E+00	4.97E-15	7.18E-09	5.08E-09	2.61E-09
Sc 44m	1.44E-10	1.18E-16	2.80E-17	0.00E+00	2.35E-16	2.30E-10	1.28E-08	7.46E-09
Sc 45m	1.17E-05	1.48E-17	5.97E-13	0.00E+00	4.23E-14	3.04E-07	3.64E-11	1.78E-11
Sc 46	0.021543	6.35E-07	1.43E-08	0.00E+00	2.57E-07	4.07E-01	1.20E+00	5.42E+00
Sc 46m	0.009497	7.24E-13	3.32E-09	0.00E+00	4.67E-09	3.21E-03	2.85E-05	1.93E-05
Sc 47	0.000154	1.86E-10	1.49E-10	0.00E+00	9.92E-11	6.58E-05	3.08E-03	4.17E-03
Sc 48	1.93E-07	1.29E-13	2.51E-13	0.00E+00	3.83E-12	6.26E-06	1.21E-05	7.86E-06
Sc 49	0.000772	1.15E-11	3.76E-09	0.00E+00	1.53E-11	8.99E-06	2.34E-03	1.14E-03
Sc 50	5.21E-10	2.36E-19	5.02E-15	0.00E+00	9.87E-15	1.63E-08	2.70E-10	1.35E-10
Ti 45	5.33E-10	2.35E-17	1.18E-15	0.00E+00	2.75E-15	3.36E-09	2.96E-09	1.83E-09
Ti 51	0.00116	1.82E-12	5.98E-09	0.00E+00	2.51E-09	2.77E-03	6.44E-04	4.72E-04
V 52	0.154459	1.60E-10	9.75E-07	0.00E+00	1.33E-06	2.28E+00	8.00E-02	5.26E-02
V 53	4.36E-09	1.99E-18	2.60E-14	0.00E+00	2.70E-14	4.40E-08	7.91E-10	5.81E-10
Cr 51	0.002172	2.35E-08	4.96E-11	0.00E+00	4.22E-10	5.25E-04	3.05E-03	2.97E-03
Cr 55	0.000302	3.12E-13	1.96E-09	0.00E+00	7.59E-12	2.18E-06	1.56E-05	6.81E-06
Cr 56	1.49E-05	2.63E-14	5.36E-11	0.00E+00	8.20E-12	7.23E-06	3.81E-06	1.66E-06

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Mn 54	2.01E-05	2.59E-09	5.02E-13	0.00E+00	9.96E-11	1.54E-04	5.28E-04	1.12E-03
Mn 56	0.028703	1.32E-09	1.40E-07	0.00E+00	2.89E-07	5.01E-01	2.65E-01	1.27E-01
Mn 57	6.25E-07	3.05E-16	4.07E-12	0.00E+00	2.79E-13	3.74E-07	2.78E-08	1.34E-08
Mn 58	4.86E-10	1.63E-19	4.94E-15	0.00E+00	6.87E-15	1.14E-08	5.04E-11	2.52E-11
Mn 58m	1.14E-10	1.58E-21	1.91E-15	0.00E+00	8.12E-17	1.38E-10	3.59E-13	1.73E-13
Fe 53	1.79E-10	4.29E-19	1.17E-15	0.00E+00	1.26E-15	1.52E-09	6.09E-11	5.96E-11
Fe 55	0.028324	1.19E-05	7.09E-10	0.00E+00	2.81E-10	2.06E-03	3.46E-01	8.07E-01
Fe 59	0.0047	9.44E-08	3.29E-09	0.00E+00	3.31E-08	5.52E-02	3.13E-01	6.96E-01
Fe 60	1.42E-10	3.57E-08	7.38E-17	0.00E+00	0.00E+00	0.00E+00	5.78E-07	1.47E-06
Fe 61	5.29E-07	1.03E-15	3.31E-12	0.00E+00	4.37E-12	7.14E-06	1.65E-07	1.61E-07
Co 57	1.77E-08	2.10E-12	2.10E-15	0.00E+00	1.30E-14	1.21E-08	1.38E-07	6.56E-07
Co 58	5.49E-06	1.73E-10	1.12E-12	0.00E+00	3.18E-11	4.75E-05	1.50E-04	4.26E-04
Co 58m	5.32E-06	8.79E-13	7.30E-13	0.00E+00	5.75E-14	4.23E-07	4.72E-06	3.35E-06
Co 60	0.01703	1.51E-05	9.76E-09	0.00E+00	2.53E-07	4.24E-01	2.14E+00	1.95E+01
Co 60m	0.006284	2.10E-11	2.10E-09	0.00E+00	2.53E-10	8.48E-04	3.95E-04	3.26E-04
Co 61	0.000627	2.01E-11	1.72E-09	0.00E+00	3.37E-10	3.25E-04	1.72E-03	1.18E-03
Co 62	1.71E-10	8.45E-20	1.64E-15	0.00E+00	1.62E-15	2.82E-09	4.11E-11	3.04E-11
Co 62m	1.29E-10	5.93E-19	7.75E-16	0.00E+00	2.07E-15	3.55E-09	2.25E-10	1.01E-10
Co 63	2.46E-10	3.76E-20	2.32E-15	0.00E+00	1.74E-16	2.25E-10	1.00E-11	7.10E-12
Ni 57	3.57E-10	2.32E-16	3.43E-16	0.00E+00	4.15E-15	6.76E-09	1.15E-08	7.00E-09
Ni 59	1.73E-06	2.17E-05	4.75E-14	0.00E+00	2.62E-14	1.80E-07	4.04E-06	2.82E-05
Ni 63	0.000645	1.13E-05	6.56E-11	0.00E+00	0.00E+00	0.00E+00	3.58E-03	3.11E-02
Ni 65	0.000713	3.72E-11	2.66E-09	0.00E+00	2.33E-09	3.99E-03	4.75E-03	2.38E-03
Ni 68	1.82E-10	2.08E-20	7.38E-16	0.00E+00	7.38E-16	7.55E-10	8.07E-12	4.17E-12
Ni 69	3.91E-10	2.72E-20	2.64E-15	0.00E+00	6.47E-15	1.11E-08	1.45E-11	7.67E-12
Cu 62	6.07E-10	1.95E-18	4.62E-15	0.00E+00	3.64E-15	4.44E-09	1.37E-09	8.54E-10
Cu 64	0.002687	6.96E-10	2.00E-09	0.00E+00	3.04E-09	3.87E-03	1.19E-02	1.19E-02
Cu 66	0.000856	1.53E-12	5.43E-09	0.00E+00	4.16E-10	6.47E-04	5.07E-04	3.14E-04
Cu 67	2.66E-07	3.51E-13	2.45E-13	0.00E+00	1.82E-13	1.28E-07	3.34E-06	6.00E-06
Cu 68	6.29E-10	1.18E-19	5.48E-15	0.00E+00	3.80E-15	6.36E-09	8.15E-11	5.12E-11
Cu 68m	1.57E-10	2.12E-19	1.89E-16	0.00E+00	1.02E-15	1.47E-09	2.03E-10	1.22E-10
Cu 69	5.24E-10	5.76E-19	3.21E-15	0.00E+00	6.90E-16	1.08E-09	2.33E-10	1.55E-10
Cu 70	3E-10	8.37E-21	4.98E-15	0.00E+00	9.25E-16	1.44E-09	7.55E-12	4.66E-12
Cu 70m	9.36E-10	2.73E-19	9.66E-15	0.00E+00	1.57E-14	2.55E-08	3.36E-10	2.08E-10
Cu 71	2.9E-09	3.55E-19	2.51E-14	0.00E+00	2.14E-14	3.07E-08	3.86E-10	2.36E-10

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Cu 72	4.95E-09	2.09E-19	8.72E-14	0.00E+00	5.71E-14	9.63E-08	2.75E-10	1.78E-10
Cu 73	8.37E-09	2.11E-19	9.85E-14	0.00E+00	3.62E-14	3.78E-08	2.79E-10	1.73E-10
Cu 74	7.73E-09	8.11E-20	8.81E-14	0.00E+00	2.25E-13	2.74E-07	2.49E-10	1.54E-10
Cu 75	7.21E-09	6.23E-20	9.51E-14	0.00E+00	8.92E-14	1.14E-07	1.57E-10	9.60E-11
Zn 63	5.18E-10	6.65E-18	2.81E-15	0.00E+00	3.39E-15	4.28E-09	1.51E-09	7.09E-10
Zn 65	0.001497	1.82E-07	6.20E-11	0.00E+00	5.17E-09	8.52E-03	2.16E-01	1.22E-01
Zn 69	0.001126	2.35E-11	2.14E-09	0.00E+00	4.07E-14	4.86E-08	1.29E-03	1.17E-03
Zn 69m	9.3E-05	2.81E-11	1.22E-11	0.00E+00	2.30E-10	2.81E-04	1.14E-03	9.29E-04
Zn 71	2.93E-06	2.71E-15	1.82E-11	0.00E+00	5.48E-12	7.37E-06	8.03E-07	5.53E-07
Zn 71m	2.87E-07	2.56E-14	9.14E-13	0.00E+00	2.68E-12	3.39E-06	2.55E-06	1.70E-06
Zn 72	1E-08	1.07E-14	6.10E-15	0.00E+00	9.06E-15	8.30E-09	5.19E-07	4.82E-07
Zn 73	2.1E-08	3.19E-18	2.30E-13	0.00E+00	1.48E-14	2.44E-08	1.55E-09	1.09E-09
Zn 73m	8.41E-09	3.15E-19	3.73E-14	0.00E+00	4.22E-14	4.28E-08	1.99E-10	1.37E-10
Zn 74	5.85E-08	3.66E-17	2.77E-13	0.00E+00	1.04E-13	1.19E-07	3.89E-08	2.60E-08
Zn 75	1.02E-07	6.91E-18	1.19E-12	0.00E+00	1.10E-12	1.86E-06	7.92E-09	5.66E-09
Zn 76	1.58E-07	6.05E-18	1.24E-12	0.00E+00	1.24E-12	1.36E-06	9.34E-09	6.42E-09
Ga 67	3.14E-15	5.24E-21	5.57E-22	0.00E+00	2.88E-21	3.02E-15	2.20E-14	2.78E-14
Ga 68	1.3E-09	3.17E-17	5.68E-15	0.00E+00	7.28E-15	9.02E-09	4.79E-09	2.35E-09
Ga 70	0.001053	8.28E-12	4.02E-09	0.00E+00	4.56E-11	7.15E-05	1.21E-03	6.23E-04
Ga 72	0.00143	4.63E-10	4.26E-09	0.00E+00	2.29E-08	4.02E-02	5.82E-02	2.80E-02
Ga 73	1.33E-07	1.51E-14	3.84E-13	0.00E+00	1.59E-13	1.57E-07	1.28E-06	6.90E-07
Ga 74	6.88E-08	2.20E-16	4.08E-13	0.00E+00	1.23E-12	2.17E-06	1.86E-07	9.68E-08
Ga 74m	1.57E-09	9.78E-20	1.57E-16	0.00E+00	4.00E-16	3.21E-10	8.72E-11	4.36E-11
Ga 75	1.65E-07	1.42E-16	1.35E-12	0.00E+00	6.55E-14	7.91E-08	5.67E-08	2.93E-08
Ga 76	3.47E-07	6.33E-17	4.27E-12	0.00E+00	5.76E-12	1.04E-05	6.43E-08	3.34E-08
Ga 77	5.79E-07	5.14E-17	7.25E-12	0.00E+00	1.57E-12	2.22E-06	4.07E-08	2.06E-08
Ga 78	5.27E-07	2.00E-17	7.62E-12	0.00E+00	7.78E-12	1.34E-05	2.34E-08	1.27E-08
Ga 79	5.51E-07	1.16E-17	7.29E-12	9.15E-13	6.01E-12	1.24E-05	2.86E-08	1.49E-08
Ge 71	0.000265	1.65E-09	7.53E-12	0.00E+00	6.60E-12	4.74E-05	1.18E-04	1.08E-04
Ge 73m	6.58E-05	2.13E-16	2.18E-11	0.00E+00	4.30E-12	1.74E-05	1.66E-09	1.29E-09
Ge 75	4.39E-05	1.45E-12	1.10E-10	0.00E+00	9.10E-12	8.01E-06	7.48E-05	5.85E-05
Ge 75m	1.46E-05	4.62E-15	7.14E-12	0.00E+00	4.92E-12	4.79E-06	3.13E-07	2.43E-07
Ge 77	1.51E-06	4.18E-13	5.74E-12	0.00E+00	9.62E-12	1.26E-05	1.84E-05	2.06E-05
Ge 77m	1.92E-06	6.94E-16	1.16E-11	0.00E+00	7.53E-13	6.45E-07	9.97E-08	7.83E-08
Ge 78	1.51E-06	5.43E-14	2.12E-12	0.00E+00	2.48E-12	2.15E-06	6.69E-06	5.30E-06

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Ge 79	8.89E-07	1.19E-16	8.59E-12	0.00E+00	1.62E-12	2.64E-06	3.62E-08	2.79E-08
Ge 79m	1.93E-06	5.26E-16	1.52E-11	0.00E+00	2.04E-11	2.94E-05	2.28E-07	1.78E-07
Ge 80	4.65E-06	9.72E-16	2.76E-11	0.00E+00	1.19E-11	2.39E-05	4.48E-07	3.61E-07
Ge 81	3.47E-06	1.89E-16	3.25E-11	0.00E+00	5.45E-11	8.36E-05	1.28E-07	1.01E-07
Ge 81m	7.72E-07	4.15E-17	1.00E-11	0.00E+00	9.08E-12	1.69E-05	2.83E-08	2.20E-08
As 76	2.27E-05	1.45E-11	1.43E-10	0.00E+00	5.83E-11	8.03E-05	1.35E-03	6.22E-04
As 77	3.08E-06	2.94E-12	4.13E-12	0.00E+00	1.45E-13	1.49E-07	4.56E-05	4.44E-05
As 78	1.57E-06	5.90E-14	1.19E-11	0.00E+00	1.25E-11	2.03E-05	1.22E-05	5.17E-06
As 79	3.19E-06	1.21E-14	1.57E-11	0.00E+00	4.16E-13	4.83E-07	1.09E-06	1.77E-06
As 80	6.28E-06	7.35E-16	8.08E-11	0.00E+00	3.02E-11	3.31E-05	2.28E-07	3.72E-07
As 81	9.22E-06	2.18E-15	8.52E-11	0.00E+00	7.98E-12	1.11E-05	5.12E-07	8.87E-07
As 82	4.71E-06	6.84E-16	8.81E-11	0.00E+00	9.58E-12	1.60E-05	2.44E-07	4.01E-07
As 82m	5.51E-06	5.45E-16	6.66E-11	0.00E+00	9.71E-11	1.60E-04	2.86E-07	4.69E-07
As 83	1.04E-05	1.02E-15	8.45E-11	0.00E+00	1.25E-10	2.21E-04	5.39E-07	9.62E-07
As 84	6.07E-06	2.48E-16	7.19E-11	0.00E+00	1.92E-10	1.06E-04	2.25E-07	4.04E-07
Se 75	4.89E-06	3.36E-10	4.25E-13	0.00E+00	1.13E-11	1.05E-05	4.71E-04	2.35E-04
Se 77m	1.37E-05	1.63E-15	5.76E-12	0.00E+00	7.14E-12	5.86E-06	5.59E-08	3.10E-08
Se 79	6.96E-10	1.72E-07	2.17E-16	0.00E+00	0.00E+00	0.00E+00	7.47E-08	1.75E-07
Se 79m	5.94E-05	9.72E-14	2.88E-11	0.00E+00	4.91E-12	1.19E-05	1.10E-09	6.15E-10
Se 81	0.000135	1.07E-12	4.86E-10	0.00E+00	6.82E-12	6.53E-06	1.34E-04	7.47E-05
Se 81m	2.01E-05	4.95E-13	1.02E-11	0.00E+00	2.15E-12	4.30E-06	3.94E-05	3.79E-05
Se 83	1.47E-05	1.45E-13	5.22E-11	0.00E+00	2.10E-10	3.53E-04	2.55E-05	1.85E-05
Se 83m	1.14E-05	5.86E-15	9.03E-11	0.00E+00	6.43E-11	1.06E-04	2.86E-06	1.81E-06
Se 84	3.57E-05	4.94E-14	1.13E-10	0.00E+00	8.88E-11	1.08E-04	2.11E-05	1.45E-05
Se 85	3.64E-05	8.68E-15	3.49E-10	0.00E+00	5.13E-10	9.09E-04	9.29E-06	5.25E-06
Br 80	1.79E-08	1.34E-16	7.70E-14	0.00E+00	8.19E-15	1.09E-08	2.06E-08	6.24E-09
Br 80m	4.41E-09	4.96E-16	1.62E-15	0.00E+00	6.35E-16	2.21E-09	1.80E-08	1.24E-08
Br 82	2.67E-05	2.46E-11	2.26E-11	0.00E+00	4.17E-10	6.20E-04	5.33E-04	6.22E-04
Br 82m	2.47E-05	6.56E-14	1.03E-11	0.00E+00	1.20E-12	5.16E-06	2.38E-06	1.92E-06
Br 83	2.72E-05	1.72E-12	5.17E-11	0.00E+00	1.21E-12	1.48E-06	4.33E-05	4.84E-05
Br 84	3.81E-05	5.41E-13	2.49E-10	0.00E+00	3.98E-10	7.52E-04	1.24E-04	5.22E-05
Br 84m	2.47E-06	6.63E-15	1.34E-11	0.00E+00	4.06E-11	6.59E-05	4.49E-06	1.37E-06
Br 85	5.45E-05	7.06E-14	3.40E-10	0.00E+00	2.13E-11	3.39E-05	1.94E-05	5.85E-06
Br 86	6.1E-05	2.56E-14	6.95E-10	0.00E+00	1.24E-09	2.26E-03	2.48E-05	7.45E-06
Br 87	0.000065	2.79E-14	7.25E-10	8.48E-11	1.29E-09	2.60E-03	1.18E-06	3.61E-07

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Br 88	4.59E-05	5.91E-15	4.58E-10	5.99E-11	1.17E-09	1.76E-03	1.56E-05	4.76E-06
Kr 81m	2.09E-09	1.98E-19	7.27E-16	0.00E+00	1.63E-15	1.22E-09	5.09E-12	7.10E-12
Kr 83m	3.56E-05	1.73E-12	8.31E-12	0.00E+00	5.15E-13	3.20E-06	9.50E-06	1.32E-05
Kr 85	1.12E-05	2.86E-08	1.67E-11	0.00E+00	1.49E-13	1.82E-07	1.16E-03	1.08E-01
Kr 85m	5.54E-05	6.72E-12	8.38E-11	0.00E+00	5.16E-11	4.07E-05	3.48E-04	5.12E-04
Kr 87	9.82E-05	3.46E-12	7.86E-10	0.00E+00	4.61E-10	8.02E-04	9.45E-04	1.31E-03
Kr 88	0.000126	1.00E-11	2.72E-10	0.00E+00	1.46E-09	2.71E-03	6.06E-03	8.86E-03
Kr 89	0.000138	2.07E-13	6.29E-10	0.00E+00	2.56E-09	2.55E-03	1.43E-04	2.35E-04
Kr 90	0.000125	3.21E-14	9.56E-10	0.00E+00	9.13E-10	1.52E-03	2.63E-05	3.64E-05
Rb 84	1.54E-08	3.31E-13	1.31E-14	0.00E+00	8.08E-14	1.19E-07	1.59E-06	5.68E-07
Rb 84m	5.87E-09	5.35E-17	2.79E-15	0.00E+00	1.33E-14	1.40E-08	4.13E-09	7.82E-10
Rb 86	0.002949	3.61E-08	1.16E-08	0.00E+00	1.69E-09	2.71E-03	3.06E-01	1.02E-01
Rb 86m	0.000355	1.65E-13	2.10E-11	0.00E+00	1.15E-09	1.41E-03	1.58E-05	2.89E-06
Rb 88	0.000448	3.73E-12	5.48E-09	0.00E+00	1.69E-09	3.08E-03	1.49E-03	2.65E-04
Rb 89	0.000162	1.18E-12	8.90E-10	0.00E+00	2.14E-09	3.79E-03	2.81E-04	8.37E-05
Rb 90	0.000121	1.47E-13	1.34E-09	0.00E+00	1.56E-09	3.22E-03	8.49E-05	1.56E-05
Rb 90m	5.38E-05	1.11E-13	4.07E-10	0.00E+00	1.18E-09	1.92E-03	8.16E-05	1.47E-05
Rb 91	0.00016	7.51E-14	1.48E-09	0.00E+00	2.21E-09	4.47E-03	7.68E-05	1.36E-05
Rb 92	0.000119	4.38E-15	2.47E-09	1.34E-10	2.78E-10	3.18E-03	9.27E-06	1.54E-06
Rb 93	8.48E-05	3.98E-15	1.32E-09	2.01E-10	9.65E-10	1.34E-03	9.41E-06	1.57E-06
Rb 94	3.52E-05	7.91E-16	5.90E-10	8.55E-11	8.59E-10	1.34E-03	2.21E-06	3.51E-07
Sr 85	1.38E-05	5.84E-10	7.52E-13	0.00E+00	4.25E-11	5.50E-05	2.87E-04	4.15E-04
Sr 85m	1.17E-05	3.57E-13	9.19E-13	0.00E+00	1.50E-11	1.32E-05	2.64E-06	1.86E-06
Sr 87m	0.000391	3.04E-11	1.56E-10	0.00E+00	7.42E-10	7.83E-04	4.34E-04	3.04E-04
Sr 89	0.00018	6.20E-09	6.22E-10	0.00E+00	1.38E-12	1.45E-06	1.73E-02	5.26E-02
Sr 90	8.77E-05	6.37E-07	1.02E-10	0.00E+00	0.00E+00	0.00E+00	9.09E-02	5.19E-01
Sr 91	0.000181	5.00E-11	6.89E-10	0.00E+00	7.56E-10	1.16E-03	4.35E-03	2.75E-03
Sr 92	0.000189	1.50E-11	2.01E-10	0.00E+00	1.55E-09	2.64E-03	3.01E-03	1.61E-03
Sr 93	0.000203	7.36E-13	1.15E-09	0.00E+00	2.12E-09	3.77E-03	8.28E-05	4.14E-05
Sr 94	0.000192	1.20E-13	9.47E-10	0.00E+00	1.62E-09	2.77E-03	1.56E-05	5.96E-06
Sr 95	0.000146	3.08E-14	1.81E-09	0.00E+00	1.16E-09	2.21E-03	5.08E-06	2.11E-06
Sr 96	9.39E-05	8.47E-16	1.26E-09	0.00E+00	4.96E-10	7.36E-04	1.43E-07	9.04E-08
Y 88	1.08E-09	7.78E-14	4.35E-17	0.00E+00	1.73E-14	3.11E-08	5.22E-08	1.77E-07
Y 89m	3.52E-06	4.45E-16	1.61E-13	0.00E+00	1.88E-11	2.88E-05	4.94E-08	6.89E-08
Y 90	0.000918	1.69E-09	5.07E-09	0.00E+00	1.67E-11	2.09E-06	9.18E-02	5.10E-02

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Y 90m	6.77E-07	6.20E-14	1.95E-13	0.00E+00	2.54E-12	2.85E-06	4.26E-06	2.51E-06
Y 91	0.000182	7.42E-09	6.48E-10	0.00E+00	5.38E-12	6.33E-06	1.61E-02	5.98E-02
Y 91m	9.07E-05	2.18E-12	1.51E-11	0.00E+00	2.84E-10	3.47E-04	3.69E-05	3.69E-05
Y 92	0.00019	1.98E-11	1.63E-09	0.00E+00	2.85E-10	4.46E-04	3.45E-03	1.27E-03
Y 93	0.000213	6.37E-11	1.48E-09	0.00E+00	1.17E-10	1.76E-04	9.45E-03	3.31E-03
Y 93m	0.00008	5.40E-16	3.80E-11	0.00E+00	3.22E-10	3.80E-04	1.27E-07	9.47E-08
Y 94	0.000218	2.08E-12	2.32E-09	0.00E+00	1.16E-09	1.57E-03	6.54E-04	2.26E-04
Y 95	0.000217	1.13E-12	1.72E-09	0.00E+00	1.36E-09	3.19E-03	3.69E-04	1.29E-04
Y 96	0.000103	4.72E-15	1.95E-09	0.00E+00	5.86E-11	9.91E-05	1.76E-06	2.45E-06
Y 96m	8.36E-05	6.84E-15	9.18E-10	0.00E+00	2.22E-09	3.71E-03	4.95E-06	6.81E-06
Y 97	5.77E-05	1.84E-15	7.46E-10	0.00E+00	5.65E-10	1.27E-03	4.70E-10	6.41E-10
Y 97m	9.26E-05	9.63E-16	1.27E-09	0.00E+00	9.66E-10	2.83E-03	5.14E-07	7.20E-07
Y 98	2.76E-05	1.56E-16	4.15E-10	1.06E-10	5.86E-10	2.72E-04	3.88E-07	5.30E-07
Y 98m	6.63E-05	1.15E-15	8.55E-10	0.00E+00	1.35E-09	2.01E-03	1.08E-06	1.52E-06
Zr 89	2.06E-10	4.58E-16	1.13E-16	0.00E+00	3.10E-16	4.34E-10	6.01E-09	4.19E-09
Zr 90m	1.03E-07	6.82E-19	0.00E+00	0.00E+00	1.42E-12	2.80E-06	3.43E-10	1.64E-10
Zr 93	2.44E-09	9.71E-07	2.77E-16	0.00E+00	0.00E+00	0.00E+00	9.94E-08	2.26E-06
Zr 95	0.000224	1.04E-08	1.57E-10	0.00E+00	9.69E-10	1.35E-03	7.87E-03	4.89E-02
Zr 97	0.000214	1.12E-10	9.24E-10	0.00E+00	2.45E-10	3.74E-04	1.66E-02	7.27E-03
Zr 98	0.000211	5.62E-14	1.14E-09	0.00E+00	0.00E+00	0.00E+00	3.28E-05	1.56E-05
Zr 99	0.000193	3.72E-15	1.76E-09	0.00E+00	9.62E-10	1.17E-03	3.21E-06	1.57E-06
Nb 91m	1.69E-10	7.18E-15	9.38E-17	0.00E+00	3.82E-17	9.86E-11	3.95E-09	1.44E-08
Nb 92m	5.74E-08	4.10E-13	2.20E-15	0.00E+00	3.30E-13	5.23E-07	1.28E-06	1.25E-06
Nb 93m	2.15E-05	9.01E-08	3.69E-12	0.00E+00	2.49E-13	1.49E-06	9.55E-05	1.43E-03
Nb 94	4.61E-06	2.42E-05	4.60E-12	0.00E+00	4.30E-11	6.31E-05	2.90E-04	8.36E-03
Nb 94m	0.005665	1.77E-11	1.18E-09	0.00E+00	4.12E-10	1.80E-03	5.24E-05	3.35E-05
Nb 95	0.005205	1.32E-07	1.38E-09	0.00E+00	2.36E-08	3.28E-02	1.12E-01	3.47E-01
Nb 95m	0.000197	5.17E-10	2.03E-10	0.00E+00	8.37E-11	1.15E-04	4.08E-03	6.41E-03
Nb 96	2.13E-05	1.52E-11	3.17E-11	0.00E+00	3.06E-10	4.44E-04	8.67E-04	5.20E-04
Nb 97	0.000215	7.99E-12	5.94E-10	0.00E+00	8.51E-10	1.19E-03	5.41E-04	3.58E-04
Nb 97m	0.000203	1.04E-13	1.80E-11	0.00E+00	8.74E-10	1.22E-03	1.20E-05	7.49E-06
Nb 98	0.000213	5.17E-15	2.46E-09	0.00E+00	1.06E-10	2.21E-04	6.22E-07	4.09E-07
Nb 98m	4.82E-06	1.29E-13	2.26E-11	0.00E+00	7.74E-11	1.20E-04	1.96E-05	1.03E-05
Nb 99	0.000142	1.79E-14	1.36E-09	0.00E+00	1.48E-10	9.28E-05	1.95E-06	1.37E-06
Nb 99m	7.57E-05	1.04E-13	6.46E-10	0.00E+00	3.38E-10	6.17E-04	1.40E-05	9.80E-06

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Nb100	0.000189	2.34E-15	2.74E-09	0.00E+00	8.34E-10	1.21E-03	4.34E-07	2.87E-07
Nb100m	2.62E-05	6.73E-16	3.18E-10	0.00E+00	3.21E-10	4.51E-04	1.65E-07	1.07E-07
Nb101	0.000172	1.09E-14	1.73E-09	0.00E+00	6.61E-10	1.57E-03	2.73E-06	1.65E-06
Nb102	0.000086	1.01E-15	9.11E-10	0.00E+00	1.58E-09	1.89E-03	4.14E-07	2.77E-07
Nb102m	4.26E-05	1.66E-15	5.75E-10	0.00E+00	5.29E-10	8.19E-04	6.31E-07	4.26E-07
Nb103	9.01E-05	1.23E-15	1.12E-09	0.00E+00	4.09E-10	8.25E-04	4.00E-07	2.74E-07
Nb104	3.11E-05	2.29E-16	3.69E-10	0.00E+00	5.88E-10	7.26E-04	1.14E-07	6.56E-08
Mo 93	2.61E-08	2.04E-08	8.73E-16	0.00E+00	1.69E-15	1.00E-08	2.99E-06	2.22E-06
Mo 93m	9.6E-09	1.95E-15	6.10E-15	0.00E+00	1.32E-13	2.14E-07	3.91E-08	6.04E-08
Mo 99	0.000301	6.26E-10	7.00E-10	0.00E+00	2.62E-10	3.43E-04	6.68E-03	1.10E-02
Mo101	0.000219	1.71E-12	6.81E-10	0.00E+00	1.91E-09	3.05E-03	3.32E-04	2.10E-04
Mo102	0.00017	1.03E-12	3.64E-10	0.00E+00	1.92E-11	1.56E-05	2.39E-04	1.89E-04
Mo103	0.000162	1.00E-13	1.26E-09	0.00E+00	6.10E-10	8.57E-04	2.93E-05	2.39E-05
Mo104	0.000131	7.24E-14	6.83E-10	0.00E+00	1.37E-10	2.31E-04	2.52E-05	1.41E-05
Mo105	9.33E-05	3.18E-14	5.42E-10	0.00E+00	1.32E-09	2.33E-04	1.59E-05	1.31E-05
Tc 95	1.75E-10	1.06E-16	5.45E-18	0.00E+00	8.29E-16	1.22E-09	1.17E-09	7.13E-10
Tc 96	1.06E-08	3.33E-14	5.13E-16	0.00E+00	1.57E-13	2.38E-07	4.31E-07	2.74E-07
Tc 96m	7.84E-09	2.06E-16	4.43E-18	0.00E+00	2.10E-15	3.12E-09	3.48E-09	2.17E-09
Tc 97m	1.25E-08	8.40E-13	6.47E-15	0.00E+00	7.06E-16	3.57E-09	2.55E-07	1.90E-06
Tc 99	1.31E-08	7.68E-07	7.86E-15	0.00E+00	5.46E-20	7.77E-14	3.11E-07	6.32E-06
Tc 99m	0.000268	5.09E-11	2.56E-11	0.00E+00	2.01E-10	1.43E-04	2.18E-04	1.98E-04
Tc100	0.000255	3.56E-14	1.99E-09	0.00E+00	1.25E-10	1.62E-04	5.75E-06	3.58E-06
Tc101	0.000219	1.67E-12	6.18E-10	0.00E+00	4.36E-10	4.65E-04	1.54E-04	9.71E-05
Tc102	0.00017	8.12E-15	1.96E-09	0.00E+00	8.16E-11	1.20E-04	1.83E-06	1.20E-06
Tc102m	4.78E-07	1.13E-15	2.21E-12	0.00E+00	7.15E-12	1.18E-05	4.24E-07	2.65E-07
Tc103	0.000165	7.53E-14	8.29E-10	0.00E+00	2.58E-10	2.48E-04	9.16E-06	6.05E-06
Tc104	0.00014	1.42E-12	1.50E-09	0.00E+00	1.86E-09	3.12E-03	4.15E-04	1.50E-04
Tc105	0.000119	5.05E-13	8.77E-10	0.00E+00	3.47E-10	4.62E-04	1.10E-04	7.48E-05
Tc106	9.04E-05	3.06E-14	1.12E-09	0.00E+00	1.13E-09	2.27E-03	1.37E-05	9.03E-06
Tc107	6.08E-05	1.21E-14	5.71E-10	0.00E+00	2.15E-10	2.69E-04	5.63E-06	3.38E-06
Tc108	2.86E-05	1.41E-15	3.83E-10	0.00E+00	2.52E-10	4.10E-04	1.16E-06	7.08E-07
Tc109	1.07E-05	1.44E-16	1.42E-10	0.00E+00	4.47E-11	5.73E-05	1.14E-07	7.10E-08
Ru 97	2.61E-05	5.61E-11	1.85E-12	0.00E+00	3.77E-11	3.17E-05	1.45E-04	1.06E-04
Ru103	0.000621	1.92E-08	2.45E-10	0.00E+00	1.83E-09	2.26E-03	1.68E-02	6.89E-02
Ru105	0.0002	2.97E-11	5.21E-10	0.00E+00	8.42E-10	1.17E-03	1.92E-03	1.33E-03

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Ru106	9.53E-05	2.85E-08	5.67E-12	0.00E+00	0.00E+00	0.00E+00	2.47E-02	2.33E-01
Ru107	7.37E-05	1.57E-13	4.72E-10	0.00E+00	1.51E-10	2.19E-04	7.36E-05	3.54E-05
Ru108	5.27E-05	1.36E-13	1.46E-10	0.00E+00	1.44E-11	9.57E-06	1.11E-04	5.27E-05
Ru109	1.98E-05	6.61E-15	1.22E-10	0.00E+00	2.47E-10	3.69E-04	6.61E-06	3.08E-06
Ru110	1.58E-05	1.95E-15	8.44E-11	0.00E+00	4.37E-11	4.46E-05	2.17E-06	9.97E-07
Ru111	6.08E-06	1.32E-16	7.21E-11	0.00E+00	2.63E-11	3.25E-05	1.55E-07	7.43E-08
Rh100	4.65E-16	3.08E-22	1.65E-22	0.00E+00	7.66E-21	1.32E-14	1.22E-14	6.02E-15
Rh103m	0.00063	1.94E-11	1.43E-10	0.00E+00	6.36E-12	1.57E-05	8.86E-05	6.30E-05
Rh104	0.000638	2.49E-13	3.71E-09	0.00E+00	5.68E-11	5.73E-05	2.83E-05	2.01E-05
Rh104m	4.84E-05	1.16E-13	2.47E-11	0.00E+00	1.31E-11	1.43E-05	1.49E-05	1.06E-05
Rh105	0.00018	2.14E-10	1.64E-10	0.00E+00	8.35E-11	8.62E-05	2.47E-03	2.34E-03
Rh105m	5.59E-05	2.08E-14	3.16E-11	0.00E+00	1.15E-11	1.14E-05	5.38E-07	4.34E-07
Rh106	0.000113	3.18E-14	9.35E-10	0.00E+00	1.46E-10	1.92E-04	5.83E-06	4.08E-06
Rh106m	1.85E-06	1.38E-13	3.53E-12	0.00E+00	3.03E-11	4.50E-05	1.10E-05	7.53E-06
Rh107	7.39E-05	9.12E-13	1.89E-10	0.00E+00	1.37E-10	1.45E-04	6.57E-05	4.65E-05
Rh108	5.38E-05	1.82E-13	2.91E-10	0.00E+00	7.22E-10	1.02E-03	6.37E-05	4.58E-05
Rh108m	3.4E-07	5.46E-17	3.63E-12	0.00E+00	1.07E-12	1.51E-06	1.38E-08	9.93E-09
Rh109	3.86E-05	2.98E-14	2.01E-10	0.00E+00	7.43E-11	7.46E-05	4.57E-06	3.00E-06
Rh110	1.6E-05	4.45E-15	1.12E-10	0.00E+00	2.43E-10	3.49E-04	1.78E-06	1.25E-06
Rh110m	2.38E-06	7.41E-17	3.19E-11	0.00E+00	4.73E-12	5.35E-06	2.11E-08	1.50E-08
Rh111	9.53E-06	1.03E-15	8.39E-11	0.00E+00	1.18E-11	3.16E-05	3.00E-07	2.19E-07
Rh112	4.69E-06	1.77E-16	5.37E-11	0.00E+00	7.45E-11	9.09E-05	1.18E-07	7.64E-08
Rh113	2.55E-06	6.95E-17	2.75E-11	0.00E+00	7.98E-12	9.55E-06	3.40E-08	2.46E-08
Rh114	5.02E-07	9.38E-18	8.03E-12	0.00E+00	1.41E-12	1.40E-06	5.94E-09	4.27E-09
Rh114m	8.53E-07	1.59E-17	1.03E-11	0.00E+00	1.27E-11	1.52E-05	1.23E-08	8.84E-09
Pd103	1.67E-05	2.24E-10	5.83E-13	0.00E+00	1.46E-12	2.83E-06	1.18E-04	2.78E-04
Pd107	3.97E-10	7.71E-07	2.21E-17	0.00E+00	0.00E+00	0.00E+00	5.43E-10	8.66E-09
Pd107m	5.31E-06	1.07E-15	1.98E-12	0.00E+00	4.78E-12	4.27E-06	4.91E-08	5.30E-08
Pd109	0.000984	4.60E-10	2.10E-09	0.00E+00	6.13E-12	4.67E-06	2.00E-02	1.35E-02
Pd109m	2.07E-05	5.65E-14	9.51E-12	0.00E+00	1.37E-11	1.00E-05	4.67E-06	4.14E-06
Pd111	2.74E-05	3.79E-13	1.35E-10	0.00E+00	7.30E-12	1.09E-05	8.02E-05	9.54E-05
Pd111m	2.99E-06	5.82E-13	3.07E-12	0.00E+00	6.79E-12	8.47E-06	5.76E-05	5.31E-05
Pd112	5.55E-06	4.02E-12	2.96E-12	0.00E+00	1.73E-13	1.03E-06	1.38E-03	1.01E-03
Pd113	3.72E-06	3.46E-15	3.06E-11	0.00E+00	1.51E-12	1.75E-06	1.65E-06	1.79E-06
Pd113m	5.81E-07	5.81E-16	0.00E+00	0.00E+00	3.44E-15	0.00E+00	2.79E-07	3.01E-07

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Pd114	1.99E-06	2.95E-15	6.27E-12	0.00E+00	3.22E-13	2.70E-07	1.77E-06	1.91E-06
Pd115	1.91E-06	4.85E-16	1.54E-11	0.00E+00	1.63E-11	1.79E-05	4.73E-07	4.73E-07
Pd116	1.33E-06	1.70E-16	7.81E-12	0.00E+00	1.38E-12	1.03E-06	1.62E-07	1.77E-07
Pd117	8.8E-07	4.56E-17	5.84E-12	0.00E+00	1.52E-11	1.60E-05	5.86E-08	6.19E-08
Pd118	4.25E-07	1.38E-17	3.74E-12	0.00E+00	1.73E-12	1.95E-06	2.20E-08	2.36E-08
Ag106	1.91E-10	2.59E-18	5.71E-16	0.00E+00	8.00E-16	9.81E-10	2.27E-10	1.13E-10
Ag107m	2.74E-06	1.14E-15	1.31E-12	0.00E+00	2.03E-13	3.16E-07	9.12E-09	6.08E-09
Ag108	0.000378	5.21E-13	1.36E-09	0.00E+00	5.12E-11	6.50E-05	2.80E-05	1.82E-05
Ag108m	6.33E-08	7.98E-09	6.02E-15	0.00E+00	6.11E-13	8.27E-07	5.38E-06	8.66E-05
Ag109m	0.00104	4.00E-13	4.75E-10	0.00E+00	6.84E-11	1.13E-04	2.96E-06	1.96E-06
Ag110	0.00108	2.60E-13	7.52E-09	0.00E+00	2.23E-10	2.75E-04	2.60E-05	1.72E-05
Ag110m	3.38E-05	7.11E-09	1.38E-11	0.00E+00	5.54E-10	8.44E-04	3.51E-03	1.50E-02
Ag111	4.71E-05	2.98E-10	9.87E-11	0.00E+00	7.36E-12	7.37E-06	2.27E-03	2.96E-03
Ag111m	3.74E-05	2.38E-14	1.24E-11	0.00E+00	1.52E-12	2.70E-06	3.04E-07	3.18E-07
Ag112	5.63E-06	6.32E-13	4.74E-11	0.00E+00	2.31E-11	3.76E-05	8.96E-05	3.54E-05
Ag113	3.6E-06	6.97E-13	1.63E-11	0.00E+00	1.54E-12	1.74E-06	5.20E-05	3.33E-05
Ag113m	7.12E-07	4.89E-16	5.93E-13	0.00E+00	5.15E-13	5.79E-07	3.95E-08	2.55E-08
Ag114	2.02E-06	9.61E-17	2.52E-11	0.00E+00	3.26E-12	4.85E-06	1.80E-08	1.20E-08
Ag114m	2.45E-08	3.71E-22	1.48E-14	0.00E+00	1.41E-14	2.49E-08	7.62E-14	5.08E-14
Ag115	1.54E-06	1.93E-14	7.11E-12	0.00E+00	1.03E-11	1.68E-05	3.42E-06	1.65E-06
Ag115m	6.21E-07	1.18E-16	3.11E-12	0.00E+00	1.68E-12	1.61E-06	1.70E-08	1.04E-08
Ag116	1.39E-06	2.25E-15	1.31E-11	0.00E+00	1.73E-11	3.03E-05	6.66E-07	4.36E-07
Ag116m	1.57E-07	1.69E-17	1.73E-12	0.00E+00	1.21E-12	1.52E-06	4.29E-09	2.90E-09
Ag117	4.91E-07	3.70E-16	3.80E-12	0.00E+00	3.18E-12	5.56E-06	7.80E-08	4.90E-08
Ag117m	7.71E-07	4.27E-17	6.87E-12	0.00E+00	2.95E-12	3.16E-06	7.99E-09	5.14E-09
Ag118	7.09E-07	2.74E-17	1.05E-11	0.00E+00	3.75E-12	4.55E-06	1.21E-08	8.13E-09
Ag118m	5.03E-07	1.05E-17	3.72E-12	0.00E+00	4.47E-12	7.24E-06	5.21E-09	3.53E-09
Ag119	8.82E-07	1.95E-17	9.26E-12	0.00E+00	6.99E-12	1.16E-05	1.11E-08	6.53E-09
Ag120	4.99E-07	6.20E-18	6.75E-12	0.00E+00	3.18E-12	3.18E-06	3.14E-09	2.03E-09
Ag121	4.65E-07	3.99E-18	6.78E-12	0.00E+00	2.33E-12	1.17E-05	2.41E-09	1.62E-09
Ag122	3.5E-08	1.82E-19	7.48E-13	0.00E+00	2.33E-13	3.12E-07	1.30E-10	8.69E-11
Cd107	2.59E-06	5.77E-13	9.65E-14	0.00E+00	3.27E-13	5.92E-07	5.95E-06	7.97E-06
Cd109	5.3E-05	2.05E-08	1.80E-12	0.00E+00	4.76E-12	9.40E-06	3.92E-03	1.59E-02
Cd111m	6.98E-06	2.00E-13	4.34E-12	0.00E+00	1.21E-11	1.05E-05	2.84E-05	3.87E-05
Cd113m	8.29E-09	3.59E-11	9.00E-15	0.00E+00	3.51E-18	3.64E-12	7.05E-06	3.37E-05

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Cd115	4.81E-05	9.41E-11	9.03E-11	0.00E+00	5.51E-11	6.66E-05	2.49E-03	1.96E-03
Cd115m	6.27E-06	2.46E-10	2.24E-11	0.00E+00	1.27E-12	1.94E-06	7.66E-04	1.79E-03
Cd117	1.54E-06	1.43E-13	3.93E-12	0.00E+00	9.94E-12	1.58E-05	1.60E-05	9.69E-06
Cd117m	1.17E-06	1.46E-13	1.42E-12	0.00E+00	1.41E-11	2.46E-05	1.21E-05	9.06E-06
Cd118	1.17E-06	3.70E-14	1.71E-12	0.00E+00	0.00E+00	0.00E+00	2.91E-05	3.86E-05
Cd119	7.6E-07	1.29E-15	3.04E-12	0.00E+00	7.54E-12	1.13E-05	1.91E-06	1.97E-06
Cd119m	3.96E-07	5.51E-16	1.35E-12	0.00E+00	5.53E-12	9.04E-06	8.06E-07	1.07E-06
Cd120	1.1E-06	5.96E-16	4.29E-12	0.00E+00	1.13E-14	1.16E-08	6.54E-07	8.99E-07
Cd121	6.1E-07	8.17E-17	4.77E-12	0.00E+00	6.32E-12	1.02E-05	1.31E-07	1.74E-07
Cd121m	4.78E-07	2.46E-17	3.20E-12	0.00E+00	6.35E-12	1.14E-05	4.42E-08	5.84E-08
Cd122	7.41E-07	4.63E-17	4.62E-12	0.00E+00	3.12E-12	3.25E-06	7.40E-08	1.01E-07
Cd123	3.62E-07	8.68E-18	2.73E-12	0.00E+00	6.12E-12	8.11E-06	2.01E-08	2.55E-08
Cd124	1.6E-07	1.76E-18	1.94E-12	0.00E+00	1.14E-13	8.00E-08	3.97E-09	5.33E-09
Cd125	1.2E-08	9.27E-20	1.24E-13	0.00E+00	2.20E-13	2.60E-07	2.48E-10	3.27E-10
In113m	2.55E-06	1.52E-13	1.98E-12	0.00E+00	3.93E-12	4.15E-06	2.64E-06	1.88E-06
In114	0.000131	9.49E-14	5.96E-10	0.00E+00	3.39E-12	2.81E-06	5.80E-06	4.21E-06
In114m	7.64E-05	3.33E-09	6.38E-11	0.00E+00	4.03E-11	4.54E-05	1.16E-02	2.63E-02
In115m	4.96E-05	8.16E-12	5.03E-11	0.00E+00	4.78E-11	5.17E-05	1.58E-04	1.08E-04
In116	1.18E-05	1.72E-15	9.48E-11	0.00E+00	3.68E-13	2.51E-08	1.79E-07	1.31E-07
In116m	4.31E-05	1.45E-12	7.99E-11	0.00E+00	6.37E-10	1.08E-03	1.02E-04	7.18E-05
In116n	2.36E-05	5.26E-16	1.32E-11	0.00E+00	9.53E-12	7.95E-06	4.36E-08	3.05E-08
In117	1.95E-06	5.31E-14	3.05E-12	0.00E+00	8.01E-12	8.90E-06	2.24E-06	2.09E-06
In117m	1.43E-06	1.03E-13	3.67E-12	0.00E+00	7.69E-13	7.56E-07	6.34E-06	3.80E-06
In118	1.18E-06	6.19E-17	1.20E-11	0.00E+00	2.44E-12	4.00E-06	9.63E-09	7.01E-09
In119	4.97E-07	7.54E-16	1.80E-12	0.00E+00	2.26E-12	3.14E-06	7.72E-08	5.70E-08
In119m	7.21E-07	8.21E-15	4.49E-12	0.00E+00	4.69E-14	7.09E-08	1.26E-06	4.54E-07
In120	1.22E-06	4.00E-17	1.72E-11	0.00E+00	2.40E-12	4.08E-06	8.14E-09	5.88E-09
In121	1.08E-06	2.69E-16	6.29E-12	0.00E+00	5.98E-12	9.00E-06	3.89E-08	2.81E-08
In121m	4.92E-07	1.23E-15	4.43E-12	0.00E+00	2.02E-13	2.84E-07	1.53E-07	1.09E-07
In122	1.71E-06	2.77E-17	2.56E-11	0.00E+00	6.48E-12	1.15E-05	6.32E-09	4.74E-09
In123	1.65E-06	1.08E-16	1.32E-11	0.00E+00	1.08E-11	1.75E-05	2.39E-08	1.53E-08
In123m	3.99E-07	2.08E-16	4.77E-12	0.00E+00	1.55E-13	1.59E-07	3.99E-08	2.51E-08
In124	1.22E-06	4.30E-17	1.54E-11	0.00E+00	1.96E-11	3.66E-05	1.49E-08	1.09E-08
In124m	9.64E-07	2.54E-17	9.61E-12	0.00E+00	2.18E-11	3.49E-05	9.99E-09	7.49E-09
In125	2.38E-06	6.14E-17	2.47E-11	0.00E+00	1.83E-11	3.07E-05	1.41E-08	1.06E-08

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
In125m	5.5E-07	7.43E-17	7.89E-12	0.00E+00	5.48E-13	3.57E-07	1.95E-08	1.47E-08
In126	1.2E-06	2.01E-17	1.73E-11	0.00E+00	2.00E-11	3.87E-05	7.54E-09	5.32E-09
In126m	1.7E-06	2.76E-17	1.90E-11	0.00E+00	4.35E-11	7.06E-05	1.20E-08	8.82E-09
In127	1.79E-06	2.31E-17	2.34E-11	0.00E+00	1.87E-11	3.22E-05	9.26E-09	7.27E-09
In127m	4.12E-07	1.71E-17	6.69E-12	2.68E-13	1.22E-12	1.83E-06	8.23E-09	5.94E-09
In128	6.76E-07	6.90E-18	1.11E-11	0.00E+00	1.23E-11	2.43E-05	3.50E-09	2.23E-09
Sn113	2.52E-06	2.51E-10	9.39E-14	0.00E+00	3.48E-13	6.04E-07	6.82E-05	2.52E-04
Sn113m	7.16E-07	8.98E-15	2.49E-13	0.00E+00	6.14E-14	1.21E-07	6.36E-08	1.51E-07
Sn117m	7.65E-06	9.32E-11	7.18E-12	0.00E+00	7.10E-12	5.68E-06	2.01E-04	6.80E-04
Sn119m	4.16E-07	1.11E-10	1.93E-13	0.00E+00	2.81E-14	6.05E-08	5.24E-06	3.39E-05
Sn121	1.32E-05	1.37E-11	8.98E-12	0.00E+00	0.00E+00	0.00E+00	1.12E-04	1.12E-04
Sn121m	4.57E-08	8.51E-10	9.58E-15	0.00E+00	1.38E-15	2.99E-09	6.43E-07	7.62E-06
Sn123	3.92E-07	4.77E-11	1.21E-12	0.00E+00	1.86E-14	2.61E-08	3.05E-05	1.18E-04
Sn123m	4.33E-06	1.14E-13	1.22E-11	0.00E+00	3.63E-12	2.49E-06	6.09E-06	4.33E-06
Sn125	4.68E-06	4.31E-11	2.23E-11	0.00E+00	8.77E-12	1.42E-05	5.37E-04	5.37E-04
Sn125m	5.2E-06	3.29E-14	2.46E-11	0.00E+00	1.07E-11	1.14E-05	3.27E-06	7.50E-06
Sn126	8.26E-10	7.04E-08	5.34E-16	0.00E+00	2.75E-16	2.49E-10	1.44E-07	8.56E-07
Sn127	1.15E-05	9.77E-13	3.34E-11	0.00E+00	1.26E-10	2.04E-04	8.50E-05	5.52E-05
Sn127m	6.37E-06	1.78E-14	3.78E-11	0.00E+00	2.15E-11	2.88E-05	2.83E-06	7.31E-06
Sn128	2.74E-05	1.10E-12	4.08E-11	0.00E+00	9.73E-11	1.24E-04	1.52E-04	9.32E-05
Sn128m	1.83E-05	1.35E-15	8.46E-12	0.00E+00	2.18E-10	3.47E-04	4.20E-07	6.57E-07
Sn129	1.32E-05	2.17E-14	5.23E-11	0.00E+00	1.94E-10	1.77E-04	8.29E-06	1.95E-05
Sn129m	2.65E-05	1.25E-13	9.56E-11	0.00E+00	3.81E-10	5.78E-04	4.61E-05	1.08E-04
Sn130	1.3E-05	3.33E-14	6.30E-11	0.00E+00	1.23E-11	8.76E-05	1.25E-05	2.83E-05
Sn130m	2.83E-05	3.33E-14	7.72E-11	0.00E+00	3.95E-10	6.85E-05	1.36E-05	3.14E-05
Sn131	7.57E-06	3.43E-15	3.95E-11	0.00E+00	1.06E-10	3.47E-04	1.96E-06	4.20E-06
Sn131m	1.71E-05	1.22E-14	1.12E-10	0.00E+00	2.43E-10	2.64E-04	6.97E-06	1.52E-05
Sb120	8.26E-10	8.38E-18	1.50E-15	0.00E+00	2.25E-15	2.83E-09	4.28E-10	2.23E-10
Sb120m	4.07E-10	2.15E-15	1.09E-16	0.00E+00	5.94E-15	9.13E-09	1.81E-08	1.66E-08
Sb122	0.000834	2.10E-09	2.79E-09	0.00E+00	2.16E-09	2.70E-03	5.24E-02	3.39E-02
Sb122m	0.000053	1.44E-13	2.92E-11	0.00E+00	2.22E-11	2.40E-05	5.10E-06	3.14E-06
Sb124	0.0005	2.86E-08	1.13E-09	0.00E+00	5.52E-09	9.27E-03	4.62E-02	1.59E-01
Sb124m	7.54E-06	7.70E-15	5.10E-12	0.00E+00	1.96E-11	2.64E-05	2.79E-07	1.76E-07
Sb124n	2.51E-06	3.34E-14	3.83E-13	0.00E+00	5.02E-15	3.70E-08	7.42E-07	5.47E-07
Sb125	1.9E-05	1.83E-08	1.14E-11	0.00E+00	4.85E-11	6.36E-05	7.74E-04	8.44E-03

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Sb126	3.34E-07	4.00E-12	6.59E-13	0.00E+00	5.45E-12	7.50E-06	2.97E-05	3.96E-05
Sb126m	1.73E-07	2.21E-15	6.41E-13	0.00E+00	1.62E-12	2.20E-06	2.31E-07	1.28E-07
Sb126n	1.57E-07	1.93E-17	2.09E-14	0.00E+00	3.53E-16	2.45E-09	2.04E-09	1.11E-09
Sb127	1.92E-05	7.18E-11	3.59E-11	0.00E+00	7.51E-11	9.96E-05	1.21E-03	1.35E-03
Sb128	3.44E-06	1.27E-12	8.59E-12	0.00E+00	6.31E-11	8.71E-05	9.68E-05	5.35E-05
Sb128m	3.13E-05	2.21E-13	1.71E-10	0.00E+00	3.71E-10	5.00E-04	3.82E-05	1.74E-05
Sb129	5.17E-05	9.28E-12	1.09E-10	0.00E+00	4.23E-10	6.51E-04	8.04E-04	4.79E-04
Sb129m	1.05E-05	1.27E-13	6.21E-11	0.00E+00	9.19E-11	1.28E-04	2.13E-05	1.13E-05
Sb130	4.62E-05	1.28E-12	1.90E-10	0.00E+00	8.93E-10	1.28E-03	1.55E-04	9.05E-05
Sb130m	3.71E-05	1.61E-13	2.19E-10	0.00E+00	5.47E-10	8.10E-04	3.43E-05	1.78E-05
Sb131	9.55E-05	1.53E-12	4.70E-10	0.00E+00	9.60E-10	1.56E-03	3.53E-04	1.56E-04
Sb132	3.65E-05	1.08E-13	2.90E-10	0.00E+00	5.11E-10	7.33E-04	2.70E-05	1.30E-05
Sb132m	3.51E-05	6.90E-14	2.63E-10	0.00E+00	5.27E-10	8.01E-04	1.69E-05	8.45E-06
Sb133	5.07E-05	8.85E-14	1.32E-10	0.00E+00	7.22E-10	1.27E-03	3.00E-05	8.81E-06
Te121	3.35E-07	5.95E-12	1.96E-14	0.00E+00	1.15E-12	1.43E-06	5.33E-06	5.09E-06
Te121m	3.64E-08	5.19E-12	1.73E-14	0.00E+00	4.68E-14	4.90E-08	3.10E-06	7.68E-06
Te123m	4.97E-05	5.60E-09	2.97E-11	0.00E+00	4.37E-11	3.47E-05	2.58E-03	9.38E-03
Te125m	6.76E-06	3.75E-10	4.36E-12	0.00E+00	1.44E-12	2.87E-06	2.18E-04	1.05E-03
Te127	5.54E-05	2.10E-11	7.36E-11	0.00E+00	1.59E-12	1.89E-06	3.48E-04	2.87E-04
Te127m	2.03E-06	2.15E-10	9.88E-13	0.00E+00	1.39E-13	2.82E-07	1.73E-04	7.36E-04
Te129	7.16E-05	3.42E-12	2.31E-10	0.00E+00	2.57E-11	3.42E-05	1.67E-04	1.03E-04
Te129m	1.97E-05	6.56E-10	2.80E-11	0.00E+00	4.54E-12	6.94E-06	2.18E-03	5.75E-03
Te131	0.000135	2.35E-12	5.73E-10	0.00E+00	3.38E-10	4.17E-04	4.34E-04	1.40E-04
Te131m	3.21E-05	4.03E-11	3.70E-11	0.00E+00	2.72E-10	3.99E-04	2.26E-03	1.12E-03
Te132	0.000185	6.03E-10	1.13E-10	0.00E+00	2.56E-10	2.55E-04	2.60E-02	1.37E-02
Te133	0.000106	9.38E-13	4.53E-10	0.00E+00	7.55E-10	1.17E-03	2.83E-04	7.85E-05
Te133m	0.00013	5.08E-12	4.07E-10	0.00E+00	1.48E-09	2.17E-03	1.34E-03	4.17E-04
Te134	0.000174	5.18E-12	2.37E-10	0.00E+00	8.85E-10	1.09E-03	7.08E-04	4.38E-04
Te135	8.18E-05	1.86E-14	1.13E-09	0.00E+00	2.33E-10	3.95E-04	5.45E-06	1.21E-05
I 128	2.32E-05	3.95E-13	1.02E-10	0.00E+00	1.21E-11	1.47E-05	3.96E-05	1.72E-05
I 130	6.48E-05	3.32E-11	1.11E-10	0.00E+00	8.21E-10	1.11E-03	4.79E-03	1.61E-03
I 130m	4.22E-05	2.62E-13	4.76E-11	0.00E+00	2.98E-11	4.01E-05	3.90E-04	6.40E-05
I 131	0.000161	1.30E-09	1.83E-10	0.00E+00	3.65E-10	3.95E-04	1.31E-01	4.41E-02
I 132	0.000191	1.84E-11	5.55E-10	0.00E+00	2.56E-09	3.72E-03	2.05E-03	7.78E-04
I 132m	4.6E-06	2.68E-13	4.43E-12	0.00E+00	9.40E-12	1.29E-05	3.74E-05	1.48E-05

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
I 133	0.000253	2.23E-10	6.14E-10	0.00E+00	9.12E-10	1.19E-03	4.03E-02	1.41E-02
I 133m	1.53E-05	1.62E-15	4.44E-12	0.00E+00	1.43E-10	2.12E-04	1.19E-05	1.81E-06
I 134	0.000261	9.79E-12	9.60E-10	0.00E+00	4.04E-09	6.27E-03	1.06E-03	5.32E-04
I 134m	5.54E-05	1.46E-13	2.86E-11	0.00E+00	7.95E-11	7.82E-05	2.46E-04	4.30E-05
I 135	0.000218	6.21E-11	4.72E-10	0.00E+00	2.06E-09	3.54E-03	7.51E-03	2.59E-03
I 136	7.49E-05	7.58E-14	8.71E-10	0.00E+00	1.06E-09	1.96E-03	1.39E-03	2.08E-04
I 136m	7.45E-05	4.04E-14	9.76E-10	0.00E+00	1.11E-09	1.40E-03	8.00E-04	1.21E-04
I 137	8.84E-05	2.63E-14	1.06E-09	3.51E-10	6.44E-10	1.11E-03	1.31E-04	1.96E-05
Xe129m	1.96E-07	1.72E-12	2.14E-13	0.00E+00	6.01E-14	1.06E-07	1.45E-05	4.79E-05
Xe131m	2.94E-06	3.50E-11	2.48E-12	0.00E+00	3.69E-13	6.73E-07	1.63E-04	6.63E-04
Xe133	0.000263	1.40E-09	2.11E-10	0.00E+00	7.19E-11	7.87E-05	1.26E-02	2.92E-02
Xe133m	9.38E-06	2.09E-11	1.07E-11	0.00E+00	2.27E-12	3.08E-06	5.21E-04	1.01E-03
Xe134m	9.68E-06	3.33E-17	3.91E-12	0.00E+00	1.09E-10	1.61E-04	5.37E-09	7.52E-09
Xe135	2.52E-05	9.87E-12	4.73E-11	0.00E+00	3.72E-11	3.40E-05	4.57E-04	6.25E-04
Xe135m	6.44E-05	7.24E-13	3.63E-11	0.00E+00	1.65E-10	2.03E-04	6.44E-05	8.82E-05
Xe137	0.000245	6.83E-13	2.20E-09	0.00E+00	3.42E-10	3.76E-04	9.08E-05	1.36E-04
Xe138	0.000203	2.11E-12	8.07E-10	0.00E+00	1.35E-09	2.34E-03	7.51E-04	1.05E-03
Xe139	0.000134	6.56E-14	1.43E-09	0.00E+00	7.32E-10	1.22E-03	2.88E-05	3.97E-05
Cs131	2.61E-05	2.53E-10	9.84E-13	0.00E+00	3.57E-12	7.12E-06	5.59E-05	4.53E-05
Cs132	8.91E-08	5.88E-13	7.46E-15	0.00E+00	3.78E-13	5.34E-07	1.65E-06	9.89E-07
Cs134	0.007122	5.51E-06	6.90E-09	0.00E+00	6.56E-08	9.16E-02	5.01E+00	5.27E+00
Cs134m	0.001124	1.40E-10	7.45E-10	0.00E+00	1.80E-10	2.48E-04	8.32E-04	2.50E-03
Cs135	1.03E-07	9.28E-05	4.06E-14	0.00E+00	0.00E+00	0.00E+00	7.59E-06	3.26E-05
Cs135m	2.64E-05	1.01E-12	5.79E-12	0.00E+00	2.50E-10	3.66E-04	1.86E-05	1.57E-05
Cs136	0.008386	1.14E-07	7.05E-09	0.00E+00	1.07E-07	1.63E-01	9.31E-01	8.69E-01
Cs136m	0.000137	3.13E-14	5.00E-10	0.00E+00	5.00E-10	5.19E-04	2.18E-06	1.16E-06
Cs137	0.000123	1.42E-06	1.36E-10	0.00E+00	2.75E-14	0.00E+00	5.91E-02	1.77E-01
Cs138	0.00024	5.68E-12	1.81E-09	0.00E+00	3.37E-09	5.80E-03	8.18E-04	3.82E-04
Cs138m	2.38E-05	5.05E-14	4.59E-11	0.00E+00	5.92E-11	8.97E-05	7.91E-06	3.78E-06
Cs139	0.000227	1.56E-12	2.21E-09	0.00E+00	4.03E-10	8.71E-04	2.35E-04	1.18E-04
Cs140	0.000191	1.51E-13	2.11E-09	0.00E+00	1.81E-09	4.26E-03	2.76E-05	1.49E-05
Cs141	0.000141	4.38E-14	1.32E-09	2.25E-10	9.50E-10	1.15E-03	2.39E-05	1.20E-05
Ba131	2.61E-05	3.03E-10	7.17E-12	0.00E+00	7.12E-11	8.42E-05	4.35E-04	8.42E-04
Ba131m	6.54E-06	6.65E-14	4.27E-12	0.00E+00	2.99E-12	2.92E-06	1.19E-06	1.89E-06
Ba133	1.94E-05	7.64E-08	6.18E-12	0.00E+00	4.64E-11	5.05E-05	1.08E-03	7.20E-03

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Ba133m	1.78E-06	2.89E-12	2.34E-12	0.00E+00	7.08E-13	8.85E-07	3.57E-05	3.04E-05
Ba135m	0.000229	2.83E-10	2.83E-10	0.00E+00	7.88E-11	9.14E-05	3.64E-03	3.05E-03
Ba136m	5.37E-06	2.00E-17	3.41E-12	0.00E+00	6.13E-11	9.58E-05	3.18E-09	1.65E-09
Ba137m	0.000127	2.35E-13	4.72E-11	0.00E+00	4.49E-10	6.26E-04	1.22E-05	6.09E-06
Ba139	0.001227	7.53E-11	6.53E-09	0.00E+00	3.35E-10	2.70E-04	5.45E-03	2.68E-03
Ba140	0.000239	3.26E-09	4.44E-10	0.00E+00	2.59E-10	3.16E-04	2.30E-02	5.12E-02
Ba141	0.000228	3.13E-12	1.21E-09	0.00E+00	1.31E-09	1.51E-03	5.92E-04	2.87E-04
Ba142	0.000222	1.77E-12	6.17E-10	0.00E+00	9.98E-10	2.09E-02	2.87E-04	1.80E-04
Ba143	0.000167	3.06E-14	1.19E-09	0.00E+00	8.60E-10	5.02E-04	1.79E-05	8.64E-06
La140	0.024443	4.40E-08	7.75E-08	0.00E+00	3.35E-07	5.63E-01	1.81E+00	9.95E-01
La141	0.000234	4.13E-11	1.31E-09	0.00E+00	6.39E-11	1.04E-04	3.12E-03	1.30E-03
La142	0.000235	1.62E-11	1.20E-09	0.00E+00	3.30E-09	6.16E-03	1.57E-03	7.74E-04
La143	0.000205	2.20E-12	1.52E-09	0.00E+00	1.58E-10	5.58E-04	4.25E-04	1.59E-04
La144	0.000163	8.51E-14	1.34E-09	0.00E+00	2.17E-09	3.53E-03	1.03E-05	4.42E-06
La145	0.00011	3.41E-14	5.52E-10	0.00E+00	9.62E-10	6.95E-04	4.87E-06	1.95E-06
La146	3.08E-05	2.50E-15	3.51E-10	0.00E+00	4.17E-10	3.86E-04	5.70E-07	2.39E-07
La146m	2.97E-05	3.84E-15	3.83E-10	0.00E+00	2.33E-10	2.83E-04	7.81E-07	3.41E-07
La147	2.97E-05	1.55E-15	2.82E-10	0.00E+00	2.22E-10	5.11E-05	2.97E-07	1.10E-07
Ce137	3.94E-06	1.55E-12	1.18E-13	0.00E+00	9.46E-13	1.64E-06	3.64E-06	1.46E-06
Ce137m	5.26E-07	7.90E-13	6.33E-13	0.00E+00	1.73E-13	2.33E-07	1.05E-05	8.56E-06
Ce139	7.25E-07	1.06E-10	1.47E-13	0.00E+00	6.93E-13	6.28E-07	6.97E-06	5.09E-05
Ce139m	3.02E-08	2.09E-17	9.86E-15	0.00E+00	1.25E-13	1.74E-07	7.82E-10	1.90E-09
Ce141	0.001425	5.00E-08	1.44E-09	0.00E+00	6.47E-10	4.99E-04	3.74E-02	2.00E-01
Ce143	0.000268	4.03E-10	6.94E-10	0.00E+00	4.33E-10	5.00E-04	1.09E-02	8.22E-03
Ce144	0.000173	5.42E-08	9.38E-11	0.00E+00	1.99E-11	1.79E-05	3.32E-02	3.39E-01
Ce145	0.000131	2.98E-13	5.91E-10	0.00E+00	4.66E-10	6.51E-04	2.90E-05	5.81E-05
Ce146	0.000101	1.11E-12	1.55E-10	0.00E+00	1.07E-10	1.27E-04	1.45E-04	3.46E-04
Ce147	7.42E-05	5.51E-14	5.64E-10	0.00E+00	7.66E-11	8.88E-05	7.68E-06	1.54E-05
Ce148	5.18E-05	3.80E-14	1.93E-10	0.00E+00	9.30E-11	8.09E-05	6.13E-06	1.44E-05
Ce149	2.57E-05	1.77E-15	9.39E-11	0.00E+00	4.03E-10	8.23E-05	5.43E-07	1.33E-06
Pr140	5.58E-09	1.41E-17	1.80E-14	0.00E+00	1.80E-14	2.24E-08	1.18E-09	9.91E-10
Pr142	0.005705	4.94E-09	2.74E-08	0.00E+00	1.98E-09	3.54E-03	2.74E-01	1.16E-01
Pr142m	0.001985	2.19E-11	0.00E+00	0.00E+00	4.33E-11	3.20E-04	1.25E-03	5.14E-04
Pr143	0.000266	3.94E-09	4.95E-10	0.00E+00	1.40E-17	1.95E-11	1.18E-02	2.36E-02
Pr144	0.000176	2.33E-12	1.25E-09	0.00E+00	3.52E-11	5.39E-05	3.25E-04	1.17E-04

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Pr144m	4.74E-06	2.51E-14	1.33E-12	0.00E+00	3.84E-13	8.13E-07	3.69E-06	1.35E-06
Pr145	0.000131	3.63E-11	5.24E-10	0.00E+00	2.15E-11	2.99E-05	1.89E-03	8.25E-04
Pr146	0.000102	1.91E-12	7.98E-10	0.00E+00	6.10E-10	9.96E-04	3.28E-04	2.75E-04
Pr147	7.89E-05	8.39E-13	3.56E-10	0.00E+00	3.93E-10	4.70E-04	9.64E-05	5.26E-05
Pr148	5.35E-05	9.55E-14	5.59E-10	0.00E+00	2.27E-10	3.41E-04	1.72E-05	1.44E-05
Pr148m	7.07E-06	1.11E-14	7.19E-11	0.00E+00	3.96E-11	5.05E-05	2.15E-06	1.81E-06
Pr149	4.04E-05	7.25E-14	2.63E-10	0.00E+00	1.00E-10	9.86E-05	1.79E-05	1.64E-05
Pr150	2.6E-05	2.11E-15	3.44E-10	0.00E+00	8.55E-11	1.24E-04	4.24E-07	3.56E-07
Pr151	1.49E-05	3.76E-15	1.30E-10	0.00E+00	5.77E-11	4.96E-05	1.59E-06	1.32E-06
Nd141	2.2E-09	2.46E-16	1.85E-16	0.00E+00	9.79E-16	1.60E-09	6.75E-10	4.07E-10
Nd141m	4.59E-10	3.58E-19	1.60E-16	0.00E+00	1.89E-15	2.63E-09	9.33E-12	5.60E-12
Nd147	0.000164	2.04E-09	2.63E-10	0.00E+00	1.34E-10	1.63E-04	6.68E-03	1.46E-02
Nd149	7.65E-05	6.27E-12	2.31E-10	0.00E+00	1.68E-10	1.82E-04	3.40E-04	2.52E-04
Nd151	3.76E-05	3.76E-13	1.20E-10	0.00E+00	2.11E-10	3.00E-04	4.18E-05	2.37E-05
Nd152	1.55E-05	1.43E-13	3.24E-11	0.00E+00	1.50E-11	1.39E-05	8.63E-06	5.06E-06
Nd153	9.16E-06	3.97E-15	7.64E-11	0.00E+00	5.05E-12	5.61E-06	2.78E-07	1.73E-07
Nd154	4.82E-06	1.70E-15	2.26E-11	0.00E+00	1.13E-11	1.62E-05	1.78E-07	1.12E-07
Pm145	2.4E-06	1.72E-08	1.74E-13	9.25E-20	4.48E-13	8.81E-07	9.76E-06	3.20E-04
Pm146	2.15E-08	4.86E-11	1.21E-14	0.00E+00	9.64E-14	1.29E-07	7.18E-07	1.67E-05
Pm147	5.64E-05	6.08E-08	2.07E-11	0.00E+00	1.43E-15	1.36E-09	5.43E-04	1.04E-02
Pm148	5.6E-05	3.41E-10	2.41E-10	0.00E+00	1.92E-10	3.08E-04	5.60E-03	4.56E-03
Pm148m	3.01E-06	1.40E-10	3.06E-12	0.00E+00	3.54E-11	4.79E-05	1.90E-04	6.35E-04
Pm149	0.000122	3.07E-10	2.65E-10	0.00E+00	9.16E-12	9.94E-06	4.46E-03	3.29E-03
Pm150	6.33E-06	8.12E-13	2.80E-11	0.00E+00	5.60E-11	8.81E-05	6.09E-05	3.04E-05
Pm151	3.79E-05	5.12E-11	6.81E-11	0.00E+00	7.28E-11	8.26E-05	1.02E-03	6.44E-04
Pm152	1.63E-05	5.43E-14	1.35E-10	0.00E+00	1.42E-11	2.03E-05	2.78E-06	2.54E-06
Pm152m	3.89E-08	2.36E-16	2.08E-13	0.00E+00	3.47E-13	5.08E-07	1.87E-08	1.73E-08
Pm152n	6.67E-08	7.76E-16	2.88E-13	0.00E+00	8.55E-13	1.13E-06	7.41E-08	6.91E-08
Pm153	1.1E-05	4.84E-14	4.47E-11	0.00E+00	3.50E-12	3.00E-06	1.51E-06	1.55E-06
Pm154	5.04E-06	7.02E-15	2.64E-11	0.00E+00	5.36E-11	9.50E-05	6.16E-07	5.60E-07
Pm154m	1.99E-06	4.39E-15	1.06E-11	0.00E+00	2.18E-11	3.61E-05	3.97E-07	3.68E-07
Pm155	5.14E-06	3.39E-15	3.44E-11	0.00E+00	9.01E-12	4.70E-06	2.66E-07	2.47E-07
Pm156	2.69E-06	9.93E-16	1.68E-11	0.00E+00	3.53E-11	3.68E-05	1.20E-07	1.10E-07
Pm157	1.45E-06	2.20E-16	1.45E-11	0.00E+00	4.09E-12	4.79E-06	2.09E-08	1.98E-08
Sm145	8.19E-06	3.09E-09	1.43E-12	0.00E+00	3.06E-12	5.69E-06	6.36E-05	4.85E-04

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Sm151	1.82E-07	6.92E-09	2.15E-14	0.00E+00	1.55E-17	7.40E-11	6.60E-07	2.70E-05
Sm153	0.000489	1.11E-09	7.79E-10	0.00E+00	1.82E-10	2.30E-04	1.34E-02	1.14E-02
Sm155	0.000446	8.11E-12	1.57E-09	0.00E+00	2.76E-10	1.79E-04	4.78E-04	2.80E-04
Sm156	3.64E-06	1.70E-12	4.34E-12	0.00E+00	2.69E-12	2.04E-06	3.36E-05	2.96E-05
Sm157	2.71E-06	1.83E-14	1.93E-13	0.00E+00	8.56E-12	8.65E-06	8.34E-07	5.12E-07
Sm158	1.62E-06	7.52E-15	4.61E-12	0.00E+00	3.18E-12	3.39E-06	7.21E-07	4.56E-07
Sm159	8.45E-07	1.33E-16	6.91E-12	0.00E+00	2.59E-12	2.86E-06	2.41E-08	1.38E-08
Eu152	3.8E-10	2.18E-12	2.91E-16	0.00E+00	2.62E-15	3.99E-09	1.97E-08	5.90E-07
Eu152m	5.56E-08	2.50E-14	1.66E-13	0.00E+00	1.03E-13	1.56E-07	1.03E-06	4.53E-07
Eu154	4.47E-06	1.65E-08	7.28E-12	0.00E+00	3.30E-11	5.13E-05	3.31E-04	8.77E-03
Eu154m	8.24E-06	3.13E-13	4.03E-12	0.00E+00	3.63E-12	4.59E-06	4.27E-07	6.10E-07
Eu155	7.81E-06	1.64E-08	3.08E-12	0.00E+00	2.97E-12	2.87E-06	9.25E-05	1.99E-03
Eu156	0.000892	1.62E-08	2.37E-09	0.00E+00	6.79E-09	1.18E-02	7.26E-02	1.12E-01
Eu157	6.71E-05	5.10E-11	7.08E-12	0.00E+00	1.16E-10	1.46E-04	1.49E-03	6.96E-04
Eu158	1.86E-06	7.16E-14	1.06E-11	0.00E+00	1.19E-11	1.92E-05	6.46E-06	3.23E-06
Eu159	1.12E-06	1.77E-14	5.88E-12	0.00E+00	1.82E-12	2.33E-06	2.57E-06	9.95E-07
Eu160	7.44E-07	5.57E-16	6.07E-12	0.00E+00	8.00E-12	1.08E-05	1.71E-07	7.70E-08
Eu161	4.24E-07	1.51E-16	3.74E-12	0.00E+00	9.78E-13	1.10E-06	4.24E-08	1.88E-08
Eu162	2.17E-07	2.90E-17	1.47E-12	0.00E+00	2.97E-12	3.15E-06	1.61E-08	7.31E-09
Gd153	8.07E-10	2.27E-13	2.09E-16	0.00E+00	5.10E-16	6.91E-10	8.06E-09	6.27E-08
Gd159	0.002586	2.43E-09	4.78E-09	0.00E+00	7.96E-10	9.18E-04	4.69E-02	2.58E-02
Gd161	0.000242	7.59E-13	8.32E-10	0.00E+00	5.63E-10	5.99E-04	4.39E-05	7.25E-05
Gd162	3.39E-07	2.62E-15	7.08E-13	0.00E+00	8.57E-13	1.05E-06	3.51E-07	5.51E-07
Gd163	1.61E-07	1.58E-16	3.70E-13	0.00E+00	1.90E-12	8.67E-07	3.10E-08	4.76E-08
Gd164	7.97E-08	3.68E-17	5.43E-13	0.00E+00	4.24E-13	4.49E-07	9.14E-09	1.42E-08
Tb157	1.11E-09	4.82E-11	3.75E-17	0.00E+00	6.83E-17	1.64E-10	1.40E-09	4.93E-08
Tb158	6.59E-10	5.26E-11	3.95E-16	0.00E+00	3.14E-15	4.76E-09	2.68E-08	1.12E-06
Tb158m	3.46E-07	5.09E-17	1.69E-13	0.00E+00	4.95E-14	8.92E-08	2.82E-10	2.69E-10
Tb160	0.001834	1.62E-07	2.76E-09	0.00E+00	1.22E-08	1.84E-02	1.09E-01	4.75E-01
Tb161	0.000928	7.88E-09	1.10E-09	0.00E+00	1.86E-10	3.17E-04	2.47E-02	4.46E-02
Tb162	4.91E-06	3.21E-14	1.57E-11	0.00E+00	3.22E-11	4.43E-05	2.72E-06	2.54E-06
Tb163	1.74E-07	2.93E-15	3.46E-13	0.00E+00	8.11E-13	9.37E-07	1.67E-07	1.54E-07
Tb164	9.32E-08	2.44E-16	3.87E-14	0.00E+00	1.29E-12	1.94E-06	2.97E-08	2.76E-08
Tb165	4.46E-08	8.26E-17	2.62E-13	0.00E+00	1.32E-13	1.36E-07	8.58E-09	7.92E-09
Tb166	2.03E-08	2.48E-17	9.91E-14	0.00E+00	2.81E-13	2.85E-07	4.12E-09	4.12E-09

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Dy157	8.03E-07	3.27E-13	6.32E-14	0.00E+00	1.67E-12	1.86E-06	1.81E-06	8.91E-07
Dy159	1.15E-08	2.02E-12	8.74E-16	0.00E+00	3.10E-15	5.41E-09	4.25E-08	1.57E-07
Dy165	0.002678	3.29E-10	7.08E-09	0.00E+00	4.22E-10	5.25E-04	1.09E-02	5.95E-03
Dy165m	0.001719	1.90E-12	1.07E-09	0.00E+00	1.97E-10	3.03E-04	7.63E-05	4.26E-05
Dy166	1.06E-05	4.56E-11	9.75E-12	0.00E+00	2.48E-12	3.52E-06	6.25E-04	7.42E-04
Dy167	1.5E-08	8.25E-17	6.31E-14	0.00E+00	4.75E-14	5.53E-08	8.88E-09	4.83E-09
Dy168	5.15E-09	3.91E-17	9.37E-15	0.00E+00	1.79E-14	2.65E-08	6.67E-09	3.62E-09
Dy169	2.13E-09	1.24E-18	1.20E-14	0.00E+00	1.20E-14	1.23E-08	2.53E-10	1.42E-10
Dy170	8.1E-10	2.49E-19	3.35E-15	0.00E+00	3.35E-15	3.41E-09	6.89E-11	3.90E-11
Ho164	1.81E-09	4.51E-17	1.97E-15	0.00E+00	3.02E-16	4.93E-10	6.35E-10	5.62E-10
Ho164m	7.89E-10	2.59E-17	4.30E-16	0.00E+00	2.25E-16	4.36E-10	4.67E-10	3.51E-10
Ho166	0.003751	5.32E-09	1.54E-08	0.00E+00	6.47E-10	1.06E-03	1.94E-01	9.02E-02
Ho166m	9.89E-09	5.51E-09	6.02E-15	0.00E+00	1.01E-13	1.37E-07	7.32E-07	4.39E-05
Ho167	0.000204	3.36E-11	2.50E-10	0.00E+00	4.34E-10	4.29E-04	6.25E-04	5.35E-04
Ho168	5.46E-09	1.46E-17	2.32E-14	0.00E+00	2.73E-14	4.02E-08	1.48E-09	1.31E-09
Ho169	2.52E-09	9.96E-18	9.01E-15	0.00E+00	7.18E-15	1.04E-08	7.08E-10	6.34E-10
Ho170	1.03E-09	2.59E-18	5.10E-15	0.00E+00	1.12E-14	1.64E-08	4.57E-10	3.81E-10
Er165	2.24E-08	1.22E-14	6.87E-16	0.00E+00	5.03E-15	8.97E-09	1.58E-08	6.56E-09
Er167m	0.008786	2.96E-13	4.66E-09	0.00E+00	6.16E-09	3.90E-03	3.58E-06	4.55E-06
Er169	0.002177	2.62E-08	1.33E-09	0.00E+00	2.63E-13	1.62E-06	2.98E-02	8.05E-02
Er171	1.48E-06	6.06E-13	3.62E-12	0.00E+00	3.26E-12	3.24E-06	1.97E-05	1.20E-05
Er172	1.43E-09	3.87E-15	1.09E-15	0.00E+00	4.38E-15	5.69E-09	5.30E-08	5.83E-08
Tm168	2.19E-10	2.62E-14	1.60E-16	0.00E+00	1.57E-15	2.17E-09	7.77E-09	2.51E-08
Tm170	0.001684	2.82E-07	3.28E-09	0.00E+00	5.49E-11	5.65E-05	8.10E-02	4.36E-01
Tm171	9.25E-05	8.49E-08	1.39E-11	0.00E+00	3.42E-13	3.25E-07	3.76E-04	4.79E-03
Tm172	0.0001	3.51E-10	3.10E-10	0.00E+00	2.89E-10	4.93E-04	6.32E-03	4.09E-03
Tm173	1.41E-07	6.42E-14	2.58E-13	0.00E+00	3.24E-13	3.40E-07	1.62E-06	9.39E-07
Yb169	3.15E-10	1.30E-14	1.98E-16	0.00E+00	6.10E-16	4.17E-10	8.26E-09	3.49E-08
Yb175	6.89E-07	3.87E-12	4.97E-13	0.00E+00	3.27E-13	3.14E-07	1.12E-05	1.86E-05
Yb177	2.62E-09	2.80E-16	6.53E-15	0.00E+00	2.89E-15	4.15E-09	8.54E-09	6.70E-09
Yb177m	1.07E-09	1.08E-19	1.13E-15	0.00E+00	9.49E-16	7.32E-10	4.76E-12	3.97E-12
Lu176m	1.94E-06	4.01E-13	5.46E-12	0.00E+00	1.65E-13	1.75E-07	1.22E-05	8.62E-06
Lu177	9.02E-07	8.19E-12	7.88E-13	0.00E+00	1.97E-13	1.68E-07	1.77E-05	4.00E-05
Lu177m	9.69E-10	2.11E-13	4.72E-16	0.00E+00	9.64E-16	1.01E-09	6.10E-08	5.74E-07
Lu178	7.35E-08	1.98E-15	3.14E-13	0.00E+00	6.28E-14	1.05E-07	1.28E-07	7.08E-08

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Lu178m	5.25E-10	1.15E-17	1.53E-15	0.00E+00	3.28E-15	3.45E-09	7.39E-10	6.41E-10
Lu179	1.62E-10	4.24E-17	4.41E-16	0.00E+00	2.88E-17	2.60E-11	1.26E-09	7.19E-10
Hf174	1.92E-28	1.87E-16	0.00E+00	2.85E-33	0.00E+00	0.00E+00	5.48E-25	2.56E-24
Hf175	1.61E-10	1.51E-14	4.35E-17	0.00E+00	3.47E-16	3.52E-10	2.44E-09	7.15E-09
Hf177m	6.99E-08	1.18E-18	9.98E-14	0.00E+00	4.43E-13	4.13E-07	3.10E-11	6.21E-11
Hf177n	1.74E-10	8.43E-18	2.60E-16	0.00E+00	1.22E-15	1.25E-09	5.22E-10	5.80E-10
Hf178m	3.12E-08	1.97E-18	2.62E-14	0.00E+00	1.86E-13	1.97E-07	4.51E-11	9.13E-11
Hf179m	0.000103	3.04E-14	7.37E-11	0.00E+00	1.44E-10	1.27E-04	2.17E-07	4.18E-07
Hf179n	3.74E-07	1.29E-11	3.76E-13	0.00E+00	2.05E-12	2.13E-06	1.66E-05	5.25E-05
Hf180m	1.06E-05	3.35E-12	9.33E-12	0.00E+00	6.23E-11	6.71E-05	6.66E-05	5.09E-05
Hf181	0.002344	1.38E-07	2.84E-09	0.00E+00	7.37E-09	8.33E-03	9.54E-02	4.34E-01
Hf182m	1.07E-06	6.35E-14	1.29E-12	0.00E+00	6.20E-12	6.80E-06	1.66E-06	1.82E-06
Hf183	3.58E-05	2.23E-12	8.92E-11	0.00E+00	1.64E-10	2.20E-04	9.68E-05	7.56E-05
Ta180	4.86E-09	2.26E-15	1.85E-15	0.00E+00	1.32E-15	1.23E-09	9.72E-09	7.92E-09
Ta182	0.000117	1.87E-08	1.50E-10	0.00E+00	8.90E-10	1.41E-03	6.49E-03	4.33E-02
Ta182m	2.57E-06	1.17E-17	2.18E-13	0.00E+00	2.92E-14	2.16E-07	1.43E-11	3.42E-11
Ta182n	2.52E-06	3.86E-14	3.65E-12	0.00E+00	3.80E-12	2.98E-06	1.12E-06	1.96E-06
Ta183	0.0041	2.92E-08	8.49E-09	0.00E+00	6.97E-09	6.57E-03	1.97E-01	3.19E-01
Ta184	7.14E-06	3.65E-12	2.13E-11	0.00E+00	6.96E-11	8.75E-05	1.80E-04	1.14E-04
W 181	5.71E-06	9.56E-10	4.29E-13	0.00E+00	1.39E-12	1.38E-06	1.60E-05	5.70E-06
W 183m	0.007203	6.13E-13	7.86E-09	0.00E+00	5.36E-09	5.44E-03	8.53E-06	1.01E-06
W 185	0.031351	3.33E-06	2.36E-08	0.00E+00	9.32E-12	7.62E-06	5.10E-01	1.39E-01
W 185m	0.012565	2.06E-11	1.28E-08	0.00E+00	1.92E-09	3.04E-03	1.81E-04	2.23E-05
W 187	0.00377	5.37E-09	6.74E-09	0.00E+00	9.88E-09	1.27E-02	8.79E-02	2.65E-02
W 188	4.71E-06	4.71E-10	2.78E-12	0.00E+00	5.28E-14	4.69E-08	3.66E-04	9.94E-05
W 189	4.25E-08	4.91E-16	2.10E-13	0.00E+00	3.10E-13	3.73E-07	5.03E-08	5.98E-09
Re184	1.42E-09	7.62E-14	4.14E-16	0.00E+00	7.53E-15	1.07E-08	5.27E-08	1.00E-07
Re184m	1.42E-10	3.32E-14	1.10E-16	0.00E+00	3.28E-16	3.96E-10	7.89E-09	3.42E-08
Re186	0.032946	1.77E-07	6.61E-08	0.00E+00	3.42E-09	2.73E-03	1.83E+00	1.34E+00
Re186m	6.27E-10	6.51E-08	2.53E-16	0.00E+00	2.23E-16	4.41E-10	5.10E-08	2.78E-07
Re188	0.007886	8.03E-09	3.65E-08	0.00E+00	2.70E-09	3.07E-03	4.09E-01	1.58E-01
Re188m	0.000213	3.96E-12	1.04E-10	0.00E+00	9.35E-11	9.01E-05	2.37E-04	1.03E-04
Re189	3.75E-07	5.50E-13	7.12E-13	0.00E+00	1.33E-13	1.27E-07	1.08E-05	5.97E-06
Os185	6.87E-09	9.13E-13	7.47E-16	0.00E+00	2.93E-14	4.04E-08	1.30E-07	4.07E-07
Os189m	0.002803	8.12E-10	4.03E-10	0.00E+00	3.34E-11	2.46E-04	1.87E-03	5.50E-04

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Os190m	8.45E-07	8.45E-15	5.85E-13	0.00E+00	7.95E-12	9.60E-06	1.25E-06	1.34E-06
Os191	0.00733	1.65E-07	3.69E-09	0.00E+00	1.74E-09	1.71E-03	1.55E-01	5.15E-01
Os191m	0.005359	4.28E-09	2.11E-09	0.00E+00	2.50E-10	6.57E-04	1.90E-02	3.17E-02
Os192m	9.32E-07	9.36E-17	8.90E-13	0.00E+00	1.04E-11	1.22E-05	1.66E-08	1.76E-08
Os193	0.001022	1.92E-09	2.28E-09	0.00E+00	4.06E-10	4.43E-04	3.06E-02	1.97E-02
Os194	4.07E-07	1.32E-09	7.81E-14	0.00E+00	5.55E-15	1.05E-08	3.62E-05	1.28E-03
Os195	3.73E-08	2.52E-16	1.58E-13	0.00E+00	3.15E-14	4.48E-08	2.76E-08	2.35E-08
Ir190	3.33E-10	5.81E-15	1.42E-16	0.00E+00	2.92E-15	3.52E-09	1.48E-08	2.96E-08
Ir191m	1.41E-07	1.17E-17	8.09E-14	0.00E+00	6.29E-14	6.57E-08	1.09E-10	2.24E-10
Ir191n	6.22E-08	5.79E-18	1.69E-14	0.00E+00	6.89E-13	8.41E-07	6.68E-10	1.36E-09
Ir192	0.001456	1.58E-07	1.88E-09	0.00E+00	7.05E-09	7.85E-03	7.54E-02	3.55E-01
Ir192m	0.005227	7.68E-12	1.69E-09	0.00E+00	7.56E-11	5.47E-04	2.71E-05	6.58E-05
Ir192n	2.67E-10	3.45E-11	2.61E-16	0.00E+00	4.88E-18	2.99E-11	3.06E-09	3.85E-07
Ir193m	0.000745	1.17E-08	3.24E-10	0.00E+00	1.06E-11	6.86E-05	7.44E-03	3.58E-02
Ir194	0.006646	7.88E-09	3.19E-08	0.00E+00	3.59E-09	4.45E-03	3.20E-01	1.38E-01
Ir194m	6.15E-06	1.56E-09	3.02E-12	0.00E+00	8.49E-11	1.05E-04	4.78E-04	2.96E-03
Ir195	6.83E-05	1.06E-11	1.54E-10	0.00E+00	2.35E-11	2.52E-05	2.53E-04	1.79E-04
Ir195m	1.01E-05	2.40E-12	2.06E-11	0.00E+00	2.45E-11	2.91E-05	7.87E-05	6.37E-05
Pt191	2.95E-09	1.25E-14	1.11E-15	0.00E+00	4.76E-15	5.15E-09	3.71E-08	1.20E-08
Pt193	0.000154	4.14E-06	7.15E-12	0.00E+00	3.07E-11	3.60E-05	1.76E-04	1.19E-04
Pt193m	0.0003	1.92E-09	2.45E-10	0.00E+00	2.19E-11	4.55E-05	4.99E-03	1.33E-03
Pt195m	0.000171	1.03E-09	1.72E-10	0.00E+00	7.72E-11	9.88E-05	4.00E-03	1.14E-03
Pt197	5.21E-05	6.51E-11	7.86E-11	0.00E+00	7.53E-12	9.51E-06	7.71E-04	1.64E-04
Pt197m	3.13E-06	3.12E-13	5.88E-12	0.00E+00	1.41E-12	1.80E-06	9.72E-06	2.78E-06
Pt199	3.46E-10	1.13E-17	1.11E-15	0.00E+00	4.13E-16	4.96E-10	5.00E-10	1.54E-10
Au197m	1.11E-07	1.51E-17	1.22E-13	0.00E+00	1.49E-13	1.41E-07	4.54E-10	4.12E-10
Au198	2.89E-05	1.18E-10	5.61E-11	0.00E+00	6.90E-11	8.44E-05	1.07E-03	9.19E-04
Au198m	2.47E-08	8.63E-14	3.84E-14	0.00E+00	7.74E-14	6.77E-08	1.19E-06	1.83E-06
Au199	4.59E-05	2.20E-10	3.95E-11	0.00E+00	2.61E-11	2.05E-05	7.47E-04	1.34E-03
Au200	7.84E-08	4.04E-15	3.44E-13	0.00E+00	1.27E-13	1.95E-07	1.97E-07	1.02E-07
Au200m	1.02E-10	1.22E-16	1.52E-16	0.00E+00	1.20E-15	1.42E-09	4.16E-09	2.72E-09
Hg197	9.6E-09	3.90E-14	3.94E-15	0.00E+00	4.18E-15	4.76E-09	8.17E-08	1.07E-07
Hg197m	4.62E-09	6.93E-15	5.49E-15	0.00E+00	2.13E-15	2.09E-09	8.03E-08	9.05E-08
Hg199m	6.97E-06	3.10E-13	1.44E-11	0.00E+00	7.62E-12	6.73E-06	7.99E-06	8.25E-06
Hg203	0.000841	6.09E-08	4.94E-10	0.00E+00	1.18E-09	1.03E-03	5.91E-02	7.46E-02

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Hg205	1.69E-05	9.58E-14	5.37E-11	0.00E+00	6.90E-13	5.10E-07	3.38E-06	2.50E-06
Tl202	2.68E-09	5.07E-14	3.57E-16	0.00E+00	7.41E-15	8.77E-09	4.46E-08	1.88E-08
Tl204	0.000562	1.22E-06	7.87E-10	0.00E+00	3.53E-12	3.53E-06	2.50E-02	8.11E-03
Tl206	1.59E-05	7.32E-14	5.07E-11	0.00E+00	1.33E-13	6.38E-09	4.47E-07	3.83E-07
Tl206m	1.1E-08	4.52E-17	9.96E-15	0.00E+00	1.62E-13	2.15E-07	1.62E-09	1.38E-09
Tl207	1.13E-07	5.94E-16	3.30E-13	0.00E+00	2.24E-15	2.24E-09	3.31E-09	2.85E-09
Tl208	1.69E-09	5.70E-18	5.94E-15	0.00E+00	3.39E-14	6.30E-08	2.56E-10	2.18E-10
Pb203	1.1E-09	3.69E-15	3.41E-16	0.00E+00	2.05E-15	1.87E-09	9.76E-09	8.94E-09
Pb203m	3.2E-10	3.62E-20	3.25E-16	0.00E+00	1.24E-15	1.89E-09	1.66E-12	1.66E-12
Pb204m	9.39E-09	6.87E-16	5.75E-15	0.00E+00	1.16E-13	1.67E-07	7.64E-08	7.99E-08
Pb207m	4.98E-07	7.35E-18	0.00E+00	0.00E+00	4.82E-12	7.17E-06	5.89E-10	6.45E-10
Pb209	2.31E-07	5.02E-14	2.71E-13	0.00E+00	0.00E+00	0.00E+00	4.88E-07	5.22E-07
Pb212	4.69E-09	3.38E-15	4.86E-15	0.00E+00	4.02E-15	3.60E-09	1.04E-06	3.30E-05
Bi208m	1.71E-08	8.12E-22	7.29E-15	0.00E+00	1.52E-13	2.14E-07	9.47E-15	4.42E-15
Bi210	7.33E-05	5.91E-10	1.68E-10	2.68E-15	2.94E-13	1.29E-10	3.53E-03	2.52E-01
Bi210m	1.94E-10	3.42E-07	5.40E-17	5.76E-15	3.01E-16	2.95E-10	1.08E-07	2.44E-05
Bi211	1.13E-07	2.76E-16	6.76E-15	4.49E-12	3.20E-14	3.29E-08	2.69E-07	1.26E-07
Bi212	4.69E-09	3.20E-16	1.39E-14	6.17E-14	3.02E-15	4.66E-09	4.51E-08	5.38E-06
Po210	7.33E-05	1.63E-08	3.63E-17	2.35E-09	3.84E-15	5.88E-09	3.25E+00	1.17E+01
Po211	3.08E-09	2.97E-20	2.87E-18	1.38E-13	1.41E-16	1.99E-10	5.58E-10	8.65E-10
Po216	4.69E-09	1.30E-20	0.00E+00	1.92E-13	4.03E-19	6.17E-13	2.26E-10	7.98E-10
Rn220	4.69E-09	5.09E-18	0.00E+00	1.78E-13	1.93E-17	2.35E-11	6.94E-08	1.60E-07
Ra224	4.69E-09	2.91E-14	6.20E-17	1.61E-13	2.80E-16	2.47E-10	1.13E-05	5.90E-04
Ra229	2.85E-07	1.39E-15	9.92E-13	0.00E+00	9.92E-13	1.04E-06	2.43E-05	8.97E-04
Ac229	2.85E-07	2.18E-14	6.61E-13	0.00E+00	7.43E-13	3.37E-06	7.07E-06	7.70E-04
Th228	4.7E-09	5.74E-12	6.04E-16	1.53E-13	8.99E-17	2.38E-10	1.25E-05	6.96E-03
Th231	3.07E-07	5.77E-13	3.00E-13	0.00E+00	4.70E-14	1.50E-07	3.86E-06	3.75E-06
Th233	0.00212	5.86E-11	5.18E-09	0.00E+00	4.71E-10	6.36E-04	1.41E-02	1.41E-02
Th235	9.48E-10	8.18E-18	3.60E-15	0.00E+00	3.60E-15	3.71E-09	7.37E-09	7.37E-09
Pa232	3.01E-07	7.00E-13	3.00E-13	0.00E+00	1.67E-12	2.45E-06	8.01E-06	1.11E-04
Pa233	0.002095	1.01E-07	2.44E-09	0.00E+00	2.68E-09	3.05E-03	6.74E-02	3.02E-01
Pa234	1.45E-05	7.33E-12	3.31E-11	0.00E+00	1.23E-10	1.82E-04	2.73E-04	2.14E-04
Pa234m	1.52E-05	2.22E-14	7.36E-11	0.00E+00	1.78E-12	2.41E-06	4.05E-07	9.00E-05
Pa235	9.93E-10	3.00E-17	2.73E-15	0.00E+00	5.81E-17	5.76E-11	3.09E-10	6.98E-08
U 232	9.26E-09	4.20E-10	9.25E-16	2.96E-13	9.25E-17	4.85E-10	1.13E-04	1.27E-02

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
U 233	6.6E-09	6.85E-07	2.97E-16	1.92E-13	4.79E-17	2.40E-10	1.25E-05	2.34E-03
U 234	2.86E-09	4.60E-07	2.40E-16	8.21E-14	2.46E-17	1.37E-10	5.19E-06	9.95E-04
U 235m	0.000125	4.05E-12	5.62E-14	0.00E+00	0.00E+00	4.15E-24	7.84E-08	1.94E-07
U 237	2.16E-05	2.65E-10	2.56E-11	0.00E+00	1.84E-11	1.99E-05	6.08E-04	1.52E-03
U 239	0.001846	5.51E-11	4.49E-09	0.00E+00	5.64E-10	6.00E-04	1.84E-03	1.64E-03
Np238	1.99E-05	7.68E-11	2.74E-11	0.00E+00	7.60E-11	1.22E-04	6.70E-04	2.58E-03
Np239	0.001841	7.94E-09	2.87E-09	0.00E+00	1.99E-09	2.02E-03	5.45E-02	6.81E-02
Np240	1.67E-06	1.38E-13	4.61E-12	0.00E+00	1.23E-11	1.76E-05	5.06E-06	5.55E-06
Np240m	3.09E-06	2.92E-14	1.25E-11	0.00E+00	6.16E-12	8.66E-06	9.71E-07	4.11E-05
Pu238	2.04E-07	1.19E-08	1.36E-14	6.76E-12	1.88E-15	1.11E-08	1.74E-03	8.32E-01
Pu239	7.67E-09	1.24E-07	3.36E-16	2.38E-13	3.22E-17	1.80E-10	7.10E-05	3.41E-02
Pu240	5.46E-08	2.41E-07	3.60E-15	1.70E-12	4.41E-16	2.61E-09	5.05E-04	2.43E-01
Pu241	6.72E-06	6.52E-08	2.09E-13	4.78E-15	6.58E-17	8.28E-11	1.19E-03	5.72E-01
Pu242	3.48E-09	8.81E-07	1.94E-16	1.03E-13	2.67E-17	1.53E-10	3.09E-05	1.42E-02
Pu243	0.000206	7.90E-11	2.12E-10	0.00E+00	3.06E-11	3.36E-05	6.47E-04	6.54E-04
Pu245	1.02E-08	8.39E-15	2.01E-14	0.00E+00	2.41E-14	3.08E-08	2.72E-07	1.63E-07
Am241	2.82E-09	8.23E-10	6.57E-16	9.32E-14	4.72E-16	8.23E-10	2.09E-05	1.00E-02
Am242	5.96E-06	7.38E-12	6.38E-12	0.00E+00	6.12E-13	1.21E-06	6.62E-05	4.41E-03
Am243	6.07E-08	3.04E-07	8.62E-15	1.93E-12	2.05E-14	1.96E-08	4.49E-04	2.16E-01
Am244	1.27E-05	1.00E-11	2.33E-11	0.00E+00	6.36E-11	9.42E-05	2.17E-04	1.74E-03
Am244m	0.000191	6.44E-12	5.70E-10	0.00E+00	1.41E-11	2.56E-05	2.05E-04	1.13E-03
Am245	1.02E-08	1.64E-15	1.73E-14	0.00E+00	1.68E-15	1.67E-09	2.34E-08	2.12E-08
Cm242	4.81E-06	1.45E-09	2.90E-13	1.77E-10	3.92E-14	2.33E-07	2.14E-03	1.05E+00
Cm243	1.55E-09	3.16E-11	1.28E-15	5.45E-14	1.22E-15	1.32E-09	8.59E-06	3.95E-03
Cm244	5.45E-05	6.73E-07	2.78E-12	1.90E-09	4.20E-13	2.48E-06	2.42E-01	1.15E+02
Cm245	2.16E-09	1.26E-08	1.04E-15	6.96E-14	1.20E-15	1.30E-09	1.68E-05	7.90E-03
Cm246	1.93E-08	6.27E-08	9.36E-16	6.30E-13	3.43E-16	7.98E-10	1.50E-04	6.98E-02
Cm249	4.48E-08	3.81E-15	7.54E-14	0.00E+00	5.23E-15	7.50E-09	5.14E-08	6.63E-08
Bk249	2.35E-09	1.44E-12	4.61E-16	1.10E-18	4.39E-19	2.54E-12	8.44E-08	1.39E-05
Bk250	4.23E-08	1.09E-14	7.45E-14	0.00E+00	2.27E-13	3.62E-07	2.19E-07	1.57E-06
Cf252	5.78E-09	1.08E-11	2.06E-16	4.05E-13	7.45E-15	1.91E-10	1.93E-05	4.28E-03

* This value does not include 14C produced from neutron activation of 14N, which is a major contributor to the 14C inventory in irradiated graphite.

9.2 Appendix B

Table 27: Average Composition and Radioactivity Properties Predicted for Post-Irradiation (24 Full Power Years) PBMR Side Reflector (Quantities for 1 kg graphite; cut-off activity 10-1 Ci) [19]

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
H 3	0.020495	2.13E-06	6.97E-10	0.00E+00	0.00E+00	0.00E+00	3.20E-02	1.98E-01
He 6	4.91E-05	2.12E-17	6.08E-10	0.00E+00	2.20E-12	2.52E-06	8.02E-08	1.12E-07
Li 8	0.000717	4.28E-16	5.25E-08	2.64E-08	2.79E-10	4.85E-04	5.28E-06	3.27E-06
Li 9	1.43E-09	2.05E-22	6.46E-14	0.00E+00	3.39E-16	5.76E-10	1.49E-13	9.20E-14
Be 10	1.59E-08	7.11E-07	3.07E-14	0.00E+00	0.00E+00	0.00E+00	8.35E-07	2.66E-05
Be 11	4.68E-08	6.32E-19	3.26E-12	2.54E-14	9.94E-13	2.14E-06	1.31E-09	1.14E-09
B 12	0.000495	1.07E-17	2.80E-08	2.95E-11	4.02E-10	5.65E-04	1.05E-07	5.27E-08
B 13	4.09E-05	8.17E-19	1.63E-09	3.38E-12	8.15E-11	1.56E-04	5.52E-09	2.76E-09
C 14*	0.004514	1.01E-03	2.60E-09	0.00E+00	0.00E+00	0.00E+00	1.90E-01	1.90E+00
C 15	7.9E-08	2.58E-19	4.32E-12	0.00E+00	5.48E-12	1.28E-05	2.08E-09	1.61E-09
N 13	9.8E-09	6.76E-18	2.85E-14	0.00E+00	5.94E-14	7.24E-08	4.72E-09	3.45E-09
N 16	6.5E-08	6.58E-19	2.67E-12	2.96E-17	4.61E-12	1.08E-05	4.55E-09	3.43E-09
Ne 23	1.35E-05	1.02E-15	1.74E-10	0.00E+00	1.59E-11	1.98E-05	1.15E-06	1.61E-06
Na 24	0.137459	1.58E-08	8.86E-07	0.00E+00	6.60E-06	1.28E+01	4.30E+00	2.70E+00
Na 24m	0.09773	4.20E-15	1.57E-08	0.00E+00	5.35E-07	6.53E-01	1.28E-06	7.82E-07
Na 25	2.18E-07	2.88E-17	2.58E-12	0.00E+00	7.52E-13	1.13E-06	2.15E-09	1.29E-09
Na 26	9.26E-10	2.30E-21	1.96E-14	0.00E+00	1.29E-14	2.43E-08	4.05E-13	2.36E-13
Mg 27	0.000152	2.06E-13	1.22E-09	0.00E+00	1.56E-09	2.43E-03	1.95E-04	9.99E-05
Al 26m	3.23E-10	4.72E-21	2.87E-15	0.00E+00	2.05E-15	2.49E-09	4.37E-12	3.12E-12
Al 28	0.026014	8.68E-12	3.77E-07	0.00E+00	5.43E-07	1.03E+00	1.75E-02	1.26E-02
Al 29	6.54E-07	6.62E-16	4.74E-12	0.00E+00	6.72E-12	1.18E-05	6.38E-07	4.56E-07
Al 30	2.44E-09	2.37E-20	3.56E-14	0.00E+00	5.46E-14	1.09E-07	4.66E-11	3.30E-11
Si 31	0.000613	1.59E-11	4.04E-09	0.00E+00	1.48E-11	1.04E-05	6.80E-03	3.36E-03
Si 32	5.54E-10	1.64E-11	7.95E-16	0.00E+00	0.00E+00	0.00E+00	4.30E-08	8.44E-06
P 30	3.04E-10	1.21E-19	2.73E-15	0.00E+00	1.94E-15	2.37E-09	9.01E-11	2.25E-10
P 32	0.00178	6.22E-09	1.41E-08	0.00E+00	3.48E-11	3.55E-05	3.05E-01	4.31E-01
P 33	0.003216	2.06E-08	3.04E-09	0.00E+00	0.00E+00	0.00E+00	5.95E-02	3.72E-01
P 34	2.11E-07	7.87E-18	6.58E-12	0.00E+00	1.00E-12	1.93E-06	1.20E-08	3.06E-08
S 35	0.008941	2.10E-07	1.97E-09	0.00E+00	0.00E+00	0.00E+00	1.93E-01	4.77E-01
S 37	7.43E-06	7.29E-15	1.46E-10	0.00E+00	5.41E-10	1.16E-03	1.72E-05	1.49E-05
Cl 34	4.06E-10	1.87E-21	1.55E-15	0.00E+00	7.82E-16	9.46E-10	3.98E-13	1.47E-13

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Cl 36	6.33E-05	1.95E-03	9.65E-11	0.00E+00	1.07E-14	1.86E-08	2.28E-03	1.79E-02
Cl 38	0.010851	8.15E-11	2.76E-07	0.00E+00	2.71E-07	5.15E-01	1.36E-01	5.09E-02
Cl 38m	0.001292	3.11E-15	9.27E-12	0.00E+00	1.45E-08	2.02E-02	6.33E-06	2.43E-06
Ar 37	0.058649	5.82E-07	1.28E-09	0.00E+00	1.75E-10	8.98E-04	9.47E-02	1.01E+00
Ar 39	5.58E-07	1.64E-08	1.16E-12	0.00E+00	0.00E+00	0.00E+00	7.94E-05	7.94E-03
Ar 41	2.6E-05	6.22E-13	4.03E-10	0.00E+00	1.12E-09	1.92E-03	1.63E-03	2.28E-03
K 38	3.9E-10	5.99E-19	2.77E-15	0.00E+00	7.36E-15	1.27E-08	4.75E-10	1.14E-10
K 40	2.22E-10	3.17E-05	8.95E-16	0.00E+00	2.70E-16	4.82E-10	6.64E-08	2.25E-08
K 42	0.001676	2.78E-10	3.83E-08	0.00E+00	8.01E-09	1.41E-02	7.26E-02	2.03E-02
K 43	3.29E-08	1.00E-14	1.12E-13	0.00E+00	3.49E-13	4.34E-07	5.64E-07	3.16E-07
K 44	7.3E-09	3.78E-17	6.92E-14	0.00E+00	1.15E-13	2.12E-07	2.53E-08	6.01E-09
Ca 39	5.96E-10	1.77E-21	8.65E-15	0.00E+00	3.45E-15	4.21E-09	3.37E-12	7.59E-12
Ca 41	1.21E-05	1.42E-04	3.78E-13	0.00E+00	5.82E-14	4.04E-07	1.58E-04	1.50E-04
Ca 45	0.003627	2.03E-07	3.22E-09	0.00E+00	4.87E-16	3.57E-09	1.85E-01	9.64E-01
Ca 47	6.7E-06	1.09E-11	3.65E-11	0.00E+00	1.12E-10	1.91E-04	1.06E-03	1.39E-03
Ca 49	0.0004	9.08E-13	3.98E-09	0.00E+00	1.45E-08	3.12E-02	3.72E-03	8.29E-03
Sc 44	6.48E-10	3.57E-17	1.39E-15	0.00E+00	4.97E-15	7.18E-09	5.08E-09	2.61E-09
Sc 44m	2.4E-10	1.97E-16	2.80E-17	0.00E+00	2.35E-16	2.30E-10	1.28E-08	7.46E-09
Sc 45m	1.73E-05	2.18E-17	5.97E-13	0.00E+00	4.23E-14	3.04E-07	3.64E-11	1.78E-11
Sc 46	0.019041	5.62E-07	1.43E-08	0.00E+00	2.57E-07	4.07E-01	1.20E+00	5.42E+00
Sc 46m	0.008416	6.41E-13	3.32E-09	0.00E+00	4.67E-09	3.21E-03	2.85E-05	1.93E-05
Sc 47	6.83E-05	8.22E-11	1.49E-10	0.00E+00	9.92E-11	6.58E-05	3.08E-03	4.17E-03
Sc 48	1.96E-07	1.31E-13	2.51E-13	0.00E+00	3.83E-12	6.26E-06	1.21E-05	7.86E-06
Sc 49	0.0004	5.96E-12	3.76E-09	0.00E+00	1.53E-11	8.99E-06	2.34E-03	1.14E-03
Sc 50	3.36E-10	1.53E-19	5.02E-15	0.00E+00	9.87E-15	1.63E-08	2.70E-10	1.35E-10
Ti 45	4.61E-10	2.04E-17	1.18E-15	0.00E+00	2.75E-15	3.36E-09	2.96E-09	1.83E-09
Ti 51	0.000465	7.31E-13	5.98E-09	0.00E+00	2.51E-09	2.77E-03	6.44E-04	4.72E-04
V 52	0.08873	9.18E-11	9.75E-07	0.00E+00	1.33E-06	2.28E+00	8.00E-02	5.26E-02
V 53	3.58E-09	1.64E-18	2.60E-14	0.00E+00	2.70E-14	4.40E-08	7.91E-10	5.81E-10
Cr 51	0.001706	1.84E-08	4.96E-11	0.00E+00	4.22E-10	5.25E-04	3.05E-03	2.97E-03
Cr 55	9.52E-05	9.84E-14	1.96E-09	0.00E+00	7.59E-12	2.18E-06	1.56E-05	6.81E-06
Cr 56	1.79E-06	3.17E-15	5.36E-11	0.00E+00	8.20E-12	7.23E-06	3.81E-06	1.66E-06
Mn 54	1.87E-05	2.41E-09	5.02E-13	0.00E+00	9.96E-11	1.54E-04	5.28E-04	1.12E-03
Mn 56	0.016519	7.60E-10	1.40E-07	0.00E+00	2.89E-07	5.01E-01	2.65E-01	1.27E-01
Mn 57	3.31E-07	1.62E-16	4.07E-12	0.00E+00	2.79E-13	3.74E-07	2.78E-08	1.34E-08

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Mn 58	2.09E-10	7.01E-20	4.94E-15	0.00E+00	6.87E-15	1.14E-08	5.04E-11	2.52E-11
Mn 58m	4.91E-11	6.81E-22	1.91E-15	0.00E+00	8.12E-17	1.38E-10	3.59E-13	1.73E-13
Fe 53	1.78E-10	4.27E-19	1.17E-15	0.00E+00	1.26E-15	1.52E-09	6.09E-11	5.96E-11
Fe 55	0.024459	1.03E-05	7.09E-10	0.00E+00	2.81E-10	2.06E-03	3.46E-01	8.07E-01
Fe 59	0.001127	2.26E-08	3.29E-09	0.00E+00	3.31E-08	5.52E-02	3.13E-01	6.96E-01
Fe 60	2.25E-11	5.65E-09	7.38E-17	0.00E+00	0.00E+00	0.00E+00	5.78E-07	1.47E-06
Fe 61	4.21E-08	8.16E-17	3.31E-12	0.00E+00	4.37E-12	7.14E-06	1.65E-07	1.61E-07
Co 57	2.28E-08	2.70E-12	2.10E-15	0.00E+00	1.30E-14	1.21E-08	1.38E-07	6.56E-07
Co 58	9.26E-06	2.91E-10	1.12E-12	0.00E+00	3.18E-11	4.75E-05	1.50E-04	4.26E-04
Co 58m	7.33E-06	1.21E-12	7.30E-13	0.00E+00	5.75E-14	4.23E-07	4.72E-06	3.35E-06
Co 60	0.015476	1.37E-05	9.76E-09	0.00E+00	2.53E-07	4.24E-01	2.14E+00	1.95E+01
Co 60m	0.006789	2.27E-11	2.10E-09	0.00E+00	2.53E-10	8.48E-04	3.95E-04	3.26E-04
Co 61	0.000291	9.34E-12	1.72E-09	0.00E+00	3.37E-10	3.25E-04	1.72E-03	1.18E-03
Co 62	1.76E-10	8.69E-20	1.64E-15	0.00E+00	1.62E-15	2.82E-09	4.11E-11	3.04E-11
Co 62m	1.27E-10	5.81E-19	7.75E-16	0.00E+00	2.07E-15	3.55E-09	2.25E-10	1.01E-10
Co 63	1.69E-10	2.58E-20	2.32E-15	0.00E+00	1.74E-16	2.25E-10	1.00E-11	7.10E-12
Ni 57	4.39E-10	2.84E-16	3.43E-16	0.00E+00	4.15E-15	6.76E-09	1.15E-08	7.00E-09
Ni 59	2.05E-06	2.57E-05	4.75E-14	0.00E+00	2.62E-14	1.80E-07	4.04E-06	2.82E-05
Ni 63	0.000508	8.85E-06	6.56E-11	0.00E+00	0.00E+00	0.00E+00	3.58E-03	3.11E-02
Ni 65	0.000232	1.21E-11	2.66E-09	0.00E+00	2.33E-09	3.99E-03	4.75E-03	2.38E-03
Ni 68	1.47E-10	1.68E-20	7.38E-16	0.00E+00	7.38E-16	7.55E-10	8.07E-12	4.17E-12
Ni 69	3.04E-10	2.12E-20	2.64E-15	0.00E+00	6.47E-15	1.11E-08	1.45E-11	7.67E-12
Cu 62	6.43E-10	2.06E-18	4.62E-15	0.00E+00	3.64E-15	4.44E-09	1.37E-09	8.54E-10
Cu 64	0.001522	3.94E-10	2.00E-09	0.00E+00	3.04E-09	3.87E-03	1.19E-02	1.19E-02
Cu 66	0.000402	7.20E-13	5.43E-09	0.00E+00	4.16E-10	6.47E-04	5.07E-04	3.14E-04
Cu 67	1.38E-07	1.83E-13	2.45E-13	0.00E+00	1.82E-13	1.28E-07	3.34E-06	6.00E-06
Cu 68	5.11E-10	9.57E-20	5.48E-15	0.00E+00	3.80E-15	6.36E-09	8.15E-11	5.12E-11
Cu 68m	1.34E-10	1.82E-19	1.89E-16	0.00E+00	1.02E-15	1.47E-09	2.03E-10	1.22E-10
Cu 69	4.1E-10	4.51E-19	3.21E-15	0.00E+00	6.90E-16	1.08E-09	2.33E-10	1.55E-10
Cu 70	2.26E-10	6.30E-21	4.98E-15	0.00E+00	9.25E-16	1.44E-09	7.55E-12	4.66E-12
Cu 70m	7.18E-10	2.09E-19	9.66E-15	0.00E+00	1.57E-14	2.55E-08	3.36E-10	2.08E-10
Cu 71	2.17E-09	2.66E-19	2.51E-14	0.00E+00	2.14E-14	3.07E-08	3.86E-10	2.36E-10
Cu 72	3.68E-09	1.55E-19	8.72E-14	0.00E+00	5.71E-14	9.63E-08	2.75E-10	1.78E-10
Cu 73	6.16E-09	1.55E-19	9.85E-14	0.00E+00	3.62E-14	3.78E-08	2.79E-10	1.73E-10
Cu 74	5.69E-09	5.98E-20	8.81E-14	0.00E+00	2.25E-13	2.74E-07	2.49E-10	1.54E-10

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Cu 75	5.25E-09	4.54E-20	9.51E-14	0.00E+00	8.92E-14	1.14E-07	1.57E-10	9.60E-11
Zn 63	4.96E-10	6.38E-18	2.81E-15	0.00E+00	3.39E-15	4.28E-09	1.51E-09	7.09E-10
Zn 65	0.000896	1.09E-07	6.20E-11	0.00E+00	5.17E-09	8.52E-03	2.16E-01	1.22E-01
Zn 69	0.000576	1.20E-11	2.14E-09	0.00E+00	4.07E-14	4.86E-08	1.29E-03	1.17E-03
Zn 69m	4.75E-05	1.44E-11	1.22E-11	0.00E+00	2.30E-10	2.81E-04	1.14E-03	9.29E-04
Zn 71	1.49E-06	1.37E-15	1.82E-11	0.00E+00	5.48E-12	7.37E-06	8.03E-07	5.53E-07
Zn 71m	1.46E-07	1.30E-14	9.14E-13	0.00E+00	2.68E-12	3.39E-06	2.55E-06	1.70E-06
Zn 72	7.37E-09	7.87E-15	6.10E-15	0.00E+00	9.06E-15	8.30E-09	5.19E-07	4.82E-07
Zn 73	1.53E-08	2.33E-18	2.30E-13	0.00E+00	1.48E-14	2.44E-08	1.55E-09	1.09E-09
Zn 73m	6.11E-09	2.29E-19	3.73E-14	0.00E+00	4.22E-14	4.28E-08	1.99E-10	1.37E-10
Zn 74	4.24E-08	2.66E-17	2.77E-13	0.00E+00	1.04E-13	1.19E-07	3.89E-08	2.60E-08
Zn 75	7.37E-08	5.00E-18	1.19E-12	0.00E+00	1.10E-12	1.86E-06	7.92E-09	5.66E-09
Zn 76	1.13E-07	4.34E-18	1.24E-12	0.00E+00	1.24E-12	1.36E-06	9.34E-09	6.42E-09
Ga 67	3.68E-15	6.16E-21	5.57E-22	0.00E+00	2.88E-21	3.02E-15	2.20E-14	2.78E-14
Ga 68	1.22E-09	2.97E-17	5.68E-15	0.00E+00	7.28E-15	9.02E-09	4.79E-09	2.35E-09
Ga 70	0.000577	4.54E-12	4.02E-09	0.00E+00	4.56E-11	7.15E-05	1.21E-03	6.23E-04
Ga 72	0.000869	2.81E-10	4.26E-09	0.00E+00	2.29E-08	4.02E-02	5.82E-02	2.80E-02
Ga 73	5.43E-08	6.16E-15	3.84E-13	0.00E+00	1.59E-13	1.57E-07	1.28E-06	6.90E-07
Ga 74	4.99E-08	1.59E-16	4.08E-13	0.00E+00	1.23E-12	2.17E-06	1.86E-07	9.68E-08
Ga 74m	1.14E-09	7.08E-20	1.57E-16	0.00E+00	4.00E-16	3.21E-10	8.72E-11	4.36E-11
Ga 75	1.19E-07	1.03E-16	1.35E-12	0.00E+00	6.55E-14	7.91E-08	5.67E-08	2.93E-08
Ga 76	2.5E-07	4.56E-17	4.27E-12	0.00E+00	5.76E-12	1.04E-05	6.43E-08	3.34E-08
Ga 77	4.18E-07	3.71E-17	7.25E-12	0.00E+00	1.57E-12	2.22E-06	4.07E-08	2.06E-08
Ga 78	3.86E-07	1.47E-17	7.62E-12	0.00E+00	7.78E-12	1.34E-05	2.34E-08	1.27E-08
Ga 79	4.02E-07	8.44E-18	7.29E-12	9.15E-13	6.01E-12	1.24E-05	2.86E-08	1.49E-08
Ge 71	0.000101	6.27E-10	7.53E-12	0.00E+00	6.60E-12	4.74E-05	1.18E-04	1.08E-04
Ge 73m	2.42E-05	7.83E-17	2.18E-11	0.00E+00	4.30E-12	1.74E-05	1.66E-09	1.29E-09
Ge 75	2.02E-05	6.66E-13	1.10E-10	0.00E+00	9.10E-12	8.01E-06	7.48E-05	5.85E-05
Ge 75m	6.7E-06	2.12E-15	7.14E-12	0.00E+00	4.92E-12	4.79E-06	3.13E-07	2.43E-07
Ge 77	8.95E-07	2.48E-13	5.74E-12	0.00E+00	9.62E-12	1.26E-05	1.84E-05	2.06E-05
Ge 77m	1.17E-06	4.21E-16	1.16E-11	0.00E+00	7.53E-13	6.45E-07	9.97E-08	7.83E-08
Ge 78	1.09E-06	3.94E-14	2.12E-12	0.00E+00	2.48E-12	2.15E-06	6.69E-06	5.30E-06
Ge 79	6.46E-07	8.63E-17	8.59E-12	0.00E+00	1.62E-12	2.64E-06	3.62E-08	2.79E-08
Ge 79m	1.4E-06	3.81E-16	1.52E-11	0.00E+00	2.04E-11	2.94E-05	2.28E-07	1.78E-07
Ge 80	3.35E-06	7.00E-16	2.76E-11	0.00E+00	1.19E-11	2.39E-05	4.48E-07	3.61E-07

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Ge 81	2.51E-06	1.37E-16	3.25E-11	0.00E+00	5.45E-11	8.36E-05	1.28E-07	1.01E-07
Ge 81m	5.58E-07	3.00E-17	1.00E-11	0.00E+00	9.08E-12	1.69E-05	2.83E-08	2.20E-08
As 76	1.08E-05	6.91E-12	1.43E-10	0.00E+00	5.83E-11	8.03E-05	1.35E-03	6.22E-04
As 77	1.85E-06	1.76E-12	4.13E-12	0.00E+00	1.45E-13	1.49E-07	4.56E-05	4.44E-05
As 78	1.14E-06	4.27E-14	1.19E-11	0.00E+00	1.25E-11	2.03E-05	1.22E-05	5.17E-06
As 79	2.31E-06	8.75E-15	1.57E-11	0.00E+00	4.16E-13	4.83E-07	1.09E-06	1.77E-06
As 80	4.54E-06	5.31E-16	8.08E-11	0.00E+00	3.02E-11	3.31E-05	2.28E-07	3.72E-07
As 81	6.73E-06	1.59E-15	8.52E-11	0.00E+00	7.98E-12	1.11E-05	5.12E-07	8.87E-07
As 82	3.4E-06	4.93E-16	8.81E-11	0.00E+00	9.58E-12	1.60E-05	2.44E-07	4.01E-07
As 82m	4.03E-06	3.98E-16	6.66E-11	0.00E+00	9.71E-11	1.60E-04	2.86E-07	4.69E-07
As 83	7.47E-06	7.36E-16	8.45E-11	0.00E+00	1.25E-10	2.21E-04	5.39E-07	9.62E-07
As 84	4.37E-06	1.79E-16	7.19E-11	0.00E+00	1.92E-10	1.06E-04	2.25E-07	4.04E-07
Se 75	1.52E-05	1.05E-09	4.25E-13	0.00E+00	1.13E-11	1.05E-05	4.71E-04	2.35E-04
Se 77m	4.24E-05	5.01E-15	5.76E-12	0.00E+00	7.14E-12	5.86E-06	5.59E-08	3.10E-08
Se 79	4.25E-10	1.05E-07	2.17E-16	0.00E+00	0.00E+00	0.00E+00	7.47E-08	1.75E-07
Se 79m	3.24E-05	5.31E-14	2.88E-11	0.00E+00	4.91E-12	1.19E-05	1.10E-09	6.15E-10
Se 81	7.16E-05	5.67E-13	4.86E-10	0.00E+00	6.82E-12	6.53E-06	1.34E-04	7.47E-05
Se 81m	1.06E-05	2.61E-13	1.02E-11	0.00E+00	2.15E-12	4.30E-06	3.94E-05	3.79E-05
Se 83	1.05E-05	1.04E-13	5.22E-11	0.00E+00	2.10E-10	3.53E-04	2.55E-05	1.85E-05
Se 83m	7.85E-06	4.04E-15	9.03E-11	0.00E+00	6.43E-11	1.06E-04	2.86E-06	1.81E-06
Se 84	2.56E-05	3.54E-14	1.13E-10	0.00E+00	8.88E-11	1.08E-04	2.11E-05	1.45E-05
Se 85	2.6E-05	6.22E-15	3.49E-10	0.00E+00	5.13E-10	9.09E-04	9.29E-06	5.25E-06
Br 80	6.41E-09	4.80E-17	7.70E-14	0.00E+00	8.19E-15	1.09E-08	2.06E-08	6.24E-09
Br 80m	1.67E-09	1.87E-16	1.62E-15	0.00E+00	6.35E-16	2.21E-09	1.80E-08	1.24E-08
Br 82	8.67E-06	8.01E-12	2.26E-11	0.00E+00	4.17E-10	6.20E-04	5.33E-04	6.22E-04
Br 82m	8E-06	2.12E-14	1.03E-11	0.00E+00	1.20E-12	5.16E-06	2.38E-06	1.92E-06
Br 83	1.92E-05	1.21E-12	5.17E-11	0.00E+00	1.21E-12	1.48E-06	4.33E-05	4.84E-05
Br 84	2.74E-05	3.89E-13	2.49E-10	0.00E+00	3.98E-10	7.52E-04	1.24E-04	5.22E-05
Br 84m	1.78E-06	4.78E-15	1.34E-11	0.00E+00	4.06E-11	6.59E-05	4.49E-06	1.37E-06
Br 85	3.91E-05	5.06E-14	3.40E-10	0.00E+00	2.13E-11	3.39E-05	1.94E-05	5.85E-06
Br 86	4.38E-05	1.84E-14	6.95E-10	0.00E+00	1.24E-09	2.26E-03	2.48E-05	7.45E-06
Br 87	4.66E-05	2.00E-14	7.25E-10	8.48E-11	1.29E-09	2.60E-03	1.18E-06	3.61E-07
Br 88	3.3E-05	4.25E-15	4.58E-10	5.99E-11	1.17E-09	1.76E-03	1.56E-05	4.76E-06
Kr 81m	4.34E-10	4.11E-20	7.27E-16	0.00E+00	1.63E-15	1.22E-09	5.09E-12	7.10E-12
Kr 83m	2.09E-05	1.01E-12	8.31E-12	0.00E+00	5.15E-13	3.20E-06	9.50E-06	1.32E-05

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Kr 85	7.43E-06	1.89E-08	1.67E-11	0.00E+00	1.49E-13	1.82E-07	1.16E-03	1.08E-01
Kr 85m	3.95E-05	4.79E-12	8.38E-11	0.00E+00	5.16E-11	4.07E-05	3.48E-04	5.12E-04
Kr 87	7.03E-05	2.48E-12	7.86E-10	0.00E+00	4.61E-10	8.02E-04	9.45E-04	1.31E-03
Kr 88	9.01E-05	7.18E-12	2.72E-10	0.00E+00	1.46E-09	2.71E-03	6.06E-03	8.86E-03
Kr 89	9.87E-05	1.48E-13	6.29E-10	0.00E+00	2.56E-09	2.55E-03	1.43E-04	2.35E-04
Kr 90	8.91E-05	2.30E-14	9.56E-10	0.00E+00	9.13E-10	1.52E-03	2.63E-05	3.64E-05
Rb 84	1.47E-08	3.17E-13	1.31E-14	0.00E+00	8.08E-14	1.19E-07	1.59E-06	5.68E-07
Rb 84m	5.58E-09	5.08E-17	2.79E-15	0.00E+00	1.33E-14	1.40E-08	4.13E-09	7.82E-10
Rb 86	0.001694	2.08E-08	1.16E-08	0.00E+00	1.69E-09	2.71E-03	3.06E-01	1.02E-01
Rb 86m	0.000204	9.47E-14	2.10E-11	0.00E+00	1.15E-09	1.41E-03	1.58E-05	2.89E-06
Rb 88	0.000279	2.32E-12	5.48E-09	0.00E+00	1.69E-09	3.08E-03	1.49E-03	2.65E-04
Rb 89	0.000116	8.42E-13	8.90E-10	0.00E+00	2.14E-09	3.79E-03	2.81E-04	8.37E-05
Rb 90	8.64E-05	1.05E-13	1.34E-09	0.00E+00	1.56E-09	3.22E-03	8.49E-05	1.56E-05
Rb 90m	3.87E-05	7.96E-14	4.07E-10	0.00E+00	1.18E-09	1.92E-03	8.16E-05	1.47E-05
Rb 91	0.000115	5.41E-14	1.48E-09	0.00E+00	2.21E-09	4.47E-03	7.68E-05	1.36E-05
Rb 92	8.67E-05	3.19E-15	2.47E-09	1.34E-10	2.78E-10	3.18E-03	9.27E-06	1.54E-06
Rb 93	6.22E-05	2.92E-15	1.32E-09	2.01E-10	9.65E-10	1.34E-03	9.41E-06	1.57E-06
Rb 94	2.6E-05	5.84E-16	5.90E-10	8.55E-11	8.59E-10	1.34E-03	2.21E-06	3.51E-07
Sr 85	8.06E-06	3.40E-10	7.52E-13	0.00E+00	4.25E-11	5.50E-05	2.87E-04	4.15E-04
Sr 85m	6.77E-06	2.07E-13	9.19E-13	0.00E+00	1.50E-11	1.32E-05	2.64E-06	1.86E-06
Sr 87m	0.000177	1.38E-11	1.56E-10	0.00E+00	7.42E-10	7.83E-04	4.34E-04	3.04E-04
Sr 89	0.000126	4.33E-09	6.22E-10	0.00E+00	1.38E-12	1.45E-06	1.73E-02	5.26E-02
Sr 90	5.61E-05	4.07E-07	1.02E-10	0.00E+00	0.00E+00	0.00E+00	9.09E-02	5.19E-01
Sr 91	0.00013	3.60E-11	6.89E-10	0.00E+00	7.56E-10	1.16E-03	4.35E-03	2.75E-03
Sr 92	0.000137	1.09E-11	2.01E-10	0.00E+00	1.55E-09	2.64E-03	3.01E-03	1.61E-03
Sr 93	0.000148	5.36E-13	1.15E-09	0.00E+00	2.12E-09	3.77E-03	8.28E-05	4.14E-05
Sr 94	0.00014	8.79E-14	9.47E-10	0.00E+00	1.62E-09	2.77E-03	1.56E-05	5.96E-06
Sr 95	0.000108	2.27E-14	1.81E-09	0.00E+00	1.16E-09	2.21E-03	5.08E-06	2.11E-06
Sr 96	6.94E-05	6.25E-16	1.26E-09	0.00E+00	4.96E-10	7.36E-04	1.43E-07	9.04E-08
Y 88	1.06E-09	7.63E-14	4.35E-17	0.00E+00	1.73E-14	3.11E-08	5.22E-08	1.77E-07
Y 89m	3.09E-06	3.91E-16	1.61E-13	0.00E+00	1.88E-11	2.88E-05	4.94E-08	6.89E-08
Y 90	0.000487	8.96E-10	5.07E-09	0.00E+00	1.67E-11	2.09E-06	9.18E-02	5.10E-02
Y 90m	3.6E-07	3.29E-14	1.95E-13	0.00E+00	2.54E-12	2.85E-06	4.26E-06	2.51E-06
Y 91	0.000131	5.34E-09	6.48E-10	0.00E+00	5.38E-12	6.33E-06	1.61E-02	5.98E-02
Y 91m	6.53E-05	1.57E-12	1.51E-11	0.00E+00	2.84E-10	3.47E-04	3.69E-05	3.69E-05

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Y 92	0.000138	1.43E-11	1.63E-09	0.00E+00	2.85E-10	4.46E-04	3.45E-03	1.27E-03
Y 93	0.000155	4.64E-11	1.48E-09	0.00E+00	1.17E-10	1.76E-04	9.45E-03	3.31E-03
Y 93m	5.83E-05	3.94E-16	3.80E-11	0.00E+00	3.22E-10	3.80E-04	1.27E-07	9.47E-08
Y 94	0.00016	1.52E-12	2.32E-09	0.00E+00	1.16E-09	1.57E-03	6.54E-04	2.26E-04
Y 95	0.00016	8.30E-13	1.72E-09	0.00E+00	1.36E-09	3.19E-03	3.69E-04	1.29E-04
Y 96	7.63E-05	3.48E-15	1.95E-09	0.00E+00	5.86E-11	9.91E-05	1.76E-06	2.45E-06
Y 96m	6.19E-05	5.06E-15	9.18E-10	0.00E+00	2.22E-09	3.71E-03	4.95E-06	6.81E-06
Y 97	4.27E-05	1.36E-15	7.46E-10	0.00E+00	5.65E-10	1.27E-03	4.70E-10	6.41E-10
Y 97m	6.89E-05	7.16E-16	1.27E-09	0.00E+00	9.66E-10	2.83E-03	5.14E-07	7.20E-07
Y 98	2.06E-05	1.17E-16	4.15E-10	1.06E-10	5.86E-10	2.72E-04	3.88E-07	5.30E-07
Y 98m	5.02E-05	8.71E-16	8.55E-10	0.00E+00	1.35E-09	2.01E-03	1.08E-06	1.52E-06
Zr 89	1.62E-10	3.59E-16	1.13E-16	0.00E+00	3.10E-16	4.34E-10	6.01E-09	4.19E-09
Zr 90m	4.6E-08	3.04E-19	0.00E+00	0.00E+00	1.42E-12	2.80E-06	3.43E-10	1.64E-10
Zr 93	1.63E-09	6.47E-07	2.77E-16	0.00E+00	0.00E+00	0.00E+00	9.94E-08	2.26E-06
Zr 95	0.000164	7.64E-09	1.57E-10	0.00E+00	9.69E-10	1.35E-03	7.87E-03	4.89E-02
Zr 97	0.000158	8.23E-11	9.24E-10	0.00E+00	2.45E-10	3.74E-04	1.66E-02	7.27E-03
Zr 98	0.000157	4.19E-14	1.14E-09	0.00E+00	0.00E+00	0.00E+00	3.28E-05	1.56E-05
Zr 99	0.000144	2.78E-15	1.76E-09	0.00E+00	9.62E-10	1.17E-03	3.21E-06	1.57E-06
Nb 91m	1.57E-10	6.66E-15	9.38E-17	0.00E+00	3.82E-17	9.86E-11	3.95E-09	1.44E-08
Nb 92m	5.28E-08	3.77E-13	2.20E-15	0.00E+00	3.30E-13	5.23E-07	1.28E-06	1.25E-06
Nb 93m	1.87E-05	7.84E-08	3.69E-12	0.00E+00	2.49E-13	1.49E-06	9.55E-05	1.43E-03
Nb 94	3.08E-06	1.62E-05	4.60E-12	0.00E+00	4.30E-11	6.31E-05	2.90E-04	8.36E-03
Nb 94m	0.003192	9.98E-12	1.18E-09	0.00E+00	4.12E-10	1.80E-03	5.24E-05	3.35E-05
Nb 95	0.001983	5.04E-08	1.38E-09	0.00E+00	2.36E-08	3.28E-02	1.12E-01	3.47E-01
Nb 95m	7.28E-05	1.91E-10	2.03E-10	0.00E+00	8.37E-11	1.15E-04	4.08E-03	6.41E-03
Nb 96	5.24E-06	3.74E-12	3.17E-11	0.00E+00	3.06E-10	4.44E-04	8.67E-04	5.20E-04
Nb 97	0.000159	5.89E-12	5.94E-10	0.00E+00	8.51E-10	1.19E-03	5.41E-04	3.58E-04
Nb 97m	0.000149	7.70E-14	1.80E-11	0.00E+00	8.74E-10	1.22E-03	1.20E-05	7.49E-06
Nb 98	0.000158	3.85E-15	2.46E-09	0.00E+00	1.06E-10	2.21E-04	6.22E-07	4.09E-07
Nb 98m	3.59E-06	9.59E-14	2.26E-11	0.00E+00	7.74E-11	1.20E-04	1.96E-05	1.03E-05
Nb 99	0.000106	1.33E-14	1.36E-09	0.00E+00	1.48E-10	9.28E-05	1.95E-06	1.37E-06
Nb 99m	5.65E-05	7.73E-14	6.46E-10	0.00E+00	3.38E-10	6.17E-04	1.40E-05	9.80E-06
Nb100	0.000142	1.76E-15	2.74E-09	0.00E+00	8.34E-10	1.21E-03	4.34E-07	2.87E-07
Nb100m	1.98E-05	5.07E-16	3.18E-10	0.00E+00	3.21E-10	4.51E-04	1.65E-07	1.07E-07
Nb101	0.00013	8.23E-15	1.73E-09	0.00E+00	6.61E-10	1.57E-03	2.73E-06	1.65E-06

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Nb102	6.53E-05	7.67E-16	9.11E-10	0.00E+00	1.58E-09	1.89E-03	4.14E-07	2.77E-07
Nb102m	3.24E-05	1.26E-15	5.75E-10	0.00E+00	5.29E-10	8.19E-04	6.31E-07	4.26E-07
Nb103	6.94E-05	9.50E-16	1.12E-09	0.00E+00	4.09E-10	8.25E-04	4.00E-07	2.74E-07
Nb104	2.41E-05	1.78E-16	3.69E-10	0.00E+00	5.88E-10	7.26E-04	1.14E-07	6.56E-08
Mo 93	1.94E-08	1.52E-08	8.73E-16	0.00E+00	1.69E-15	1.00E-08	2.99E-06	2.22E-06
Mo 93m	6.31E-09	1.28E-15	6.10E-15	0.00E+00	1.32E-13	2.14E-07	3.91E-08	6.04E-08
Mo 99	0.000216	4.49E-10	7.00E-10	0.00E+00	2.62E-10	3.43E-04	6.68E-03	1.10E-02
Mo101	0.000159	1.24E-12	6.81E-10	0.00E+00	1.91E-09	3.05E-03	3.32E-04	2.10E-04
Mo102	0.000129	7.84E-13	3.64E-10	0.00E+00	1.92E-11	1.56E-05	2.39E-04	1.89E-04
Mo103	0.000124	7.70E-14	1.26E-09	0.00E+00	6.10E-10	8.57E-04	2.93E-05	2.39E-05
Mo104	0.000101	5.59E-14	6.83E-10	0.00E+00	1.37E-10	2.31E-04	2.52E-05	1.41E-05
Mo105	7.24E-05	2.47E-14	5.42E-10	0.00E+00	1.32E-09	2.33E-04	1.59E-05	1.31E-05
Tc 95	1.67E-10	1.01E-16	5.45E-18	0.00E+00	8.29E-16	1.22E-09	1.17E-09	7.13E-10
Tc 96	9.25E-09	2.91E-14	5.13E-16	0.00E+00	1.57E-13	2.38E-07	4.31E-07	2.74E-07
Tc 96m	6.84E-09	1.80E-16	4.43E-18	0.00E+00	2.10E-15	3.12E-09	3.48E-09	2.17E-09
Tc 97m	8.52E-09	5.71E-13	6.47E-15	0.00E+00	7.06E-16	3.57E-09	2.55E-07	1.90E-06
Tc 99	1.15E-08	6.71E-07	7.86E-15	0.00E+00	5.46E-20	7.77E-14	3.11E-07	6.32E-06
Tc 99m	0.000191	3.63E-11	2.56E-11	0.00E+00	2.01E-10	1.43E-04	2.18E-04	1.98E-04
Tc100	0.000128	1.79E-14	1.99E-09	0.00E+00	1.25E-10	1.62E-04	5.75E-06	3.58E-06
Tc101	0.000159	1.21E-12	6.18E-10	0.00E+00	4.36E-10	4.65E-04	1.54E-04	9.71E-05
Tc102	0.000129	6.16E-15	1.96E-09	0.00E+00	8.16E-11	1.20E-04	1.83E-06	1.20E-06
Tc102m	3.56E-07	8.38E-16	2.21E-12	0.00E+00	7.15E-12	1.18E-05	4.24E-07	2.65E-07
Tc103	0.000127	5.79E-14	8.29E-10	0.00E+00	2.58E-10	2.48E-04	9.16E-06	6.05E-06
Tc104	0.000108	1.10E-12	1.50E-09	0.00E+00	1.86E-09	3.12E-03	4.15E-04	1.50E-04
Tc105	9.25E-05	3.92E-13	8.77E-10	0.00E+00	3.47E-10	4.62E-04	1.10E-04	7.48E-05
Tc106	7.04E-05	2.38E-14	1.12E-09	0.00E+00	1.13E-09	2.27E-03	1.37E-05	9.03E-06
Tc107	4.71E-05	9.38E-15	5.71E-10	0.00E+00	2.15E-10	2.69E-04	5.63E-06	3.38E-06
Tc108	2.18E-05	1.08E-15	3.83E-10	0.00E+00	2.52E-10	4.10E-04	1.16E-06	7.08E-07
Tc109	8.21E-06	1.11E-16	1.42E-10	0.00E+00	4.47E-11	5.73E-05	1.14E-07	7.10E-08
Ru 97	1.73E-05	3.73E-11	1.85E-12	0.00E+00	3.77E-11	3.17E-05	1.45E-04	1.06E-04
Ru103	0.000354	1.10E-08	2.45E-10	0.00E+00	1.83E-09	2.26E-03	1.68E-02	6.89E-02
Ru105	0.00014	2.08E-11	5.21E-10	0.00E+00	8.42E-10	1.17E-03	1.92E-03	1.33E-03
Ru106	7.37E-05	2.20E-08	5.67E-12	0.00E+00	0.00E+00	0.00E+00	2.47E-02	2.33E-01
Ru107	5.7E-05	1.22E-13	4.72E-10	0.00E+00	1.51E-10	2.19E-04	7.36E-05	3.54E-05
Ru108	3.99E-05	1.03E-13	1.46E-10	0.00E+00	1.44E-11	9.57E-06	1.11E-04	5.27E-05

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Ru109	1.52E-05	5.05E-15	1.22E-10	0.00E+00	2.47E-10	3.69E-04	6.61E-06	3.08E-06
Ru110	1.19E-05	1.46E-15	8.44E-11	0.00E+00	4.37E-11	4.46E-05	2.17E-06	9.97E-07
Ru111	4.67E-06	1.01E-16	7.21E-11	0.00E+00	2.63E-11	3.25E-05	1.55E-07	7.43E-08
Rh100	4.95E-16	3.28E-22	1.65E-22	0.00E+00	7.66E-21	1.32E-14	1.22E-14	6.02E-15
Rh103m	0.00036	1.10E-11	1.43E-10	0.00E+00	6.36E-12	1.57E-05	8.86E-05	6.30E-05
Rh104	0.000934	3.64E-13	3.71E-09	0.00E+00	5.68E-11	5.73E-05	2.83E-05	2.01E-05
Rh104m	7.09E-05	1.70E-13	2.47E-11	0.00E+00	1.31E-11	1.43E-05	1.49E-05	1.06E-05
Rh105	0.000132	1.57E-10	1.64E-10	0.00E+00	8.35E-11	8.62E-05	2.47E-03	2.34E-03
Rh105m	3.92E-05	1.46E-14	3.16E-11	0.00E+00	1.15E-11	1.14E-05	5.38E-07	4.34E-07
Rh106	8.04E-05	2.27E-14	9.35E-10	0.00E+00	1.46E-10	1.92E-04	5.83E-06	4.08E-06
Rh106m	7.26E-07	5.40E-14	3.53E-12	0.00E+00	3.03E-11	4.50E-05	1.10E-05	7.53E-06
Rh107	5.72E-05	7.05E-13	1.89E-10	0.00E+00	1.37E-10	1.45E-04	6.57E-05	4.65E-05
Rh108	4.06E-05	1.38E-13	2.91E-10	0.00E+00	7.22E-10	1.02E-03	6.37E-05	4.58E-05
Rh108m	2.3E-07	3.70E-17	3.63E-12	0.00E+00	1.07E-12	1.51E-06	1.38E-08	9.93E-09
Rh109	2.91E-05	2.24E-14	2.01E-10	0.00E+00	7.43E-11	7.46E-05	4.57E-06	3.00E-06
Rh110	1.2E-05	3.34E-15	1.12E-10	0.00E+00	2.43E-10	3.49E-04	1.78E-06	1.25E-06
Rh110m	1.28E-06	4.00E-17	3.19E-11	0.00E+00	4.73E-12	5.35E-06	2.11E-08	1.50E-08
Rh111	6.56E-06	7.09E-16	8.39E-11	0.00E+00	1.18E-11	3.16E-05	3.00E-07	2.19E-07
Rh112	3.03E-06	1.14E-16	5.37E-11	0.00E+00	7.45E-11	9.09E-05	1.18E-07	7.64E-08
Rh113	1.84E-06	5.02E-17	2.75E-11	0.00E+00	7.98E-12	9.55E-06	3.40E-08	2.46E-08
Rh114	3.95E-07	7.37E-18	8.03E-12	0.00E+00	1.41E-12	1.40E-06	5.94E-09	4.27E-09
Rh114m	6.63E-07	1.24E-17	1.03E-11	0.00E+00	1.27E-11	1.52E-05	1.23E-08	8.84E-09
Pd103	9.67E-06	1.29E-10	5.83E-13	0.00E+00	1.46E-12	2.83E-06	1.18E-04	2.78E-04
Pd107	2.52E-10	4.89E-07	2.21E-17	0.00E+00	0.00E+00	0.00E+00	5.43E-10	8.66E-09
Pd107m	2.57E-06	5.20E-16	1.98E-12	0.00E+00	4.78E-12	4.27E-06	4.91E-08	5.30E-08
Pd109	0.000745	3.48E-10	2.10E-09	0.00E+00	6.13E-12	4.67E-06	2.00E-02	1.35E-02
Pd109m	1.57E-05	4.27E-14	9.51E-12	0.00E+00	1.37E-11	1.00E-05	4.67E-06	4.14E-06
Pd111	1.64E-05	2.27E-13	1.35E-10	0.00E+00	7.30E-12	1.09E-05	8.02E-05	9.54E-05
Pd111m	1.61E-06	3.13E-13	3.07E-12	0.00E+00	6.79E-12	8.47E-06	5.76E-05	5.31E-05
Pd112	3.35E-06	2.43E-12	2.96E-12	0.00E+00	1.73E-13	1.03E-06	1.38E-03	1.01E-03
Pd113	2.3E-06	2.15E-15	3.06E-11	0.00E+00	1.51E-12	1.75E-06	1.65E-06	1.79E-06
Pd113m	2.31E-07	2.31E-16	0.00E+00	0.00E+00	3.44E-15	0.00E+00	2.79E-07	3.01E-07
Pd114	1.43E-06	2.13E-15	6.27E-12	0.00E+00	3.22E-13	2.70E-07	1.77E-06	1.91E-06
Pd115	1.3E-06	3.32E-16	1.54E-11	0.00E+00	1.63E-11	1.79E-05	4.73E-07	4.73E-07
Pd116	9.78E-07	1.25E-16	7.81E-12	0.00E+00	1.38E-12	1.03E-06	1.62E-07	1.77E-07

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Pd117	6.58E-07	3.41E-17	5.84E-12	0.00E+00	1.52E-11	1.60E-05	5.86E-08	6.19E-08
Pd118	3.27E-07	1.06E-17	3.74E-12	0.00E+00	1.73E-12	1.95E-06	2.20E-08	2.36E-08
Ag106	2.66E-10	3.59E-18	5.71E-16	0.00E+00	8.00E-16	9.81E-10	2.27E-10	1.13E-10
Ag107m	1.86E-06	7.78E-16	1.31E-12	0.00E+00	2.03E-13	3.16E-07	9.12E-09	6.08E-09
Ag108	0.00056	7.72E-13	1.36E-09	0.00E+00	5.12E-11	6.50E-05	2.80E-05	1.82E-05
Ag108m	1.2E-07	1.51E-08	6.02E-15	0.00E+00	6.11E-13	8.27E-07	5.38E-06	8.66E-05
Ag109m	0.00078	3.00E-13	4.75E-10	0.00E+00	6.84E-11	1.13E-04	2.96E-06	1.96E-06
Ag110	0.000881	2.12E-13	7.52E-09	0.00E+00	2.23E-10	2.75E-04	2.60E-05	1.72E-05
Ag110m	3.25E-05	6.84E-09	1.38E-11	0.00E+00	5.54E-10	8.44E-04	3.51E-03	1.50E-02
Ag111	2.76E-05	1.75E-10	9.87E-11	0.00E+00	7.36E-12	7.37E-06	2.27E-03	2.96E-03
Ag111m	2.2E-05	1.40E-14	1.24E-11	0.00E+00	1.52E-12	2.70E-06	3.04E-07	3.18E-07
Ag112	3.38E-06	3.80E-13	4.74E-11	0.00E+00	2.31E-11	3.76E-05	8.96E-05	3.54E-05
Ag113	2.23E-06	4.31E-13	1.63E-11	0.00E+00	1.54E-12	1.74E-06	5.20E-05	3.33E-05
Ag113m	4.36E-07	3.00E-16	5.93E-13	0.00E+00	5.15E-13	5.79E-07	3.95E-08	2.55E-08
Ag114	1.46E-06	6.91E-17	2.52E-11	0.00E+00	3.26E-12	4.85E-06	1.80E-08	1.20E-08
Ag114m	1.65E-08	2.50E-22	1.48E-14	0.00E+00	1.41E-14	2.49E-08	7.62E-14	5.08E-14
Ag115	1.05E-06	1.31E-14	7.11E-12	0.00E+00	1.03E-11	1.68E-05	3.42E-06	1.65E-06
Ag115m	4.15E-07	7.87E-17	3.11E-12	0.00E+00	1.68E-12	1.61E-06	1.70E-08	1.04E-08
Ag116	1.02E-06	1.66E-15	1.31E-11	0.00E+00	1.73E-11	3.03E-05	6.66E-07	4.36E-07
Ag116m	1.13E-07	1.22E-17	1.73E-12	0.00E+00	1.21E-12	1.52E-06	4.29E-09	2.90E-09
Ag117	3.67E-07	2.77E-16	3.80E-12	0.00E+00	3.18E-12	5.56E-06	7.80E-08	4.90E-08
Ag117m	5.82E-07	3.22E-17	6.87E-12	0.00E+00	2.95E-12	3.16E-06	7.99E-09	5.14E-09
Ag118	5.44E-07	2.10E-17	1.05E-11	0.00E+00	3.75E-12	4.55E-06	1.21E-08	8.13E-09
Ag118m	3.86E-07	8.06E-18	3.72E-12	0.00E+00	4.47E-12	7.24E-06	5.21E-09	3.53E-09
Ag119	6.97E-07	1.54E-17	9.26E-12	0.00E+00	6.99E-12	1.16E-05	1.11E-08	6.53E-09
Ag120	4.01E-07	4.99E-18	6.75E-12	0.00E+00	3.18E-12	3.18E-06	3.14E-09	2.03E-09
Ag121	3.61E-07	3.09E-18	6.78E-12	0.00E+00	2.33E-12	1.17E-05	2.41E-09	1.62E-09
Ag122	2.62E-08	1.36E-19	7.48E-13	0.00E+00	2.33E-13	3.12E-07	1.30E-10	8.69E-11
Cd107	1.51E-06	3.36E-13	9.65E-14	0.00E+00	3.27E-13	5.92E-07	5.95E-06	7.97E-06
Cd109	3.2E-05	1.24E-08	1.80E-12	0.00E+00	4.76E-12	9.40E-06	3.92E-03	1.59E-02
Cd111m	3.76E-06	1.08E-13	4.34E-12	0.00E+00	1.21E-11	1.05E-05	2.84E-05	3.87E-05
Cd113m	6.65E-09	2.88E-11	9.00E-15	0.00E+00	3.51E-18	3.64E-12	7.05E-06	3.37E-05
Cd115	2.9E-05	5.68E-11	9.03E-11	0.00E+00	5.51E-11	6.66E-05	2.49E-03	1.96E-03
Cd115m	3.81E-06	1.50E-10	2.24E-11	0.00E+00	1.27E-12	1.94E-06	7.66E-04	1.79E-03
Cd117	1.02E-06	9.49E-14	3.93E-12	0.00E+00	9.94E-12	1.58E-05	1.60E-05	9.69E-06

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Cd117m	8.11E-07	1.02E-13	1.42E-12	0.00E+00	1.41E-11	2.46E-05	1.21E-05	9.06E-06
Cd118	9E-07	2.84E-14	1.71E-12	0.00E+00	0.00E+00	0.00E+00	2.91E-05	3.86E-05
Cd119	5.98E-07	1.02E-15	3.04E-12	0.00E+00	7.54E-12	1.13E-05	1.91E-06	1.97E-06
Cd119m	3.06E-07	4.27E-16	1.35E-12	0.00E+00	5.53E-12	9.04E-06	8.06E-07	1.07E-06
Cd120	8.66E-07	4.68E-16	4.29E-12	0.00E+00	1.13E-14	1.16E-08	6.54E-07	8.99E-07
Cd121	4.74E-07	6.35E-17	4.77E-12	0.00E+00	6.32E-12	1.02E-05	1.31E-07	1.74E-07
Cd121m	3.76E-07	1.94E-17	3.20E-12	0.00E+00	6.35E-12	1.14E-05	4.42E-08	5.84E-08
Cd122	5.74E-07	3.59E-17	4.62E-12	0.00E+00	3.12E-12	3.25E-06	7.40E-08	1.01E-07
Cd123	2.74E-07	6.56E-18	2.73E-12	0.00E+00	6.12E-12	8.11E-06	2.01E-08	2.55E-08
Cd124	1.24E-07	1.36E-18	1.94E-12	0.00E+00	1.14E-13	8.00E-08	3.97E-09	5.33E-09
Cd125	9.34E-09	7.24E-20	1.24E-13	0.00E+00	2.20E-13	2.60E-07	2.48E-10	3.27E-10
In113m	1.71E-06	1.02E-13	1.98E-12	0.00E+00	3.93E-12	4.15E-06	2.64E-06	1.88E-06
In114	0.000125	9.11E-14	5.96E-10	0.00E+00	3.39E-12	2.81E-06	5.80E-06	4.21E-06
In114m	7.37E-05	3.21E-09	6.38E-11	0.00E+00	4.03E-11	4.54E-05	1.16E-02	2.63E-02
In115m	3.01E-05	4.94E-12	5.03E-11	0.00E+00	4.78E-11	5.17E-05	1.58E-04	1.08E-04
In116	7.79E-06	1.14E-15	9.48E-11	0.00E+00	3.68E-13	2.51E-08	1.79E-07	1.31E-07
In116m	2.85E-05	9.60E-13	7.99E-11	0.00E+00	6.37E-10	1.08E-03	1.02E-04	7.18E-05
In116n	1.56E-05	3.47E-16	1.32E-11	0.00E+00	9.53E-12	7.95E-06	4.36E-08	3.05E-08
In117	1.33E-06	3.63E-14	3.05E-12	0.00E+00	8.01E-12	8.90E-06	2.24E-06	2.09E-06
In117m	9.47E-07	6.86E-14	3.67E-12	0.00E+00	7.69E-13	7.56E-07	6.34E-06	3.80E-06
In118	9.09E-07	4.75E-17	1.20E-11	0.00E+00	2.44E-12	4.00E-06	9.63E-09	7.01E-09
In119	3.86E-07	5.87E-16	1.80E-12	0.00E+00	2.26E-12	3.14E-06	7.72E-08	5.70E-08
In119m	5.67E-07	6.46E-15	4.49E-12	0.00E+00	4.69E-14	7.09E-08	1.26E-06	4.54E-07
In120	9.56E-07	3.13E-17	1.72E-11	0.00E+00	2.40E-12	4.08E-06	8.14E-09	5.88E-09
In121	8.53E-07	2.11E-16	6.29E-12	0.00E+00	5.98E-12	9.00E-06	3.89E-08	2.81E-08
In121m	3.83E-07	9.56E-16	4.43E-12	0.00E+00	2.02E-13	2.84E-07	1.53E-07	1.09E-07
In122	1.34E-06	2.17E-17	2.56E-11	0.00E+00	6.48E-12	1.15E-05	6.32E-09	4.74E-09
In123	1.29E-06	8.41E-17	1.32E-11	0.00E+00	1.08E-11	1.75E-05	2.39E-08	1.53E-08
In123m	3.11E-07	1.62E-16	4.77E-12	0.00E+00	1.55E-13	1.59E-07	3.99E-08	2.51E-08
In124	9.54E-07	3.35E-17	1.54E-11	0.00E+00	1.96E-11	3.66E-05	1.49E-08	1.09E-08
In124m	7.55E-07	1.99E-17	9.61E-12	0.00E+00	2.18E-11	3.49E-05	9.99E-09	7.49E-09
In125	1.82E-06	4.69E-17	2.47E-11	0.00E+00	1.83E-11	3.07E-05	1.41E-08	1.06E-08
In125m	4.2E-07	5.67E-17	7.89E-12	0.00E+00	5.48E-13	3.57E-07	1.95E-08	1.47E-08
In126	9.06E-07	1.52E-17	1.73E-11	0.00E+00	2.00E-11	3.87E-05	7.54E-09	5.32E-09
In126m	1.29E-06	2.09E-17	1.90E-11	0.00E+00	4.35E-11	7.06E-05	1.20E-08	8.82E-09

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
In127	1.34E-06	1.74E-17	2.34E-11	0.00E+00	1.87E-11	3.22E-05	9.26E-09	7.27E-09
In127m	3.09E-07	1.29E-17	6.69E-12	2.68E-13	1.22E-12	1.83E-06	8.23E-09	5.94E-09
In128	5.1E-07	5.20E-18	1.11E-11	0.00E+00	1.23E-11	2.43E-05	3.50E-09	2.23E-09
Sn113	1.68E-06	1.67E-10	9.39E-14	0.00E+00	3.48E-13	6.04E-07	6.82E-05	2.52E-04
Sn113m	4.74E-07	5.95E-15	2.49E-13	0.00E+00	6.14E-14	1.21E-07	6.36E-08	1.51E-07
Sn117m	5.46E-06	6.65E-11	7.18E-12	0.00E+00	7.10E-12	5.68E-06	2.01E-04	6.80E-04
Sn119m	2.77E-07	7.38E-11	1.93E-13	0.00E+00	2.81E-14	6.05E-08	5.24E-06	3.39E-05
Sn121	7.46E-06	7.75E-12	8.98E-12	0.00E+00	0.00E+00	0.00E+00	1.12E-04	1.12E-04
Sn121m	3.73E-08	6.93E-10	9.58E-15	0.00E+00	1.38E-15	2.99E-09	6.43E-07	7.62E-06
Sn123	3.06E-07	3.72E-11	1.21E-12	0.00E+00	1.86E-14	2.61E-08	3.05E-05	1.18E-04
Sn123m	2.77E-06	7.26E-14	1.22E-11	0.00E+00	3.63E-12	2.49E-06	6.09E-06	4.33E-06
Sn125	3.56E-06	3.28E-11	2.23E-11	0.00E+00	8.77E-12	1.42E-05	5.37E-04	5.37E-04
Sn125m	3.64E-06	2.30E-14	2.46E-11	0.00E+00	1.07E-11	1.14E-05	3.27E-06	7.50E-06
Sn126	5.65E-10	4.82E-08	5.34E-16	0.00E+00	2.75E-16	2.49E-10	1.44E-07	8.56E-07
Sn127	8.54E-06	7.26E-13	3.34E-11	0.00E+00	1.26E-10	2.04E-04	8.50E-05	5.52E-05
Sn127m	4.7E-06	1.31E-14	3.78E-11	0.00E+00	2.15E-11	2.88E-05	2.83E-06	7.31E-06
Sn128	2.04E-05	8.22E-13	4.08E-11	0.00E+00	9.73E-11	1.24E-04	1.52E-04	9.32E-05
Sn128m	1.37E-05	1.01E-15	8.46E-12	0.00E+00	2.18E-10	3.47E-04	4.20E-07	6.57E-07
Sn129	9.72E-06	1.60E-14	5.23E-11	0.00E+00	1.94E-10	1.77E-04	8.29E-06	1.95E-05
Sn129m	1.97E-05	9.33E-14	9.56E-11	0.00E+00	3.81E-10	5.78E-04	4.61E-05	1.08E-04
Sn130	9.64E-06	2.48E-14	6.30E-11	0.00E+00	1.23E-11	8.76E-05	1.25E-05	2.83E-05
Sn130m	2.11E-05	2.48E-14	7.72E-11	0.00E+00	3.95E-10	6.85E-05	1.36E-05	3.14E-05
Sn131	5.64E-06	2.55E-15	3.95E-11	0.00E+00	1.06E-10	3.47E-04	1.96E-06	4.20E-06
Sn131m	1.28E-05	9.08E-15	1.12E-10	0.00E+00	2.43E-10	2.64E-04	6.97E-06	1.52E-05
Sb120	9.55E-10	9.69E-18	1.50E-15	0.00E+00	2.25E-15	2.83E-09	4.28E-10	2.23E-10
Sb120m	4.69E-10	2.48E-15	1.09E-16	0.00E+00	5.94E-15	9.13E-09	1.81E-08	1.66E-08
Sb122	0.000652	1.64E-09	2.79E-09	0.00E+00	2.16E-09	2.70E-03	5.24E-02	3.39E-02
Sb122m	4.14E-05	1.13E-13	2.92E-11	0.00E+00	2.22E-11	2.40E-05	5.10E-06	3.14E-06
Sb124	0.000361	2.07E-08	1.13E-09	0.00E+00	5.52E-09	9.27E-03	4.62E-02	1.59E-01
Sb124m	5.42E-06	5.54E-15	5.10E-12	0.00E+00	1.96E-11	2.64E-05	2.79E-07	1.76E-07
Sb124n	1.8E-06	2.40E-14	3.83E-13	0.00E+00	5.02E-15	3.70E-08	7.42E-07	5.47E-07
Sb125	1.12E-05	1.08E-08	1.14E-11	0.00E+00	4.85E-11	6.36E-05	7.74E-04	8.44E-03
Sb126	2.09E-07	2.50E-12	6.59E-13	0.00E+00	5.45E-12	7.50E-06	2.97E-05	3.96E-05
Sb126m	5.97E-08	7.64E-16	6.41E-13	0.00E+00	1.62E-12	2.20E-06	2.31E-07	1.28E-07
Sb126n	5.42E-08	6.66E-18	2.09E-14	0.00E+00	3.53E-16	2.45E-09	2.04E-09	1.11E-09

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Sb127	1.42E-05	5.32E-11	3.59E-11	0.00E+00	7.51E-11	9.96E-05	1.21E-03	1.35E-03
Sb128	2.55E-06	9.36E-13	8.59E-12	0.00E+00	6.31E-11	8.71E-05	9.68E-05	5.35E-05
Sb128m	2.33E-05	1.65E-13	1.71E-10	0.00E+00	3.71E-10	5.00E-04	3.82E-05	1.74E-05
Sb129	3.83E-05	6.87E-12	1.09E-10	0.00E+00	4.23E-10	6.51E-04	8.04E-04	4.79E-04
Sb129m	7.7E-06	9.35E-14	6.21E-11	0.00E+00	9.19E-11	1.28E-04	2.13E-05	1.13E-05
Sb130	3.44E-05	9.50E-13	1.90E-10	0.00E+00	8.93E-10	1.28E-03	1.55E-04	9.05E-05
Sb130m	2.75E-05	1.20E-13	2.19E-10	0.00E+00	5.47E-10	8.10E-04	3.43E-05	1.78E-05
Sb131	7.14E-05	1.14E-12	4.70E-10	0.00E+00	9.60E-10	1.56E-03	3.53E-04	1.56E-04
Sb132	2.73E-05	8.04E-14	2.90E-10	0.00E+00	5.11E-10	7.33E-04	2.70E-05	1.30E-05
Sb132m	2.62E-05	5.15E-14	2.63E-10	0.00E+00	5.27E-10	8.01E-04	1.69E-05	8.45E-06
Sb133	3.79E-05	6.62E-14	1.32E-10	0.00E+00	7.22E-10	1.27E-03	3.00E-05	8.81E-06
Te121	1.82E-07	3.23E-12	1.96E-14	0.00E+00	1.15E-12	1.43E-06	5.33E-06	5.09E-06
Te121m	2.02E-08	2.88E-12	1.73E-14	0.00E+00	4.68E-14	4.90E-08	3.10E-06	7.68E-06
Te123m	2.77E-05	3.12E-09	2.97E-11	0.00E+00	4.37E-11	3.47E-05	2.58E-03	9.38E-03
Te125m	3.57E-06	1.98E-10	4.36E-12	0.00E+00	1.44E-12	2.87E-06	2.18E-04	1.05E-03
Te127	3.48E-05	1.32E-11	7.36E-11	0.00E+00	1.59E-12	1.89E-06	3.48E-04	2.87E-04
Te127m	2.05E-06	2.18E-10	9.88E-13	0.00E+00	1.39E-13	2.82E-07	1.73E-04	7.36E-04
Te129	4.99E-05	2.38E-12	2.31E-10	0.00E+00	2.57E-11	3.42E-05	1.67E-04	1.03E-04
Te129m	1.42E-05	4.75E-10	2.80E-11	0.00E+00	4.54E-12	6.94E-06	2.18E-03	5.75E-03
Te131	0.000096	1.67E-12	5.73E-10	0.00E+00	3.38E-10	4.17E-04	4.34E-04	1.40E-04
Te131m	2.3E-05	2.88E-11	3.70E-11	0.00E+00	2.72E-10	3.99E-04	2.26E-03	1.12E-03
Te132	0.000137	4.47E-10	1.13E-10	0.00E+00	2.56E-10	2.55E-04	2.60E-02	1.37E-02
Te133	7.91E-05	6.99E-13	4.53E-10	0.00E+00	7.55E-10	1.17E-03	2.83E-04	7.85E-05
Te133m	9.65E-05	3.78E-12	4.07E-10	0.00E+00	1.48E-09	2.17E-03	1.34E-03	4.17E-04
Te134	0.00013	3.86E-12	2.37E-10	0.00E+00	8.85E-10	1.09E-03	7.08E-04	4.38E-04
Te135	6.11E-05	1.39E-14	1.13E-09	0.00E+00	2.33E-10	3.95E-04	5.45E-06	1.21E-05
I 128	9.42E-06	1.60E-13	1.02E-10	0.00E+00	1.21E-11	1.47E-05	3.96E-05	1.72E-05
I 130	3.08E-05	1.58E-11	1.11E-10	0.00E+00	8.21E-10	1.11E-03	4.79E-03	1.61E-03
I 130m	2.01E-05	1.25E-13	4.76E-11	0.00E+00	2.98E-11	4.01E-05	3.90E-04	6.40E-05
I 131	0.000115	9.25E-10	1.83E-10	0.00E+00	3.65E-10	3.95E-04	1.31E-01	4.41E-02
I 132	0.000142	1.36E-11	5.55E-10	0.00E+00	2.56E-09	3.72E-03	2.05E-03	7.78E-04
I 132m	3.39E-06	1.97E-13	4.43E-12	0.00E+00	9.40E-12	1.29E-05	3.74E-05	1.48E-05
I 133	0.000188	1.66E-10	6.14E-10	0.00E+00	9.12E-10	1.19E-03	4.03E-02	1.41E-02
I 133m	1.13E-05	1.20E-15	4.44E-12	0.00E+00	1.43E-10	2.12E-04	1.19E-05	1.81E-06
I 134	0.000195	7.30E-12	9.60E-10	0.00E+00	4.04E-09	6.27E-03	1.06E-03	5.32E-04

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
I 134m	4.14E-05	1.09E-13	2.86E-11	0.00E+00	7.95E-11	7.82E-05	2.46E-04	4.30E-05
I 135	0.000163	4.64E-11	4.72E-10	0.00E+00	2.06E-09	3.54E-03	7.51E-03	2.59E-03
I 136	5.58E-05	5.65E-14	8.71E-10	0.00E+00	1.06E-09	1.96E-03	1.39E-03	2.08E-04
I 136m	5.57E-05	3.02E-14	9.76E-10	0.00E+00	1.11E-09	1.40E-03	8.00E-04	1.21E-04
I 137	6.61E-05	1.96E-14	1.06E-09	3.51E-10	6.44E-10	1.11E-03	1.31E-04	1.96E-05
Xe129m	4.09E-08	3.58E-13	2.14E-13	0.00E+00	6.01E-14	1.06E-07	1.45E-05	4.79E-05
Xe131m	1.52E-06	1.81E-11	2.48E-12	0.00E+00	3.69E-13	6.73E-07	1.63E-04	6.63E-04
Xe133	0.000192	1.02E-09	2.11E-10	0.00E+00	7.19E-11	7.87E-05	1.26E-02	2.92E-02
Xe133m	6.47E-06	1.44E-11	1.07E-11	0.00E+00	2.27E-12	3.08E-06	5.21E-04	1.01E-03
Xe134m	7.04E-06	2.42E-17	3.91E-12	0.00E+00	1.09E-10	1.61E-04	5.37E-09	7.52E-09
Xe135	3.26E-05	1.28E-11	4.73E-11	0.00E+00	3.72E-11	3.40E-05	4.57E-04	6.25E-04
Xe135m	4.78E-05	5.36E-13	3.63E-11	0.00E+00	1.65E-10	2.03E-04	6.44E-05	8.82E-05
Xe137	0.000178	4.96E-13	2.20E-09	0.00E+00	3.42E-10	3.76E-04	9.08E-05	1.36E-04
Xe138	0.00015	1.56E-12	8.07E-10	0.00E+00	1.35E-09	2.34E-03	7.51E-04	1.05E-03
Xe139	9.89E-05	4.83E-14	1.43E-09	0.00E+00	7.32E-10	1.22E-03	2.88E-05	3.97E-05
Cs131	2.15E-05	2.09E-10	9.84E-13	0.00E+00	3.57E-12	7.12E-06	5.59E-05	4.53E-05
Cs132	5.11E-08	3.37E-13	7.46E-15	0.00E+00	3.78E-13	5.34E-07	1.65E-06	9.89E-07
Cs134	0.013135	1.02E-05	6.90E-09	0.00E+00	6.56E-08	9.16E-02	5.01E+00	5.27E+00
Cs134m	0.001627	2.02E-10	7.45E-10	0.00E+00	1.80E-10	2.48E-04	8.32E-04	2.50E-03
Cs135	6.4E-08	5.80E-05	4.06E-14	0.00E+00	0.00E+00	0.00E+00	7.59E-06	3.26E-05
Cs135m	2.45E-05	9.31E-13	5.79E-12	0.00E+00	2.50E-10	3.66E-04	1.86E-05	1.57E-05
Cs136	0.002824	3.83E-08	7.05E-09	0.00E+00	1.07E-07	1.63E-01	9.31E-01	8.69E-01
Cs136m	4.67E-05	1.07E-14	5.00E-10	0.00E+00	5.00E-10	5.19E-04	2.18E-06	1.16E-06
Cs137	8.2E-05	9.47E-07	1.36E-10	0.00E+00	2.75E-14	0.00E+00	5.91E-02	1.77E-01
Cs138	0.000177	4.18E-12	1.81E-09	0.00E+00	3.37E-09	5.80E-03	8.18E-04	3.82E-04
Cs138m	1.75E-05	3.72E-14	4.59E-11	0.00E+00	5.92E-11	8.97E-05	7.91E-06	3.78E-06
Cs139	0.000167	1.14E-12	2.21E-09	0.00E+00	4.03E-10	8.71E-04	2.35E-04	1.18E-04
Cs140	0.000141	1.12E-13	2.11E-09	0.00E+00	1.81E-09	4.26E-03	2.76E-05	1.49E-05
Cs141	0.000104	3.24E-14	1.32E-09	2.25E-10	9.50E-10	1.15E-03	2.39E-05	1.20E-05
Ba131	2.16E-05	2.50E-10	7.17E-12	0.00E+00	7.12E-11	8.42E-05	4.35E-04	8.42E-04
Ba131m	5.39E-06	5.48E-14	4.27E-12	0.00E+00	2.99E-12	2.92E-06	1.19E-06	1.89E-06
Ba133	1.26E-05	4.96E-08	6.18E-12	0.00E+00	4.64E-11	5.05E-05	1.08E-03	7.20E-03
Ba133m	1.23E-06	1.99E-12	2.34E-12	0.00E+00	7.08E-13	8.85E-07	3.57E-05	3.04E-05
Ba135m	0.000139	1.72E-10	2.83E-10	0.00E+00	7.88E-11	9.14E-05	3.64E-03	3.05E-03
Ba136m	3.01E-06	1.12E-17	3.41E-12	0.00E+00	6.13E-11	9.58E-05	3.18E-09	1.65E-09

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Ba137m	8.28E-05	1.54E-13	4.72E-11	0.00E+00	4.49E-10	6.26E-04	1.22E-05	6.09E-06
Ba139	0.000667	4.09E-11	6.53E-09	0.00E+00	3.35E-10	2.70E-04	5.45E-03	2.68E-03
Ba140	0.000175	2.40E-09	4.44E-10	0.00E+00	2.59E-10	3.16E-04	2.30E-02	5.12E-02
Ba141	0.000168	2.30E-12	1.21E-09	0.00E+00	1.31E-09	1.51E-03	5.92E-04	2.87E-04
Ba142	0.000163	1.30E-12	6.17E-10	0.00E+00	9.98E-10	2.09E-02	2.87E-04	1.80E-04
Ba143	0.000122	2.25E-14	1.19E-09	0.00E+00	8.60E-10	5.02E-04	1.79E-05	8.64E-06
La140	0.015803	2.84E-08	7.75E-08	0.00E+00	3.35E-07	5.63E-01	1.81E+00	9.95E-01
La141	0.000171	3.03E-11	1.31E-09	0.00E+00	6.39E-11	1.04E-04	3.12E-03	1.30E-03
La142	0.000172	1.19E-11	1.20E-09	0.00E+00	3.30E-09	6.16E-03	1.57E-03	7.74E-04
La143	0.00015	1.62E-12	1.52E-09	0.00E+00	1.58E-10	5.58E-04	4.25E-04	1.59E-04
La144	0.00012	6.24E-14	1.34E-09	0.00E+00	2.17E-09	3.53E-03	1.03E-05	4.42E-06
La145	8.09E-05	2.51E-14	5.52E-10	0.00E+00	9.62E-10	6.95E-04	4.87E-06	1.95E-06
La146	2.29E-05	1.86E-15	3.51E-10	0.00E+00	4.17E-10	3.86E-04	5.70E-07	2.39E-07
La146m	2.21E-05	2.86E-15	3.83E-10	0.00E+00	2.33E-10	2.83E-04	7.81E-07	3.41E-07
La147	2.22E-05	1.16E-15	2.82E-10	0.00E+00	2.22E-10	5.11E-05	2.97E-07	1.10E-07
Ce137	2.64E-06	1.04E-12	1.18E-13	0.00E+00	9.46E-13	1.64E-06	3.64E-06	1.46E-06
Ce137m	3.53E-07	5.30E-13	6.33E-13	0.00E+00	1.73E-13	2.33E-07	1.05E-05	8.56E-06
Ce139	5.02E-07	7.36E-11	1.47E-13	0.00E+00	6.93E-13	6.28E-07	6.97E-06	5.09E-05
Ce139m	1.73E-08	1.20E-17	9.86E-15	0.00E+00	1.25E-13	1.74E-07	7.82E-10	1.90E-09
Ce141	0.000563	1.97E-08	1.44E-09	0.00E+00	6.47E-10	4.99E-04	3.74E-02	2.00E-01
Ce143	0.00018	2.72E-10	6.94E-10	0.00E+00	4.33E-10	5.00E-04	1.09E-02	8.22E-03
Ce144	0.000126	3.95E-08	9.38E-11	0.00E+00	1.99E-11	1.79E-05	3.32E-02	3.39E-01
Ce145	9.61E-05	2.19E-13	5.91E-10	0.00E+00	4.66E-10	6.51E-04	2.90E-05	5.81E-05
Ce146	7.43E-05	8.19E-13	1.55E-10	0.00E+00	1.07E-10	1.27E-04	1.45E-04	3.46E-04
Ce147	5.49E-05	4.07E-14	5.64E-10	0.00E+00	7.66E-11	8.88E-05	7.68E-06	1.54E-05
Ce148	3.84E-05	2.82E-14	1.93E-10	0.00E+00	9.30E-11	8.09E-05	6.13E-06	1.44E-05
Ce149	1.92E-05	1.32E-15	9.39E-11	0.00E+00	4.03E-10	8.23E-05	5.43E-07	1.33E-06
Pr140	6.79E-09	1.71E-17	1.80E-14	0.00E+00	1.80E-14	2.24E-08	1.18E-09	9.91E-10
Pr142	0.003776	3.27E-09	2.74E-08	0.00E+00	1.98E-09	3.54E-03	2.74E-01	1.16E-01
Pr142m	0.001314	1.45E-11	0.00E+00	0.00E+00	4.33E-11	3.20E-04	1.25E-03	5.14E-04
Pr143	0.00018	2.67E-09	4.95E-10	0.00E+00	1.40E-17	1.95E-11	1.18E-02	2.36E-02
Pr144	0.000127	1.68E-12	1.25E-09	0.00E+00	3.52E-11	5.39E-05	3.25E-04	1.17E-04
Pr144m	2.65E-06	1.40E-14	1.33E-12	0.00E+00	3.84E-13	8.13E-07	3.69E-06	1.35E-06
Pr145	9.64E-05	2.67E-11	5.24E-10	0.00E+00	2.15E-11	2.99E-05	1.89E-03	8.25E-04
Pr146	7.53E-05	1.41E-12	7.98E-10	0.00E+00	6.10E-10	9.96E-04	3.28E-04	2.75E-04

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Pr147	5.84E-05	6.21E-13	3.56E-10	0.00E+00	3.93E-10	4.70E-04	9.64E-05	5.26E-05
Pr148	3.97E-05	7.09E-14	5.59E-10	0.00E+00	2.27E-10	3.41E-04	1.72E-05	1.44E-05
Pr148m	5.25E-06	8.26E-15	7.19E-11	0.00E+00	3.96E-11	5.05E-05	2.15E-06	1.81E-06
Pr149	3.01E-05	5.40E-14	2.63E-10	0.00E+00	1.00E-10	9.86E-05	1.79E-05	1.64E-05
Pr150	1.95E-05	1.58E-15	3.44E-10	0.00E+00	8.55E-11	1.24E-04	4.24E-07	3.56E-07
Pr151	1.12E-05	2.83E-15	1.30E-10	0.00E+00	5.77E-11	4.96E-05	1.59E-06	1.32E-06
Nd141	1.67E-09	1.87E-16	1.85E-16	0.00E+00	9.79E-16	1.60E-09	6.75E-10	4.07E-10
Nd141m	3.5E-10	2.73E-19	1.60E-16	0.00E+00	1.89E-15	2.63E-09	9.33E-12	5.60E-12
Nd147	9.16E-05	1.14E-09	2.63E-10	0.00E+00	1.34E-10	1.63E-04	6.68E-03	1.46E-02
Nd149	4.9E-05	4.02E-12	2.31E-10	0.00E+00	1.68E-10	1.82E-04	3.40E-04	2.52E-04
Nd151	2.52E-05	2.52E-13	1.20E-10	0.00E+00	2.11E-10	3.00E-04	4.18E-05	2.37E-05
Nd152	1.19E-05	1.10E-13	3.24E-11	0.00E+00	1.50E-11	1.39E-05	8.63E-06	5.06E-06
Nd153	6.89E-06	2.99E-15	7.64E-11	0.00E+00	5.05E-12	5.61E-06	2.78E-07	1.73E-07
Nd154	3.66E-06	1.29E-15	2.26E-11	0.00E+00	1.13E-11	1.62E-05	1.78E-07	1.12E-07
Pm145	2.16E-06	1.55E-08	1.74E-13	9.25E-20	4.48E-13	8.81E-07	9.76E-06	3.20E-04
Pm146	2.2E-08	4.96E-11	1.21E-14	0.00E+00	9.64E-14	1.29E-07	7.18E-07	1.67E-05
Pm147	4.41E-05	4.75E-08	2.07E-11	0.00E+00	1.43E-15	1.36E-09	5.43E-04	1.04E-02
Pm148	2.55E-05	1.55E-10	2.41E-10	0.00E+00	1.92E-10	3.08E-04	5.60E-03	4.56E-03
Pm148m	2.6E-06	1.21E-10	3.06E-12	0.00E+00	3.54E-11	4.79E-05	1.90E-04	6.35E-04
Pm149	6.8E-05	1.72E-10	2.65E-10	0.00E+00	9.16E-12	9.94E-06	4.46E-03	3.29E-03
Pm150	1.88E-06	2.41E-13	2.80E-11	0.00E+00	5.60E-11	8.81E-05	6.09E-05	3.04E-05
Pm151	2.54E-05	3.44E-11	6.81E-11	0.00E+00	7.28E-11	8.26E-05	1.02E-03	6.44E-04
Pm152	1.25E-05	4.16E-14	1.35E-10	0.00E+00	1.42E-11	2.03E-05	2.78E-06	2.54E-06
Pm152m	1.37E-08	8.31E-17	2.08E-13	0.00E+00	3.47E-13	5.08E-07	1.87E-08	1.73E-08
Pm152n	2.35E-08	2.74E-16	2.88E-13	0.00E+00	8.55E-13	1.13E-06	7.41E-08	6.91E-08
Pm153	8.26E-06	3.63E-14	4.47E-11	0.00E+00	3.50E-12	3.00E-06	1.51E-06	1.55E-06
Pm154	3.83E-06	5.33E-15	2.64E-11	0.00E+00	5.36E-11	9.50E-05	6.16E-07	5.60E-07
Pm154m	1.49E-06	3.28E-15	1.06E-11	0.00E+00	2.18E-11	3.61E-05	3.97E-07	3.68E-07
Pm155	3.92E-06	2.58E-15	3.44E-11	0.00E+00	9.01E-12	4.70E-06	2.66E-07	2.47E-07
Pm156	2.05E-06	7.57E-16	1.68E-11	0.00E+00	3.53E-11	3.68E-05	1.20E-07	1.10E-07
Pm157	1.11E-06	1.68E-16	1.45E-11	0.00E+00	4.09E-12	4.79E-06	2.09E-08	1.98E-08
Sm145	5.67E-06	2.14E-09	1.43E-12	0.00E+00	3.06E-12	5.69E-06	6.36E-05	4.85E-04
Sm151	3.21E-07	1.22E-08	2.15E-14	0.00E+00	1.55E-17	7.40E-11	6.60E-07	2.70E-05
Sm153	0.000548	1.24E-09	7.79E-10	0.00E+00	1.82E-10	2.30E-04	1.34E-02	1.14E-02
Sm155	0.000293	5.34E-12	1.57E-09	0.00E+00	2.76E-10	1.79E-04	4.78E-04	2.80E-04

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Sm156	2.75E-06	1.29E-12	4.34E-12	0.00E+00	2.69E-12	2.04E-06	3.36E-05	2.96E-05
Sm157	2.06E-06	1.39E-14	1.93E-13	0.00E+00	8.56E-12	8.65E-06	8.34E-07	5.12E-07
Sm158	1.23E-06	5.68E-15	4.61E-12	0.00E+00	3.18E-12	3.39E-06	7.21E-07	4.56E-07
Sm159	6.41E-07	1.01E-16	6.91E-12	0.00E+00	2.59E-12	2.86E-06	2.41E-08	1.38E-08
Eu152	1.26E-09	7.26E-12	2.91E-16	0.00E+00	2.62E-15	3.99E-09	1.97E-08	5.90E-07
Eu152m	1.04E-07	4.68E-14	1.66E-13	0.00E+00	1.03E-13	1.56E-07	1.03E-06	4.53E-07
Eu154	1.35E-05	4.99E-08	7.28E-12	0.00E+00	3.30E-11	5.13E-05	3.31E-04	8.77E-03
Eu154m	1.2E-05	4.56E-13	4.03E-12	0.00E+00	3.63E-12	4.59E-06	4.27E-07	6.10E-07
Eu155	1.92E-05	4.03E-08	3.08E-12	0.00E+00	2.97E-12	2.87E-06	9.25E-05	1.99E-03
Eu156	0.001005	1.82E-08	2.37E-09	0.00E+00	6.79E-09	1.18E-02	7.26E-02	1.12E-01
Eu157	3.98E-05	3.02E-11	7.08E-12	0.00E+00	1.16E-10	1.46E-04	1.49E-03	6.96E-04
Eu158	1.36E-06	5.24E-14	1.06E-11	0.00E+00	1.19E-11	1.92E-05	6.46E-06	3.23E-06
Eu159	8.4E-07	1.33E-14	5.88E-12	0.00E+00	1.82E-12	2.33E-06	2.57E-06	9.95E-07
Eu160	5.59E-07	4.18E-16	6.07E-12	0.00E+00	8.00E-12	1.08E-05	1.71E-07	7.70E-08
Eu161	3.2E-07	1.14E-16	3.74E-12	0.00E+00	9.78E-13	1.10E-06	4.24E-08	1.88E-08
Eu162	1.65E-07	2.20E-17	1.47E-12	0.00E+00	2.97E-12	3.15E-06	1.61E-08	7.31E-09
Gd153	3.11E-09	8.76E-13	2.09E-16	0.00E+00	5.10E-16	6.91E-10	8.06E-09	6.27E-08
Gd159	0.001296	1.22E-09	4.78E-09	0.00E+00	7.96E-10	9.18E-04	4.69E-02	2.58E-02
Gd161	0.000137	4.31E-13	8.32E-10	0.00E+00	5.63E-10	5.99E-04	4.39E-05	7.25E-05
Gd162	2.54E-07	1.97E-15	7.08E-13	0.00E+00	8.57E-13	1.05E-06	3.51E-07	5.51E-07
Gd163	1.2E-07	1.18E-16	3.70E-13	0.00E+00	1.90E-12	8.67E-07	3.10E-08	4.76E-08
Gd164	5.98E-08	2.76E-17	5.43E-13	0.00E+00	4.24E-13	4.49E-07	9.14E-09	1.42E-08
Tb157	5.24E-09	2.28E-10	3.75E-17	0.00E+00	6.83E-17	1.64E-10	1.40E-09	4.93E-08
Tb158	3.13E-09	2.50E-10	3.95E-16	0.00E+00	3.14E-15	4.76E-09	2.68E-08	1.12E-06
Tb158m	7.46E-07	1.10E-16	1.69E-13	0.00E+00	4.95E-14	8.92E-08	2.82E-10	2.69E-10
Tb160	0.001102	9.76E-08	2.76E-09	0.00E+00	1.22E-08	1.84E-02	1.09E-01	4.75E-01
Tb161	0.000353	3.00E-09	1.10E-09	0.00E+00	1.86E-10	3.17E-04	2.47E-02	4.46E-02
Tb162	1.32E-06	8.64E-15	1.57E-11	0.00E+00	3.22E-11	4.43E-05	2.72E-06	2.54E-06
Tb163	1.29E-07	2.18E-15	3.46E-13	0.00E+00	8.11E-13	9.37E-07	1.67E-07	1.54E-07
Tb164	6.89E-08	1.80E-16	3.87E-14	0.00E+00	1.29E-12	1.94E-06	2.97E-08	2.76E-08
Tb165	3.28E-08	6.07E-17	2.62E-13	0.00E+00	1.32E-13	1.36E-07	8.58E-09	7.92E-09
Tb166	1.48E-08	1.82E-17	9.91E-14	0.00E+00	2.81E-13	2.85E-07	4.12E-09	4.12E-09
Dy157	1.72E-06	7.01E-13	6.32E-14	0.00E+00	1.67E-12	1.86E-06	1.81E-06	8.91E-07
Dy159	1.07E-07	1.88E-11	8.74E-16	0.00E+00	3.10E-15	5.41E-09	4.25E-08	1.57E-07
Dy165	0.001821	2.24E-10	7.08E-09	0.00E+00	4.22E-10	5.25E-04	1.09E-02	5.95E-03

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Dy165m	0.001167	1.29E-12	1.07E-09	0.00E+00	1.97E-10	3.03E-04	7.63E-05	4.26E-05
Dy166	3.79E-06	1.64E-11	9.75E-12	0.00E+00	2.48E-12	3.52E-06	6.25E-04	7.42E-04
Dy167	8.71E-09	4.79E-17	6.31E-14	0.00E+00	4.75E-14	5.53E-08	8.88E-09	4.83E-09
Dy168	3.66E-09	2.78E-17	9.37E-15	0.00E+00	1.79E-14	2.65E-08	6.67E-09	3.62E-09
Dy169	1.51E-09	8.82E-19	1.20E-14	0.00E+00	1.20E-14	1.23E-08	2.53E-10	1.42E-10
Dy170	5.79E-10	1.78E-19	3.35E-15	0.00E+00	3.35E-15	3.41E-09	6.89E-11	3.90E-11
Ho164	5.19E-09	1.29E-16	1.97E-15	0.00E+00	3.02E-16	4.93E-10	6.35E-10	5.62E-10
Ho164m	2.27E-09	7.45E-17	4.30E-16	0.00E+00	2.25E-16	4.36E-10	4.67E-10	3.51E-10
Ho166	0.006546	9.29E-09	1.54E-08	0.00E+00	6.47E-10	1.06E-03	1.94E-01	9.02E-02
Ho166m	3.41E-08	1.90E-08	6.02E-15	0.00E+00	1.01E-13	1.37E-07	7.32E-07	4.39E-05
Ho167	0.000357	5.89E-11	2.50E-10	0.00E+00	4.34E-10	4.29E-04	6.25E-04	5.35E-04
Ho168	3.84E-09	1.03E-17	2.32E-14	0.00E+00	2.73E-14	4.02E-08	1.48E-09	1.31E-09
Ho169	1.74E-09	6.88E-18	9.01E-15	0.00E+00	7.18E-15	1.04E-08	7.08E-10	6.34E-10
Ho170	7.07E-10	1.78E-18	5.10E-15	0.00E+00	1.12E-14	1.64E-08	4.57E-10	3.81E-10
Er165	2.61E-08	1.42E-14	6.87E-16	0.00E+00	5.03E-15	8.97E-09	1.58E-08	6.56E-09
Er167m	0.005632	1.90E-13	4.66E-09	0.00E+00	6.16E-09	3.90E-03	3.58E-06	4.55E-06
Er169	0.000651	7.84E-09	1.33E-09	0.00E+00	2.63E-13	1.62E-06	2.98E-02	8.05E-02
Er171	1.29E-07	5.31E-14	3.62E-12	0.00E+00	3.26E-12	3.24E-06	1.97E-05	1.20E-05
Er172	1.94E-10	5.25E-16	1.09E-15	0.00E+00	4.38E-15	5.69E-09	5.30E-08	5.83E-08
Tm168	1.33E-10	1.59E-14	1.60E-16	0.00E+00	1.57E-15	2.17E-09	7.77E-09	2.51E-08
Tm170	0.000446	7.47E-08	3.28E-09	0.00E+00	5.49E-11	5.65E-05	8.10E-02	4.36E-01
Tm171	1.65E-05	1.51E-08	1.39E-11	0.00E+00	3.42E-13	3.25E-07	3.76E-04	4.79E-03
Tm172	9.26E-06	3.23E-11	3.10E-10	0.00E+00	2.89E-10	4.93E-04	6.32E-03	4.09E-03
Tm173	7.87E-09	3.58E-15	2.58E-13	0.00E+00	3.24E-13	3.40E-07	1.62E-06	9.39E-07
Yb169	1.23E-10	5.10E-15	1.98E-16	0.00E+00	6.10E-16	4.17E-10	8.26E-09	3.49E-08
Yb175	1.44E-08	8.06E-14	4.97E-13	0.00E+00	3.27E-13	3.14E-07	1.12E-05	1.86E-05
Yb177	1.47E-09	1.56E-16	6.53E-15	0.00E+00	2.89E-15	4.15E-09	8.54E-09	6.70E-09
Yb177m	5.95E-10	5.98E-20	1.13E-15	0.00E+00	9.49E-16	7.32E-10	4.76E-12	3.97E-12
Lu176m	2.58E-06	5.33E-13	5.46E-12	0.00E+00	1.65E-13	1.75E-07	1.22E-05	8.62E-06
Lu177	1.24E-06	1.13E-11	7.88E-13	0.00E+00	1.97E-13	1.68E-07	1.77E-05	4.00E-05
Lu177m	1.28E-09	2.77E-13	4.72E-16	0.00E+00	9.64E-16	1.01E-09	6.10E-08	5.74E-07
Lu178	5.54E-08	1.49E-15	3.14E-13	0.00E+00	6.28E-14	1.05E-07	1.28E-07	7.08E-08
Lu178m	4.06E-10	8.87E-18	1.53E-15	0.00E+00	3.28E-15	3.45E-09	7.39E-10	6.41E-10
Lu179	1.44E-10	3.77E-17	4.41E-16	0.00E+00	2.88E-17	2.60E-11	1.26E-09	7.19E-10
Hf172	3.27E-18	2.94E-21	0.00E+00	2.85E-33	0.00E+00	0.00E+00	5.48E-25	2.56E-24

Nuclide	Activity (Ci)	Mass (g)	β-Energy (kW)	α-Energy (kW)	γ-Energy (kW)	Dose Rate (Sv/hr)	Ingestion Dose (Sv)	Inhalation Dose (Sv)
Hf174	2.28E-24	2.22E-12	4.35E-17	0.00E+00	3.47E-16	3.52E-10	2.44E-09	7.15E-09
Hf177m	7.91E-08	1.34E-18	9.98E-14	0.00E+00	4.43E-13	4.13E-07	3.10E-11	6.21E-11
Hf177n	2.1E-10	1.01E-17	2.60E-16	0.00E+00	1.22E-15	1.25E-09	5.22E-10	5.80E-10
Hf178m	3.68E-08	2.32E-18	2.62E-14	0.00E+00	1.86E-13	1.97E-07	4.51E-11	9.13E-11
Hf179m	0.000219	6.48E-14	7.37E-11	0.00E+00	1.44E-10	1.27E-04	2.17E-07	4.18E-07
Hf179n	8.3E-07	2.86E-11	3.76E-13	0.00E+00	2.05E-12	2.13E-06	1.66E-05	5.25E-05
Hf180m	1.65E-05	5.20E-12	9.33E-12	0.00E+00	6.23E-11	6.71E-05	6.66E-05	5.09E-05
Hf181	0.001361	7.99E-08	2.84E-09	0.00E+00	7.37E-09	8.33E-03	9.54E-02	4.34E-01
Hf182m	4.13E-07	2.46E-14	1.29E-12	0.00E+00	6.20E-12	6.80E-06	1.66E-06	1.82E-06
Hf183	7.11E-06	4.43E-13	8.92E-11	0.00E+00	1.64E-10	2.20E-04	9.68E-05	7.56E-05
Ta180	6.44E-09	2.99E-15	1.85E-15	0.00E+00	1.32E-15	1.23E-09	9.72E-09	7.92E-09
Ta182	0.00021	3.35E-08	1.50E-10	0.00E+00	8.90E-10	1.41E-03	6.49E-03	4.33E-02
Ta182m	2.34E-06	1.07E-17	2.18E-13	0.00E+00	2.92E-14	2.16E-07	1.43E-11	3.42E-11
Ta182n	2.29E-06	3.51E-14	3.65E-12	0.00E+00	3.80E-12	2.98E-06	1.12E-06	1.96E-06
Ta183	0.003592	2.56E-08	8.49E-09	0.00E+00	6.97E-09	6.57E-03	1.97E-01	3.19E-01
Ta184	3.7E-06	1.89E-12	2.13E-11	0.00E+00	6.96E-11	8.75E-05	1.80E-04	1.14E-04
W 181	9.09E-06	1.52E-09	4.29E-13	0.00E+00	1.39E-12	1.38E-06	1.60E-05	5.70E-06
W 183m	0.004922	4.19E-13	7.86E-09	0.00E+00	5.36E-09	5.44E-03	8.53E-06	1.01E-06
W 185	0.021984	2.34E-06	2.36E-08	0.00E+00	9.32E-12	7.62E-06	5.10E-01	1.39E-01
W 185m	0.009195	1.51E-11	1.28E-08	0.00E+00	1.92E-09	3.04E-03	1.81E-04	2.23E-05
W 187	0.003603	5.13E-09	6.74E-09	0.00E+00	9.88E-09	1.27E-02	8.79E-02	2.65E-02
W 188	2.86E-06	2.85E-10	2.78E-12	0.00E+00	5.28E-14	4.69E-08	3.66E-04	9.94E-05
W 189	1.42E-08	1.64E-16	2.10E-13	0.00E+00	3.10E-13	3.73E-07	5.03E-08	5.98E-09
Re184	2.6E-09	1.39E-13	4.14E-16	0.00E+00	7.53E-15	1.07E-08	5.27E-08	1.00E-07
Re184m	2.82E-10	6.57E-14	1.10E-16	0.00E+00	3.28E-16	3.96E-10	7.89E-09	3.42E-08
Re186	0.021889	1.18E-07	6.61E-08	0.00E+00	3.42E-09	2.73E-03	1.83E+00	1.34E+00
Re186m	5.64E-10	5.86E-08	2.53E-16	0.00E+00	2.23E-16	4.41E-10	5.10E-08	2.78E-07
Re188	0.013803	1.41E-08	3.65E-08	0.00E+00	2.70E-09	3.07E-03	4.09E-01	1.58E-01
Re188m	0.000373	6.94E-12	1.04E-10	0.00E+00	9.35E-11	9.01E-05	2.37E-04	1.03E-04
Re189	4.28E-07	6.27E-13	7.12E-13	0.00E+00	1.33E-13	1.27E-07	1.08E-05	5.97E-06
Os185	8.2E-09	1.09E-12	7.47E-16	0.00E+00	2.93E-14	4.04E-08	1.30E-07	4.07E-07
Os189m	0.002053	5.95E-10	4.03E-10	0.00E+00	3.34E-11	2.46E-04	1.87E-03	5.50E-04
Os190m	6E-07	6.00E-15	5.85E-13	0.00E+00	7.95E-12	9.60E-06	1.25E-06	1.34E-06

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