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Revision 1

MARVEL Decommissioning Plan

MARVEL

Shutdown, Decommissioning, Temporary Storage, Fuel Cycle

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ACRONYMS

Be	Beryllium
CCA	Criticality Control Area
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIA	Central Insurance Absorber
D&D	Deactivation and Decommissioning
e-GaInSn	Gallium-Indium-Tin eutectic
EBC	Equivalent Boron Content
ECA	Engineering Cost Analysis
HALEU	High-assay low-enriched uranium
ICDF	Idaho CERCLA Disposal Facility
IEC	Idaho Environmental Coalition
IHX	Intermediate Heat Exchanger
INL	Idaho National Laboratory
LLW	Low Level Waste
MARVEL	Microreactor Application Research Validation and Evaluation
NaK	Sodium-Potassium Eutectic
PIE	post-irradiation examination
RCS	Reactivity Control System
Rx	Reactor
SS	Stainless Steel
TFFF	TRIGA Fuel Fabrication Facility
TI	TRIGA International
TREAT	Transient Reactor Test Facility
T-REXC	TREAT microReactor eXperiment Cell
TRIGA	Training, Research, Isotopes, General Atomics
WAC	waste acceptance criteria
WEP	Water Extended Polyester

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MARVEL Decommissioning Plan

1. INTRODUCTION

The purpose of this document is to update and formally document decommissioning plans for the Microreactor Applications Research Validation and Evaluation (MARVEL) microreactor. The update provides additional fidelity to the preliminary decommissioning schedule, including an estimate of the cooling time needed before access can be granted for dismantling. The sequence and duration of cleaning and decontamination form part of the schedule.

An updated cost profile is provided based on the schedule activities and assumed MARVEL storage containers, location for storage, and responsibility for MARVEL fuel in long-term interim storage. Options for potential high assay low enriched uranium (HALEU) recovery and post irradiation examination (PIE) are discussed, although they are not part of the planning assumptions, schedule, or cost profile. Exploration of those options would increase MARVEL's value but would likely involve intra-programmatic agreements that are not mature enough to support a cost estimate.

Primary assumptions in this planning document include:

- Operational testing consists of three continuous days of operation followed by four days of non-operation.
- Decommissioning will occur after start-up testing and two years of operational testing.
- All MARVEL fuel will be transported to long-term intermediate storage at the CPP-603 used fuel storage facility
- Sodium-potassium (NaK) coolant can be disposed as Class B radioactive waste
- The balance of the reactor's primary components can be disposed of at an available disposal facility.

Finally, we present the next steps for confirming assumptions, exploiting opportunities, and filling knowledge gaps. Given that there is considerable uncertainty in MARVEL's operation and end users, some information is provided to the extent that it is known with the recognition that further updates and agreements will be needed.

1.1 MARVEL Project Description

The MARVEL Project will demonstrate a new microreactor concept and associated processes. MARVEL is a scaled, prototypic microreactor intended for installation and demonstration in the north storage pit at the Transient Reactor Test Facility (TREAT) reactor building (MFC-720). Process demonstrations include design and authorization processes, new fabrication processes, power production, and streamlined readiness, start-up, and National Environmental Policy Act (NEPA) processes.

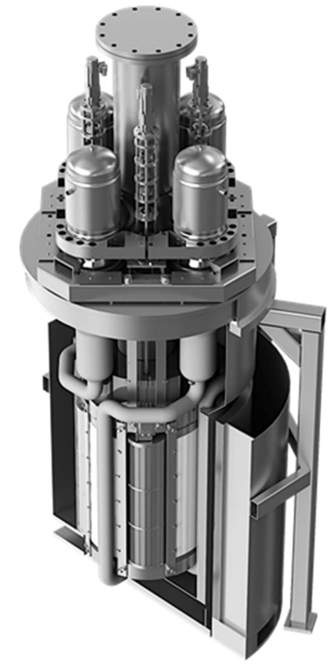

Figure 1. Conceptual rendering of MARVEL reactor.

Microreactors are defined as factory fabricated, transportable, and self-adjusting, with power rated between approximately 1 MWth and 50 MWth. MARVEL is scaled smaller by a factor of 10 to 500 times. MARVEL will be fueled with stainless steel-clad Training, Research, Isotope, General Atomics (TRIGA) fuel, composed of UZrH alloy, enriched to 19.75%. Heat removal will be by natural circulation of eutectic sodium-potassium (NaK) primary coolant through four parallel primary loops. Heat from the primary loop coolant will be transferred through identical tube-and-shell heat exchangers to four Stirling engines used for power production. Reactivity control will employ a beryllium reflector and control drum, with boron carbide (B_4C) on one face of the drum for negative reactivity.

The primary reactor vessel and reactivity control systems will fit within TREAT's north storage pit and occupy a space smaller than 8-feet long, 12-feet wide, and 10-feet high (less than 960 cubic feet, roughly equivalent in size to a small bedroom). Additional equipment needed for testing, such as heat rejection equipment and microgrid components, will be installed outside MFC-720 in portable trailers or in other temporary arrangements. Installation of support equipment, such as MARVEL control cabinets inside MFC-720, will be temporary. Permanent TREAT modifications are excluded from the project.

The equipment storage pit in the North High Bay of the TREAT Reactor Building is being configured as part of a separate, Institutionally funded General Plant Project (IGPP) intended to establish a multipurpose, technology-agnostic critical experiment testing capability (designated the TREAT microReactor eXperiment Cell, or T-REXC). TREAT facility modifications to establish T-REXC for this purpose includes establishing appropriate radiation shielding, providing appropriate support systems to the pit (e.g., electrical, HVAC, instruments, and controls), and the installation of generic reactor components such as neutron source and neutron reflectors. This equipment will be applicable to most critical experiments and small-scale microreactor demonstrations.

The MARVEL reactor will be remotely operated from the MFC-724 control room. It will be fabricated off-site and temporarily installed in T-REXC. It will not be permanently affixed and, at the end of its useful life, will be defueled and removed. The equipment will then be dispositioned as appropriate. MARVEL is anticipated to operate 2–3 days per week for 2 years. It is anticipated that a cooldown period of approximately 6 months will be required before decommissioning could begin. This number will need be verified via radiological monitoring.

1.2 Decommissioning per the Environmental Assessment

Deactivation and decommissioning (D&D) of the MARVEL microreactor is anticipated to occur in phases that vary in length and scope. Because the TREAT Reactor building must be evacuated when the TREAT reactor is actively running, D&D activities cannot take place during this time.

The first phase of decommissioning begins upon final shutdown of the reactor after completion of critical project operations. This phase includes monitoring the reactor and other equipment as systems cool down and radiation levels decay. Systems or components not exposed to a high radiation field will be disconnected and stored for re-use on other projects or dispositioned. This includes draining, breaking down, and storing equipment from the heat rejection system located outside of the reactor pit. The subsequent phases of the MARVEL microreactor D&D are dependent on the power history and decay times of the radioactive isotopes in the core, coolant, and activated equipment, which could be from months to years after shutdown.

When radiation levels are low enough for safe pit access, the heat removal system, high-grade heat exchanger used in some operating configurations, pit HVAC, and the intermediate heat exchanger (IHX) will be decommissioned. Then the bulk of the NaK primary coolant (most of the 61 gallons or 120 kg) will be drained from the system, and residual NaK remaining on pipes, vessels, and other components in the reactor vessel systems will be reacted and disposed of accordingly. This is detailed in Section 5.2.

After deactivating the residual NaK in the core, defueling begins with evacuating the argon cover gas and removing the vessel head to access the fuel. Fuel pins will be removed one at a time, and each will undergo gross decontamination to verify it is dry and clean. Radiation and contamination surveys will be performed as each assembly is removed. After inspection the assemblies will be placed in designated shipping or storage containers following criticality control protocols. Containers are intended to be dry stored at CPP-603. Any post-irradiation examination or reprocessing costs and schedule are not considered as part of this work scope. Section 5.4 discusses the used research fuel in more detail.

The next step is the removal of the IHX. The IHX is anticipated to contain a Gallium-Indium-Tin eutectic in a liquid form, designated as e-GaInSn. After the core is defueled and coolants removed, the nuclear instruments will be disconnected and disposed of or stored for re-use. Power to in-pit systems will be disconnected, and reactivity control systems will be removed and disposed of separate from the reactor vessel. The activated beryllium can also be removed from the motor systems and managed as discussed in Section 5.6.

At this point the reactor pressure vessel will be grouted, removed, and disposed of.

1.3 ANALYSIS OF ALTERNATIVES

In the fall off 2022 the Idaho Environmental Coalition, LLC (IEC) worked with the TREAT engineering and operations staff to develop a sequence of events, including a draft budget and schedule. This work provides the basis for the current decommissioning plan. The project design has continued to evolve, but the assumptions are largely still valid for forming a basis of estimate. There were five separate options developed which can be summarized as:

Option 1 – Driven by complete hazard removal (primarily Beryllium - Be). The total removal is based on the value of Be, without regard to the added risk for retrieval. Again, the cost and schedule scores low due to the additional hazard removal, plus the extension of Be controls, containers, and waste disposal if required.

Option 2 – Driven by minimal hazard removal. Minimal hazard removal is defined as the lowest number of beryllium blocks required for post-irradiation testing. The quantities of hazards are anticipated to meet the waste acceptance criteria (WAC) for Idaho CERCLA Disposal Facility (ICDF). Additionally, this option provides for less risk, and some reduction in cost and schedule. The primary negative issue is the remaining Be in the reactor pit.

Option 3 – Assumes partial hazard removal and no grouting of the reactor. May or may not be a viable option due to "on contact" radiation levels. If grouting is not required, this option provides for additional savings in multiple options based on the cost of preparations for and grouting.

Option 4 – Provides the most cost and schedule savings of any option. Basically, it prepares the reactor as in Option 2, but it remains in the pit at TREAT and is grouted in place. Implementation would result in a significant reduction in cost, schedule, and risk. The downside is the loss of use of the pit for future TREAT operations.

Option 5 – The question was raised whether the reactor could be moved to another facility and processed for disposition. This option is very unlikely because of issues moving a vessel with NaK and used fuel, the need for an alternate Hazard Category II facility, regulatory approval complications, increased health and safety issues, and significant cost/schedule increases. This is considered a non-viable alternative.

The various options were ranked for suitability. The best option from a strict schedule and cost perspective is Option 4, which is to prepare the reactor to remain in place and grout it into the TREAT pit. This is deemed untenable due to the long-term loss of TREX-C for TREAT operations.

The second ranked option, and the path chosen, is to proceed with minimal hazard removal. Largely, this means leaving the Beryllium (Be) reflector blocks inside of the TREX-C.

Table 1 gives relative cost and schedule comparison for each option. These options were normalized to an estimated cost and schedule for Option 1. The reason for normalization was to avoid incomplete cost or schedule information.

Table 1. Options for disposal.

Option #	Description	Schedule (Relative)	Cost (Relative)
1	Full Disassembly	1.0	1.0
2	Partial Hazard Removal	0.83	0.91
3	No Grouting	0.76	0.89
4	TREAT Disposal	0.69	0.86
5	Facility Relocation	N/A	N/A

In general, the less the reactor is disturbed from its shutdown condition, the lower the cost. It is recommended to start the generation of a standalone engineering evaluation and cost analysis approximately 18 months in advance of the start of the D&D activities. The options above are meant to provide a range of options but are not all inclusive. Other options and pathways can be devised.

There are several important assumptions underpinning this table. The design has evolved since this initial estimate, several of the assumptions will need to be re-evaluated. These assumptions are categorized as risks and will be addressed as is possible.

A. Technical/Engineering:

1. The EE/CA & RCRA Closure Plan will be the acceptable regulatory framework for work in TREAT (Marvel Reactor work only).
2. TREAT infrastructure and safety documentation will support decommissioning activity (e.g., floor loading, crane capacity).
3. Reactor assembly tools and equipment will be retained, made available, and will be adequate for disassembly.
4. Certified containers for reactor internals movements exist and are available.
5. Reactor disassembly will require shielding for in-process work and grouting for final shielding.
6. No additional utilities or temporary power will be required.
7. Waste from Rx D&D work will be considered CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) waste and disposed of in ICDF. **This assumption must be verified and an agreement must be reached with ICDF.**
8. Off-site waste disposal locations (such as the Waste Isolation Pilot Plant (WIPP), Energy Solutions) will be available to support receipt and disposition of qualified waste in accordance with delivery schedules.

B. Planning/Financial:

1. The estimate is based on performance by a single subcontractor. (exceptions will be noted).
2. This estimate is based on IEC labor rates, union agreements, and escalation.
3. The estimate assumes that TREAT has open access and will not cause delays in employee entry or material deliveries.
4. This work will be performed on a normal 4×10 work schedule and TREAT will be accessible during normal hours of operation.

   This assumption may be problematic as TREAT will remain in operation during D&D activities. It is anticipated that this will be performed on a shifted schedule. See C.1 below.
5. Funding target and availability remain as committed throughout the life of the project.

C. Operations:

1. TREAT operations will not be impacted by D&D work scope. Coordination, such as alternative work schedules, will be required by the D&D Team to avoid impacts to TREAT operations.
2. Operational Readiness Review will not be required.
3. Post defueling operations will be treated as less than Hazard Category III.
4. Reactor fuel long-term storage will occur at Idaho Nuclear Technical and Engineering Center (INTEC.)
5. The haul road between Materials and Fuels Complex (MFC) & ICDF will be adequate for transport of the reactor guard vessel and internal components from TREAT to ICDF.
6. The only readiness requirement will be a management self-assessment for readiness and approval to grout and dispose of the reactor,

7. No weather-related impacts are planned.
8. ICDF will be the disposal location for removed primary plant components and the reactor. All disposal components will meet the Waste Acceptance Criteria for ICDF.
9. Contractor shall secure and/or furnish Material Handling Equipment for off-loading, moving, and placing of the components and equipment.
10. This estimate assumes that the Contractor will furnish all materials and equipment; no materials will be Government Furnished Material or Free Issue.
11. Supply chain issues will not delay the schedule.
12. Crew shower facility available for use at TREAT.

2. PATH TO DECOMMISSIONING

The process to decommission a reactor, even a small test reactor, begins well in advance of the actual work. During reactor development the decommissioning plan should be further refined and agreed to prior to reactor start-up, and ideally as early as possible in the design and fabrication process. This will allow necessary features and sequencing to be implemented to aid in disassembly and disposition. The flowchart shown in Figure 2 outlines a high-level workflow of the broad steps to develop and execute the decommissioning work scope. A general timeline of the activities is presented in Table 2. These numbers should be used as rough guidance only and will be confirmed and updated during the detailed plan development. To summarize the timeline in the table, preparatory activities for decommissioning should begin 24–31 months prior to anticipated reactor shutdown, with final preparatory activities being completed during cooldown. The anticipated cost for decommissioning is currently estimated at $25–35 million. This is based on the estimate provided by IEC, escalated to a later start date, and three full-time equivalent (FTE) persons of support from Battelle Energy Alliance personnel to support IEC activities.

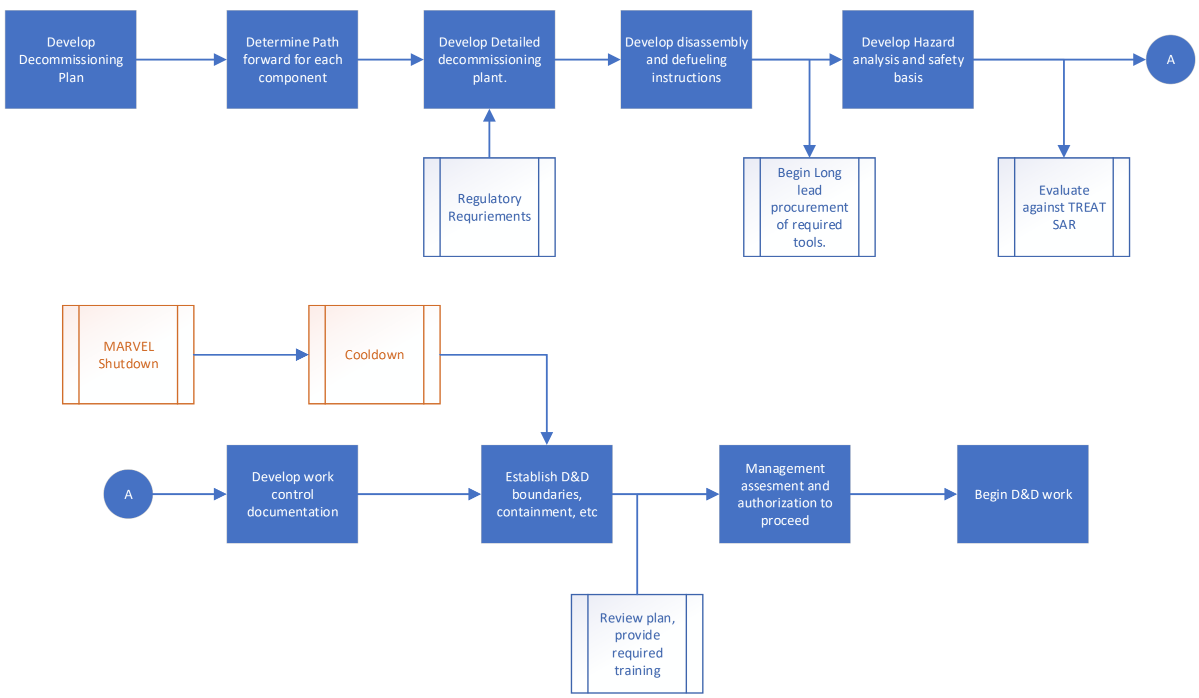

Figure 2. Flowchart showing activity sequence to begin D&D work.

Table 2. Activities and general timeline to support decommissioning. Activities above the dark line should be completed prior to shutdown.

Activity	Description	Expected Duration
Perform the Engineering Cost Analysis (ECA)	Perform the ECA analysis to ensure ICDF is a viable option for disposal of materials.	6 months (should be started as soon as able)
Update decommissioning plan	Document outlining various options for decommissioning, with high-level schedule and budget.	3–6 months
Determine path forward for decommissioning	Based on the option presented select disposition pathway for each identified component or material.	3–6 months
Develop detailed decommissioning plan	Review regulatory requirements and historical documentation and develop detailed plan, estimate, and schedule for disposition of each component.	8–12 months
Develop disassembly and defueling instructions	Develop detailed instructions for disassembly and defueling of each of the reactor subsystems.	4–7 months
Develop hazard analysis and safety basis documentation	Develop required hazard analysis and safety basis documentation to perform work. Evaluate against relevant SAR and facility safety documents. Modify, review and approve documents as required.	6–8 months
Develop required work control documentation.	Develop necessary work control and training documentation.	4–6 months
Establish D&D boundaries	Turnover affected portions of TREAT to D&D operations and establish boundary and shielding as necessary.	2 months
Begin D&D work	Execute D&D work per approved plan.	18–24 months

3. MATERIAL FOR DISPOSITION

Upon completion of reactor operation and testing, the MARVEL reactor will need to be disassembled and decommissioned. The MARVEL reactor is composed of various subsystems and materials that will require varying approaches for disposition. Table 3 provides a high-level overview of the various systems and their primary materials. For reference, the entire reactor system fits into the TREX-C enclosure which has a volume of 960 cubic feet. This would be the bounding amount of waste that could be generated.

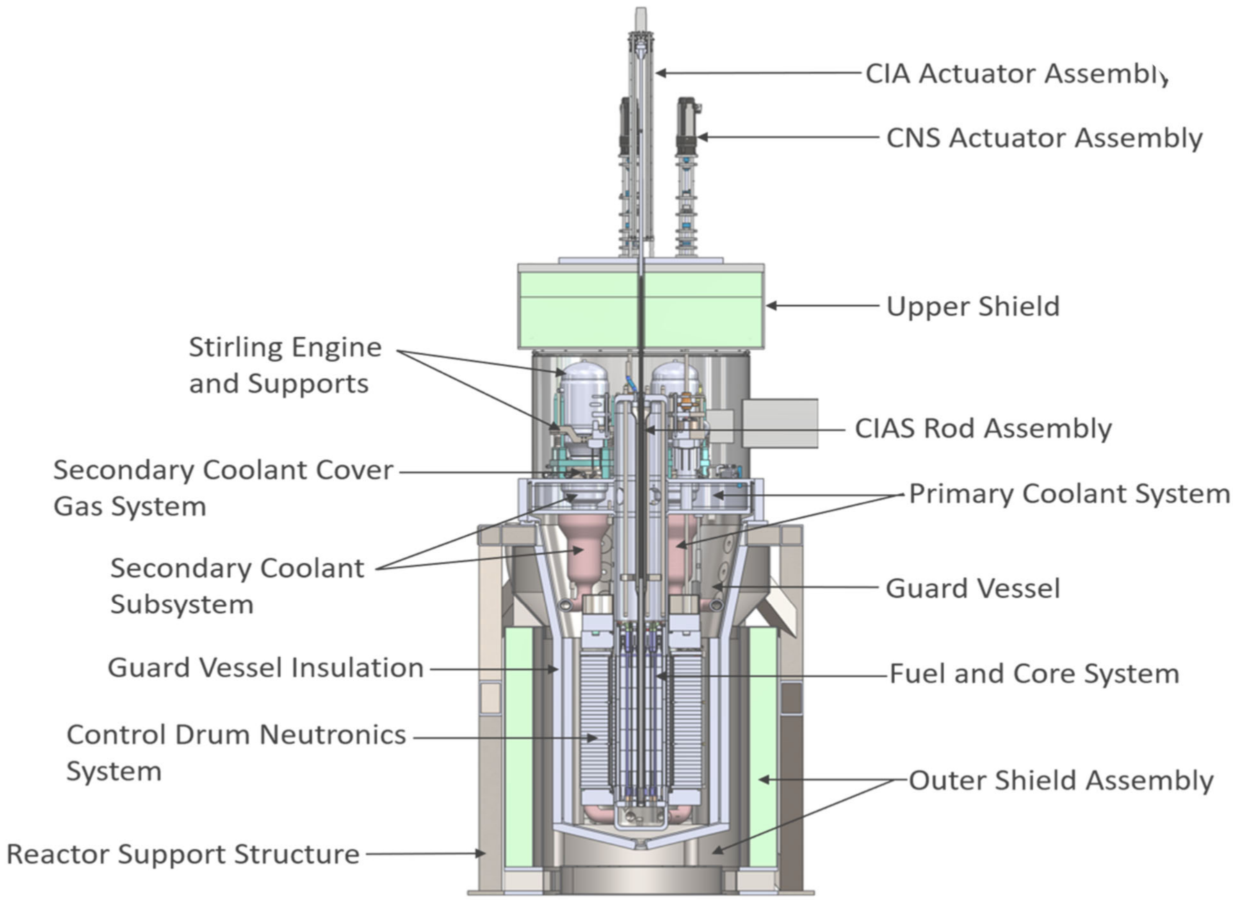

Figure 3. MARVEL Reactor Cutaway view at 90% design.

Table 3. Primary system description and material makeup.

System	Description	Primary Materials	Dose/Activation	Estimated Quantity
Reactor Fuel and Core	Fuel core consisting of 36 MARVEL fuel rods, each composed of TI fuel slugs.	U-Zr Hydride fuel in Stainless Steel Cladding.	Cladding: 0.098 DPA	~46.25 Kg Uranium. ~204 kg total.
Control Drums & CIA Rod	Four B_4C and BeO control drums installed radially around the reactor.	B_4C plates, Stainless Steel, BeO Plates.	6.0E2 RAD (Control Drum)	18 kg 304 kg
	Shutdown control rod containing B_4C absorber	Stainless Steel B_4C Pellets.	6.5E02 RAD (CIA)	<5 kg
Guard Vessel	Primary containment vessel.	316H Stainless Steel	8.81E1 n/cm^2 0.048 DPA	
Primary Coolant System	NaK liquid providing primary heat transfer from fuel to intermediate heat exchanger.	NaK fluid	—	~61 gallons, 160 kg.[6]
Intermediate Heat Exchanger Fluid	GaInSn secondary coolant provides heat transfer from primary coolant to power generation system	GaInSn coolant	—	~272kg [6]
Power Conversion System / Heat Extraction System	System used to extract usable heat from the secondary coolant system. This may include integral power conversion.	Stainless steel alloys	6.2E6 rad	~440 kg [a]
Reflectors	Neutron reflectors placed around the core.	BeO Reflectors	6.25 × 10^1 nvt	~1360 kg [7]
Reactor Support Structure	—	Stainless Steel	—	~612 kg
Shielding	Supplemental shielding for reactor.	WEP Lead Carbon Steel	—	462 kg 1285 kg 1864 kg [7]
Nuclear Instrumentation	Various nuclear instruments.	BF_3 and B-10 lined ion chambers	—	2 each

[a] This accounts for disposal of a set of power conversion systems (4x Sterling Engines). If more disposals are required it will increase the weight accordingly.

4. DECOMMISSIONING EVENT SEQUENCE

The following flowchart lays out a notional sequence of events for how dispositioning may take place.

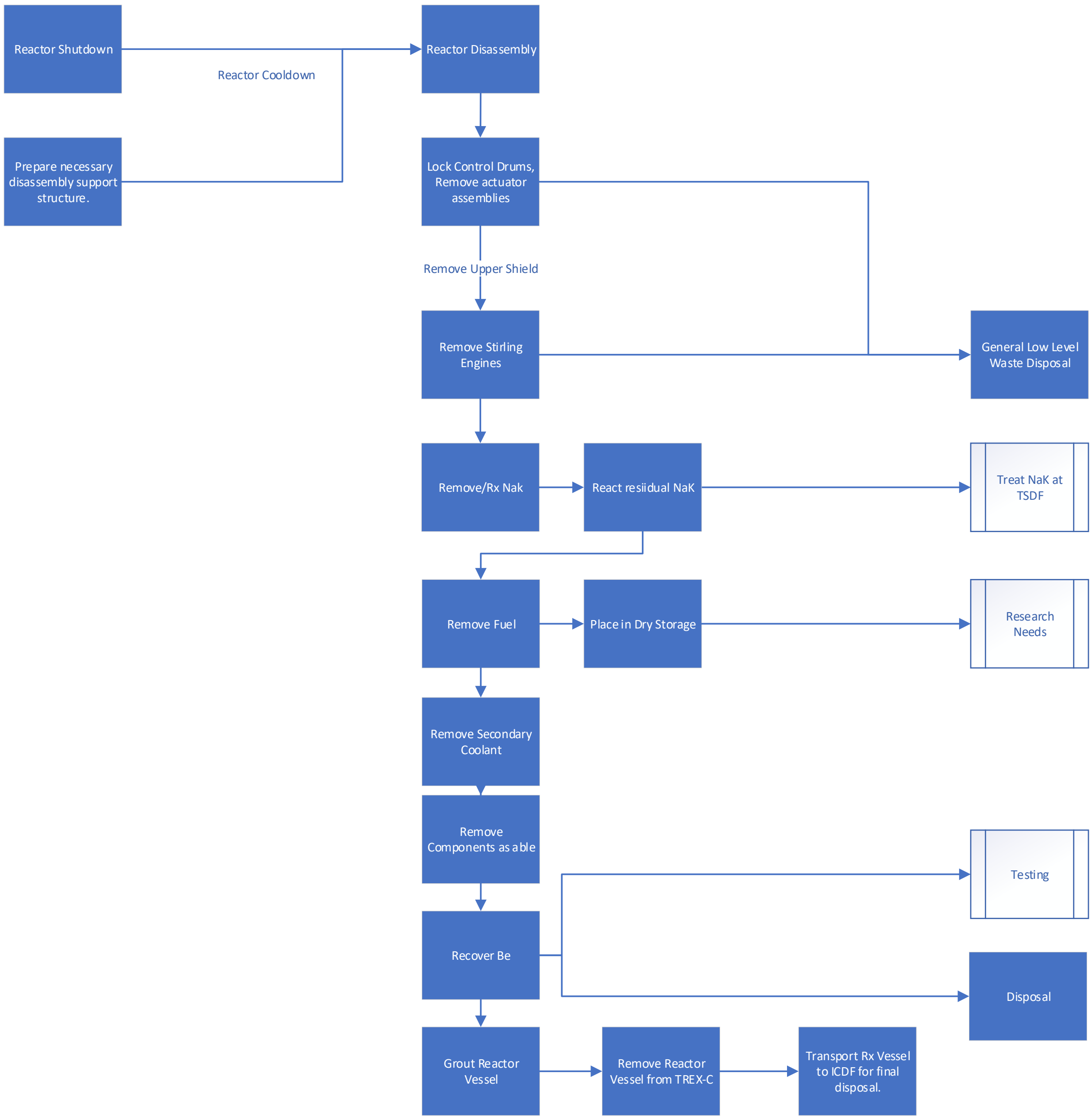

Figure 4. Flow chart for decommissioning activities.

4.1 Cooldown

After operations are deemed complete, the reactor will enter cold shutdown and configured such that it cannot be restarted. This is done by locking the control drums in the position with the largest negative reactivity. The mechanisms for operating these components will then be removed or controlled in such a way that they are no longer functional. The reactor will then stay in cold shutdown long enough for the short-lived fission products to decay until the overall radiation field is within acceptable bounds. During this time radiological monitoring of TREX-C and the reactor will determine the decay times until radiation levels decrease to the level where D&D activities can safely begin. It will be important to update models based on operational history and perform surveys to appropriately quantify expected radiation levels and determine the minimum cooldown time.

4.2 Support Equipment Removal

During the cooldown period of the reactor island, decommissioning of supporting systems, outside of the high-radiation fields, can be started. This would include any heat rejections system, power generation, load banks, etc. The equipment that has anticipated re-use could be stored until required, while equipment no longer needed could be dispositioned and removed.

4.3 Reactor Disassembly

To start disassembly, the installed components above the reactor shield blocks will all be removed and dispositioned. This may include control systems, heat rejections, CIA (Central Insurance Absorber) rod housing, and other items. Next the upper shield plate will be removed. The TREAT shield covers and blocks will be removed. Evacuation of the secondary cover gas will be required. The lower portion of the CIA system and the control drum actuators can then be removed. It is anticipated that the secondary heat removal system can then be removed. The secondary coolant and, finally, the primary coolant can be removed. The next phase will remove the fuel. After fuel removal, nuclear instrumentation can be removed and dispositioned, followed by the reactivity control system and any remaining reactor systems, which will complete MARVEL decommissioning.

5. SYSTEM DESICRIPTION AND STEPS

5.1 Reactivity Control System Removal

The reactivity control system (RCS) consists of many components. For simplification, they are divided into four subsystems: B_4C Plates, Beryllium Oxide, CIA rod, and other components. Shortly after shutdown, the RCS actuators will be removed and disposed of accordingly, and the control drums will be secured in their primary shutdown position. The RCS and CIA rod actuators are located above the reactor shield plate and should have much lower radioactivity levels than the control drums. Once the fuel and coolants are removed the remaining portions of the RCS can be removed.

B_4C plates: These plates are the neutron poison portion of the control drum and will consist of 84 independent plates split between the four control drums. These are estimated to weigh a total of approximately 18 kg. The end-of-life radiological source term is found in ECAR-7771 and is shown in Appendix A.

Be Oxide: The control drums also contain Beryllium oxide in the form of 1-inch-thick disks approximately 8.250 inches in diameter. There are 27 disks per control drum, or 108 in total. It is estimated that these will weigh approximately 304 kg.

CIA rod: The CIA rod is a rod composed of B_4C pellets clad in stainless steel (SS) which act as a neutron absorber. There is less than 1 kg of B_4C in the form of 1.8-inches tall by 0.664-inch outer diameter pellets.

Other components of the RCS include the SS hubs to connect to the actuators, various fasteners, stainless steel support structures, Inconel compression springs, zircaloy (Zr-4) reflectors, electromagnetic clutches, and various other components.

5.2 NaK Removal

The removal of the Sodium-Potassium Eutectic (NaK) primary coolant from the reactor will be required before further processing of the reactor structure. Prior to the removal of the NaK, the argon cover gas will need to be evacuated and replaced due to potential contamination. This will be accomplished by feeding clean argon, and evacuation and treatment of the contaminated argon. It is important that the argon cover remains to prevent potential oxidation of the NaK. The source term for the cover gas was generated on a per-day basis.

The NaK coolant is assumed to be composed of approximately 22% sodium and 78% potassium [2]. This assumption should be cross verified with the NaK composition actually installed. The end-of-life assessment for the isotropic concentration and dose of the sodium is shown in the appendix, but totals to 9,9140 Ci. This inventory does not account for possible contamination by interaction with fuel cladding or the vessel. It is anticipated that the first step will be the bulk draining, or removal of the NaK. After bulk draining, the International Atomic Energy Agency has reported that the NaK remaining will be on the order of 30 to 100 micrometer thick on vertical surfaces, and 1 mm thick on horizontal surfaces. The report also cites that non-gamma emitter isotopes such as Ni-63 and Fe-55 accumulate in the residual sodium film. Tritium also generally accumulates in the thin film of residual sodium and also remains trapped in the steel structure. If desired, a special process could be employed to recover the tritium generated, such as through hydrogen swamping and a cold trap [8]. The bulk sodium will be transported in 50-gallon drums to a Treatment Disposal and Storage Facility (TDSF) as mixed radioactive waste. The specific facility has not yet been identified but there are commercial vendors, such as Perma-Fix and Waste Control Specialists, that can handle this waste.

The residual sodium in the system will be removed using a steam process. In general, a mixture composed of nitrogen and a small amount of water vapor is passed through the system, causing the residual sodium to react. The gaseous products are then routed through appropriate ventilation and discharged to the atmosphere. The liquid waste stream containing sodium/potassium hydroxide will need treatment. Oxygen control is a critical safety step to avoid unintended reactions with the sodium.

5.3 Secondary Coolant System

The secondary coolant system is currently envisioned to contain e-GaInSn. The radiological source term for e-GaInSn is given in Table 9. It is assumed that the e-GaInSn is based on a mixture of 77.2, 14.4, and 8.4 atomic % of Ga, In, and Sn, respectively [3]. The assumption is that the secondary coolant would not be considered as resource conservation and recovery act (RCRA) waste. MARVEL's current power conversion and secondary loop configuration will contain approximately 272 kg of e-GaInSn.

5.4 Fuel Removal

Once the coolants are removed from the system, the defueling operations can begin. The fuel will be extracted one element at a time. After gross decontamination, its integrity will be verified, and then it will be placed into a container for transport to CPP-603 for Dry Storage. There are 36 fuel rods in the reactor, each is 39.474 inches in total length and approx. 1.414 inches in outside diameter, in the reactor. A small portion of these are anticipated to be used for PIE and characterization. ECCAR-6076 provides an expected isotopic inventory at the end of life for the fuel.

5.4.1 Transportation for storage

The currently identified storage facility for used MARVEL fuel is CPP-603 Dry Storage, the same location in which other TRIGA fuel is stored. It is assumed prior to MARVEL fuel shipment that the facility is actively running and receiving used TRIGA fuels from other sources. The costs for storage facility operations are not included in this analysis.

Before transport to CPP-603, the fuel will be inspected at TREAT as-removed from the reactor, paying special attention to cladding damage or breach. The fuel will then be loaded into a BRR cask and transported via out-of-commerce transport from TREAT to CPP-603. The BRR cask is a Type B(U)F-96 package designed for transport of used research reactor fuel. The inner cavity has nominal dimensions of 16 inches in diameter and 54 inches in length. Prior to use for MARVEL fuel, a modification to the safety analysis for CPP-603 may be necessary to add MARVEL fuel. The package is currently approved for TRIGA fuel of various forms. It is also anticipated that the current TRIGA fuel spacer and holders can be used. Once arriving at CPP-603, the fuel will be processed in accordance with facility procedures. The rough order of magnitude cost for this activity is <$1 million.

Used fuel from MARVEL would be considered research fuel and remain available for future research purposes. As such, it is not governed by the disposition constraints listed in the Idaho Settlement Agreement.

5.4.2 Alternative uses for MARVEL fuel

While dry long-term storage is proposed for MARVEL fuel, there is a multitude of alternative research uses for the fuel. A few have been explored here but would require further work to determine their viability.

The current need for HALEU produced in the United States is significant. The burn-up on MARVEL fuel will be very low and may provide an attractive source for HALEU recovery. There are a variety of processes available, such as electro-refining, which can separate uranium and zirconium and may also allow a recovery pathway for legacy TRIGA fuel depending on the inventory and burn-up. Hydrogen content and its evolution from the fuel may be of issue and an off-gassing step may be required.

Other alternative uses may include PIE study for fuel and materials performance, or repurposing for use in other applications or tests. The ideas presented here are not intended to be exhaustive, only illustrative. No costs are included in this work for fuels research.

5.5 Heat Rejection System

The heat rejection system will fit on top of the intermediate heat exchanger, at least partially underneath the shielding. If Stirling engines are used as the heat rejection system and are placed in the location indicated by the 90% design review, then the dose rates expected upon removal are captured in Appendix A. This table will be similar for any SS material in a heat removal system. In the case of the Stirling engines this is a conservative limit since it is not anticipated that a single Stirling engine can last throughout the duration of MARVEL operations.

5.6 Beryllium Recovery

There are a few sources of Beryllium (Be) in the MARVEL and TREX-C systems. These include the BeO stationary reflectors between the control drums, the plates located inside the control drums, and associated pins and fasteners. The proposed path is to remove all the BeO and store some, or all off it, in the TREX-C area. Management and storage of the BeO is not included in this cost estimate.

The second source of Be is the Be metal axial and radial reflectors located inside the Guard Vessel. These are assumed to be grouted inside the Guard Vessel when it is dispositioned, making it a mixed hazardous waste. Disposal of the Guard Vessel is included in the cost estimate as a MARVEL cost.

5.7 Grout Reactor Vessel and Disposal

Once the coolant, fuel, and other removable items are dispositioned, the reactor guard vessel and its internal components will be filled with grout and removed from the TREX-C pit.

5.8 Other Components

There is a variety of other components which constitute the remainder of the reactor systems. It is anticipated that this will be treated as low-level radioactive waste or mixed hazardous waste and disposed of accordingly. A brief list, not intended to be exhaustive, of various components is as follows: Water Extended Polyester (WEP), neutron-absorbing Felxiboron (SWX-238), B_4C powders, tungsten photon shields, and other miscellaneous items. For conservatism in the cost estimate these are assumed to be disposed of as mixed waste.

6. DISPOSTION PATHWAYS

Each of the items on the above list will need a determination for disposition of that item. While the exact process will vary based on the individual material, the disposition options can be broadly categorized in the following ways:

- Burial: These items will be prepared for long-term burial.
- Long Term Interim Storage: Stored in a long-term safe condition. May be retrieved for future use.
- Research and Investigation: Several portions of the reactor may be suitable for further post-irradiation examination, repurposing, or reprocessing. For each of these items a specific sequence of activities would need to be defined as well as scientific objectives.

6.1 Planned Disposal Routes

The following table presents MARVEL's major waste streams and their anticipated mass or volume. Of note, 36 elements are listed in the table as irradiated fuel. One element will be purchased as a spare but is not expected to be irradiated so it is not included in the waste stream.

Table 4. Summary table of waste streams and disposal amounts.

Waste Stream	Anticipated Qty	Planned disposal route[b]	Cost basis
Used Research Fuel	36 elements, 204 kg (~47 kg of U)	CPP-603 High Level Waste	\$500k-\$1,000 k [ROM Estimate from CPP-603]
NaK	~61 gallons (160 kg)	TLDF Facility	Included in IEC estimate
GaInSn	~272 kg	Low Level Waste (LLW)	
Be	2400 kg	Class A, LLW	
B_4C	~20 kg	Class A, LLW	
Stainless Steel	~1300 kg	Low Level Waste	
Misc. Materials	—	Low Level Waste	

[b] These waste classifications should be evaluated and confirm.

7. IDAHO NATIONAL LABORATORY FACILITIES AND CAPABILITIES

7.1 Existing Facilities

CPP-603 Irradiated Fuel Storage Facility (IFSF): This is an existing dry storage facility containing TRIGA Fuel elements. The intention is for the fuel to be stored here. Minor modification to the storage canister inserts may needed to accept the MARVEL fuel which is slightly longer than the legacy TRIGA Fuel.

ICDF: Existing CERCLA disposal site at INL, adjacent to INTEC.

8. RISKS AND NEXT STEPS

8.1 Risks

The table below shows a summary of risks and opportunities currently understood for the decommissioning process. The IEC estimate identifies additional risks that are more relevant to the subcontractor rather than the project.

Table 5. Identified risks to the MARVEL fuel fabrication process.

Title	Description	Mitigation
Inability to meet ICDF WAC	Planning assumption is that MARVEL waste will meet ICDF WAC based on preliminary decommissioning plan developed by IEC.	Additional management reserve for alternate disposal site. Perform ECA and Formally confirm acceptance as soon as practical.
Opportunity: Re-use of HALEU	Potential that HALEU can be recovered and demonstrate portion of the	Exploit. Collaborate with Fuel Science and Technology Directorate for technical expertise and potential funding.
Opportunity: Cost reduction via minimal treatment	Engagement with ICDF to minimize effort to meet WAC.	Exploit. Use existing blanket master contract and the ECA as a means to engage.
Extended MARVEL Operations	MARVEL operates for longer than anticipated, or starts later than anticipated. This will result in higher costs due to activation or escalation.	Additional management reserve for increased cost. Include a request for additional funding if authorized to operate longer.
TREAT Operations	TREAT Operational cadence causes work to be performed on alternative shifts increasing costs.	Work with TREAT operations for planning concurrent work scopes

8.2 Next Steps

Construction, readiness, risk realization, other organizations, and in particular, operational history have the potential to affect decommissioning plans. The following steps are recommended to ensure that plans develop and mature with the project's progress.

- Environmental checklist to confirm we are enveloped by the Environmental Assessment (EA)
- Memorandum of Understanding with Department of Energy Office of Environmental Management (EM) confirming they will take the used fuel. Confirm if required.
- Confirmation that we meet the ICDF WAC and agreement that they will accept it.
- Finalize cooldown calculation based on completed design and operational cadence.
- Verify materials, weights, and activation based on final operational analysis.
- Revise estimates with updated information, revised start date, new escalation analysis.

9. REFERENCES

[1] J. Parry, “MARVEL Reactor End of Life Enveloping Radiological Source Term,” ECAR-6076, Rev 0, Idaho National Laboratory, November 2023.

[2] D. Blaylock, “PGS Stirling Engine Radiation Lifetime Estimate,” ECAR-7447, Rev 0, Idaho National Laboratory, October 2023.

[3] C. Parisi, “Generation of RELAP5-3D Thermodynamic Property File for Gallium-Indium-Tin Eutectic ECAR-7359.

[4] G. Smith, “MARVEL Post-Shutdown Dose Analysis in the Upper Confinement” ECAR-7448. Idaho National Laboratory, November 2023

[5] D. Apsher, “MARVEL Source Term Calculations” ECAR-7771. Idaho National Laboratory, May 2024

[6] L. Lilliana , “MARVEL Guard Vessel System FEA and ASME” ECAR-6574. Idaho National Laboratory, May 2024

[7] D. Apsher, “MARVEL Shield Stress and Performance Analysis” ECAR-6583. Idaho National Laboratory, October 2023

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Appendix A: Compiled Source Terms for End-of-Life MARVEL

APPENDIX A

Table 6: Radiological Source Term for B4C Pellets. [5]

Nuclide	Ci/barn*cm	Total Ci
H-3*	2.50E-41	1.53E-13
Li-8	5.76E-26	3.53E2
Be-8	5.76E-26	3.53E2
C-14*	1.32E-32	8.10E-5
N-16*	2.58E-46	1.59E-18
O-19*	5.82E-51	3.58E-23
F-20	1.97E-30	1.21E-2
Ne-23	7.10E-45	4.36E-17
Na-24*	2.26E-49	1.39E-21
Si-31*	2.79E-42	1.71E-14
Si-32*	2.82E-53	1.73E-25
P-32*	1.99E-32	1.22E-4
P-33*	1.56E-33	9.60E-6
S-35*	1.22E-28	7.47E-1
S-37*	3.92E-36	2.41E-8
Cl-36*	5.04E-32	3.10E-4
Cl-38*	3.48E-29	2.14E-1
Ar-37*	2.80E-29	1.72E-1
Ar-39*	1.75E-35	1.07E-7
Ar-41*	2.95E-38	1.81E-10

*Isotope is included as important for dose consequence calculations.

Nuclide	Ci/barn*cm	Total Ci
Ar-42*	5.96E-48	3.66E-20
K-40*	8.84E-49	5.43E-21
K-42*	1.01E-35	6.19E-8
Ca-41*	5.42E-32	3.33E-4
Ca-45*	2.06E-28	1.27E0
Ca-47*	3.48E-31	2.14E-3
Ca-49*	2.40E-29	1.47E-1
Sc-46*	8.13E-31	4.99E-3
Ti-51*	7.26E-45	4.46E-17
V-52*	1.56E-48	9.60E-21
Cr-56*	3.48E-28	2.14E0
Mn-56*	2.78E-30	1.71E-2
Fe-55*	1.51E-27	9.25E0
Fe-59*	1.05E-28	6.46E-1
Co-60m*	9.06E-31	5.56E-3
Co-60*	1.01E-31	6.23E-4
Co-61*	1.96E-34	1.21E-6
Ni-63*	8.25E-44	5.06E-16
Ni-65*	2.41E-48	1.48E-20

Table 7. Radiological source term for B4C Powder. [5]

Nuclide	Ci/barn*cm	Total Ci
H-3*	3.55E-50	5.18E-21
Li-8	8.75E-32	1.28E-2
Be-8	8.75E-32	1.28E-2
C-14*	6.55E-36	9.56E-7
F-20	1.18E-4	1.72E-4
Si-31*	6.17E-54	9.00E-25
P-32*	1.21E-35	1.77E-6
P-33*	1.46E-39	2.12E-10
S-35*	7.37E-32	1.08E-2
S-37*	3.25E-44	4.74E-15
Cl-36*	3.05E-35	4.45E-6
Cl-38*	2.09E-32	3.05E-3
Ar-37*	1.71E-32	2.50E-3
Ar-39*	1.70E-41	2.48E-12

*Isotope is included in as important for dose consequence calculations.

Nuclide	Ci/barn*cm	Total Ci
Ar-41*	6.73E-50	9.83E-21
K-42*	9.33E-42	1.36E-12
Ca-41*	3.25E-35	4.75E-6
Ca-45*	1.24E-31	1.81E-2
Ca-47*	2.09E-34	3.05E-5
Ca-49*	1.44E-32	2.10E-3
Sc-46*	7.55E-37	1.10E-7
Cr-56*	3.22E-34	4.69E-5
Mn-56*	2.58E-36	3.77E-7
Fe-55*	9.05E-31	1.32E-1
Fe-59*	6.29E-32	9.17E-3
Co-60m*	8.40E-37	1.23E-7
Co-60*	9.40E-38	1.37E-8
Co-61*	2.81E-43	4.10E-14

Table 8. Control Drum and CIA dose rates.[2]

Tally Location	Neutron Dose Rate	Photon Dose Rate	Total Dose Rate	TID
	mrad/hr	mrad/hr	mrad/hr	rad
Control Drum Drive Lower Section (N-S)	39.9	16.9	56.8	6.0E+02
Control Drum Drive Upper Section (N-S)	23.6	23.2	46.8	5.8E+02
Control Drum Drive Lower Section (E-W)	32.7	16.6	49.3	5.4E+02
Control Drum Drive Upper Section (E-W)	22.6	19.9	42.5	5.2E+02
CIA Lower Section	33.7	22.7	56.4	6.5E+02
CIA Middle and Upper Section	20.4	21.8	42.2	5.4E+02

Table 9. Radiologic source term for e-GaInSn [5]

Nuclide	Ci/barn*cm	Total Ci
Zn-71m	1.23E-36	4.22E-8
Ga-70	7.60E-27	2.60E2
Ga-72	1.21E-26	4.15E2
Ge-71	9.71E-33	3.32E-4
Ge-75	1.06E-45	3.61E-17
As-76	4.61E-52	1.58E-23
Cd-115m	2.70E-35	9.23E-7
In-113m	7.50E-29	2.57E0
In-114m	6.31E-28	2.16E1
In-114	6.10E-28	2.09E1
In-115m	2.85E-39	9.76E-11
In-116m	1.41E-26	4.83E2
Sn-113m	8.34E-29	2.85E0
Sn-113	7.50E-29	2.57E0
Sn-117m	1.34E-29	4.60E-1
Sn-119m	3.14E-29	1.08E0
Sn-121m	1.59E-29	5.45E-1
Sn-121	1.23E-29	4.22E-1
Sn-123m	7.26E-29	2.48E0
Sn-125m	9.08E-29	3.11E0
Sb-122m	1.98E-35	6.79E-7
Sb-122	1.96E-35	6.72E-7
Sb-124n	1.22E-34	4.18E-6
Sb-124m	1.22E-34	4.18E-6
Sb-124	8.08E-35	2.77E-6
Sb-125	3.60E-29	1.23E0
Te-123m	9.46E-42	3.24E-13
Te-125m	7.55E-30	2.58E-1
Te-127m	5.85E-44	2.00E-15
Te-127	5.69E-44	1.95E-15

*Isotope is included in Ref 9 as important for dose consequence calculations.

Table 10. Radiological source term for primary cover gas. [5]

Nuclide	$\frac{Ci}{barn \cdot cm \cdot day}$	$\frac{Ci}{day}$
H-3*	1.13E-48	9.07E-19
C-14*	1.15E-43	9.25E-14
N-16*	1.70E-44	1.37E-14
O-19*	3.25E-44	2.62E-14
F-20	1.66E-55	1.34E-25
Ne-23	1.81E-40	1.46E-10
Na-24*	1.87E-50	1.50E-20
Si-31*	2.17E-54	1.75E-24
P-33*	3.76E-46	3.03E-16
S-35*	1.12E-50	8.99E-21
S-37*	3.05E-53	2.46E-23
Cl-38*	2.28E-43	1.84E-13
Ar-37*	2.11E-33	1.70E-3
Ar-39*	2.20E-38	1.77E-8
Ar-41*	4.08E-30	3.28E0
Ar-42*	6.18E-45	4.98E-15
K-42*	1.20E-39	9.64E-10
Br-80m*	2.18E-50	1.76E-20
Br-80*	2.09E-50	1.69E-20
Br-82m*	1.54E-53	1.24E-23
Br-82*	3.04E-54	2.45E-24
Kr-79*	1.18E-41	9.47E-12
Kr-81m*	4.89E-40	3.94E-10
Kr-81*	4.05E-48	3.26E-18
Kr-83m*	4.10E-39	3.30E-9
Kr-85m*	1.14E-40	9.17E-11

*Isotope is included in Ref 9 as important for dose consequence calculations.

Nuclide	$\frac{Ci}{barn \cdot cm \cdot day}$	$\frac{Ci}{day}$
Kr-85*	3.25E-45	2.62E-15
Kr-87*	9.65E-43	7.77E-13
Rb-86m*	1.79E-50	1.44E-20
Rb-86*	2.69E-52	2.17E-22
Rb-88*	5.45E-53	4.39E-23
I-125*	7.47E-44	6.02E-14
I-126*	5.84E-50	4.70E-20
I-128*	8.09E-54	6.52E-24
Xe-125*	1.11E-41	8.92E-12
Xe-127m*	2.73E-43	2.20E-13
Xe-127*	5.14E-45	4.14E-15
Xe-129m*	6.23E-43	5.02E-13
Xe-131m*	1.01E-42	8.10E-13
Xe-133m*	4.08E-42	3.28E-12
Xe-133*	2.71E-43	2.18E-13
Xe-135m*	3.43E-42	2.76E-12
Xe-135*	2.84E-42	2.29E-12
Xe-137*	2.86E-42	2.30E-12
Cs-134m*	9.63E-52	7.76E-22
Cs-134*	2.02E-55	1.63E-25
Cs-135*	1.50E-51	1.21E-21
Cs-136*	1.57E-52	1.26E-22
Cs-137*	1.79E-46	1.44E-16
Cs-138m*	4.12E-52	3.32E-22
Cs-138*	3.22E-52	2.60E-22
Ba-137m*	1.69E-46	1.36E-16

Table 11. Isotopic inventory of MARVEL NaK at end of life assuming 200 kg of material [1].

Isotope	Total Curies	Isotope	Total Curies
h-3	7.5494E-03	p-34	2.2016E-07
c-14	9.2193E-14	s-35	5.1180E-02
c-15	3.1343E-15	s-37	2.9073E-06
n-16	4.1864E-07	cl-36	6.3314E-03
o-19	6.1471E-08	cl-38	3.6469E+00
f-20	3.8563E+01	cl-38m	6.5863E-01
ne-23	8.6974E+01	ar-37	6.1145E-03
na-22	9.0896E-02	ar-39	1.7502E+02
na-24	5.5357E+03	ar-41	1.6956E+01
na-24m	4.2526E+03	ar-42	3.3788E-08
na-25	6.2107E-06	k-40	1.8169E-04
mg-27	3.6332E-15	k-42	3.0384E+03
al-28	1.1974E-16	k-43	9.4939E-05
al-29	1.5887E-14	k-44	4.3668E-12
al-30	2.0848E-13	ca-41	3.8059E-10
si-31	2.7825E-11	ca-45	7.7239E-12
si-32	3.8617E-11	sc-45m	1.4675E-16
p-32	6.7910E-06	sc-46	4.5938E-16
p-33	1.6497E-03	sc-46m	3.7632E-16
		Total	9.9139E+03

Table 12. End-of-life radiological source term for the MARVEL reactor fuel [1]

Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci
h-3	5.2701E-05	1.1076E+00	y-92	2.8806E-01	6.0541E+03	i-128	1.5162E-05	3.1866E-01
tm-173	1.0463E-17	2.1990E-13	nb-92	1.4682E-19	3.0857E-15	ag-129	1.1514E-09	2.4199E-05
yb-175	1.8475E-11	3.8829E-07	nb-92m	1.7140E-14	3.6023E-10	cd-129	7.3630E-07	1.5475E-02
yb-177	1.7657E-11	3.7109E-07	se-93	2.0066E-07	4.2172E-03	in-129	1.3943E-03	2.9304E+01
lu-173	2.3111E-11	4.8572E-07	br-93	2.3261E-04	4.8887E+00	in-129m	1.2445E-03	2.6155E+01
lu-174	6.1154E-13	1.2853E-08	kr-93	2.3960E-02	5.0356E+02	sn-129	1.4627E-02	3.0741E+02
lu-174m	7.8089E-13	1.6412E-08	rb-93	1.7110E-01	3.5960E+03	sn-129m	9.6326E-03	2.0245E+02
lu-176	1.3278E-19	2.7906E-15	sr-93	2.9955E-01	6.2956E+03	sb-129	2.7208E-02	5.7183E+02
lu-176m	1.6812E-08	3.5333E-04	y-93	3.0467E-01	6.4032E+03	sb-129m	5.4601E-04	1.1475E+01
lu-177	4.7984E-10	1.0085E-05	y-93m	1.0462E-01	2.1988E+03	te-129	2.5971E-02	5.4583E+02
lu-177m	3.9358E-13	8.2718E-09	zr-93	3.1065E-07	6.5289E-03	te-129m	4.5744E-03	9.6139E+01
hf-173	3.6277E-11	7.6243E-07	nb-93m	1.2712E-08	2.6717E-04	i-129	2.3987E-09	5.0413E-05
hf-174	3.0105E-19	6.3271E-15	mo-93	4.0585E-15	8.5297E-11	xe-129m	2.4077E-10	5.0602E-06
hf-175	3.9144E-06	8.2268E-02	mo-93m	4.2466E-13	8.9250E-09	cs-129	2.0862E-21	4.3845E-17
hf-177m	9.9838E-08	2.0983E-03	se-94	5.3994E-09	1.1348E-04	ag-130	3.0838E-07	6.4812E-03
hf-178m	3.3658E-08	7.0738E-04	br-94	1.5081E-05	3.1695E-01	cd-130	4.0468E-03	8.5051E+01
hf-179m	1.0233E-03	2.1506E+01	kr-94	4.5934E-03	9.6539E+01	in-130	4.6134E-03	9.6959E+01
hf-180m	2.2242E-06	4.6746E-02	rb-94	8.0846E-02	1.6991E+03	in-130m	3.9351E-04	8.2703E+00
hf-181	6.2959E-05	1.3232E+00	sr-94	2.9091E-01	6.1140E+03	sn-130	3.0087E-02	6.3233E+02
hf-182	8.4641E-15	1.7789E-10	y-94	3.1003E-01	6.5158E+03	sn-130m	2.9365E-02	6.1716E+02
ta-178	4.5815E-18	9.6288E-14	nb-94	1.6339E-12	3.4339E-08	sb-130	3.5686E-02	7.5001E+02
ta-179	2.6851E-14	5.6432E-10	nb-94m	1.5514E-08	3.2605E-04	sb-130m	4.9878E-02	1.0483E+03
ta-180	2.6019E-11	5.4684E-07	br-95	2.1187E-07	4.4528E-03	i-130	3.4691E-05	7.2909E-01
ta-182	3.4145E-07	7.1762E-03	kr-95	4.3896E-04	9.2255E+00	i-130m	1.8161E-05	3.8169E-01
ta-182m	4.7065E-11	9.8916E-07	rb-95	3.7976E-02	7.9813E+02	cd-131	7.4572E-04	1.5673E+01
ta-183	3.5893E-08	7.5436E-04	sr-95	2.5377E-01	5.3334E+03	in-131	6.3483E-04	1.3342E+01
w-178	1.0142E-21	2.1315E-17	y-95	3.0701E-01	6.4524E+03	in-131m	2.8621E-04	6.0152E+00
w-181	4.0537E-14	8.5196E-10	zr-95	3.3005E-01	6.9366E+03	sn-131	2.3262E-02	4.8889E+02
w-183m	1.9248E-09	4.0453E-05	nb-95	3.2978E-01	6.9309E+03	sn-131m	2.2249E-02	4.6760E+02
w-185	2.9166E-15	6.1298E-11	nb-95m	3.5665E-03	7.4956E+01	sb-131	1.2475E-01	2.6218E+03
w-185m	1.1369E-17	2.3894E-13	tc-95	2.7385E-21	5.7555E-17	te-131	1.2599E-01	2.6479E+03
w-187	1.5193E-21	3.1931E-17	br-96	1.1351E-07	2.3856E-03	te-131m	2.0402E-02	4.2878E+02

Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci
re-186	9.9548E-18	2.0922E-13	kr-96	1.8179E-03	3.8206E+01	i-131	1.4115E-01	2.9665E+03
tl-206	1.8555E-21	3.8997E-17	rb-96	1.0588E-02	2.2253E+02	xe-131m	1.5330E-03	3.2219E+01
tl-207	1.0000E-12	2.1017E-08	sr-96	1.8292E-01	3.8444E+03	cs-131	8.6409E-11	1.8160E-06
tl-208	1.2987E-11	2.7295E-07	y-96	1.9556E-01	4.1100E+03	ba-131	3.2379E-17	6.8050E-13
tl-209	6.3372E-17	1.3319E-12	y-96m	9.4726E-02	1.9908E+03	cd-132	1.2146E-07	2.5527E-03
tl-210	1.8904E-21	3.9730E-17	zr-96	2.5703E-17	5.4019E-13	in-132	3.3313E-04	7.0013E+00
pb-207m	2.3558E-18	4.9511E-14	nb-96	8.1708E-05	1.7172E+00	sn-132	2.9244E-02	6.1462E+02
pb-209	2.8831E-15	6.0594E-11	tc-96	1.8878E-17	3.9676E-13	sb-132	8.7093E-02	1.8304E+03
pb-210	1.2684E-15	2.6658E-11	br-97	5.6090E-10	1.1788E-05	sb-132m	5.0369E-02	1.0586E+03
pb-211	1.0028E-12	2.1076E-08	kr-97	3.2234E-06	6.7746E-02	te-132	2.0979E-01	4.4091E+03
pb-212	3.6134E-11	7.5942E-07	rb-97	1.8805E-03	3.9522E+01	i-132	2.1295E-01	4.4755E+03
pb-214	8.9950E-18	1.8905E-13	sr-97	8.5555E-02	1.7981E+03	i-132m	5.3062E-04	1.1152E+01
bi-210	1.2421E-15	2.6105E-11	y-97	1.4859E-01	3.1229E+03	cs-132	6.4854E-08	1.3630E-03
bi-211	1.0028E-12	2.1076E-08	y-97m	8.8292E-02	1.8556E+03	in-133	1.3046E-05	2.7419E-01
bi-212	3.6135E-11	7.5944E-07	zr-97	3.1698E-01	6.6619E+03	sn-133	5.4093E-03	1.1369E+02
bi-213	2.8805E-15	6.0539E-11	nb-97	3.1766E-01	6.6762E+03	sb-133	1.0253E-01	2.1549E+03
bi-214	8.9968E-18	1.8908E-13	nb-97m	3.0141E-01	6.3347E+03	te-133	1.6402E-01	3.4472E+03
po-210	7.1935E-16	1.5118E-11	tc-97	8.8931E-18	1.8690E-13	te-133m	1.8130E-01	3.8103E+03
po-211	2.7677E-15	5.8168E-11	tc-97m	1.5802E-11	3.3211E-07	i-133	3.2270E-01	6.7821E+03
po-212	2.3148E-11	4.8650E-07	ru-97	3.9688E-16	8.3411E-12	i-133m	2.2849E-02	4.8021E+02
po-213	2.8174E-15	5.9213E-11	kr-98	7.7967E-05	1.6386E+00	xe-133	3.2471E-01	6.8244E+03
po-214	4.4355E-14	9.3220E-10	rb-98	2.4538E-04	5.1571E+00	xe-133m	9.3406E-03	1.9631E+02
po-215	1.0028E-12	2.1076E-08	sr-98	4.0300E-02	8.4698E+02	ba-133	4.9655E-13	1.0436E-08
po-216	3.6120E-11	7.5913E-07	y-98	9.6757E-02	2.0335E+03	in-134	4.9080E-07	1.0315E-02
po-218	8.9968E-18	1.8908E-13	y-98m	5.6135E-02	1.1798E+03	sn-134	9.5057E-04	1.9978E+01
at-217	2.8807E-15	6.0543E-11	zr-98	2.7405E-01	5.7597E+03	sb-134	1.8207E-02	3.8265E+02
at-218	1.7994E-21	3.7818E-17	nb-98	2.7932E-01	5.8704E+03	sb-134m	1.8699E-02	3.9299E+02
rn-217	2.0165E-19	4.2380E-15	nb-98m	1.8096E-03	3.8032E+01	te-134	3.3664E-01	7.0751E+03
rn-218	4.4346E-14	9.3201E-10	tc-98	2.1828E-14	4.5875E-10	i-134	3.7910E-01	7.9675E+03
rn-219	1.0028E-12	2.1076E-08	kr-99	1.5138E-08	3.1815E-04	i-134m	1.7785E-02	3.7378E+02
rn-220	3.6120E-11	7.5913E-07	rb-99	1.4215E-05	2.9875E-01	xe-134m	1.6642E-03	3.4976E+01
rn-222	8.9948E-18	1.8904E-13	sr-99	7.3592E-03	1.5467E+02	cs-134	4.2816E-04	8.9986E+00
fr-221	2.8807E-15	6.0543E-11	y-99	1.0312E-01	2.1673E+03	cs-134m	1.4788E-04	3.1080E+00

Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci
fr-222	4.1777E-21	8.7802E-17	zr-99	2.7462E-01	5.7716E+03	in-135	1.2551E-08	2.6378E-04
fr-223	1.5587E-14	3.2759E-10	nb-99	1.7925E-01	3.7673E+03	sn-135	4.3006E-05	9.0385E-01
ra-222	4.4346E-14	9.3201E-10	nb-99m	1.1715E-01	2.4621E+03	sb-135	7.6759E-03	1.6132E+02
ra-223	1.0028E-12	2.1076E-08	mo-99	2.9609E-01	6.2229E+03	te-135	1.6244E-01	3.4140E+03
ra-224	3.6117E-11	7.5906E-07	tc-99	1.9916E-06	4.1857E-02	i-135	3.0579E-01	6.4267E+03
ra-225	3.0235E-15	6.3544E-11	tc-99m	2.6757E-01	5.6235E+03	xe-135	3.0874E-01	6.4887E+03
ra-226	9.1987E-18	1.9333E-13	kr-100	5.3458E-08	1.1235E-03	xe-135m	5.7902E-02	1.2169E+03
ra-227	4.1935E-17	8.8134E-13	rb-100	1.9239E-03	4.0434E+01	cs-135	1.8634E-07	3.9163E-03
ra-228	9.6375E-18	2.0255E-13	sr-100	1.9854E-03	4.1727E+01	cs-135m	1.6080E-05	3.3795E-01
ac-225	2.8800E-15	6.0528E-11	y-100	3.3610E-02	7.0637E+02	ba-135m	9.8187E-09	2.0636E-04
ac-226	6.9596E-17	1.4627E-12	zr-100	2.7292E-01	5.7359E+03	la-135	2.8198E-13	5.9263E-09
ac-227	1.1295E-12	2.3738E-08	nb-100	2.8715E-01	6.0350E+03	sn-136	1.6929E-06	3.5579E-02
ac-228	4.7292E-13	9.9393E-09	nb-100m	1.5304E-02	3.2164E+02	sb-136	7.0587E-04	1.4835E+01
th-226	4.4346E-14	9.3201E-10	mo-100	5.8289E-20	1.2250E-15	te-136	6.7005E-02	1.4082E+03
th-227	1.0346E-12	2.1744E-08	tc-100	1.0493E-03	2.2053E+01	i-136	1.3081E-01	2.7492E+03
th-228	3.6855E-11	7.7457E-07	rb-101	1.0572E-07	2.2219E-03	i-136m	6.1595E-02	1.2945E+03
th-229	5.7055E-16	1.1991E-11	sr-101	2.4271E-04	5.1010E+00	cs-136	5.3498E-04	1.1244E+01
th-230	3.1676E-14	6.6573E-10	y-101	1.4408E-02	3.0281E+02	cs-136m	1.6851E-04	3.5415E+00
th-231	8.5970E-07	1.8068E-02	zr-101	1.5085E-01	3.1704E+03	ba-136m	5.9535E-05	1.2512E+00
th-232	8.7055E-17	1.8296E-12	nb-101	2.4351E-01	5.1178E+03	sn-137	9.0292E-07	1.8976E-02
th-233	1.1120E-09	2.3371E-05	mo-101	2.5227E-01	5.3019E+03	sb-137	3.3853E-03	7.1148E+01
th-234	5.5002E-07	1.1560E-02	tc-101	2.5228E-01	5.3021E+03	te-137	2.0370E-02	4.2811E+02
pa-229	3.6386E-15	7.6472E-11	rh-101	2.4108E-12	5.0667E-08	i-137	1.4890E-01	3.1294E+03
pa-230	5.9159E-13	1.2433E-08	rh-101m	5.5765E-12	1.1720E-07	xe-137	2.9689E-01	6.2397E+03
pa-231	3.6300E-11	7.6291E-07	pd-101	2.7698E-17	5.8212E-13	cs-137	1.3572E-02	2.8524E+02
pa-232	1.7531E-08	3.6845E-04	rb-102	3.8900E-09	8.1755E-05	ba-137m	1.2862E-02	2.7032E+02
pa-233	4.1793E-09	8.7836E-05	sr-102	1.2391E-05	2.6042E-01	la-137	3.2410E-14	6.8115E-10
pa-234m	5.5003E-07	1.1560E-02	y-102	1.3649E-02	2.8686E+02	ce-137	6.3892E-14	1.3428E-09
pa-234	8.8133E-10	1.8523E-05	zr-102	1.0103E-01	2.1233E+03	sb-138	4.7797E-06	1.0045E-01
pa-235	8.3828E-08	1.7618E-03	nb-102	1.3991E-01	2.9405E+03	te-138	3.5743E-03	7.5120E+01
u-230	4.4249E-14	9.2997E-10	nb-102m	3.8928E-02	8.1814E+02	i-138	7.3370E-02	1.5420E+03
u-231	9.2613E-15	1.9464E-10	mo-102	2.1047E-01	4.4234E+03	xe-138	3.0375E-01	6.3839E+03
u-232	1.7915E-10	3.7652E-06	tc-102	2.1094E-01	4.4333E+03	cs-138	3.2448E-01	6.8195E+03

Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci
u-233	5.6669E-12	1.1910E-07	tc-102m	4.6646E-04	9.8035E+00	cs-138m	1.0878E-02	2.2862E+02
u-234	3.4295E-09	7.2077E-05	rh-102	6.5569E-09	1.3781E-04	la-138	1.9923E-17	4.1872E-13
u-235	8.5966E-07	1.8067E-02	rh-102m	1.0017E-09	2.1053E-05	sb-139	2.7780E-07	5.8385E-03
u-235m	2.8547E-06	5.9997E-02	sr-103	2.0944E-07	4.4018E-03	te-139	3.9790E-04	8.3626E+00
u-236	7.2351E-08	1.5206E-03	y-103	2.1536E-04	4.5262E+00	i-139	3.8151E-02	8.0181E+02
u-237	7.5195E-03	1.5804E+02	zr-103	2.7022E-02	5.6792E+02	xe-139	2.4253E-01	5.0972E+03
u-238	5.5001E-07	1.1559E-02	nb-103	9.7008E-02	2.0388E+03	cs-139	3.0656E-01	6.4429E+03
u-239	2.2162E+00	4.6577E+04	mo-103	1.4851E-01	3.1212E+03	ba-139	3.0991E-01	6.5133E+03
np-234	4.0389E-19	8.4885E-15	tc-103	1.5233E-01	3.2015E+03	ce-139	4.2717E-08	8.9777E-04
np-235	2.4149E-12	5.0753E-08	ru-103	1.5212E-01	3.1971E+03	ce-139m	2.0606E-08	4.3307E-04
np-236m	1.2248E-09	2.5741E-05	rh-103m	1.5047E-01	3.1624E+03	pr-139	1.0452E-11	2.1967E-07
np-236	1.2337E-15	2.5928E-11	pd-103	1.4199E-10	2.9842E-06	te-140	7.9952E-04	1.6803E+01
np-237	3.3786E-09	7.1007E-05	sr-104	2.0175E-08	4.2401E-04	i-140	7.8653E-03	1.6530E+02
np-238	6.3204E-05	1.3283E+00	y-104	3.7706E-05	7.9246E-01	xe-140	1.7585E-01	3.6958E+03
np-239	2.2105E+00	4.6458E+04	zr-104	4.7028E-03	9.8838E+01	cs-140	2.7642E-01	5.8095E+03
np-240m	4.0991E-05	8.6150E-01	nb-104	1.9773E-02	4.1557E+02	ba-140	3.0022E-01	6.3097E+03
np-240	2.4233E-05	5.0930E-01	nb-104m	1.5021E-02	3.1569E+02	la-140	3.0056E-01	6.3168E+03
np-241	9.3003E-14	1.9546E-09	mo-104	9.1872E-02	1.9309E+03	pr-140	4.3425E-08	9.1265E-04
pu-236	1.0958E-10	2.3030E-06	tc-104	9.6575E-02	2.0297E+03	nd-140	1.9412E-15	4.0798E-11
pu-237m	8.1895E-11	1.7212E-06	rh-104	1.7931E-03	3.7685E+01	te-141	5.1451E-06	1.0813E-01
pu-237	3.6697E-10	7.7125E-06	rh-104m	1.3637E-04	2.8661E+00	i-141	2.0752E-03	4.3614E+01
pu-238	4.2914E-07	9.0191E-03	sr-105	2.7085E-09	5.6924E-05	xe-141	6.1243E-02	1.2871E+03
pu-239	1.2418E-04	2.6099E+00	y-105	2.3890E-06	5.0209E-02	cs-141	2.0244E-01	4.2546E+03
pu-240	4.4849E-06	9.4258E-02	zr-105	5.4806E-03	1.1518E+02	ba-141	2.8191E-01	5.9248E+03
pu-241	5.8048E-05	1.2200E+00	nb-105	1.3702E-02	2.8797E+02	la-141	2.8282E-01	5.9440E+03
pu-242	6.1566E-12	1.2939E-07	mo-105	4.9016E-02	1.0302E+03	ce-141	2.8216E-01	5.9301E+03
pu-243	1.9190E-08	4.0331E-04	tc-105	5.2384E-02	1.1009E+03	nd-141	1.0840E-10	2.2782E-06
pu-245	5.1851E-18	1.0897E-13	ru-105	5.2426E-02	1.1018E+03	nd-141m	2.1293E-11	4.4751E-07
am-239	7.3738E-16	1.5497E-11	rh-105	5.0343E-02	1.0580E+03	te-142	1.5925E-07	3.3469E-03
am-240	3.2038E-12	6.7334E-08	rh-105m	1.4860E-02	3.1231E+02	i-142	3.0330E-04	6.3744E+00
am-241	4.6805E-08	9.8369E-04	ag-105	4.3190E-20	9.0772E-16	xe-142	2.1901E-02	4.6029E+02
am-242m	1.1425E-10	2.4012E-06	ag-105m	2.5212E-20	5.2988E-16	cs-142	1.3184E-01	2.7709E+03
am-242	5.1239E-07	1.0769E-02	y-106	4.7934E-09	1.0074E-04	ba-142	2.7716E-01	5.8250E+03

Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci
am-243	7.3871E-13	1.5525E-08	zr-106	2.4608E-06	5.1718E-02	la-142	2.8184E-01	5.9234E+03
am-244m	7.2807E-11	1.5302E-06	nb-106	1.2256E-03	2.5758E+01	pr-142	1.0806E-04	2.2711E+00
am-244	4.8621E-12	1.0219E-07	mo-106	2.1067E-02	4.4276E+02	pr-142m	3.7719E-05	7.9273E-01
am-245	5.1856E-18	1.0898E-13	tc-106	2.3665E-02	4.9736E+02	i-143	5.7957E-06	1.2181E-01
cm-240	4.6125E-17	9.6940E-13	ru-106	1.6998E-02	3.5724E+02	xe-143	2.1514E-03	4.5216E+01
cm-241	8.9643E-15	1.8840E-10	rh-106	1.7031E-02	3.5794E+02	cs-143	7.0679E-02	1.4854E+03
cm-242	1.7169E-07	3.6084E-03	rh-106m	3.6591E-06	7.6903E-02	ba-143	2.6693E-01	5.6100E+03
cm-243	7.7884E-13	1.6369E-08	ag-106	2.5618E-15	5.3841E-11	la-143	2.8576E-01	6.0058E+03
cm-244	9.8528E-13	2.0707E-08	ag-106m	5.7718E-15	1.2130E-10	ce-143	2.8660E-01	6.0234E+03
cm-245	2.2576E-18	4.7448E-14	y-107	1.0820E-09	2.2740E-05	pr-143	2.8720E-01	6.0360E+03
cm-246	2.2571E-21	4.7437E-17	zr-107	4.2731E-07	8.9807E-03	pm-143	3.7460E-20	7.8729E-16
fe-65	3.2219E-11	6.7714E-07	nb-107	2.2941E-04	4.8215E+00	sm-143	4.4080E-22	9.2642E-18
co-65	3.2219E-11	6.7714E-07	mo-107	7.3514E-03	1.5450E+02	i-144	1.4537E-07	3.0552E-03
ni-65	3.2220E-11	6.7716E-07	tc-107	9.7828E-03	2.0560E+02	xe-144	3.6399E-04	7.6499E+00
cr-66	1.9959E-12	4.1947E-08	ru-107	1.0385E-02	2.1826E+02	cs-144	2.1320E-02	4.4808E+02
mn-66	2.9613E-10	6.2237E-06	rh-107	1.0439E-02	2.1939E+02	ba-144	2.1110E-01	4.4366E+03
fe-66	5.5093E-09	1.1579E-04	pd-107	1.9914E-09	4.1853E-05	la-144	2.6314E-01	5.5304E+03
co-66	1.0528E-08	2.2126E-04	pd-107m	6.3111E-08	1.3264E-03	ce-144	2.2075E-01	4.6395E+03
ni-66	1.1366E-08	2.3888E-04	ag-107m	7.2373E-13	1.5210E-08	pr-144	2.2079E-01	4.6403E+03
cu-66	1.1378E-08	2.3913E-04	cd-107	8.1268E-18	1.7080E-13	pr-144m	2.1271E-03	4.4705E+01
cr-67	5.4629E-13	1.1481E-08	y-108	4.3359E-12	9.1127E-08	nd-144	8.6629E-17	1.8207E-12
mn-67	2.4751E-10	5.2019E-06	zr-108	2.2361E-08	4.6996E-04	pm-144	4.1542E-16	8.7308E-12
fe-67	1.0196E-08	2.1429E-04	nb-108	1.9588E-05	4.1168E-01	xe-145	1.2788E-05	2.6876E-01
co-67	3.3472E-08	7.0347E-04	mo-108	2.0245E-03	4.2549E+01	cs-145	4.0247E-03	8.4586E+01
ni-67	4.1433E-08	8.7079E-04	tc-108	3.6742E-03	7.7220E+01	ba-145	9.4285E-02	1.9816E+03
cu-67	4.1575E-08	8.7377E-04	ru-108	4.5978E-03	9.6631E+01	la-145	1.8555E-01	3.8997E+03
ga-67	5.4494E-19	1.1453E-14	rh-108	4.6121E-03	9.6932E+01	ce-145	1.8983E-01	3.9896E+03
mn-68	5.0816E-11	1.0680E-06	rh-108m	1.4274E-05	2.9999E-01	pr-145	1.8985E-01	3.9900E+03
fe-68	6.0971E-09	1.2814E-04	ag-108	2.5530E-10	5.3656E-06	pm-145	6.0107E-12	1.2633E-07
co-68	3.8597E-08	8.1119E-04	ag-108m	2.5262E-13	5.3093E-09	sm-145	8.1413E-12	1.7110E-07
ni-68	7.3016E-08	1.5346E-03	zr-109	2.0704E-08	4.3513E-04	xe-146	1.1498E-06	2.4165E-02
cu-68	7.4272E-08	1.5610E-03	nb-109	2.5236E-05	5.3038E-01	cs-146	4.4855E-04	9.4271E+00
cu-68m	1.0868E-09	2.2841E-05	mo-109	9.0475E-04	1.9015E+01	ba-146	4.5143E-02	9.4876E+02

Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci
ga-68	1.0847E-14	2.2797E-10	tc-109	1.9373E-03	4.0716E+01	la-146	8.1073E-02	1.7039E+03
mn-69	6.8314E-12	1.4357E-07	ru-109	2.7429E-03	5.7647E+01	la-146m	3.5907E-02	7.5465E+02
fe-69	2.1138E-09	4.4425E-05	rh-109	2.7950E-03	5.8742E+01	ce-146	1.4499E-01	3.0472E+03
co-69	3.8947E-08	8.1854E-04	pd-109	2.8012E-03	5.8872E+01	pr-146	1.4518E-01	3.0512E+03
ni-69	1.2719E-07	2.6731E-03	pd-109m	1.8600E-07	3.9091E-03	pm-146	7.1392E-09	1.5004E-04
cu-69	1.3854E-07	2.9117E-03	ag-109m	2.7999E-03	5.8845E+01	sm-146	1.0355E-16	2.1763E-12
zn-69	1.3875E-07	2.9161E-03	cd-109	7.2409E-13	1.5218E-08	xe-147	9.6812E-08	2.0347E-03
zn-69m	1.7147E-10	3.6038E-06	zr-110	5.6888E-10	1.1956E-05	cs-147	1.1575E-04	2.4327E+00
ge-69	3.6066E-19	7.5799E-15	nb-110	9.1152E-07	1.9157E-02	ba-147	1.2190E-02	2.5619E+02
fe-70	5.8485E-10	1.2292E-05	mo-110	2.3558E-04	4.9511E+00	la-147	4.4394E-02	9.3302E+02
co-70	2.5941E-08	5.4520E-04	tc-110	9.1032E-04	1.9132E+01	ce-147	9.2400E-02	1.9420E+03
ni-70	2.2507E-07	4.7303E-03	ru-110	1.8196E-03	3.8242E+01	pr-147	1.0892E-01	2.2891E+03
cu-70	2.5730E-07	5.4076E-03	rh-110	1.4570E-05	3.0621E-01	nd-147	1.0886E-01	2.2879E+03
cu-70m	4.2344E-08	8.8994E-04	rh-110m	1.8342E-03	3.8549E+01	pm-147	4.3666E-02	9.1772E+02
ga-70	4.5622E-11	9.5883E-07	ag-110	3.5461E-05	7.4528E-01	sm-147	3.0477E-13	6.4053E-09
fe-71	1.0215E-10	2.1469E-06	ag-110m	9.2264E-07	1.9391E-02	cs-148	2.2875E-06	4.8076E-02
co-71	1.5407E-08	3.2381E-04	nb-111	2.0227E-07	4.2511E-03	ba-148	1.2325E-03	2.5903E+01
ni-71	3.0705E-07	6.4532E-03	mo-111	2.4028E-05	5.0499E-01	la-148	1.8601E-02	3.9093E+02
cu-71	5.5263E-07	1.1615E-02	tc-111	2.9709E-04	6.2439E+00	ce-148	7.7329E-02	1.6252E+03
zn-71	5.5813E-07	1.1730E-02	ru-111	1.0825E-03	2.2751E+01	pr-148	7.9355E-02	1.6678E+03
zn-71m	2.5839E-08	5.4305E-04	rh-111	1.1621E-03	2.4424E+01	pr-148m	2.0376E-03	4.2824E+01
ge-71	2.4757E-13	5.2031E-09	pd-111	1.1625E-03	2.4432E+01	pm-148	1.0593E-03	2.2263E+01
ge-71m	9.1995E-14	1.9334E-09	pd-111m	3.6107E-07	7.5885E-03	pm-148m	8.0848E-04	1.6992E+01
fe-72	1.4802E-11	3.1109E-07	ag-111	1.1505E-03	2.4180E+01	sm-148	2.0244E-19	4.2546E-15
co-72	5.9772E-09	1.2562E-04	ag-111m	1.1544E-03	2.4262E+01	cs-149	4.7687E-08	1.0022E-03
ni-72	4.6989E-07	9.8756E-03	cd-111m	1.0718E-10	2.2526E-06	ba-149	8.1700E-05	1.7171E+00
cu-72	1.2779E-06	2.6857E-02	in-111	6.6306E-18	1.3935E-13	la-149	4.4074E-03	9.2629E+01
zn-72	1.6548E-06	3.4779E-02	in-111m	1.3313E-18	2.7980E-14	ce-149	3.8304E-02	8.0503E+02
ga-72	1.6594E-06	3.4875E-02	sn-111	3.8657E-22	8.1245E-18	pr-149	5.2548E-02	1.1044E+03
ga-72m	6.0455E-08	1.2706E-03	nb-112	2.3184E-09	4.8725E-05	nd-149	5.2927E-02	1.1124E+03
as-72	1.3371E-15	2.8102E-11	mo-112	2.3016E-06	4.8372E-02	pm-149	5.2295E-02	1.0991E+03
co-73	2.3568E-09	4.9532E-05	tc-112	6.3595E-05	1.3366E+00	eu-149	1.2277E-13	2.5802E-09
ni-73	4.3764E-07	9.1978E-03	ru-112	6.6882E-04	1.4056E+01	cs-150	3.3452E-09	7.0305E-05

Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci
cu-73	3.1501E-06	6.6205E-02	rh-112	8.2032E-04	1.7241E+01	ba-150	6.0842E-06	1.2787E-01
zn-73	5.7256E-06	1.2033E-01	pd-112	8.2691E-04	1.7379E+01	la-150	6.5363E-04	1.3737E+01
ga-73	5.8079E-06	1.2206E-01	ag-112	8.2969E-04	1.7437E+01	ce-150	2.0348E-02	4.2765E+02
ge-73m	5.7222E-06	1.2026E-01	in-112	4.1322E-14	8.6846E-10	pr-150	3.0729E-02	6.4583E+02
as-73	9.8617E-14	2.0726E-09	in-112m	3.3318E-14	7.0024E-10	nd-150	5.6820E-21	1.1942E-16
se-73	1.0431E-20	2.1923E-16	nb-113	4.2997E-10	9.0366E-06	pm-150	4.7991E-05	1.0086E+00
se-73m	6.4504E-21	1.3557E-16	mo-113	2.3619E-07	4.9640E-03	cs-151	5.6726E-10	1.1922E-05
co-74	3.4577E-10	7.2670E-06	tc-113	1.5773E-05	3.3150E-01	ba-151	6.7261E-07	1.4136E-02
ni-74	2.6164E-07	5.4988E-03	ru-113	3.8414E-04	8.0734E+00	la-151	8.0145E-05	1.6844E+00
cu-74	3.9641E-06	8.3313E-02	rh-113	7.7277E-04	1.6241E+01	ce-151	5.1970E-03	1.0922E+02
zn-74	1.6648E-05	3.4989E-01	pd-113	8.3067E-04	1.7458E+01	pr-151	1.6891E-02	3.5499E+02
ga-74	1.7381E-05	3.6529E-01	ag-113	5.4446E-04	1.1443E+01	nd-151	2.0778E-02	4.3669E+02
ga-74m	4.1893E-07	8.8046E-03	ag-113m	7.9561E-04	1.6721E+01	pm-151	2.0771E-02	4.3654E+02
as-74	8.8209E-12	1.8539E-07	cd-113	9.1940E-20	1.9323E-15	sm-151	2.9604E-04	6.2218E+00
co-75	4.7669E-11	1.0018E-06	cd-113m	5.7970E-07	1.2183E-02	gd-151	3.6587E-13	7.6894E-09
ni-75	8.8828E-08	1.8669E-03	in-113m	4.6194E-14	9.7085E-10	ba-152	1.0810E-08	2.2719E-04
cu-75	5.4041E-06	1.1358E-01	sn-113	1.3990E-15	2.9403E-11	la-152	6.1587E-06	1.2944E-01
zn-75	4.4158E-05	9.2806E-01	sn-113m	1.5871E-15	3.3356E-11	ce-152	1.1231E-03	2.3604E+01
ga-75	5.4124E-05	1.1375E+00	mo-114	9.7748E-09	2.0544E-04	pr-152	6.3418E-03	1.3328E+02
ge-75	5.4445E-05	1.1443E+00	tc-114	2.2448E-06	4.7179E-02	nd-152	1.3223E-02	2.7791E+02
ge-75m	2.2716E-06	4.7742E-02	ru-114	1.2621E-04	2.6525E+00	pm-152	1.3275E-02	2.7900E+02
se-75	6.3163E-14	1.3275E-09	rh-114	4.2995E-04	9.0362E+00	pm-152m	8.2155E-05	1.7266E+00
ni-76	2.9481E-08	6.1960E-04	pd-114	6.4459E-04	1.3547E+01	eu-152	5.7888E-07	1.2166E-02
cu-76	4.4629E-06	9.3796E-02	ag-114	6.8728E-04	1.4444E+01	eu-152m	9.1251E-06	1.9178E-01
zn-76	1.0087E-04	2.1200E+00	in-114	1.2161E-09	2.5559E-05	gd-152	2.9649E-20	6.2313E-16
ga-76	1.5471E-04	3.2515E+00	in-114m	6.9507E-10	1.4608E-05	ba-153	4.8837E-10	1.0264E-05
as-76	6.3795E-08	1.3408E-03	mo-115	8.2695E-10	1.7380E-05	la-153	5.0604E-07	1.0635E-02
ni-77	3.6052E-09	7.5770E-05	tc-115	3.7989E-07	7.9841E-03	ce-153	1.2079E-04	2.5386E+00
cu-77	2.3680E-06	4.9768E-02	ru-115	2.8584E-05	6.0074E-01	pr-153	2.0794E-03	4.3702E+01
zn-77	1.5923E-04	3.3465E+00	rh-115	2.6698E-04	5.6111E+00	nd-153	7.5430E-03	1.5853E+02
ga-77	3.6609E-04	7.6940E+00	pd-115	6.5130E-04	1.3688E+01	pm-153	8.0065E-03	1.6827E+02
ge-77	3.9927E-04	8.3914E+00	ag-115	6.7366E-04	1.4158E+01	sm-153	8.4873E-03	1.7838E+02
ge-77m	4.7458E-06	9.9742E-02	ag-115m	5.7119E-05	1.2005E+00	gd-153	1.9476E-08	4.0932E-04

Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci
as-77	3.7093E-04	7.7958E+00	cd-115	6.7867E-04	1.4263E+01	la-154	1.9824E-08	4.1664E-04
se-77m	1.2351E-06	2.5958E-02	cd-115m	3.8977E-05	8.1917E-01	ce-154	9.8851E-06	2.0775E-01
br-77	2.3774E-14	4.9965E-10	in-115	2.1266E-18	4.4694E-14	pr-154	3.1717E-04	6.6659E+00
br-77m	1.8487E-14	3.8854E-10	in-115m	6.9177E-04	1.4539E+01	nd-154	3.2381E-03	6.8054E+01
ni-78	3.8511E-10	8.0938E-06	tc-116	3.7689E-08	7.9210E-04	pm-154	3.5270E-03	7.4126E+01
cu-78	6.0151E-07	1.2642E-02	ru-116	5.8625E-06	1.2321E-01	pm-154m	2.8911E-04	6.0762E+00
zn-78	1.7541E-04	3.6866E+00	rh-116	8.7448E-05	1.8379E+00	eu-154	1.1379E-05	2.3915E-01
ga-78	6.8340E-04	1.4363E+01	pd-116	4.7825E-04	1.0051E+01	eu-154m	2.4489E-06	5.1468E-02
ge-78	1.0336E-03	2.1723E+01	ag-116	7.0545E-04	1.4826E+01	la-155	5.5057E-10	1.1571E-05
as-78	1.0406E-03	2.1870E+01	ag-116m	4.0334E-05	8.4769E-01	ce-155	6.9966E-07	1.4705E-02
br-78	2.7201E-12	5.7168E-08	in-116	5.2255E-06	1.0982E-01	pr-155	5.4553E-05	1.1465E+00
cu-79	2.7512E-08	5.7821E-04	in-116m	8.6523E-06	1.8184E-01	nd-155	9.8906E-04	2.0787E+01
zn-79	8.0652E-05	1.6950E+00	tc-117	1.6885E-09	3.5487E-05	pm-155	1.6624E-03	3.4938E+01
ga-79	9.1654E-04	1.9263E+01	ru-117	9.7361E-07	2.0462E-02	sm-155	1.7416E-03	3.6603E+01
ge-79	1.4758E-03	3.1017E+01	rh-117	4.2586E-05	8.9502E-01	eu-155	3.8295E-04	8.0484E+00
ge-79m	6.2222E-04	1.3077E+01	pd-117	5.0820E-04	1.0681E+01	tb-155	3.3738E-15	7.0906E-11
as-79	2.2047E-03	4.6336E+01	ag-117	5.9505E-04	1.2506E+01	ce-156	4.0068E-08	8.4210E-04
se-79	1.0399E-08	2.1855E-04	ag-117m	8.4438E-05	1.7746E+00	pr-156	5.7686E-06	1.2124E-01
se-79m	2.1526E-03	4.5241E+01	cd-117	5.7154E-04	1.2012E+01	nd-156	2.7553E-04	5.7908E+00
br-79m	1.8755E-10	3.9417E-06	cd-117m	1.4237E-04	2.9922E+00	pm-156	6.7232E-04	1.4130E+01
kr-79	1.4184E-14	2.9810E-10	in-117	4.3607E-04	9.1648E+00	sm-156	8.4776E-04	1.7817E+01
kr-79m	7.1139E-15	1.4951E-10	in-117m	5.2528E-04	1.1040E+01	eu-156	1.1630E-03	2.4443E+01
cu-80	5.0384E-09	1.0589E-04	sn-117m	1.5192E-06	3.1929E-02	tb-156	2.1048E-13	4.4236E-09
zn-80	1.2623E-05	2.6530E-01	sb-117	1.6926E-20	3.5573E-16	tb-156m	2.1139E-14	4.4427E-10
ga-80	5.8661E-04	1.2329E+01	tc-118	4.0533E-10	8.5187E-06	ce-157	1.5408E-09	3.2383E-05
ge-80	5.5129E-03	1.1586E+02	ru-118	1.9314E-07	4.0592E-03	pr-157	5.8305E-07	1.2254E-02
as-80	6.1873E-03	1.3004E+02	rh-118	1.1859E-05	2.4924E-01	nd-157	3.7326E-05	7.8447E-01
br-80	1.0997E-08	2.3112E-04	pd-118	2.2087E-04	4.6420E+00	pm-157	2.1447E-04	4.5075E+00
br-80m	7.0884E-09	1.4898E-04	ag-118	4.4977E-04	9.4527E+00	sm-157	3.7284E-04	7.8359E+00
zn-81	3.1722E-07	6.6669E-03	ag-118m	2.0264E-04	4.2588E+00	eu-157	3.7845E-04	7.9538E+00
ga-81	4.0072E-04	8.4219E+00	cd-118	6.5523E-04	1.3771E+01	tb-157	6.2418E-14	1.3118E-09
ge-81	6.3390E-03	1.3323E+02	in-118	6.5552E-04	1.3777E+01	dy-157	1.7938E-20	3.7700E-16
ge-81m	1.6620E-04	3.4930E+00	in-118m	9.4851E-08	1.9935E-03	pr-158	3.5012E-08	7.3584E-04

Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci
as-81	9.4395E-03	1.9839E+02	sb-118	1.5390E-15	3.2345E-11	nd-158	5.1704E-06	1.0867E-01
se-81	9.8272E-03	2.0654E+02	sb-118m	2.2233E-15	4.6727E-11	pm-158	5.2416E-05	1.1016E+00
se-81m	6.7603E-04	1.4208E+01	ru-119	1.9536E-08	4.1058E-04	sm-158	1.9157E-04	4.0262E+00
kr-81	8.5599E-16	1.7990E-11	rh-119	2.7430E-06	5.7649E-02	eu-158	2.0163E-04	4.2376E+00
kr-81m	3.2233E-11	6.7743E-07	pd-119	5.8943E-05	1.2388E+00	tb-158	4.5931E-13	9.6532E-09
rb-81	4.8541E-15	1.0202E-10	ag-119	4.5102E-04	9.4790E+00	tb-158m	1.6987E-11	3.5701E-07
zn-82	5.7049E-07	1.1990E-02	cd-119	4.4573E-04	9.3678E+00	pr-159	1.6102E-09	3.3841E-05
ga-82	3.0071E-04	6.3200E+00	cd-119m	2.4816E-04	5.2155E+00	nd-159	4.2068E-07	8.8413E-03
ge-82	6.3501E-03	1.3346E+02	in-119	3.3102E-04	6.9570E+00	pm-159	9.8261E-06	2.0651E-01
as-82	1.2427E-02	2.6118E+02	in-119m	4.0372E-04	8.4849E+00	sm-159	5.8035E-05	1.2197E+00
as-82m	1.3858E-03	2.9125E+01	sn-119m	2.0096E-05	4.2235E-01	eu-159	7.0741E-05	1.4867E+00
br-82	1.1238E-05	2.3619E-01	sb-119	9.7596E-13	2.0512E-08	gd-159	7.1284E-05	1.4982E+00
br-82m	8.2370E-06	1.7312E-01	te-119	3.0500E-21	6.4101E-17	dy-159	1.5041E-13	3.1611E-09
zn-83	9.7211E-09	2.0431E-04	ru-120	1.9433E-09	4.0842E-05	nd-160	3.1197E-08	6.5566E-04
ga-83	1.2061E-05	2.5348E-01	rh-120	7.1430E-07	1.5012E-02	pm-160	1.2379E-06	2.6017E-02
ge-83	1.5847E-03	3.3305E+01	pd-120	1.4448E-04	3.0365E+00	sm-160	1.6606E-05	3.4900E-01
as-83	1.5443E-02	3.2456E+02	ag-120	2.0975E-04	4.4083E+00	eu-160	2.4737E-05	5.1989E-01
se-83	2.2082E-02	4.6409E+02	ag-120m	4.7636E-05	1.0012E+00	tb-160	2.9335E-07	6.1653E-03
se-83m	2.0129E-03	4.2305E+01	cd-120	6.7493E-04	1.4185E+01	nd-161	1.4218E-09	2.9882E-05
br-83	2.5754E-02	5.4127E+02	in-120	6.8579E-04	1.4413E+01	pm-161	1.4162E-07	2.9764E-03
kr-83m	2.5748E-02	5.4114E+02	in-120m	2.1720E-05	4.5648E-01	sm-161	2.8777E-06	6.0480E-02
rb-83	4.0678E-11	8.5492E-07	sb-120	1.1079E-10	2.3285E-06	eu-161	7.5293E-06	1.5824E-01
sr-83	8.2150E-16	1.7265E-11	sb-120m	6.6496E-11	1.3975E-06	gd-161	9.0048E-06	1.8925E-01
ga-84	5.2842E-04	1.1106E+01	rh-121	1.0210E-07	2.1458E-03	tb-161	8.9810E-06	1.8875E-01
ge-84	1.4222E-03	2.9890E+01	pd-121	9.0257E-06	1.8969E-01	ho-161	2.3160E-15	4.8675E-11
as-84	1.0404E-02	2.1866E+02	ag-121	1.7653E-04	3.7101E+00	ho-161m	1.6450E-17	3.4573E-13
se-84	4.6409E-02	9.7537E+02	cd-121	3.8115E-04	8.0106E+00	pm-162	1.0948E-08	2.3009E-04
br-84	4.7298E-02	9.9405E+02	cd-121m	1.9516E-04	4.1016E+00	sm-162	3.9711E-07	8.3460E-03
br-84m	8.2743E-04	1.7390E+01	in-121	4.4518E-04	9.3563E+00	eu-162	1.6801E-06	3.5310E-02
rb-84	1.7447E-09	3.6668E-05	in-121m	2.7498E-04	5.7792E+00	gd-162	2.9393E-06	6.1775E-02
ga-85	9.5730E-08	2.0119E-03	sn-121	6.8434E-04	1.4383E+01	tb-162	2.9923E-06	6.2889E-02
ge-85	1.2309E-04	2.5870E+00	sn-121m	1.6028E-06	3.3686E-02	ho-162	4.0787E-14	8.5721E-10
as-85	9.9169E-03	2.0842E+02	te-121	2.6524E-13	5.5745E-09	ho-162m	3.9094E-14	8.2163E-10

Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci	Isotope	Ci per cm^3	Total Core Ci
se-85	5.0997E-02	1.0718E+03	te-121m	1.1695E-13	2.4579E-09	pm-163	1.1221E-09	2.3583E-05
br-85	6.2196E-02	1.3072E+03	i-121	4.2371E-22	8.9050E-18	sm-163	6.8021E-08	1.4296E-03
kr-85	1.6556E-03	3.4795E+01	rh-122	1.2858E-08	2.7023E-04	eu-163	5.0853E-07	1.0688E-02
kr-85m	6.2381E-02	1.3110E+03	pd-122	2.2267E-06	4.6798E-02	gd-163	1.2150E-06	2.5535E-02
sr-85	1.0120E-11	2.1269E-07	ag-122	3.2050E-05	6.7359E-01	tb-163	1.3037E-06	2.7400E-02
sr-85m	5.9106E-12	1.2422E-07	ag-122m	2.9815E-05	6.2662E-01	ho-163	1.2945E-16	2.7206E-12
ga-86	1.5215E-06	3.1977E-02	cd-122	6.9842E-04	1.4679E+01	ho-163m	1.0850E-13	2.2803E-09
ge-86	2.8002E-02	5.8851E+02	in-122	7.4749E-04	1.5710E+01	er-163	2.5596E-19	5.3795E-15
as-86	2.7638E-02	5.8086E+02	in-122m	9.1961E-05	1.9327E+00	sm-164	1.1994E-08	2.5208E-04
se-86	6.5456E-02	1.3757E+03	sb-122	1.5076E-06	3.1685E-02	eu-164	1.3245E-07	2.7837E-03
br-86	8.6868E-02	1.8257E+03	sb-122m	1.1800E-07	2.4800E-03	gd-164	4.6234E-07	9.7169E-03
rb-86	5.9730E-06	1.2553E-01	pd-123	4.5736E-07	9.6122E-03	tb-164	5.3864E-07	1.1320E-02
rb-86m	9.2925E-07	1.9530E-02	ag-123	2.8003E-05	5.8853E-01	ho-164	5.7350E-12	1.2053E-07
ge-87	1.0160E-04	2.1353E+00	cd-123	5.6381E-04	1.1849E+01	ho-164m	4.0169E-12	8.4422E-08
as-87	2.1377E-03	4.4928E+01	in-123	4.0119E-04	8.4317E+00	sm-165	1.4729E-09	3.0956E-05
se-87	3.7461E-02	7.8731E+02	in-123m	4.0975E-04	8.6116E+00	eu-165	3.6835E-08	7.7415E-04
br-87	9.7707E-02	2.0535E+03	sn-123	5.8526E-05	1.2300E+00	gd-165	1.8036E-07	3.7906E-03
kr-87	1.2231E-01	2.5706E+03	sn-123m	8.1664E-04	1.7163E+01	tb-165	2.5738E-07	5.4093E-03
rb-87	3.5582E-12	7.4782E-08	te-123m	7.9967E-10	1.6807E-05	dy-165	2.8028E-07	5.8906E-03
sr-87m	4.6076E-06	9.6837E-02	i-123	8.3774E-14	1.7607E-09	dy-165m	1.0728E-08	2.2547E-04
y-87	2.5116E-12	5.2786E-08	pd-124	8.4864E-08	1.7836E-03	er-165	6.8918E-14	1.4484E-09
y-87m	2.8466E-16	5.9826E-12	ag-124	3.1322E-05	6.5829E-01	eu-166	8.9236E-09	1.8755E-04
ge-88	2.4360E-06	5.1197E-02	cd-124	6.4810E-04	1.3621E+01	gd-166	7.4417E-08	1.5640E-03
as-88	6.0387E-03	1.2691E+02	in-124	7.6985E-04	1.6180E+01	tb-166	1.3004E-07	2.7330E-03
se-88	1.7065E-02	3.5865E+02	in-124m	1.2174E-04	2.5586E+00	dy-166	1.4449E-07	3.0367E-03
br-88	8.4265E-02	1.7710E+03	sb-124	1.7554E-06	3.6893E-02	ho-166	1.4643E-07	3.0775E-03
kr-88	1.6940E-01	3.5602E+03	sb-124m	3.4639E-07	7.2800E-03	ho-166m	1.1998E-13	2.5216E-09
rb-88	1.7052E-01	3.5838E+03	i-124	7.5754E-19	1.5921E-14	tm-166	3.4878E-21	7.3302E-17
y-88	1.8495E-08	3.8871E-04	ag-125	1.6489E-06	3.4655E-02	eu-167	1.8670E-09	3.9238E-05
zr-88	2.7711E-14	5.8240E-10	cd-125	2.7047E-04	5.6844E+00	gd-167	2.7086E-08	5.6926E-04
ge-89	3.1438E-09	6.6073E-05	in-125	4.5672E-04	9.5988E+00	tb-167	6.2072E-08	1.3046E-03
as-89	9.6939E-06	2.0373E-01	in-125m	3.6075E-04	7.5818E+00	dy-167	7.3731E-08	1.5496E-03
se-89	2.5860E-03	5.4349E+01	sn-125	6.9708E-04	1.4650E+01	ho-167	7.4107E-08	1.5575E-03

Isotope	Ci per cm^3	Total Core Ci		Isotope	Ci per cm^3	Total Core Ci		Isotope	Ci per cm^3	Total Core Ci
br-89	5.3093E-02	1.1158E+03		sn-125m	1.1107E-03	2.3343E+01		er-167m	9.0416E-09	1.9003E-04
kr-89	2.1543E-01	4.5276E+03		sb-125	7.0306E-04	1.4776E+01		tm-167	7.8387E-17	1.6474E-12
rb-89	2.2547E-01	4.7387E+03		te-125m	1.4700E-04	3.0895E+00		gd-168	8.5454E-09	1.7960E-04
sr-89	2.2655E-01	4.7614E+03		i-125	1.6271E-12	3.4196E-08		tb-168	2.7787E-08	5.8399E-04
y-89m	1.3384E-04	2.8129E+00		xe-125	4.5205E-17	9.5006E-13		dy-168	3.6806E-08	7.7354E-04
zr-89	1.0483E-04	2.2032E+00		xe-125m	1.2062E-17	2.5350E-13		ho-168	3.7245E-08	7.8277E-04
zr-89m	1.5053E-05	3.1637E-01		ag-126	3.2834E-07	6.9007E-03		tm-168	1.0835E-14	2.2772E-10
as-90	2.2467E-07	4.7218E-03		cd-126	3.8814E-04	8.1575E+00		gd-169	1.8993E-09	3.9917E-05
se-90	6.6532E-04	1.3983E+01		in-126	5.2317E-04	1.0995E+01		tb-169	1.2558E-08	2.6393E-04
br-90	2.7346E-02	5.7473E+02		in-126m	1.3481E-04	2.8333E+00		dy-169	2.0723E-08	4.3553E-04
kr-90	2.2349E-01	4.6970E+03		sn-126	1.7462E-08	3.6700E-04		ho-169	2.1501E-08	4.5188E-04
rb-90	2.3096E-01	4.8540E+03		sb-126	4.3092E-05	9.0566E-01		er-169	2.1511E-08	4.5209E-04
rb-90m	4.2321E-02	8.8945E+02		sb-126m	8.1556E-05	1.7140E+00		yb-169	4.2095E-17	8.8470E-13
sr-90	1.3072E-02	2.7473E+02		i-126	1.4610E-09	3.0706E-05		yb-169m	5.4404E-18	1.1434E-13
y-90	1.3404E-02	2.8171E+02		ag-127	5.0312E-08	1.0574E-03		tb-170	4.0242E-09	8.4576E-05
y-90m	3.5752E-05	7.5139E-01		cd-127	3.7803E-04	7.9450E+00		dy-170	1.0003E-08	2.1023E-04
zr-90m	1.2785E-04	2.6870E+00		in-127	2.2783E-03	4.7883E+01		ho-170	1.0431E-08	2.1923E-04
nb-90	6.1901E-22	1.3010E-17		in-127m	3.7914E-04	7.9683E+00		ho-170m	4.2825E-10	9.0004E-06
as-91	2.3658E-08	4.9722E-04		sn-127	4.8555E-03	1.0205E+02		tm-170	2.9298E-10	6.1575E-06
se-91	4.4392E-05	9.3298E-01		sn-127m	2.8175E-03	5.9215E+01		tb-171	1.0775E-09	2.2646E-05
br-91	1.1030E-02	2.3182E+02		sb-127	7.9828E-03	1.6777E+02		dy-171	4.7744E-09	1.0034E-04
kr-91	1.6012E-01	3.3652E+03		te-127	8.2355E-03	1.7308E+02		ho-171	5.9666E-09	1.2540E-04
rb-91	2.6637E-01	5.5982E+03		te-127m	1.2860E-03	2.7028E+01		er-171	6.0388E-09	1.2692E-04
sr-91	2.7890E-01	5.8616E+03		xe-127	1.4712E-12	3.0920E-08		tm-171	3.0762E-09	6.4652E-05
y-91	2.7832E-01	5.8494E+03		xe-127m	2.8194E-13	5.9255E-09		lu-171	3.4838E-20	7.3218E-16
y-91m	1.6411E-01	3.4491E+03		ag-128	6.8766E-09	1.4452E-04		hf-171	1.5539E-21	3.2658E-17
nb-91	6.0225E-17	1.2657E-12		cd-128	1.6632E-04	3.4955E+00		dy-172	5.4670E-09	1.1490E-04
nb-91m	4.1143E-19	8.6469E-15		in-128	8.5918E-04	1.8057E+01		ho-172	8.1648E-09	1.7160E-04
as-92	1.0999E-09	2.3116E-05		in-128m	6.9163E-04	1.4536E+01		er-172	8.3692E-09	1.7589E-04
se-92	3.3271E-06	6.9925E-02		sn-128	1.6477E-02	3.4629E+02		tm-172	8.4008E-09	1.7656E-04
br-92	1.4189E-03	2.9821E+01		sn-128m	7.8470E-03	1.6492E+02		lu-172	5.7617E-15	1.2109E-10
kr-92	8.0862E-02	1.6995E+03		sb-128	1.1557E-03	2.4289E+01		lu-172m	5.0224E-15	1.0555E-10
rb-92	2.3061E-01	4.8467E+03		sb-128m	1.6824E-02	3.5359E+02		hf-172	4.8366E-15	1.0165E-10

Isotope	Ci per cm^3	Total Core Ci		Isotope	Ci per cm^3	Total Core Ci		Isotope	Ci per cm^3	Total Core Ci
sr-92	2.8475E-01	5.9845E+03		te-128	2.7294E-21	5.7363E-17		Total	3.2963E+01	6.9277E+05

Table 13. Stirling Engine and Other General Area Results. [2]

Tally Location	Neutron Dose Rate	Photon Dose Rate	Total Dose Rate	TID
	rad/hr	rad/hr	rad/hr	rad
Stirling Base	346.4	1.6	348.0	2.6E+06
Stirling Midsection	291.2	3.2	294.4	2.2E+06
Stirling Top	218.6	2.5	221.1	1.7E+06
Bounding Upper Confinement	496.3	6.6	502.9	3.8E+06
In Guard Vessel Above Axial Shield	430.1	171.0	601.1	6.2E+06
Guard Vessel Centerline	30,085	7,205	37,290	3.5E+08

Table 14. Pit Cover Core Centerline Dose Rates. [4]

Time (hr)	Dose Rate (rem/hr)					
	Core	NaK	Steel	Stirling	Gallium Eutectic	Total
0	1.81E+00	5.52E-03	1.59E+00	5.68E+00	1.42E+01	2.33E+01
6	4.89E-02	3.88E-03	4.52E-01	1.67E+00	1.19E+01	1.41E+01
12	2.45E-02	2.93E-03	4.52E-01	8.98E-01	8.82E+00	1.02E+01
24	1.60E-02	1.67E-03	1.72E-01	6.85E-01	4.88E+00	5.76E+00
48	1.36E-02	5.48E-04	1.62E-01	6.36E-01	1.50E+00	2.31E+00
96	1.13E-02	5.89E-05	1.55E-01	6.01E-01	1.46E-01	9.13E-01
144	1.11E-02	6.37E-06	1.52E-01	5.87E-01	1.77E-02	7.67E-01
192	9.41E-03	7.08E-07	1.50E-01	5.78E-01	5.62E-03	7.43E-01
240	8.47E-03	9.37E-08	1.49E-01	5.73E-01	4.42E-03	7.34E-01
288	7.26E-03	2.70E-08	1.48E-01	5.69E-01	4.20E-03	7.28E-01
336	6.81E-03	1.98E-08	1.47E-01	5.65E-01	4.08E-03	7.23E-01

Table 15. Pit Cover Moon Shield Edge Dose Rates. [4]

Time (hr)	Dose Rate (rem/hr)					
	Core	NaK	Steel	Stirling	Gallium Eutectic	Total
0	1.58E+00	4.04E-03	9.89E-01	5.08E+00	1.03E+01	1.79E+01
6	3.73E-02	2.85E-03	2.80E-01	1.50E+00	9.35E+00	1.12E+01
12	1.94E-02	2.16E-03	2.80E-01	8.03E-01	6.93E+00	8.03E+00
24	1.31E-02	1.23E-03	1.06E-01	6.11E-01	3.84E+00	4.58E+00
48	1.06E-02	4.04E-04	9.96E-02	5.68E-01	1.18E+00	1.86E+00
96	8.28E-03	4.34E-05	9.57E-02	5.38E-01	1.16E-01	7.58E-01
144	8.04E-03	4.70E-06	9.42E-02	5.25E-01	1.41E-02	6.42E-01
192	6.89E-03	5.20E-07	9.30E-02	5.18E-01	4.55E-03	6.22E-01
240	6.48E-03	6.82E-08	9.25E-02	5.13E-01	3.63E-03	6.16E-01
288	5.59E-03	1.89E-08	9.19E-02	5.09E-01	3.41E-03	6.10E-01
336	5.28E-03	1.36E-08	9.14E-02	5.06E-01	3.32E-03	6.06E-01

Table 16. Stirling Cavity (General, Between Stirlings) Dose Rates. [4]

Time (hr)	Dose Rate (rem/hr)					
	Core	NaK	Steel	Stirling	Gallium Eutectic	Total
0	6.80E+00	3.77E-02	1.29E+01	4.23E+01	1.65E+02	2.27E+02
6	1.85E-01	2.64E-02	3.66E+00	1.25E+01	9.37E+01	1.10E+02
12	1.02E-01	1.99E-02	3.66E+00	6.72E+00	6.95E+01	8.00E+01
24	6.80E-02	1.14E-02	1.39E+00	5.12E+00	3.86E+01	4.52E+01
48	5.34E-02	3.73E-03	1.31E+00	4.74E+00	1.61E+01	2.22E+01
96	4.67E-02	4.01E-04	1.25E+00	4.47E+00	1.59E+00	7.35E+00
144	4.07E-02	4.34E-05	1.22E+00	4.36E+00	1.49E-01	5.77E+00
192	3.61E-02	4.82E-06	1.21E+00	4.29E+00	5.16E-02	5.59E+00
240	3.31E-02	6.40E-07	1.20E+00	4.25E+00	4.14E-02	5.52E+00
288	2.92E-02	1.86E-07	1.19E+00	4.21E+00	3.94E-02	5.47E+00
336	2.61E-02	1.37E-07	1.18E+00	4.19E+00	3.84E-02	5.44E+00

Table 17: Dose Rates from Individual Stirling for Replacement. [4]

Radial Dist. (cm)	Dose Rate (rem/hr)										
	0 hrs	6 hrs	12 hrs	24 hrs	48 hrs	96 hrs	144 hrs	192 hrs	240 hrs	288 hrs	336 hrs
10	7.29E+01	2.13E+01	1.14E+01	8.49E+00	7.66E+00	6.98E+00	6.67E+00	6.50E+00	6.39E+00	6.31E+00	6.25E+00
20	1.70E+01	5.02E+00	2.70E+00	2.06E+00	1.91E+00	1.81E+00	1.76E+00	1.73E+00	1.72E+00	1.70E+00	1.69E+00
30	9.29E+00	2.74E+00	1.48E+00	1.12E+00	1.04E+00	9.85E-01	9.59E-01	9.45E-01	9.35E-01	9.28E-01	9.22E-01
40	5.84E+00	1.72E+00	9.28E-01	7.07E-01	6.56E-01	6.19E-01	6.03E-01	5.93E-01	5.87E-01	5.82E-01	5.79E-01
50	4.00E+00	1.18E+00	6.36E-01	4.84E-01	4.49E-01	4.23E-01	4.13E-01	4.07E-01	4.02E-01	3.99E-01	3.97E-01
60	2.88E+00	8.52E-01	4.59E-01	3.50E-01	3.24E-01	3.06E-01	2.97E-01	2.93E-01	2.90E-01	2.88E-01	2.86E-01
70	2.17E+00	6.41E-01	3.44E-01	2.62E-01	2.43E-01	2.29E-01	2.23E-01	2.20E-01	2.17E-01	2.16E-01	2.15E-01
80	1.69E+00	5.02E-01	2.70E-01	2.05E-01	1.89E-01	1.78E-01	1.74E-01	1.71E-01	1.69E-01	1.68E-01	1.67E-01
90	1.36E+00	4.04E-01	2.18E-01	1.66E-01	1.53E-01	1.44E-01	1.41E-01	1.39E-01	1.38E-01	1.37E-01	1.36E-01
100	1.13E+00	3.33E-01	1.79E-01	1.36E-01	1.26E-01	1.19E-01	1.16E-01	1.14E-01	1.13E-01	1.12E-01	1.11E-01