Pebble Bed Reactor Domestic Safeguards

FY21 Summary Report

Prepared for
US Department of Energy

Philip Gibbs, Jianwei Hu, Don Kovacic, and Logan Scott

Oak Ridge National Laboratory

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OAK RIDGE NATIONAL LABORATORY
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Nuclear Security Sciences Directorate

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ACRONYMS

BUMS	burnup measurement system
FHS	fuel handling system
HALEU	high-assay low enriched uranium
HTGR	high-temperature gas-cooled nuclear reactor
LWR	light water reactor
MBA	material balance area
MC&A	material control and accounting
NRC	U.S. Nuclear Regulatory Authority
ORNL	Oak Ridge National Laboratory
PBMR	pebble bed modular reactor
PBR	pebble bed reactor
SNL	Sandia National Laboratories
SNM	special nuclear material

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ABSTRACT

This report provides the work done under the DOE NE-5 Advanced Reactor Safeguards Program for Fiscal Year 2021. It focuses on Material Control and Accounting (MC&A) for pebble bed reactors (PBR). It addresses some of the main challenges where current PBR MC&A approaches are still evolving, allowing for possible safeguards and security by design efforts. In Fiscal Year 2021 efforts focused on continued vendor interactions, the impact to MC&A from the use of HALEU, reporting challenges, and projected special nuclear material (SNM) content of spent fuel for MC&A purposes using the PBMR-400 as an example.

1. SCOPE OF WORK

1.1 Introduction

This report summarizes work done under the DOE NE-5 Advanced Reactor Safeguards Program for Fiscal Year 2021 on the topic of material control and accounting (MC&A) for pebble bed reactors (PBRs).

As background, Title 10 of the Code of Federal Regulations (10 CFR) Part 74 defines MC&A requirements for special nuclear material (SNM). MC&A requirements are defined based on the strategic significance of the SNM. LWR fuel used in U.S. commercial nuclear reactors is less than 10% enriched in the isotope ^{235}U[1] which is the lowest category.

Also, even though there is plutonium in LWR spent nuclear fuel[2], LWR fuel assemblies are large, heavy, and highly radioactive, which significantly decreases the likelihood of theft. Because of this, the NRC only requires LWRs to meet the sabotage design basis threat (DBT) and not the theft/diversion DBT based on the thinking that theft/diversion is bounded by controls to mitigate sabotage. Therefore, the NRC's MC&A regulations for LWRs are less stringent and do not require the full implementation of Category I and Category II MC&A requirements when compared to other fuel cycle facilities relying more heavily on physical security.

This will not be the case with PBRs where the portability of spheres at certain points in the process is a key difference albeit the SNM content per sphere is small. Also, enrichment levels will exceed 10% which moves into Category II MC&A requirements. Therefore, PBR designs will require different nuclear material control and accounting (MC&A) methods when compared with the existing fleet of light water reactors (LWRs) that are currently licensed in the United States.

The main differences again stem from the movable nature of the fuel spheres (pebbles) during normal reactor operations. Spheres are continuously inserted and withdrawn from the reactor core and are moved throughout the reactor and associated systems via pneumatic (or hydraulic) pressure tubes, as well as other (mechanical) means. This is in notable contrast to LWRs where the fuel bundles are fixed during the operations cycle and the reactor must be shut down and the reactor head removed to insert, remove, or shuffle the fuel.

Additionally, the several hundred fuel bundles at a LWR are uniquely identified, whereas fuel spheres, in most proposed designs, will not be. A PBR will have an inventory consisting of hundreds of thousands of fuel spheres and during the operational lifetime may encounter millions of spheres that arrive as fresh fuel and ultimately are dispositioned as spent fuel. The number of spheres and their portability constitute the key differences as they relate to MC&A and security. The concept of item control or monitoring as defined within 10 CFR Part 74 will apply as one of the key approaches to manage this large number of spheres.

[1] 10,000 grams or more of ^{235}U enriched to less than 10% is defined as Category III, SNM of low strategic significance (Nuclear Regulatory Commission 2017).
[2] The presence of plutonium would typically cause SNM to be categorized as Category I, strategic SNM (Nuclear Regulatory Commission 2017).

Even so certain aspects of current LWR approaches were found to be applicable for fresh and spent fuel, as discussed in Oak Ridge National Laboratory (ORNL) report to the NRC, Model MC&A Program for a Pebble Bed Reactor (ORNL/SPR-2019/1329) [1]. This is true for fresh and spent fuel. However, the report notes that MC&A approaches currently in use for fuel cycle facilities are more closely aligned with anticipated PBR designs instead of LWR approaches—specifically, those MC&A approaches required for facilities handling SNM of moderate strategic significance (i.e., Category II) when it comes to the reactor vessel and recycle loops.

The low SNM content per sphere also needs to be balanced with the radiological aspects resulting from the theft of a single spent sphere. Considering only bulk amounts or groups does not address the potential consequence of the loss of an individual pebble if used in a radiological exposure device or a radiological dispersion device. A spent TRISO pebble will have radiation levels equivalent to a Category 1 or 2 radiological source [2] (internal communication from D. Holcomb to P. Gibbs, Oak Ridge National Laboratory, April 30, 2019).

Current PBR MC&A approaches are still evolving as vendors continue to work on plant layouts and designs for the fuel handling systems. This allows for the possible consideration of safeguards and security in the designs of these facilities.

This report focuses on fuel categorization considerations, MC&A requirements/plans, inventory reporting, and contains a more detailed analysis of fuel composition based on a PBMR-400 example. As with last year, this effort builds on the MC&A (domestic safeguards) challenges for PBRs as identified in the (ORNL) report Model MC&A Plan for Pebble Bed Reactors (ORNL/SPR-2019/1329) [1]. The referenced report was completed for the Nuclear Regulatory Commission (NRC) in response to the emergence of this non-LWR design to analyze current policy and technical guidance.

1.2 Industry Partnerships and National Laboratories

The results of the work being done by this project is intended to be applicable to any PBR design. The industry partnerships described in this report are providing important examples of leading PBR conceptual designs and, as such, it is useful to use them in considering possible MC&A approaches since they provide some detailed design information. Any results from this report should be applicable to any PBR design, within the given general reactor design characteristics, and can be used by any vendors/ designers considering MC&A approaches for PBRs.

1.2.1 X-energy – Activities in FY21

In October 2020 X-energy was selected as one of two recipients for DOE's Advanced Reactor Demonstration Program (ARDP). The Cooperative Agreement between DOE and X-energy was signed on March 1, 2021. As part of that agreement Oak Ridge National Laboratory and Sandia National Laboratory are partnering with X-energy on domestic safeguards and security. Since March efforts have been focused on getting the appropriate Non-Disclosure Agreements, work packages, and supplier agreements in place to support the work. No funding has been allocated to either national lab as of September 30, 2021, from the ARDP.

Separate from the ARDP, technical consultations took place throughout the year on burnup measurements, reactor modeling, and spent fuel plutonium declarations. These discussions were useful in informing the work and planning reflected in this report.

Expected in FY22 in parallel to the general efforts on this project will be discussions on the MC&A accounting system. A MC&A accounting system does not yet exist in the marketplace for the PBR technology. Also expected are continued discussions on measurement and statistical methods to be used in accounting for the plutonium production and uranium depletion in the spent fuel.

1.2.2 Kairos Power – Activities in FY21

The project met with Kairos Power August 3-5, 2021, at their Alameda CA HQ for working meetings related to Material Control and Accounting approaches for PBRs. Topics included:

- KP-FHR Design Overview
- Hermes Plant Layout
- General MC&A Overview
- Testing Lab Tour
- NRC Regulations Overview
- Inventory Flows and Accounting
- Item versus Bulk Accounting
- Core Design
    - Pebble Types
    - Composition over time
- Pebble Handling and Storage System
- Physical Security Design Considerations
- Fresh and Spent Fuel Handling and Storage
- Waste Handling

The objective of these meetings was twofold. One was for the ARS project team to better understand KP-FHR and Hermes design and current needs at Kairos. The second was for the lab experts to provide additional background on work done to date at the national labs under this and other projects related to pebble bed reactors to assist their design team in understanding and provide contacts/resources that could be of assistance. These types of interactions are expected to continue into FY22.

1.2.3 National Laboratories

The project team continued coordination with the following national laboratories: Sandia National Laboratories (SNL), Brookhaven National Laboratory (BNL), Argonne National Laboratory (ANL), and Idaho National Laboratory (INL). Each national laboratory brings unique skills and experiences. In FY22, collaboration across the labs will continue as part of the ARS program.

2. FISCAL YEAR 2021 FOCUS AREAS AND TASKS

2.1 Fiscal Year 2021 Overview

In FY21 work focused on the impact of the use of HALEU. This is discussed in section 2.2 on Safeguards and Security Categorization. Also, in FY21 investigations continued on the implementation of 10 CFR Part 74 and the requirements for the Fundamental Nuclear Material Control and Accounting (FNMC) Plan. This is discussed in section 2.3. The project also looked at MC&A reporting and the impact of hundreds of thousands small objects at or below reportable quantities. This is discussed in Section 2.4. Section 2.5 discusses MC&A approaches for fresh fuel receipts. Sections 2.6 discusses work done on the inventory approach for the reactor and fuel handling system. Section 2.7 provides examples of burnup analysis based on the PBMR-400 discussing how the SNM content will vary and the interplay between operations and MC&A.

2.2 PBR Safeguards and Security Categorization

In FY21 investigations continued about the impact that the use of high assay low enriched uranium (HALEU) will have on the pebble bed reactor MC&A programs. The concern being the potential cost impact of additional MC&A and Security requirements. Presentations took place on this topic during the April 2021 Stakeholder's Meeting for the ARS program and this project participated in a Panel Discussion on the same topic during the American Nuclear Society June 2021 meetings.

As background, the categorization determines the requirements in 10 CFR Part 74 that the facility must meet during the MC&A licensing process. The emerging designs for PBRs are going to be Category II based on fuel enrichment (>10% <20%) and quantities. LWRs are treated as Category III which is a lower category due to their lower enrichments.

While not necessarily true for physical security, for MC&A the conclusion to date for the most part is that the increase from Category III to Category II is not that significant. The reason is that the MC&A requirements that change going from Category III to Category II are mainly inventory frequency and detection thresholds. Inventory frequency goes from annual to every 9 months and detection thresholds are lower. Specifically on detection thresholds for Category II facilities, the NRC states the licensee shall establish and maintain an item control program that can meet these requirements established in 10 CFR 74.43(b)(5):

> *. . . be capable of detecting unauthorized removal of 200 grams or more of plutonium (Pu) or uranium-233 (U-233), or 300 grams or more of uranium-235 (U-235), as one or more whole items and/or as special nuclear material (SNM) removed from containers with high probability* (typically defined as 95%).

As noted in the *Model MC&A Plan for Pebble Bed Reactors* [1], these detection thresholds are likely easily achievable due to the dilute nature of the fuel and hence the large numbers of pebbles needed to obtain any significant quantity of SNM. Using the PBMR-400 as an example this translates to a detection threshold of:

- 300 pebbles (235U) for unirradiated pebbles, with a gross weight approximately 80 kg, or
- 1,000 - 2,000 pebbles (Pu) for irradiated pebbles, with a gross weight over 500 kg (*Note: some variability in published Pu content ranging from just over .1 to .2 grams of Pu / pebble depending upon burnup study referenced).*

Recalling the capacity of the fresh fuel containers (VP55 ~ 350 pebbles) and the Spent Fuel Containers (~2000 pebbles), these detection thresholds approach the level of an entire container.

What about Fuel Portability?

The portability of pebbles compared to LWR fuel assemblies was evaluated. Although the pebbles themselves are technically man-portable, for most of the SNM material flow at the reactor, design options exist for them to either be in containers or the reactor/fuel handling system where they would not be man-portable. For MC&A and Security the general rule of thumb in the case of closed containers of SNM pieces, is provisions should be made to assure that removal of contents would be observable.

Therefore, there are only two likely material handling steps where the pebbles become more susceptible to diversion due to their portability which are the loading and unloading processes to/from the reactor. The unloading or spent fuel part of the process is probably subject to debate since it will be done remotely in a hot cell type containment and at that point the fuel is highly radioactive making diversion even less credible.

For MC&A and Security addressing the fuel portability question focus should be directed to the material control features at the fresh fuel loading point in the process. Again, not unlike the thinking used in LWRs during *reconstitution* which is a term used to describe the process where fuel assemblies are dissembled and modified (e.g., pin changes).

This fresh fuel loading transfer step is show on figure 1 circled in red. Options for control could be multiple persons involved in the activity (e.g., two-person rule) or other means to confirm successful transfer of the pebbles from the VP55 through any intermediate steps (e.g., such as fuel conditioning) and into the reactor fuel handling system. Approaches for documentation for both MC&A and operations is again analogous to approaches used in LWRs for reconstitution. The objective is an MC&A process that provides high confidence that no pebbles are stolen or diverted during this step addressing the requirements established in 10 CFR 74.43(b)(5) discussed previously.

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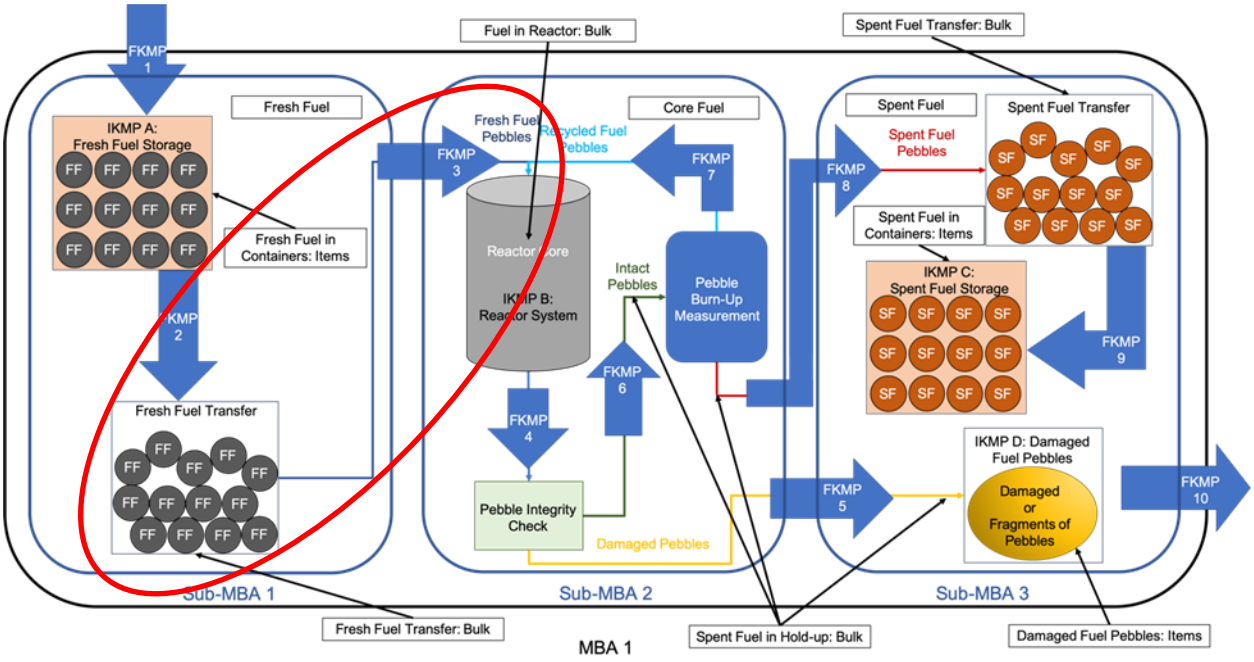
Figure 1 - Process Overview Fuel Portability



Summary

For MC&A categorizing a PBR at Category II is not likely to result in overly burdensome additional MC&A requirements. The increased physical inventory frequency from annual to every 9 months given some thought to facility layout and the inventory approach (e.g., automation) can be minimal. The lower Cat II detection thresholds are likely to be easily achievable due to the fuel diluteness and large numbers of pebbles it represents. Target quantities and volume are close to entire containers. MC&A material control focus is most needed at the point in the process where the fuel will be transition from the fresh fuel container to the reactor fuel handling system. It is at that point the portability represents the most credible location for potential theft or diversion. For other parts of the process where there are closed containers of SNM pieces, provisions should be made to assure that removal of contents would be observable.

2.3 Fundamental Nuclear Material Control Plan (FNMC)

Another question that continues to be raised is whether PBRs should be exempt from 10 CFR Part 74 Subpart D and E like LWRs. The NRC has noted during several public meetings that this is unlikely. The reasoning is that PBRs have aspects more like fuel cycle facilities and therefore do not meet the intent behind this exemption. Particularly when it comes to the bulk nature of fuel handling for the reactor.

Without getting into the debate about whether the exemption should or should not apply, it may be more useful to consider what really changes with respect to what must be done by the licensee in developing and documenting the PBR MC&A program. Actually, nothing changes because the overall scope and intent of a MC&A program is pretty consistent regardless of the facility category or even at an LWR.

Also, whether or not the NRC has to approve the FNMC plan, even with LWRs during the NRC inspection the NRC reviews and assesses the adequacy of the MC&A program and procedures in meeting performance objectives established in 10 CFR Part 74.

FNMC Plan Comparison – How different are they based on facility type or category?

In September 2021 the NRC released Revision 1 of NUREG-2159 for public comment. NUREG-2159 which is the *"Acceptable Standard Format and Content for the Fundamental Nuclear Material Control Plan Required for Special Nuclear Material of Moderate Strategic Significance"* (e.g., Category II facilities) [3] likely to be used for PBRs. While there has been some anticipation about what would be in the document, MC&A plans in general are reasonably consistent in format, content, and intent across categories of material. It is not until Category I, the highest category, are there significant additional requirements. As an illustration Figure 2 shows content side by side to include ANSI N15.8-2009 [4] which is the template used in LWRs.

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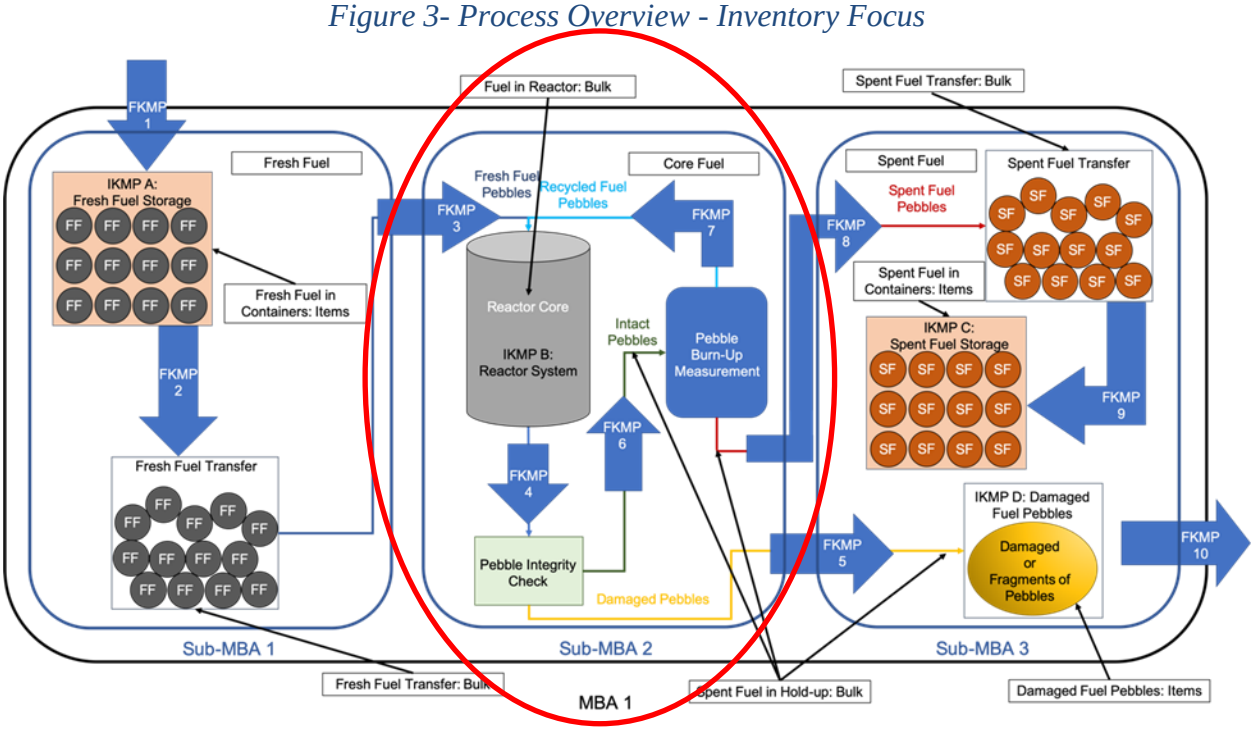
Figure 2 - FNMC Plan Comparison

Current LWR Plan ANSI N15.8-2009	Category III SNM NUREG-1065	Category II SNM NUREG-2159	Category I SNM NUREG-1280
Organization Requirements MC&A Program	Management Structure	Management Structure	Management Structure
SNM Calculations	Measurements Measurement Control Statistics	Measurements Measurement Control Statistics	Measurements Measurement Control Statistics
Physical Inventory	Physical Inventories	Physical Inventories	Physical Inventories
Internal Control	Item Control	Item Control	Process Monitoring Item Monitoring Alarm Resolution Scrap Control
Input Control Output Control	Shipper-Receiver Comparisons	Shipper-Receiver Comparisons	Shipments and Receipts
Assessments	Assessments	Assessments	Assessments
Addressed in Internal Control	Tamper-Safing	Tamper-Safing	Tamper-Safing
Note: Implied	Resolving Anomalies Information to Assist in Recover	Resolving Anomalies Information to Assist in Recover	Resolving Anomalies Information to Assist in Recover
Addressed in Organization Requirements	Designation of MBAs, ICAs, and Custodians	*Addressed in Management Structure*	Designation of MBAs, ICAs, and Custodians
Records and Reports	Recording Keeping	Recording Keeping	Recording Keeping

Circled in red are the areas of the MC&A plan which are most likely to be different for PBRs with respect to LWRs. It is also the areas where they are going to behave more like fuel cycle facilities. With that said, these differences really only apply to the reactor vessel and fuel handling system. Fresh and spent fuel (containers – analogous to fuel assemblies) will be very much like LWRs in approaches and concepts.

Figure 3- Process Overview - Inventory Focus



In FY22 this project will continue to focus on potential approaches that address the differences covering both inventory and statistical aspects. Based on discussions during FY21 if there were one recommendation that could be made regarding this area, it is in the interest of all (e.g., vendors, NRC, and DOE) to continue detailed discussions and work towards consensus on approaches in this area. In most cases designs in this area are still being developed, therefore this remains the optimum time to address the MC&A requirements minimizing their impact and cost to operations.

2.4 Material Accounting and Rounding Challenges – Reporting

Pebble Bed Reactors have large numbers of discrete objects (i.e., pebbles) at small values which will require special considerations designed into the MC&A accounting system to handle rounding for inventory and transaction reporting. This should not be construed as an issue for MC&A or security from a theft/diversion perspective since all work to date has been focused on balancing around numbers of pebbles. It is simply an accounting and reporting nuance due to large numbers of small items that will need to be addressed for periodic MC&A reporting.

The reason this becomes an issue in reporting to the Nuclear Materials Management and Safeguards System (NMMSS) is due to reporting units (number of decimal places) and different methods of data grouping used inventory and transaction reporting. Appendix A discusses in more detail things to be considered in licensee MC&A systems for NMMSS reporting and applicable regulatory references.

Rounding Guidance for Reporting

Although many facility MC&A systems may and many do carry additional decimal places, for transaction and inventory reporting purposes to NMMSS, reporting units for enriched uranium and plutonium are constrained to the nearest gram. Normal uranium is rounded to the nearest kilogram.

In both the NRC and DOE, the guidance for rounding is:

- quantities equal to or great than 0.5 of the reporting unit are rounded up to the next whole reporting unit, quantities less are rounded down.
- Transfers of multiple discrete items of 0.5 of a reporting unit or less, but of the same material type (e.g., uranium, plutonium, etc.), are typically summed to a total weight of that material type before applying rounding criteria. (This guidance is very applicable for handling the plutonium content which is quite small.)

Here's an overview of the types of differences that might be observed depending on choices in grouping, rounding, and summing of nuclear material weights for MC&A reporting.

2.4.1 Uranium Example Using PBMR-400

Assuming a loading 15,000 TRISO particle loading in a 15% enriched pebble and a reactor vessel containing 452,000 pebbles, gram quantities are shown in Figure 4.

Figure 4- Unrounded Pebbles and Reactor U Values (grams)

	Unrounded Uranium in Pebble	Unrounded Uranium in Reactor
U234	0.012	5,424
U235	1.363	616,076
U236	0.006	2,712
U238	7.705	3,482,660
Total U	9.086	4,106,872

2.4.2 Rounding Based on Two Example Groupings – Pebble and VP55 Fresh Fuel Container (~350 Pebbles)

There are multiple possible groups that could be used to receive and transfer fuel into the reactor. For this example, a single pebble and a VP55 (fresh fuel container) are compared to illustrate the impact of rounding and summing by these two potential groupings. The first column shows the actual uranium content in the reactor vessel. Rounding and summing at the pebble level is shown in column 2 with the difference from actual show in column 4. Rounding and summing at the VP55 level is shown in column 3 with the difference show in column 5.

Figure 5- Rounding at Various Groupings and Differences

		452000 Pebbles		1291.428571 VP55s	
	Unrounded Uranium Numbers in Reactor	Rounded at the Pebble Level and summed	Rounded at VP55 Level and Summed by Reactor (~1292 VP55s)	Difference if rounded at Pebble Level	Difference if rounded at VP55 Level
U234	5,424	0	5,166	(5,424)	(258)
U235	616,076	452,000	616,011	(164,076)	(65)
U236	2,712	0	2,583	(2,712)	(129)
U238	3,482,660	3,616,000	3,482,983	133,340	323
Total U	4,106,872	4,068,000	4,106,743	(38,872)	(129)

Although the differences are much smaller when rounding at the container level, any difference will result in a discrepancy to be resolved with NMMSS during the reconciliation process. This is due to how values are grouped and summed for reporting. Periodic rounding adjustments by the process outlined in NRC regulations will be necessary to balance licensee records with NMMSS.

2.4.3 Spent Fuel Containers and Plutonium Content

The difference becomes much more pronounced when the plutonium content in the spent fuel is considered due to the small amount in each pebble which is about ¼ gram. Using the PBMR-400 and assuming burnup of 160 GWd/MTU and a spent fuel container of 2000 pebbles, the differences are shown below. Individually each pebble will round to zero. The total plutonium content in the 2000 pebble group rounded at the pebble level is zero however the actual content in the container is 484 grams. Therefore, declaring Pu production and rounding at the spent fuel container level is a more reasonable and accurate approach.

Figure 6- Plutonium Rounding Spent Fuel

	Unrounded Plutonium in a Pebble (g)	Rounded at the Pebble Level and Summed (g)	Rounded at the Spent Fuel Container (g)
Pu238	0.006864	0	14
Pu239	0.08863	0	177
Pu240	0.06077	0	122
Pu241	0.04683	0	94
Pu242	0.03914	0	78
Total Pu	0.242234	0	484

2.4.4 Rounding Summary

Approaches to handle rounding adjustments are not uncommon in MC&A systems, especially fuel cycle facilities. While not prevalent in light water reactors, PBRs will behave more like fuel cycle facilities with respect to rounding. The basis and approach for rounding adjustments should be covered in the Facility's Fundamental Nuclear Material Control Plan (FNMC plan). It should describe how rounding adjustments are captured within the MC&A accounting system and subsequently reported to NMMSS. Appendix A provides additional information on the NMMSS reporting process and types of groupings, physically and accounting, that will be encountered in PBRs.

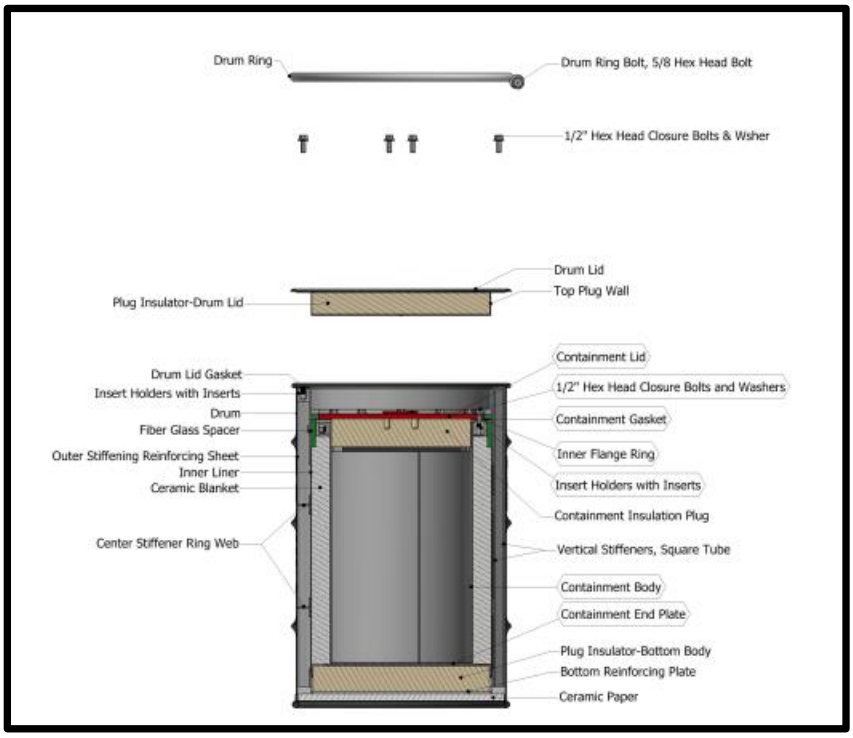
2.5 Fresh Fuel Containers – Inventory and Receipt Verification

X-energy and Kairos both plan to use fuel of varying enrichments, as well as graphite-only spheres. Visually they cannot be distinguished from one another. The MC&A system will need to identify an approach that clearly distinguishes different levels of enrichments and also precludes non-SNM items being mistaken for SNM items (Note: Section 7.4 of ANSI N15.8-2009 [4]).

Fresh Fuel Container and Process

As reported last year, the main candidate for use as fresh fuel containers is the Versa-Pac (VP55).* The VP55 is a specially configured 55-gallon package for shipment of uranium oxides, uranium metal, uranyl nitrate crystals, and other uranium compounds (e.g., uranium carbides, uranyl fluorides and uranyl carbonates, uranium hexafluoride in the special cylinders, and TRISO fuel). In this configuration, the VP55 would contain approximately 350 pebbles with a total heavy metal (uranium) weight of 3 kg with a fissile content of less than 400 g uranium-235. Some key design characteristics are shown in Figure 7.

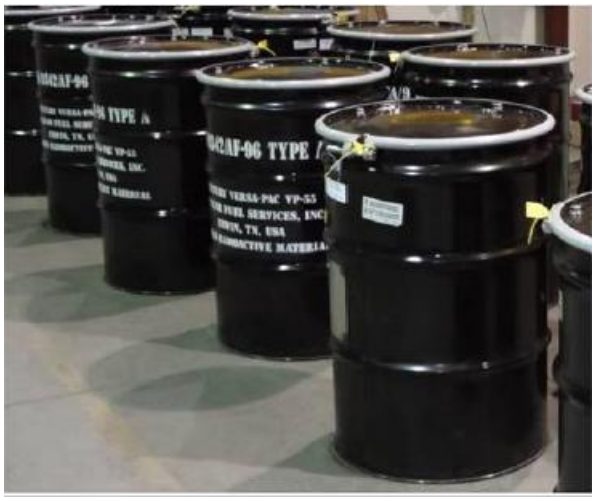
Figure 7- Versa-Pac (VP55) Fresh Fuel Container



* https://rampac.energy.gov/docs/default-source/certificates/1039342.pdf

Each container is assumed to be sealed after it is filled with fuel spheres and prior to shipment from the fuel fabrication facility to the reactor. Once the containers are received at the reactor, they are placed into the fresh fuel storage area in an operating facility. The loaded and sealed VP55 containers are shown in Figure 8.

Figure 8 - VP55 Containers Loaded and Sealed



MC&A Approach – Fresh Fuel

The MC&A approach for fresh fuel is not difficult with numerous existing acceptable parallels within other types of facilities. As noted in the section on categorization, the general rule of thumb is in the case of closed containers of SNM pieces, provisions should be made to assure that the removal of contents would be observable. Again, based on diluteness of the SNM in the pebble, 10 CFR Part 74 required detection thresholds for Category II approach an entire VP55 container which would have to be compromised.

In addition to this general concept, during the licensing process the NRC will be looking at how the following areas are addressed in the FNMC plan and operating procedures.

- Current Knowledge of Items [10 CFR 74.43(b)(5)(i) and 10 CFR 74.43(c)(1)];
- Tamper-safing [10 CFR 74.43(c)(3)];
- Receipt, Shipment, and Transfer of SNM [10 CFR 74.43(c)(2)];
- Item Storage and Handling [10 CFR 74.43(b)(5)(ii)]; and
- Item Monitoring [10 CFR 74.43(b)(5)(ii)].

Particular to VP55s for PBRs is the fact that there will be containers of differing enrichments and non-SNM (moderator) pebbles. It should be clear in handling and inventory procedures how these are identified, stored, and managed for operations and inventory.

Receipt verification is also fairly straight forward with a number of potential options shown from easiest to more difficult which include:

- simply verifying the container and tamper-indicating device's serial number;
- opening the container and counting the pebbles;
- opening the container, counting the pebbles, and measuring a sample; and
- opening the container and individually measuring each pebble.

The first, least rigorous option is defined as "unopened receipts" in 10 CFR Part 74.

> Unopened receipts *means receipts not opened by the licensee, including receipts of sealed sources, and receipts opened only for sampling and subsequently maintained under tamper-safing.*

If there is high confidence in the transfer process, then an acceptable MC&A approach would be the first which is to confirm the container's and TID's serial number and inspect the tamper-safing upon receipt and for inventory. This may be coupled with a weight measurement or quick enrichment measurement to confirm differing enrichments and non-SNM bearing containers.

High confidence means that no credible diversion strategies during transfer and storage processes were identified. This term also assumes that the processes implemented by the fuel fabricator and reactor operator for transfers and receipts have a low probability of discrepancies which would affect both MC&A, operations, and safety.

If gross weight and the container/tamper-indicating device's serial number verification are used for verification, then the numbers of pebbles and the SNM content within those pebbles would be placed into inventory based on the shipper's values and maintained until the container is opened for the fuel pebbles to be fed into the reactor.

Even for cases with low confidence in the transfer process but with fresh fuel having a short residence time in the receipt area, this approach may be acceptable. This is because opening the container for fuel loading shortly after receipt provides another potentially equally acceptable opportunity for verifying the SNM received within acceptable timelines for loss detection.

In cases with lower confidence either from credible diversion scenarios or performance violations in the transfer and storage processes, additional rigor in receipt and inventory checks may be warranted. These efforts could range from random sampling of containers and application of independent measurements up to 100% verification. Due to the labor-intensive nature of these checks, this is not an ideal approach.

2.6 Physical Inventory of Reactor Vessel

Investigations continued on physical inventory approaches for the reactor vessel. Last year the project had hoped to get into more detail in this area. However, with COVID restrictions and the fact that vendors are still in early design and testing of the fuel handling systems, while

investigations continued, none were in detail. Therefore, there has not been convergence on a physical inventory approach for the reactor vessel.

What remains to be done for both operational and MC&A performance considerations is establishing performance criteria for the pebble counting/indexing systems and a discussion on how core monitoring could be used to inform MC&A. Both will be part of the licensing reviews as vendors and the NRC review approaches proposed to monitor the core inventory.

This is also an integration point with Safety as the reactor core fissile material inventory directly impacts reactivity, and monitoring reactivity is a primary safety function. Regulatory Guide 1.2325 (ML17325A611), Advanced Reactor Design Criterion 13, "Instrumentation and control," requires monitoring of the reactor core.

From an MC&A perspective, this is the most challenging, although not necessarily difficult, aspect of PBR technology. This is the part of the process where a PBR diverges from approaches used in LWRs and behaves more like fuel cycle facilities.

Although a convergence on an approach hasn't happened yet, what was accomplished in FY21 was work on technical aspects that will inform an approach. For example, modeling and statistical analysis for burnup and production in a spent pebble based on likely pathways through the reactor was completed for the PBMR-400 and Xe-100. The results for the PBMR-400 are shown in section 2.7. The Xe-100 analysis, not included, was done under a nondisclosure agreement between X-energy and ORNL.

What is planned for FY22 using this analysis is development of example statistical approaches that could be used to monitor the actual versus expected fissile content in the spent fuel. Monitoring this could inform both operations and MC&A that the reactor is operating normally. These processes are what would be documented in the FNMC Plan and facility procedures and are integration points with operations, Safety, and MC&A.

Other Potentially Useful Studies

Other potential things to be considered that would support both domestic and international safeguards are sensitivity studies on changes in core composition. As an example, for the South African Pebble Bed Modular Reactor design [6], a sensitivity study was performed for the detection of fertile targets inserted for a single pass in the core.

This study assessed the effect of introducing target pebbles loaded with natural uranium particles to normal fuel: target pebbles were loaded and mixed with the fuel pebbles to obtain a homogenous distribution in the core. Calculations were performed for two densities of target pebbles: one that represents an additional uranium mass of 0.1% (in natural uranium) to the total enriched uranium mass of the fuel core, and one that represents an additional mass of 0.4%. The added natural uranium increases the number of neutron captures in the core, which must be compensated by increasing the number of normal fuel pebbles added every day (and consequently sending the same increased number of spent fuel pebbles in a spent fuel bin) to

keep the same reactivity margin as in the initial core so it could continue operation in a sustainable way.

The result of the calculation was that the daily number of fresh fuel pebbles must be increased by 21% in the first case and by 95% in the second case. Moreover, the quantity of plutonium produced in the target pebbles was very low. In the first case, it would take 92 years to get significant quantity, and in the second case, it would take 23 years.

This is another example and the kind of study that shows how the introduction of target pebbles would be easily detected by the fresh fuel consumption. There would also be abnormal signals for the core flux and burnup measurements, but their sensitivity was not determined in this study. However, the PBR core flux would be very sensitive to changes in fuel composition and feed rates, and process monitoring of the reactor power levels and fuel pebble feed rates could inform MC&A and security.

2.7 Burnup Analysis Calculations based on PBMR-400

In order to estimate the isotopic compositions in discharged pebbles to assist MC&A analysis at ORNL and burnup measurement analysis at Sandia National Laboratory and others, burnup analysis calculations were performed in this work based on PBMR-400, due to its publicly available reactor design and operation information [7]. For a typical burnup analysis calculation, the required input includes the following: 1) the initial fuel mass and composition; 2) the irradiation neutron spectra; 3) the irradiation power; 4) the final burnup value; 5) the cooling time after the fuel is finally discharged. The final burnup value is a product of irradiation power and irradiation time. In this work, each pebble is assumed to contain 15,000 TRISO particles [7], each of which has a kernel of 500 μm in diameter. The kernel is assumed to be filled with UO_2 with 15 wt% ^{235}U enrichment, which amounts to 9.09 gram of uranium in each fresh pebble. The final burnup is assumed to be 160 GWd/MTU. The irradiation power is assumed to be 97.4 W/gU, which was derived from PBMR-400 core power and total fuel pebble loading [7]. The cooling time is specified in later parts of this section.

As to the irradiation neutron spectra, this work leverages the work performed by Skutnik et al. [8] at ORNL that modelled the PBMR-400 in detail using SCALE [9] for reactor physics studies. Figure 9 shows the 3D SCALE model for the PBMR-400 reactor [8]. The fuel compositions used in this model were for equilibrium-core fuel compositions specified in the ND-Set3 of Ref . [7] An equilibrium core means a reactor core reaches a condition where the average fuel compositions remain largely the same from one cycle to another; therefore, this model based on equilibrium core fuel compositions can provide neutron spectra that are representative to the fuel cycle of PBMR-400. Note the center graphite reflector, the annular core filled with pebbles, and the side graphite reflector included in the model. Figure 10 shows the fast-to-thermal neutron flux spectral ratios of 5 radial zones (RZs), indicated by their distances from the core center, for the equilibrium core as functions of the core elevation. The divisions of the 5 RZs are made consistent with what were used in Ref. [7] and they are used just to facilitate analysis as there are no physical barriers between two adjacent zones. The higher the ratio is, the harder the spectrum is considered to be. Harder spectra usually lead to greater accumulations of transuranic nuclides including plutonium under irradiation. As shown, the RZs “100-110 cm” and “161-185 cm” have

the softest neutron spectra (i.e., lowest fast-to-thermal ratio) due to their proximities to either the center or side graphite reflectors shown in
Figure 99, because graphite is a neutron moderator and thus turns fast neutrons into thermal neutrons. RZ “127-144 cm” has the hardest neutron spectrum because it is farthest away from both reflectors. The remaining two RZ have relatively hard spectra compared with the two zones that are adjacent to the reflectors. Given the known influence of neutron spectra on the isotopic accumulations in fuel under irradiation, it is important to consider the variations of neutron spectra among the RZs. As to the axial variation of the neutron spectra, the spectra around the mid-height of the core are close to the average spectra for each RZ.

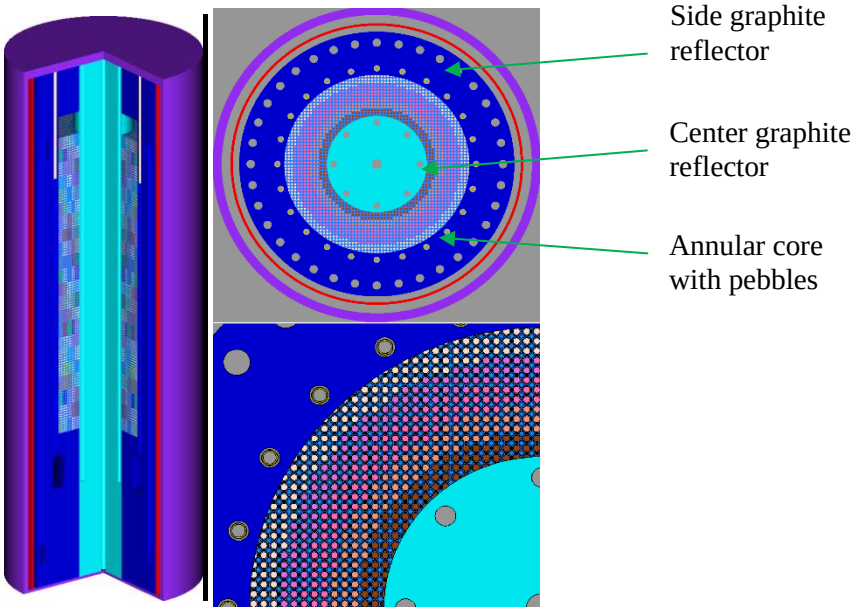


Figure 9 SCALE model for the PBMR-400 equilibrium-composition core [2], (left) axial cutaway view, (right) horizontal cut plane view at z = 100 cm.

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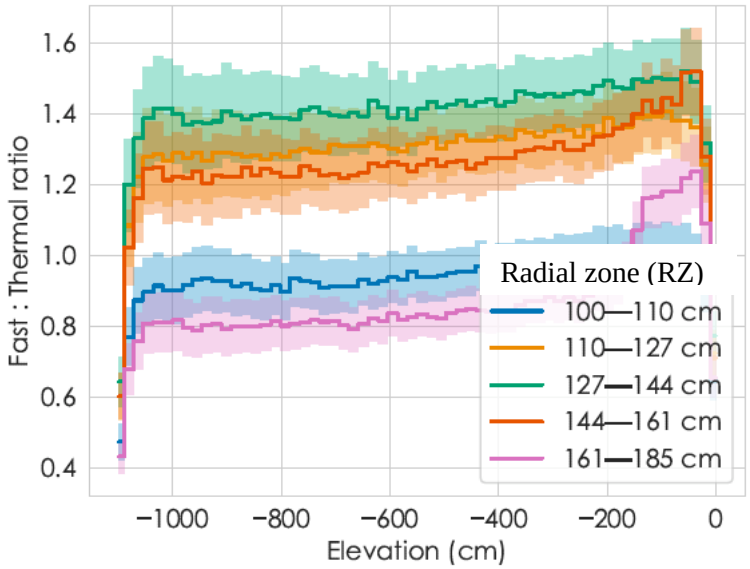

Figure 10 Spectral ratio (fast: thermal flux) for the equilibrium-composition core along the elevation of the core [2]. The thermal-fast boundary is defined at E=1.86 eV. Note that z=0 cm indicates the top of the active fuel zone.

To accurately calculate the isotopic composition in a particular discharged pebble, one needs to know the exact route this pebble has traveled through the core in its multiple passes (e.g., going different RZs at various core elevations). However, such information is usually not available because the pebbles were not individually tracked in a PBR fuel cycle. The goal of this project is not to calculate the exact isotopic composition of a particular pebble, but rather to identify the range of the isotopic compositions, especially the Pu quantities, for a typical discharged pebble after it reaches its full burnup. Therefore, the isotopic compositions of five representative pebbles were calculated in this work, with each pebble assumed to go through multiple passes through each of the five RZs until the specified final burnup (i.e., 160 GWd/MTU) is reached. For example, pebble 1 is assumed to always go through RZ1 in the core. The neutron spectra from each of the five RZs shown in Figure 1010, together with relevant information described in the beginning of this section, were used in each of the SCALE/ORIGEN [9] calculations to calculate the isotopic compositions for each of the five representative pebbles.

Error! Reference source not found. shows the uranium isotopic compositions, in the unit of gram per pebble, in a fresh pebble and in the five representative discharged pebbles. The mean and standard deviation (stdev) of the uranium isotope masses among the 5 pebbles from the different RZs are also included. The uranium isotope masses in the fresh pebble were calculated based on the assumption that each pebble contains 15,000 TRISO particles with UO_2 kernels of 500 μm in diameter and that the ^{235}U enrichment was 15 wt%. In reality, each pebble may contain a different number of TRISO particles, and the characteristics of the particles may vary from one to another. Information on such variations is not available to this project and the impacts of such variations on the final Pu inventory can be assessed in the future when the relevant information becomes available. The uranium isotopic masses in the discharged pebbles were calculated based on the assumptions that each of the five pebbles reached a final burnup of 160 GWd/MTU and that the cooling time was 0 (right after being discharged from the core). ^{235}U

has higher fission and absorption cross sections in a softer neutron spectrum, whereas ^{238}U has higher fission and absorption cross sections in a harder neutron spectrum. Such cross-section characteristics can explain why there were less ^{235}U and more ^{238}U in RZ1 and RZ5 than in the other three RZs, given that RZ1 and RZ5 had softer neutron spectra than others (Figure 10). On average, there are approximately 0.25, 6.87, 7.31 grams of ^{235}U, ^{238}U, and U total remaining in a discharged pebble with an initial enrichment of 15% and a burnup of 160 GWd/MTU.

Table 1. Uranium isotopic compositions (g/pebble) of a fresh pebble with 15% ^{235}U enrichment and of 5 discharged pebbles irradiated in 5 different radial zones (RZs) with a final burnup of 160 GWd/MTU. The mean and standard deviation (stdev) among the 5 pebbles are also included.

Isotope	Fresh pebble (g/pebble)	Discharged pebble with a burnup of 160 GWd/MTU (g/pebble)						
		RZ1	RZ2	RZ3	RZ4	RZ5	Mean	Stdev
U-234	0.0121	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	1.96E-06
U-235	1.3630	0.2386	0.2614	0.2668	0.2615	0.2423	0.2541	0.0114
U-236	0.0063	0.1797	0.1779	0.1774	0.1778	0.1794	0.1784	0.0009
U-238	7.7052	6.8940	6.8570	6.8480	6.8570	6.8880	6.8688	0.0185
U total	9.0866	7.3195	7.3035	7.2994	7.3035	7.3169	7.3085	0.0081

Error! Reference source not found. shows the plutonium isotopic compositions, in the unit of gram per pebble, of the five representative discharged pebbles. The mean and standard deviation (stdev) of the plutonium isotope masses among the 5 pebbles are also included. Greater plutonium isotopic accumulations are generally expected in harder neutron spectra mainly due to higher ^{238}U absorption cross sections in harder neutron spectra, which explains why there were higher plutonium isotopic masses in RZ2, 3, and 4 than in the other two RZ's given that the neutron spectra were harder in RZ2, 3, and 4 (Figure 10). On average, there are approximately 0.089, 0.061, 0.24 grams of ^{239}Pu, ^{240}Pu, and Pu total remaining in a discharged pebble with an initial enrichment of 15% and a burnup of 160 GWd/MTU. Figure 11 visualizes the Pu mass values contained in **Error! Reference source not found.**. These calculations were performed based on the assumptions that each of the five pebbles reached an exact final burnup of 160 GWd/MTU. In reality, discharged pebbles may have different final burnups than each other because a pebble's burnup accumulated during its final pass through the core will vary depending on the exact route it takes, assuming its burnup from previous pass was determined to be below certain safety threshold by the BUMS. The impact of such variations on the Pu quantities is recommended to be investigated in the future when the relevant information becomes available.

Error! Reference source not found. shows the mean and standard deviation values of Pu mass in two hypothesized discharged pebble containers, one of which contains 2,000 pebbles and the other contains 10,000 pebbles. The mean values for the containers were based on the mean "Pu total" value for a pebble shown in **Error! Reference source not found.**, and the standard deviation values for the containers were derived using uncertainty propagation methods based on the Pu variation in a pebble among the five different RZ's shown in **Error! Reference source not found.**. On average, a 2000-pebble container is estimated to contain 471 grams of Pu with a standard deviation of 0.36 grams, whereas a 10000-pebble is estimated to contain 2354 grams of

Pu with a standard deviation of 0.79 grams. The last column of **Error! Reference source not found.** shows the percentage of 2 standard deviations in the mean Pu mass. Note that the Pu variation results shown here considered only the impacts of different neutron spectra found in the five possible RZs. Other uncertainties, for examples, the variations in the initial isotopic mass in a fresh pebble and the variations in final burnups among the discharged pebbles, and variation in measurement accuracy of the burnup, will also have impacts on the Pu quantities in a container. It is recommended to assess such impacts when the necessary information becomes available to perform such assessments.

Appendix B includes two tables of nuclide masses at 13 different cooling times (from 0 to 30 days) in a discharged pebble. Neutron spectrum from RZ1 (110-127 cm) was used this set of calculations because the spectrum from RZ1 is close to the core average. Table 4 shows the results for a pebble with a final burnup of 80 GWd/MTU and Table 5 shows the results for 160 GWd/MTU. Both tables contain a full list of nuclides and were transmitted to Sandia National Laboratory and other labs to assist detailed burnup measurement analysis.

Table 2. Plutonium isotopic compositions (g/pebble) of 5 discharged pebbles irradiated in 5 different RZ's with a final burnup of 160 GWd/MTU. The mean and standard deviation (stdev) of Pu isotopic masses among the 5 pebbles are also included.

Isotope	RZ1	RZ2	RZ3	RZ4	RZ5	Mean	Stdev
Pu-238	0.0067	0.0069	0.0070	0.0069	0.0067	0.0069	0.0001
Pu-239	0.0824	0.0916	0.0938	0.0916	0.0838	0.0886	0.0046
Pu-240	0.0599	0.0613	0.0615	0.0612	0.0600	0.0608	0.0007
Pu-241	0.0437	0.0483	0.0494	0.0483	0.0444	0.0468	0.0023
Pu-242	0.0387	0.0394	0.0395	0.0394	0.0388	0.0391	0.0004
Pu total	0.2247	0.2405	0.2443	0.2404	0.2270	**0.2354**	**0.0079**

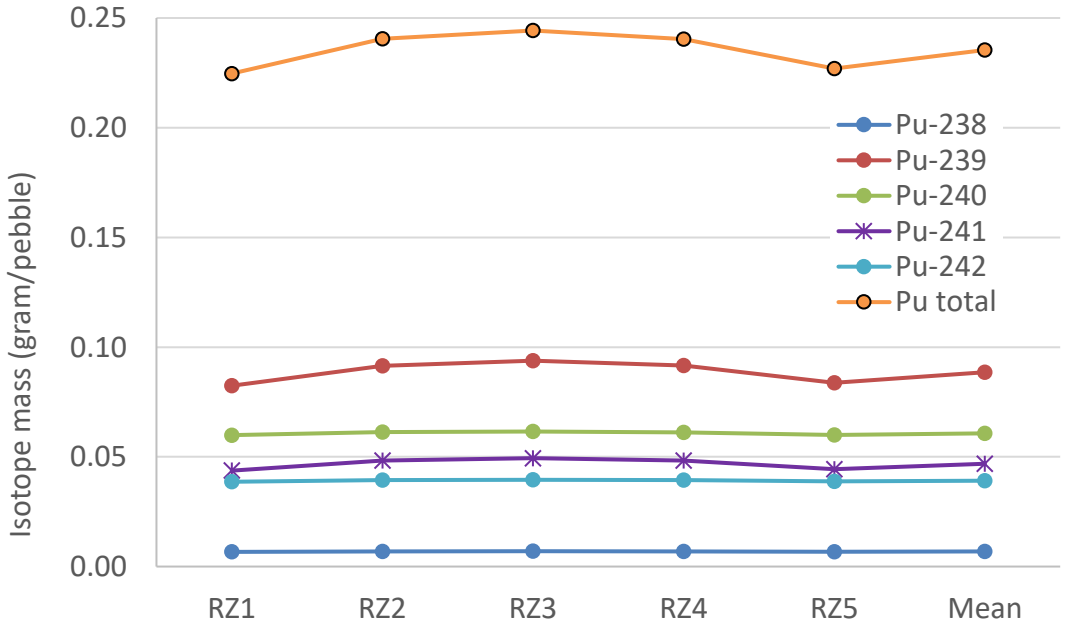

Figure 11 Plutonium isotopic compositions (g/pebble) of 5 discharged pebbles irradiated in 5 different RZ's with a final burnup of 160 GWd/MTU and the mean values among the 5 pebbles.

Table 3. The mean and standard deviation values of Pu total mass in two hypothesized discharged pebble containers, one of which contains 2,000 pebbles and the other contains 10,000 pebbles.

#Pebbles	Mean (grams)	Stdev (grams)	2Stdev(%)
2000	470.73	0.36	0.15%
10000	2353.66	0.79	0.07%

3. FY22 WORK PLANS

During FY22, there will be continued focus to work with industry which is crucial for understanding and applying MC&A approaches to PBRs. Work will continue with X-energy under this project balanced with efforts on the ARDP scope which includes both ORNL and SNL. The partnership with Kairos Power is expanding with help from the 3-day technical exchange at their Alameda headquarters in August 2021. The project team will continue to work with other national laboratories.

Emerging from the FY20 and FY21 analysis was the overlap with physical protection based on the facility layout and implementation of remote handling, all of which would affect or complement the MC&A approaches for item control. In FY22 the project will further explore this interface with industry and a project being done at SNL for the security posture of a PBR, which will focus on the vulnerability for man-portable fuel and PBR vital areas regarding, theft, sabotage, diversion, and misuse.

The project will continue investigation on the use of pebble stream average for declared uranium depletion and plutonium production in spent pebbles. In FY21 the project determined likely distributions for both a PBMR-400 and Xe-100 (proprietary). Use of stream average integrated with a measurement and statistical approach to monitor the average/variation is likely to provide the simplest and most accurate approach for material accounting in spent fuel containers.

The project will develop generic functional requirements for a PBR MC&A system that outlines approaches needed for reporting of multiple material types/enrichments (e.g., normal, enriched uranium, plutonium) and rounding caused by hundreds of thousands small items to support system development and licensing under 10 CFR Part 74.

In FY22 work will continue on measurement systems in general. This includes following work on burnup measurements being conducted by other entities to understand its impact on declarations. It also will expand to possible confirmatory measurements for both receipts of fresh fuel and spent fuel containers. Measurements for fresh fuel will address requirements for confirming shipper information, properly segregating nuclear material of differing material types or enrichments for material control and inventory and segregating non-nuclear (moderator pebbles) from nuclear bearing pebbles.

4. REFERENCES

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[2] Nuclear Regulatory Commission (NRC), “Appendix A—Category 1 and Category 2 Radioactive Materials,” 10 CFR Part 37, March 2013.

[3] U.S. NRC, *Acceptable Standard Format and Content for the Material Control and Accounting Plan Required for Special Nuclear Material of Moderate Strategic Significance*, US Nuclear Regulatory Commission NUREG-2159, Revision 1 2021.

[4] American National Standard, “Special Nuclear Material Control and Accounting Systems for Nuclear Power Plants,” ANSI N15.8-2009.

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[7] Nuclear Science Committee, Nuclear Energy Agency (NEA), "PBMR Coupled Neutronics / Thermalhydraulics Transient Benchmark The PBMR-400 Core Design, vol. 1: The Benchmark Definition," NEA/NSC/DOC(2013)10, Paris, France, 2013.

[8] S. Skutnik and W. Wieselquist, "Assessment of ORIGEN Reactor Library Development for Pebble-Bed Reactors Based on the PBMR-400 Benchmark," Oak Ridge National Laboratory, ORNL/TM-2020/1886, Oak Ridge, TN 37830, 2021.

[9] W. A. Wieselquist, R. A. Lefebvre and M. A. Jessee, "SCALE Code System, Version 6.2.4," Oak Ridge National Laboratory, ORNL/TM-2005/39, Oak Ridge, TN 37830, 2020.

APPENDIX A - NMMSS RECONCILIATION PROCESS OVERVIEW

This appendix provides more information for the discussion on rounding covered in section 2.4 It provides a brief overview of the NMMSS reconciliation process along with a discussion of the types of groupings likely to occur within a PBR for inventory and reporting.

On a periodic basis licensee nuclear material records are compared and reconciled with NMMSS by SNM quantity and material type (e.g., enriched uranium, normal uranium, and plutonium). This reconciliation is organized by material type and various subgroupings of interest within material type. Values must match gram for gram or kilogram for kilogram in transactions and inventory. Discrepancies between a licensee's are corrected during the reconciliation process.

The reporting and reconciliation process works as follows:

- Transactions during a material balance period are reported to NMMSS per the instructions in NUREG/BR-0006, Rev. 9 on DOE/NRC Forms 741 and 740M. From these reports NMMSS will generate an **independent** running balance for the facility (e.g., beginning inventory + receipts – removals = ending inventory).
- Inventory is reported to NMMSS at the end of the material balance period. The facility will submit Forms 742, Material Balance Report, and Forms 742C, Physical Inventory Listing to NMMSS which represent the facility's inventory.
- The facility's declared inventory as reported will be compared to the NMMSS running inventory balance.
- Discrepancies will be resolved through additional or correcting transactions used to update NMMSS or facility records.

Again, based on how groupings are used in the reporting and inventory process and how those groups are summed and rounded, there will be small differences between NMMSS and the facility for PBRs which will need to be resolved through this process.

Groupings in a PBR

While the total uranium content in the core can be calculated based on number pebbles and uranium loading per pebble, it arrives at the site and goes into/out of the core via a group captured in a MC&A transaction. Therefore, how transactions are grouped and summed, will determine what type and magnitude of rounding bias will occur.

There are several types of groupings that will occur in a PBR for MC&A from a physical perspective and from a reporting perspective.

Example physical groupings along with estimated numbers of pebbles in each group are:

- Discreet Pebbles – this is the smallest integral object within a PBR at 1 pebble.
- VP55 Fresh Fuel Container – The VP55 is the current certified shipping container for pebbles. It will hold around 350 fresh fuel pebbles.

- Truck – There are projected to be 71 VP55s per truck. At 350 pebbles/VP55 that equals 24,850 pebbles per truck. *Note: There could be multiple trucks in a single shipment. This example only considers one truck for illustration purposes.*
- PBMR-400 Reactor Vessel – The reactor vessel holds around 452,000 pebbles which is equal to 1808 VP55s or just over 25 trucks.
- Daily Fuel Usage – 490 pebbles per day or 1.4 VP55s
- Spent Fuel Container – Current designs will hold around 2000 pebbles

Example groupings for reporting to the NMMSS that will occur in a PBR:

- Material Type – Two-digit code to identify the nuclide being reported. There are likely to be 3 codes used in PBRs which are:
    - 20 or E2 - (uranium in enrichment of 5 percent or more but less than 20 percent)
    - 50 – plutonium (predominantly Pu239)
    - 81 – normal uranium
- COMP/FAC (composition/facility) Code – Three-digit code describing the material and/or process location. There are likely to be 4 codes used in PBRs which are:
    - 860 – In reactors and critical assemblies
    - 861 – In cooling basins (spent pebbles)
    - 864 - Materials not in process (fresh fuel)
    - 865 – Unirradiated scrap awaiting recovery (applies to loose pellets in LWR but could apply to broken pebbles)
- Other groupings
    - Other potential groups might include owner codes and material with different reporting obligations depending upon material origin.

In summary, Section 2.4 covered a few examples showing how the small rounding discrepancies likely to occur in a PBR for inventory and reporting purposes. This appendix provided additional detail on the reporting process and the types of groupings, physical and reporting, that will be present in PBRs. Instructions for reporting to NMMSS can be found in NUREG/BR-0006, Rev. 9 and NUREG/BR-0007 Rev. 8. Licensee MC&A systems will be required to report SNM inventories to NMMSS per the requirements in 10 CFR Part 74 based on these instructions.

References:

U.S. NRC, *Instructions for the Completing Nuclear Material Transaction Reports* (DOE/NRC Forms 741 and 740M), US Nuclear Regulatory Commission, NUREG/BR-0006, Revision 9, 2020

U.S. NRC, *Instructions for the Preparation and Distribution of Material Status Reports* (DOE/NRC Forms 742 and 742C), US Nuclear Regulatory Commission, NUREG/BR-0007, Revision 8, 2019

APPENDIX B – PBMR 400 CALCULATIONS

Table 4. Nuclide masses (g/pebble) in a pebble with a discharged burnup of 80 GWd/MTU as a function of cooling time.

	0 sec	15 sec	1 min	10 min	30 min	1 hr	5 hr	10 hr	1 day	3 day	7 day	15 day	30 day
he-4	7.10E-05	7.10E-05	7.10E-05	7.10E-05	7.10E-05	7.10E-05	7.10E-05	7.10E-05	7.10E-05	7.10E-05	7.11E-05	7.12E-05	7.14E-05
be-9	5.93E-05	5.93E-05	5.93E-05	5.93E-05	5.93E-05	5.93E-05	5.93E-05	5.93E-05	5.93E-05	5.93E-05	5.93E-05	5.93E-05	5.93E-05
c-12	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02
c-13	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00
c-14	4.55E-06	4.55E-06	4.55E-06	4.55E-06	4.55E-06	4.55E-06	4.55E-06	4.55E-06	4.55E-06	4.55E-06	4.55E-06	4.55E-06	4.55E-06
o-16	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00
o-17	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04
o-18	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03
si-28	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00
si-29	1.16E-01	1.16E-01	1.16E-01	1.16E-01	1.16E-01	1.16E-01	1.16E-01	1.16E-01	1.16E-01	1.16E-01	1.16E-01	1.16E-01	1.16E-01
si-30	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02
p-31	2.44E-05	2.44E-05	2.44E-05	2.44E-05	2.44E-05	2.44E-05	2.44E-05	2.44E-05	2.44E-05	2.44E-05	2.44E-05	2.44E-05	2.44E-05
u-234	9.61E-03	9.61E-03	9.61E-03	9.61E-03	9.61E-03	9.61E-03	9.61E-03	9.61E-03	9.61E-03	9.61E-03	9.61E-03	9.61E-03	9.61E-03
u-235	6.73E-01	6.73E-01	6.73E-01	6.73E-01	6.73E-01	6.73E-01	6.73E-01	6.73E-01	6.73E-01	6.73E-01	6.73E-01	6.73E-01	6.73E-01
u-236	1.21E-01	1.21E-01	1.21E-01	1.21E-01	1.21E-01	1.21E-01	1.21E-01	1.21E-01	1.21E-01	1.21E-01	1.21E-01	1.21E-01	1.21E-01
u-237	1.18E-04	1.18E-04	1.18E-04	1.18E-04	1.18E-04	1.18E-04	1.16E-04	1.13E-04	1.07E-04	8.68E-05	5.75E-05	2.53E-05	5.42E-06
u-238	7.33E+00	7.33E+00	7.33E+00	7.33E+00	7.33E+00	7.33E+00	7.33E+00	7.33E+00	7.33E+00	7.33E+00	7.33E+00	7.33E+00	7.33E+00
u-239	1.17E-05	1.16E-05	1.14E-05	8.74E-06	4.84E-06	1.99E-06	1.65E-09	2.32E-13	3.84E-24	0.00E+00	0.00E+00	0.00E+00	0.00E+00
np-237	4.37E-03	4.37E-03	4.37E-03	4.37E-03	4.37E-03	4.37E-03	4.37E-03	4.37E-03	4.38E-03	4.40E-03	4.43E-03	4.46E-03	4.48E-03
np-238	9.10E-06	9.10E-06	9.10E-06	9.08E-06	9.04E-06	8.98E-06	8.50E-06	7.94E-06	6.56E-06	3.41E-06	9.20E-07	6.70E-08	4.95E-10
np-239	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.68E-03	1.60E-03	1.51E-03	1.27E-03	7.05E-04	2.17E-04	2.07E-05	2.51E-07
pu-238	8.91E-04	8.91E-04	8.91E-04	8.91E-04	8.91E-04	8.91E-04	8.92E-04	8.92E-04	8.94E-04	8.99E-04	9.04E-04	9.11E-04	9.21E-04
pu-239	9.52E-02	9.52E-02	9.52E-02	9.53E-02	9.53E-02	9.53E-02	9.54E-02	9.54E-02	9.57E-02	9.62E-02	9.67E-02	9.69E-02	9.70E-02
pu-240	4.99E-02	4.99E-02	4.99E-02	4.99E-02	4.99E-02	4.99E-02	4.99E-02	4.99E-02	4.99E-02	4.99E-02	4.99E-02	4.99E-02	4.99E-02

pu-241	2.75E-02	2.75E-02	2.75E-02	2.75E-02	2.75E-02	2.75E-02	2.75E-02	2.75E-02	2.75E-02	2.75E-02	2.75E-02	2.75E-02	2.74E-02
pu-242	6.99E-03	6.99E-03	6.99E-03	6.99E-03	6.99E-03	6.99E-03	6.99E-03	6.99E-03	6.99E-03	6.99E-03	6.99E-03	6.99E-03	6.99E-03
am-241	6.37E-04	6.37E-04	6.37E-04	6.37E-04	6.37E-04	6.37E-04	6.38E-04	6.38E-04	6.40E-04	6.48E-04	6.62E-04	6.91E-04	7.46E-04
am-242m	1.03E-05	1.03E-05	1.03E-05	1.03E-05	1.03E-05	1.03E-05	1.03E-05	1.03E-05	1.03E-05	1.03E-05	1.03E-05	1.03E-05	1.03E-05
am-243	4.19E-04	4.19E-04	4.19E-04	4.19E-04	4.19E-04	4.19E-04	4.19E-04	4.19E-04	4.20E-04	4.20E-04	4.20E-04	4.20E-04	4.20E-04
cm-242	1.84E-04	1.84E-04	1.84E-04	1.84E-04	1.84E-04	1.84E-04	1.84E-04	1.84E-04	1.84E-04	1.83E-04	1.80E-04	1.74E-04	1.63E-04
cm-244	4.03E-05	4.03E-05	4.03E-05	4.03E-05	4.03E-05	4.03E-05	4.03E-05	4.03E-05	4.03E-05	4.03E-05	4.03E-05	4.03E-05	4.02E-05
as-75	2.69E-06	2.69E-06	2.69E-06	2.69E-06	2.69E-06	2.69E-06	2.69E-06	2.69E-06	2.69E-06	2.69E-06	2.69E-06	2.69E-06	2.69E-06
ge-76	7.43E-06	7.43E-06	7.43E-06	7.43E-06	7.43E-06	7.43E-06	7.43E-06	7.43E-06	7.43E-06	7.43E-06	7.43E-06	7.43E-06	7.43E-06
se-77	1.86E-05	1.86E-05	1.86E-05	1.86E-05	1.86E-05	1.86E-05	1.86E-05	1.86E-05	1.86E-05	1.86E-05	1.87E-05	1.87E-05	1.87E-05
se-78	5.17E-05	5.17E-05	5.17E-05	5.17E-05	5.17E-05	5.17E-05	5.17E-05	5.17E-05	5.17E-05	5.17E-05	5.17E-05	5.17E-05	5.17E-05
se-79	1.11E-04	1.11E-04	1.11E-04	1.11E-04	1.11E-04	1.11E-04	1.11E-04	1.11E-04	1.11E-04	1.11E-04	1.11E-04	1.11E-04	1.11E-04
se-80	3.08E-04	3.08E-04	3.08E-04	3.08E-04	3.08E-04	3.08E-04	3.08E-04	3.08E-04	3.08E-04	3.08E-04	3.08E-04	3.08E-04	3.08E-04
br-81	5.09E-04	5.09E-04	5.09E-04	5.09E-04	5.09E-04	5.09E-04	5.09E-04	5.09E-04	5.09E-04	5.09E-04	5.09E-04	5.09E-04	5.09E-04
se-82	7.92E-04	7.92E-04	7.92E-04	7.92E-04	7.92E-04	7.92E-04	7.92E-04	7.92E-04	7.92E-04	7.92E-04	7.92E-04	7.92E-04	7.92E-04
kr-82	5.32E-06	5.32E-06	5.32E-06	5.32E-06	5.32E-06	5.32E-06	5.32E-06	5.33E-06	5.33E-06	5.34E-06	5.35E-06	5.35E-06	5.35E-06
kr-83	1.12E-03	1.12E-03	1.12E-03	1.12E-03	1.12E-03	1.12E-03	1.12E-03	1.13E-03	1.13E-03	1.13E-03	1.13E-03	1.13E-03	1.13E-03
kr-84	2.51E-03	2.51E-03	2.51E-03	2.51E-03	2.51E-03	2.51E-03	2.51E-03	2.51E-03	2.51E-03	2.51E-03	2.51E-03	2.51E-03	2.51E-03
kr-85	6.25E-04	6.25E-04	6.25E-04	6.25E-04	6.25E-04	6.25E-04	6.25E-04	6.25E-04	6.25E-04	6.25E-04	6.25E-04	6.24E-04	6.22E-04
rb-85	2.47E-03	2.47E-03	2.47E-03	2.47E-03	2.47E-03	2.47E-03	2.47E-03	2.47E-03	2.47E-03	2.47E-03	2.47E-03	2.47E-03	2.48E-03
kr-86	4.62E-03	4.62E-03	4.62E-03	4.62E-03	4.62E-03	4.62E-03	4.62E-03	4.62E-03	4.62E-03	4.62E-03	4.62E-03	4.62E-03	4.62E-03
sr-86	2.86E-06	2.86E-06	2.86E-06	2.86E-06	2.86E-06	2.86E-06	2.86E-06	2.86E-06	2.86E-06	2.88E-06	2.90E-06	2.94E-06	2.99E-06
rb-87	6.10E-03	6.10E-03	6.10E-03	6.10E-03	6.10E-03	6.10E-03	6.10E-03	6.10E-03	6.10E-03	6.10E-03	6.10E-03	6.10E-03	6.10E-03
sr-88	8.56E-03	8.56E-03	8.56E-03	8.56E-03	8.56E-03	8.56E-03	8.57E-03	8.57E-03	8.57E-03	8.57E-03	8.57E-03	8.57E-03	8.57E-03
sr-89	8.95E-04	8.95E-04	8.95E-04	8.95E-04	8.95E-04	8.95E-04	8.93E-04	8.90E-04	8.83E-04	8.59E-04	8.13E-04	7.29E-04	5.93E-04
y-89	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.06E-02	1.07E-02	1.07E-02	1.09E-02
sr-90	1.37E-02	1.37E-02	1.37E-02	1.37E-02	1.37E-02	1.37E-02	1.37E-02	1.37E-02	1.37E-02	1.37E-02	1.37E-02	1.37E-02	1.37E-02
y-90	3.56E-06	3.56E-06	3.56E-06	3.56E-06	3.56E-06	3.55E-06	3.55E-06	3.55E-06	3.54E-06	3.52E-06	3.50E-06	3.48E-06	3.48E-06
zr-90	4.02E-04	4.02E-04	4.02E-04	4.02E-04	4.02E-04	4.02E-04	4.02E-04	4.02E-04	4.03E-04	4.05E-04	4.08E-04	4.16E-04	4.29E-04

sr-91	9.00E-06	9.00E-06	8.99E-06	8.91E-06	8.69E-06	8.39E-06	6.29E-06	4.39E-06	1.60E-06	5.06E-08	5.05E-11	5.03E-17	2.81E-28
y-91	1.34E-03	1.34E-03	1.34E-03	1.34E-03	1.34E-03	1.34E-03	1.34E-03	1.34E-03	1.34E-03	1.31E-03	1.25E-03	1.13E-03	9.49E-04
zr-91	1.33E-02	1.33E-02	1.33E-02	1.33E-02	1.33E-02	1.33E-02	1.33E-02	1.33E-02	1.33E-02	1.34E-02	1.34E-02	1.35E-02	1.37E-02
sr-92	2.71E-06	2.71E-06	2.70E-06	2.60E-06	2.39E-06	2.10E-06	7.55E-07	2.10E-07	5.85E-09	2.73E-14	5.91E-25	2.78E-46	0.00E+00
y-92	3.58E-06	3.58E-06	3.58E-06	3.58E-06	3.56E-06	3.50E-06	2.47E-06	1.24E-06	1.13E-07	1.13E-11	7.84E-20	3.69E-36	0.00E+00
zr-92	1.57E-02	1.57E-02	1.57E-02	1.57E-02	1.57E-02	1.57E-02	1.57E-02	1.57E-02	1.57E-02	1.57E-02	1.57E-02	1.57E-02	1.57E-02
y-93	1.15E-05	1.15E-05	1.15E-05	1.15E-05	1.13E-05	1.09E-05	8.31E-06	5.91E-06	2.28E-06	8.67E-08	1.26E-10	2.64E-16	5.98E-27
zr-93	1.70E-02	1.70E-02	1.70E-02	1.70E-02	1.70E-02	1.70E-02	1.70E-02	1.70E-02	1.70E-02	1.70E-02	1.70E-02	1.70E-02	1.70E-02
zr-94	1.81E-02	1.81E-02	1.81E-02	1.81E-02	1.81E-02	1.81E-02	1.81E-02	1.81E-02	1.81E-02	1.81E-02	1.81E-02	1.81E-02	1.81E-02
zr-95	1.98E-03	1.98E-03	1.98E-03	1.98E-03	1.98E-03	1.98E-03	1.98E-03	1.97E-03	1.96E-03	1.92E-03	1.84E-03	1.68E-03	1.43E-03
nb-95	1.09E-03	1.09E-03	1.09E-03	1.09E-03	1.09E-03	1.09E-03	1.09E-03	1.09E-03	1.09E-03	1.09E-03	1.08E-03	1.06E-03	1.01E-03
mo-95	1.52E-02	1.52E-02	1.52E-02	1.52E-02	1.52E-02	1.52E-02	1.52E-02	1.52E-02	1.52E-02	1.53E-02	1.54E-02	1.55E-02	1.59E-02
zr-96	1.86E-02	1.86E-02	1.86E-02	1.86E-02	1.86E-02	1.86E-02	1.86E-02	1.86E-02	1.86E-02	1.86E-02	1.86E-02	1.86E-02	1.86E-02
mo-96	3.49E-04	3.49E-04	3.49E-04	3.49E-04	3.49E-04	3.49E-04	3.49E-04	3.49E-04	3.49E-04	3.49E-04	3.49E-04	3.49E-04	3.49E-04
zr-97	2.15E-05	2.15E-05	2.15E-05	2.13E-05	2.11E-05	2.06E-05	1.75E-05	1.42E-05	7.96E-06	1.09E-06	2.06E-08	7.28E-12	2.46E-18
mo-97	1.83E-02	1.83E-02	1.83E-02	1.83E-02	1.83E-02	1.83E-02	1.83E-02	1.83E-02	1.83E-02	1.83E-02	1.83E-02	1.83E-02	1.83E-02
mo-98	1.84E-02	1.84E-02	1.84E-02	1.84E-02	1.84E-02	1.84E-02	1.84E-02	1.84E-02	1.84E-02	1.84E-02	1.84E-02	1.84E-02	1.84E-02
mo-99	9.34E-05	9.34E-05	9.34E-05	9.33E-05	9.29E-05	9.25E-05	8.87E-05	8.41E-05	7.26E-05	4.39E-05	1.60E-05	2.13E-06	4.85E-08
tc-99	1.88E-02	1.88E-02	1.88E-02	1.88E-02	1.88E-02	1.88E-02	1.88E-02	1.88E-02	1.88E-02	1.89E-02	1.89E-02	1.89E-02	1.89E-02
tc-99m	7.48E-06	7.48E-06	7.48E-06	7.48E-06	7.48E-06	7.47E-06	7.38E-06	7.17E-06	6.35E-06	3.86E-06	1.41E-06	1.87E-07	4.27E-09
mo-100	2.07E-02	2.07E-02	2.07E-02	2.07E-02	2.07E-02	2.07E-02	2.07E-02	2.07E-02	2.07E-02	2.07E-02	2.07E-02	2.07E-02	2.07E-02
ru-100	8.20E-04	8.20E-04	8.20E-04	8.20E-04	8.20E-04	8.20E-04	8.20E-04	8.20E-04	8.20E-04	8.20E-04	8.20E-04	8.20E-04	8.20E-04
ru-101	1.74E-02	1.74E-02	1.74E-02	1.74E-02	1.74E-02	1.74E-02	1.74E-02	1.74E-02	1.74E-02	1.74E-02	1.74E-02	1.74E-02	1.74E-02
ru-102	1.60E-02	1.60E-02	1.60E-02	1.60E-02	1.60E-02	1.60E-02	1.60E-02	1.60E-02	1.60E-02	1.60E-02	1.60E-02	1.60E-02	1.60E-02
ru-103	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.02E-03	1.01E-03	9.77E-04	9.11E-04	7.91E-04	6.07E-04
rh-103	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.03E-02	1.03E-02	1.03E-02	1.04E-02	1.05E-02	1.07E-02
ru-104	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02
pd-104	2.10E-03	2.10E-03	2.10E-03	2.10E-03	2.10E-03	2.10E-03	2.10E-03	2.10E-03	2.10E-03	2.10E-03	2.10E-03	2.10E-03	2.10E-03
ru-105	3.16E-06	3.16E-06	3.15E-06	3.13E-06	3.00E-06	2.78E-06	1.49E-06	6.83E-07	7.67E-08	4.27E-11	1.32E-17	1.27E-30	0.00E+00

rh-105	2.44E-05	2.44E-05	2.44E-05	2.44E-05	2.44E-05	2.44E-05	2.38E-05	2.23E-05	1.75E-05	6.85E-06	1.04E-06	2.42E-08	2.09E-11
pd-105	6.96E-03	6.96E-03	6.96E-03	6.96E-03	6.96E-03	6.96E-03	6.96E-03	6.96E-03	6.97E-03	6.98E-03	6.99E-03	6.99E-03	6.99E-03
ru-106	2.84E-03	2.84E-03	2.84E-03	2.84E-03	2.84E-03	2.84E-03	2.84E-03	2.83E-03	2.83E-03	2.82E-03	2.80E-03	2.76E-03	2.68E-03
pd-106	2.40E-03	2.40E-03	2.40E-03	2.40E-03	2.40E-03	2.40E-03	2.40E-03	2.40E-03	2.40E-03	2.41E-03	2.44E-03	2.48E-03	2.55E-03
pd-107	3.35E-03	3.35E-03	3.35E-03	3.35E-03	3.35E-03	3.35E-03	3.35E-03	3.35E-03	3.35E-03	3.35E-03	3.35E-03	3.35E-03	3.35E-03
pd-108	2.17E-03	2.17E-03	2.17E-03	2.17E-03	2.17E-03	2.17E-03	2.17E-03	2.17E-03	2.17E-03	2.17E-03	2.17E-03	2.17E-03	2.17E-03
pd-109	2.57E-06	2.57E-06	2.57E-06	2.55E-06	2.51E-06	2.44E-06	2.00E-06	1.55E-06	7.64E-07	6.73E-08	5.24E-10	3.17E-14	3.90E-22
ag-109	1.32E-03	1.32E-03	1.32E-03	1.32E-03	1.32E-03	1.32E-03	1.32E-03	1.32E-03	1.32E-03	1.32E-03	1.32E-03	1.32E-03	1.32E-03
pd-110	7.03E-04	7.03E-04	7.03E-04	7.03E-04	7.03E-04	7.03E-04	7.03E-04	7.03E-04	7.03E-04	7.03E-04	7.03E-04	7.03E-04	7.03E-04
ag-110m	4.89E-06	4.89E-06	4.89E-06	4.89E-06	4.89E-06	4.89E-06	4.89E-06	4.88E-06	4.87E-06	4.85E-06	4.79E-06	4.69E-06	4.50E-06
cd-110	1.97E-04	1.97E-04	1.97E-04	1.97E-04	1.97E-04	1.97E-04	1.97E-04	1.97E-04	1.97E-04	1.97E-04	1.97E-04	1.97E-04	1.97E-04
ag-111	7.05E-06	7.05E-06	7.05E-06	7.05E-06	7.04E-06	7.03E-06	6.93E-06	6.80E-06	6.44E-06	5.34E-06	3.68E-06	1.75E-06	4.33E-07
cd-111	3.37E-04	3.37E-04	3.37E-04	3.37E-04	3.37E-04	3.37E-04	3.37E-04	3.37E-04	3.38E-04	3.39E-04	3.40E-04	3.42E-04	3.44E-04
cd-112	1.65E-04	1.65E-04	1.65E-04	1.65E-04	1.65E-04	1.65E-04	1.65E-04	1.65E-04	1.65E-04	1.66E-04	1.66E-04	1.66E-04	1.66E-04
cd-113	2.38E-06	2.38E-06	2.38E-06	2.38E-06	2.38E-06	2.39E-06	2.40E-06	2.41E-06	2.42E-06	2.42E-06	2.42E-06	2.42E-06	2.42E-06
cd-114	2.11E-04	2.11E-04	2.11E-04	2.11E-04	2.11E-04	2.11E-04	2.11E-04	2.11E-04	2.11E-04	2.11E-04	2.11E-04	2.11E-04	2.11E-04
in-115	5.59E-05	5.59E-05	5.59E-05	5.59E-05	5.59E-05	5.59E-05	5.59E-05	5.60E-05	5.60E-05	5.61E-05	5.63E-05	5.63E-05	5.64E-05
sn-115	3.46E-06	3.46E-06	3.46E-06	3.46E-06	3.46E-06	3.46E-06	3.46E-06	3.46E-06	3.46E-06	3.47E-06	3.47E-06	3.48E-06	3.48E-06
cd-116	8.29E-05	8.29E-05	8.29E-05	8.29E-05	8.29E-05	8.29E-05	8.29E-05	8.29E-05	8.29E-05	8.29E-05	8.29E-05	8.29E-05	8.29E-05
sn-116	1.55E-05	1.55E-05	1.55E-05	1.55E-05	1.55E-05	1.55E-05	1.55E-05	1.55E-05	1.55E-05	1.55E-05	1.55E-05	1.55E-05	1.55E-05
sn-117	7.63E-05	7.63E-05	7.63E-05	7.63E-05	7.63E-05	7.63E-05	7.63E-05	7.63E-05	7.63E-05	7.63E-05	7.63E-05	7.63E-05	7.63E-05
sn-118	6.33E-05	6.33E-05	6.33E-05	6.33E-05	6.33E-05	6.33E-05	6.33E-05	6.33E-05	6.33E-05	6.33E-05	6.33E-05	6.33E-05	6.33E-05
sn-119	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05
sn-120	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05	6.65E-05
sn-121m	5.80E-06	5.80E-06	5.80E-06	5.80E-06	5.80E-06	5.80E-06	5.80E-06	5.80E-06	5.80E-06	5.80E-06	5.80E-06	5.80E-06	5.80E-06
sb-121	6.69E-05	6.69E-05	6.69E-05	6.69E-05	6.69E-05	6.69E-05	6.69E-05	6.69E-05	6.70E-05	6.70E-05	6.71E-05	6.71E-05	6.71E-05
sn-122	8.86E-05	8.86E-05	8.86E-05	8.86E-05	8.86E-05	8.86E-05	8.86E-05	8.86E-05	8.86E-05	8.86E-05	8.86E-05	8.86E-05	8.86E-05
sn-123	3.57E-06	3.57E-06	3.57E-06	3.57E-06	3.57E-06	3.57E-06	3.57E-06	3.57E-06	3.56E-06	3.52E-06	3.44E-06	3.30E-06	3.04E-06
sb-123	8.45E-05	8.45E-05	8.45E-05	8.45E-05	8.45E-05	8.45E-05	8.45E-05	8.45E-05	8.45E-05	8.46E-05	8.46E-05	8.48E-05	8.50E-05

sn-124	1.55E-04	1.55E-04	1.55E-04	1.55E-04	1.55E-04	1.55E-04	1.55E-04	1.55E-04	1.55E-04	1.55E-04	1.55E-04	1.55E-04	1.55E-04
sb-125	1.63E-04	1.63E-04	1.63E-04	1.63E-04	1.63E-04	1.63E-04	1.63E-04	1.63E-04	1.63E-04	1.63E-04	1.63E-04	1.62E-04	1.61E-04
te-125	4.41E-05	4.41E-05	4.41E-05	4.41E-05	4.41E-05	4.41E-05	4.41E-05	4.41E-05	4.42E-05	4.44E-05	4.49E-05	4.57E-05	4.74E-05
sn-126	3.62E-04	3.62E-04	3.62E-04	3.62E-04	3.62E-04	3.62E-04	3.62E-04	3.62E-04	3.62E-04	3.62E-04	3.62E-04	3.62E-04	3.62E-04
te-126	1.08E-05	1.08E-05	1.08E-05	1.08E-05	1.08E-05	1.08E-05	1.08E-05	1.08E-05	1.08E-05	1.08E-05	1.08E-05	1.09E-05	1.09E-05
sb-127	7.54E-06	7.54E-06	7.54E-06	7.54E-06	7.53E-06	7.52E-06	7.35E-06	7.09E-06	6.39E-06	4.46E-06	2.17E-06	5.14E-07	3.45E-08
te-127m	1.95E-05	1.95E-05	1.95E-05	1.95E-05	1.95E-05	1.95E-05	1.95E-05	1.96E-05	1.96E-05	1.97E-05	1.95E-05	1.88E-05	1.72E-05
i-127	8.74E-04	8.74E-04	8.74E-04	8.74E-04	8.74E-04	8.75E-04	8.75E-04	8.75E-04	8.76E-04	8.78E-04	8.80E-04	8.83E-04	8.85E-04
te-128	1.87E-03	1.87E-03	1.87E-03	1.87E-03	1.87E-03	1.87E-03	1.87E-03	1.87E-03	1.87E-03	1.87E-03	1.87E-03	1.87E-03	1.87E-03
xe-128	1.64E-05	1.64E-05	1.64E-05	1.64E-05	1.64E-05	1.64E-05	1.64E-05	1.64E-05	1.64E-05	1.64E-05	1.64E-05	1.64E-05	1.64E-05
te-129m	3.28E-05	3.28E-05	3.28E-05	3.28E-05	3.28E-05	3.28E-05	3.27E-05	3.26E-05	3.23E-05	3.10E-05	2.85E-05	2.42E-05	1.77E-05
i-129	2.99E-03	2.99E-03	2.99E-03	2.99E-03	2.99E-03	2.99E-03	2.99E-03	2.99E-03	2.99E-03	2.99E-03	2.99E-03	3.00E-03	3.00E-03
te-130	8.14E-03	8.14E-03	8.14E-03	8.14E-03	8.14E-03	8.14E-03	8.14E-03	8.14E-03	8.14E-03	8.14E-03	8.14E-03	8.14E-03	8.14E-03
xe-130	6.38E-05	6.38E-05	6.38E-05	6.38E-05	6.38E-05	6.38E-05	6.38E-05	6.39E-05	6.39E-05	6.39E-05	6.39E-05	6.39E-05	6.39E-05
te-131m	6.20E-06	6.20E-06	6.20E-06	6.18E-06	6.15E-06	6.09E-06	5.60E-06	5.05E-06	3.77E-06	1.39E-06	1.87E-07	3.42E-09	1.88E-12
i-131	1.87E-04	1.87E-04	1.87E-04	1.87E-04	1.87E-04	1.87E-04	1.85E-04	1.83E-04	1.75E-04	1.49E-04	1.07E-04	5.35E-05	1.47E-05
xe-131	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.14E-02	1.15E-02	1.15E-02	1.16E-02
xe-131m	2.91E-06	2.91E-06	2.91E-06	2.91E-06	2.91E-06	2.91E-06	2.91E-06	2.91E-06	2.91E-06	2.87E-06	2.69E-06	2.14E-06	1.14E-06
te-132	1.09E-04	1.09E-04	1.08E-04	1.08E-04	1.08E-04	1.08E-04	1.04E-04	9.92E-05	8.74E-05	5.67E-05	2.39E-05	4.23E-06	1.65E-07
i-132	3.31E-06	3.31E-06	3.31E-06	3.30E-06	3.30E-06	3.29E-06	3.19E-06	3.05E-06	2.69E-06	1.75E-06	7.34E-07	1.30E-07	5.07E-09
xe-132	2.12E-02	2.12E-02	2.12E-02	2.12E-02	2.12E-02	2.12E-02	2.12E-02	2.12E-02	2.12E-02	2.12E-02	2.13E-02	2.13E-02	2.13E-02
i-133	4.37E-05	4.37E-05	4.37E-05	4.37E-05	4.35E-05	4.30E-05	3.81E-05	3.22E-05	2.02E-05	4.08E-06	1.67E-07	2.77E-10	1.71E-15
xe-133	2.53E-04	2.53E-04	2.53E-04	2.53E-04	2.53E-04	2.53E-04	2.53E-04	2.52E-04	2.45E-04	2.03E-04	1.23E-04	4.31E-05	5.94E-06
xe-133m	3.16E-06	3.16E-06	3.16E-06	3.16E-06	3.16E-06	3.16E-06	3.15E-06	3.11E-06	2.90E-06	1.85E-06	5.68E-07	4.58E-08	3.97E-10
cs-133	2.73E-02	2.73E-02	2.73E-02	2.73E-02	2.73E-02	2.73E-02	2.73E-02	2.73E-02	2.73E-02	2.74E-02	2.74E-02	2.75E-02	2.76E-02
i-134	2.10E-06	2.10E-06	2.09E-06	2.04E-06	1.85E-06	1.51E-06	1.21E-07	2.86E-09	4.82E-14	1.49E-30	0.00E+00	0.00E+00	0.00E+00
xe-134	3.40E-02	3.40E-02	3.40E-02	3.40E-02	3.40E-02	3.40E-02	3.40E-02	3.40E-02	3.40E-02	3.40E-02	3.40E-02	3.40E-02	3.40E-02
cs-134	1.30E-03	1.30E-03	1.30E-03	1.30E-03	1.30E-03	1.30E-03	1.30E-03	1.30E-03	1.30E-03	1.30E-03	1.30E-03	1.29E-03	1.27E-03
ba-134	3.38E-04	3.38E-04	3.38E-04	3.38E-04	3.38E-04	3.38E-04	3.38E-04	3.39E-04	3.39E-04	3.42E-04	3.47E-04	3.56E-04	3.74E-04

i-135	1.33E-05	1.33E-05	1.32E-05	1.30E-05	1.26E-05	1.19E-05	7.83E-06	4.62E-06	1.05E-06	6.67E-09	2.66E-13	4.25E-22	1.36E-38
xe-135	7.18E-06	7.18E-06	7.19E-06	7.33E-06	7.60E-06	7.96E-06	9.40E-06	9.07E-06	5.08E-06	2.08E-07	1.59E-10	7.59E-17	1.06E-28
cs-135	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02
xe-136	4.69E-02	4.69E-02	4.69E-02	4.69E-02	4.69E-02	4.69E-02	4.69E-02	4.69E-02	4.69E-02	4.69E-02	4.69E-02	4.69E-02	4.69E-02
cs-136	9.68E-06	9.68E-06	9.68E-06	9.68E-06	9.67E-06	9.66E-06	9.58E-06	9.47E-06	9.19E-06	8.27E-06	6.70E-06	4.39E-06	1.99E-06
ba-136	2.52E-04	2.52E-04	2.52E-04	2.52E-04	2.52E-04	2.52E-04	2.52E-04	2.52E-04	2.52E-04	2.53E-04	2.55E-04	2.57E-04	2.59E-04
cs-137	2.72E-02	2.72E-02	2.72E-02	2.72E-02	2.72E-02	2.72E-02	2.72E-02	2.72E-02	2.72E-02	2.72E-02	2.72E-02	2.72E-02	2.72E-02
ba-137	7.17E-04	7.17E-04	7.17E-04	7.17E-04	7.17E-04	7.17E-04	7.18E-04	7.18E-04	7.19E-04	7.22E-04	7.29E-04	7.43E-04	7.69E-04
ba-138	2.96E-02	2.96E-02	2.96E-02	2.96E-02	2.96E-02	2.96E-02	2.96E-02	2.96E-02	2.96E-02	2.96E-02	2.96E-02	2.96E-02	2.96E-02
ba-139	2.75E-06	2.75E-06	2.75E-06	2.69E-06	2.38E-06	1.88E-06	2.54E-07	2.08E-08	1.88E-11	6.84E-22	9.10E-43	0.00E+00	0.00E+00
la-139	2.79E-02	2.79E-02	2.79E-02	2.79E-02	2.79E-02	2.79E-02	2.79E-02	2.79E-02	2.79E-02	2.79E-02	2.79E-02	2.79E-02	2.79E-02
ba-140	5.88E-04	5.88E-04	5.88E-04	5.88E-04	5.87E-04	5.87E-04	5.81E-04	5.75E-04	5.57E-04	5.00E-04	4.02E-04	2.60E-04	1.15E-04
la-140	8.23E-05	8.23E-05	8.23E-05	8.23E-05	8.22E-05	8.22E-05	8.18E-05	8.14E-05	7.99E-05	7.37E-05	6.05E-05	3.94E-05	1.75E-05
ce-140	2.74E-02	2.74E-02	2.74E-02	2.74E-02	2.74E-02	2.74E-02	2.74E-02	2.74E-02	2.75E-02	2.75E-02	2.76E-02	2.78E-02	2.80E-02
la-141	7.17E-06	7.17E-06	7.17E-06	7.14E-06	6.92E-06	6.45E-06	3.21E-06	1.33E-06	1.12E-07	2.30E-11	9.76E-19	1.76E-33	0.00E+00
ce-141	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.42E-03	1.41E-03	1.35E-03	1.24E-03	1.04E-03	7.58E-04
pr-141	2.43E-02	2.43E-02	2.43E-02	2.43E-02	2.43E-02	2.43E-02	2.43E-02	2.43E-02	2.44E-02	2.44E-02	2.45E-02	2.47E-02	2.50E-02
la-142	2.74E-06	2.74E-06	2.73E-06	2.68E-06	2.41E-06	1.95E-06	3.15E-07	3.21E-08	5.38E-11	1.64E-20	1.52E-39	0.00E+00	0.00E+00
ce-142	2.58E-02	2.58E-02	2.58E-02	2.58E-02	2.58E-02	2.58E-02	2.59E-02	2.59E-02	2.59E-02	2.59E-02	2.59E-02	2.59E-02	2.59E-02
nd-142	1.90E-04	1.90E-04	1.90E-04	1.90E-04	1.90E-04	1.90E-04	1.90E-04	1.90E-04	1.90E-04	1.90E-04	1.90E-04	1.90E-04	1.90E-04
ce-143	5.89E-05	5.89E-05	5.89E-05	5.88E-05	5.86E-05	5.80E-05	5.34E-05	4.81E-05	3.58E-05	1.31E-05	1.75E-06	3.11E-08	1.63E-11
pr-143	5.62E-04	5.62E-04	5.62E-04	5.62E-04	5.62E-04	5.62E-04	5.62E-04	5.62E-04	5.57E-04	5.24E-04	4.37E-04	2.92E-04	1.36E-04
nd-143	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.14E-02	2.14E-02	2.15E-02	2.17E-02	2.18E-02
ce-144	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	9.98E-03	9.93E-03	9.84E-03	9.65E-03	9.30E-03
nd-144	1.76E-02	1.76E-02	1.76E-02	1.76E-02	1.76E-02	1.76E-02	1.76E-02	1.77E-02	1.77E-02	1.77E-02	1.78E-02	1.80E-02	1.83E-02
pr-145	7.21E-06	7.21E-06	7.21E-06	7.14E-06	6.87E-06	6.49E-06	4.08E-06	2.29E-06	4.52E-07	1.74E-09	2.58E-14	5.65E-24	4.39E-42
nd-145	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02	1.66E-02
nd-146	1.44E-02	1.44E-02	1.44E-02	1.44E-02	1.44E-02	1.44E-02	1.44E-02	1.44E-02	1.44E-02	1.44E-02	1.44E-02	1.44E-02	1.44E-02
nd-147	1.94E-04	1.94E-04	1.94E-04	1.94E-04	1.94E-04	1.94E-04	1.92E-04	1.89E-04	1.82E-04	1.61E-04	1.25E-04	7.53E-05	2.92E-05

pm-147	5.93E-03	5.93E-03	5.93E-03	5.93E-03	5.93E-03	5.93E-03	5.93E-03	5.93E-03	5.94E-03	5.95E-03	5.97E-03	5.98E-03	5.96E-03
sm-147	1.93E-03	1.93E-03	1.93E-03	1.93E-03	1.93E-03	1.93E-03	1.93E-03	1.93E-03	1.93E-03	1.94E-03	1.96E-03	1.99E-03	2.06E-03
nd-148	8.10E-03	8.10E-03	8.10E-03	8.10E-03	8.10E-03	8.10E-03	8.10E-03	8.10E-03	8.10E-03	8.10E-03	8.10E-03	8.10E-03	8.10E-03
pm-148	1.95E-05	1.95E-05	1.95E-05	1.95E-05	1.95E-05	1.94E-05	1.90E-05	1.85E-05	1.72E-05	1.33E-05	8.00E-06	2.93E-06	5.13E-07
pm-148m	2.94E-05	2.94E-05	2.94E-05	2.94E-05	2.94E-05	2.94E-05	2.93E-05	2.92E-05	2.89E-05	2.79E-05	2.61E-05	2.28E-05	1.78E-05
sm-148	1.52E-03	1.52E-03	1.52E-03	1.52E-03	1.52E-03	1.52E-03	1.53E-03	1.53E-03	1.53E-03	1.53E-03	1.54E-03	1.55E-03	1.56E-03
pm-149	2.65E-05	2.65E-05	2.65E-05	2.65E-05	2.65E-05	2.64E-05	2.54E-05	2.39E-05	1.99E-05	1.06E-05	3.04E-06	2.48E-07	2.25E-09
sm-149	7.74E-05	7.74E-05	7.74E-05	7.74E-05	7.75E-05	7.77E-05	7.91E-05	8.07E-05	8.47E-05	9.39E-05	1.02E-04	1.04E-04	1.05E-04
nd-150	3.58E-03	3.58E-03	3.58E-03	3.58E-03	3.58E-03	3.58E-03	3.58E-03	3.58E-03	3.58E-03	3.58E-03	3.58E-03	3.58E-03	3.58E-03
sm-150	5.78E-03	5.78E-03	5.78E-03	5.78E-03	5.78E-03	5.78E-03	5.78E-03	5.78E-03	5.78E-03	5.78E-03	5.78E-03	5.78E-03	5.78E-03
pm-151	5.66E-06	5.66E-06	5.66E-06	5.65E-06	5.62E-06	5.56E-06	5.04E-06	4.46E-06	3.17E-06	9.83E-07	9.44E-08	8.70E-10	1.33E-13
sm-151	4.24E-04	4.24E-04	4.24E-04	4.24E-04	4.24E-04	4.24E-04	4.25E-04	4.25E-04	4.27E-04	4.29E-04	4.30E-04	4.30E-04	4.30E-04
sm-152	2.98E-03	2.98E-03	2.98E-03	2.98E-03	2.98E-03	2.98E-03	2.98E-03	2.98E-03	2.98E-03	2.98E-03	2.98E-03	2.98E-03	2.98E-03
sm-153	1.40E-05	1.40E-05	1.40E-05	1.40E-05	1.39E-05	1.38E-05	1.30E-05	1.21E-05	9.82E-06	4.80E-06	1.15E-06	6.56E-08	3.06E-10
eu-153	1.91E-03	1.91E-03	1.91E-03	1.91E-03	1.91E-03	1.91E-03	1.91E-03	1.91E-03	1.91E-03	1.92E-03	1.92E-03	1.92E-03	1.92E-03
sm-154	6.19E-04	6.19E-04	6.19E-04	6.19E-04	6.19E-04	6.19E-04	6.19E-04	6.19E-04	6.19E-04	6.19E-04	6.19E-04	6.19E-04	6.19E-04
eu-154	2.95E-04	2.95E-04	2.95E-04	2.95E-04	2.95E-04	2.95E-04	2.95E-04	2.95E-04	2.95E-04	2.95E-04	2.95E-04	2.94E-04	2.93E-04
gd-154	1.60E-05	1.60E-05	1.60E-05	1.60E-05	1.60E-05	1.60E-05	1.60E-05	1.61E-05	1.61E-05	1.62E-05	1.65E-05	1.70E-05	1.80E-05
eu-155	5.25E-05	5.25E-05	5.25E-05	5.25E-05	5.25E-05	5.25E-05	5.25E-05	5.25E-05	5.25E-05	5.25E-05	5.24E-05	5.22E-05	5.19E-05
eu-156	2.79E-05	2.79E-05	2.79E-05	2.79E-05	2.79E-05	2.79E-05	2.77E-05	2.75E-05	2.68E-05	2.45E-05	2.04E-05	1.42E-05	7.15E-06
gd-156	5.80E-04	5.80E-04	5.80E-04	5.80E-04	5.80E-04	5.80E-04	5.80E-04	5.80E-04	5.81E-04	5.84E-04	5.88E-04	5.94E-04	6.01E-04
gd-157	2.16E-06	2.16E-06	2.16E-06	2.16E-06	2.16E-06	2.17E-06	2.21E-06	2.25E-06	2.32E-06	2.39E-06	2.40E-06	2.40E-06	2.40E-06
gd-158	2.17E-04	2.17E-04	2.17E-04	2.17E-04	2.17E-04	2.17E-04	2.17E-04	2.17E-04	2.17E-04	2.17E-04	2.17E-04	2.17E-04	2.17E-04
tb-159	3.41E-05	3.41E-05	3.41E-05	3.41E-05	3.41E-05	3.41E-05	3.41E-05	3.41E-05	3.41E-05	3.41E-05	3.41E-05	3.41E-05	3.41E-05
gd-160	1.52E-05	1.52E-05	1.52E-05	1.52E-05	1.52E-05	1.52E-05	1.52E-05	1.52E-05	1.52E-05	1.52E-05	1.52E-05	1.52E-05	1.52E-05
dy-161	5.51E-06	5.51E-06	5.51E-06	5.51E-06	5.51E-06	5.51E-06	5.51E-06	5.51E-06	5.52E-06	5.54E-06	5.58E-06	5.62E-06	5.65E-06
dy-162	3.54E-06	3.54E-06	3.54E-06	3.54E-06	3.54E-06	3.54E-06	3.54E-06	3.54E-06	3.54E-06	3.54E-06	3.54E-06	3.54E-06	3.54E-06
totals	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02

Table 5. Nuclide masses (g/pebble) in a pebble with a discharged burnup of 160 GWd/MTU as a function of cooling time.

	0 sec	15 sec	1 min	10 min	30 min	1 hr	5 hr	10 hr	1 day	3 day	7 day	15 day	30 day
h-3	2.25E-06	2.25E-06	2.25E-06	2.25E-06	2.25E-06	2.25E-06	2.25E-06	2.25E-06	2.25E-06	2.25E-06	2.25E-06	2.25E-06	2.24E-06
he-4	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.90E-04	1.91E-04
be-9	1.39E-04	1.39E-04	1.39E-04	1.39E-04	1.39E-04	1.39E-04	1.39E-04	1.39E-04	1.39E-04	1.39E-04	1.39E-04	1.39E-04	1.39E-04
be-10	2.82E-06	2.82E-06	2.82E-06	2.82E-06	2.82E-06	2.82E-06	2.82E-06	2.82E-06	2.82E-06	2.82E-06	2.82E-06	2.82E-06	2.82E-06
c-12	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02	1.91E+02
c-13	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00	2.24E+00
c-14	1.07E-05	1.07E-05	1.07E-05	1.07E-05	1.07E-05	1.07E-05	1.07E-05	1.07E-05	1.07E-05	1.07E-05	1.07E-05	1.07E-05	1.07E-05
o-16	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00	1.22E+00
o-17	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04	4.93E-04
o-18	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03	2.81E-03
mg-25	4.10E-06	4.10E-06	4.10E-06	4.10E-06	4.10E-06	4.10E-06	4.10E-06	4.10E-06	4.10E-06	4.10E-06	4.10E-06	4.10E-06	4.10E-06
si-28	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00	2.20E+00
si-29	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01
si-30	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02	7.92E-02
p-31	5.73E-05	5.73E-05	5.73E-05	5.73E-05	5.73E-05	5.73E-05	5.73E-05	5.73E-05	5.73E-05	5.73E-05	5.73E-05	5.73E-05	5.73E-05
u-234	7.18E-03	7.18E-03	7.18E-03	7.18E-03	7.18E-03	7.18E-03	7.18E-03	7.18E-03	7.18E-03	7.18E-03	7.18E-03	7.18E-03	7.18E-03
u-235	2.61E-01	2.61E-01	2.61E-01	2.61E-01	2.61E-01	2.61E-01	2.61E-01	2.61E-01	2.61E-01	2.61E-01	2.61E-01	2.61E-01	2.61E-01
u-236	1.78E-01	1.78E-01	1.78E-01	1.78E-01	1.78E-01	1.78E-01	1.78E-01	1.78E-01	1.78E-01	1.78E-01	1.78E-01	1.78E-01	1.78E-01
u-237	2.45E-04	2.45E-04	2.45E-04	2.45E-04	2.45E-04	2.44E-04	2.40E-04	2.35E-04	2.21E-04	1.80E-04	1.19E-04	5.25E-05	1.13E-05
u-238	6.86E+00	6.86E+00	6.86E+00	6.86E+00	6.86E+00	6.86E+00	6.86E+00	6.86E+00	6.86E+00	6.86E+00	6.86E+00	6.86E+00	6.86E+00
u-239	1.55E-05	1.54E-05	1.50E-05	1.15E-05	6.39E-06	2.62E-06	2.18E-09	3.07E-13	5.07E-24	0.00E+00	0.00E+00	0.00E+00	0.00E+00
np-237	1.35E-02	1.35E-02	1.35E-02	1.35E-02	1.35E-02	1.35E-02	1.35E-02	1.35E-02	1.35E-02	1.36E-02	1.36E-02	1.37E-02	1.38E-02
np-238	4.00E-05	4.00E-05	4.00E-05	3.99E-05	3.97E-05	3.95E-05	3.74E-05	3.49E-05	2.88E-05	1.50E-05	4.04E-06	2.95E-07	2.17E-09
np-239	2.24E-03	2.24E-03	2.24E-03	2.24E-03	2.23E-03	2.22E-03	2.12E-03	1.99E-03	1.68E-03	9.32E-04	2.87E-04	2.73E-05	3.36E-07

pu-238	6.94E-03	6.94E-03	6.94E-03	6.94E-03	6.94E-03	6.94E-03	6.94E-03	6.95E-03	6.96E-03	6.98E-03	7.00E-03	7.03E-03	7.08E-03
pu-239	9.16E-02	9.16E-02	9.16E-02	9.16E-02	9.16E-02	9.16E-02	9.17E-02	9.18E-02	9.21E-02	9.29E-02	9.35E-02	9.38E-02	9.38E-02
pu-240	6.13E-02	6.13E-02	6.13E-02	6.13E-02	6.13E-02	6.13E-02	6.13E-02	6.13E-02	6.13E-02	6.13E-02	6.13E-02	6.13E-02	6.13E-02
pu-241	4.83E-02	4.83E-02	4.83E-02	4.83E-02	4.83E-02	4.83E-02	4.83E-02	4.83E-02	4.83E-02	4.83E-02	4.82E-02	4.82E-02	4.81E-02
pu-242	3.94E-02	3.94E-02	3.94E-02	3.94E-02	3.94E-02	3.94E-02	3.94E-02	3.94E-02	3.94E-02	3.94E-02	3.94E-02	3.94E-02	3.94E-02
pu-243	5.60E-06	5.59E-06	5.58E-06	5.47E-06	5.22E-06	4.86E-06	2.78E-06	1.38E-06	1.95E-07	2.37E-10	3.51E-16	1.79E-18	1.79E-18
am-241	1.42E-03	1.42E-03	1.42E-03	1.42E-03	1.42E-03	1.42E-03	1.42E-03	1.42E-03	1.42E-03	1.44E-03	1.46E-03	1.51E-03	1.61E-03
am-242m	2.68E-05	2.68E-05	2.68E-05	2.68E-05	2.68E-05	2.68E-05	2.68E-05	2.68E-05	2.68E-05	2.68E-05	2.68E-05	2.68E-05	2.68E-05
am-242	5.47E-06	5.47E-06	5.47E-06	5.44E-06	5.36E-06	5.24E-06	4.41E-06	3.55E-06	1.94E-06	2.43E-07	4.16E-09	3.47E-10	3.46E-10
am-243	6.19E-03	6.19E-03	6.19E-03	6.19E-03	6.19E-03	6.19E-03	6.19E-03	6.20E-03	6.20E-03	6.20E-03	6.20E-03	6.20E-03	6.20E-03
cm-242	9.13E-04	9.13E-04	9.13E-04	9.13E-04	9.13E-04	9.13E-04	9.13E-04	9.13E-04	9.12E-04	9.05E-04	8.90E-04	8.60E-04	8.07E-04
cm-243	1.94E-05	1.94E-05	1.94E-05	1.94E-05	1.94E-05	1.94E-05	1.94E-05	1.94E-05	1.94E-05	1.94E-05	1.94E-05	1.94E-05	1.94E-05
cm-244	1.65E-03	1.65E-03	1.65E-03	1.65E-03	1.65E-03	1.65E-03	1.65E-03	1.65E-03	1.65E-03	1.65E-03	1.65E-03	1.65E-03	1.64E-03
cm-245	7.44E-05	7.44E-05	7.44E-05	7.44E-05	7.44E-05	7.44E-05	7.44E-05	7.44E-05	7.44E-05	7.44E-05	7.44E-05	7.44E-05	7.44E-05
cm-246	6.99E-06	6.99E-06	6.99E-06	6.99E-06	6.99E-06	6.99E-06	6.99E-06	6.99E-06	6.99E-06	6.99E-06	6.99E-06	6.99E-06	6.99E-06
as-75	5.14E-06	5.14E-06	5.14E-06	5.14E-06	5.14E-06	5.14E-06	5.14E-06	5.14E-06	5.14E-06	5.14E-06	5.14E-06	5.14E-06	5.14E-06
ge-76	1.40E-05	1.40E-05	1.40E-05	1.40E-05	1.40E-05	1.40E-05	1.40E-05	1.40E-05	1.40E-05	1.40E-05	1.40E-05	1.40E-05	1.40E-05
se-77	3.35E-05	3.35E-05	3.35E-05	3.35E-05	3.35E-05	3.35E-05	3.35E-05	3.35E-05	3.35E-05	3.35E-05	3.35E-05	3.35E-05	3.35E-05
se-78	9.96E-05	9.96E-05	9.96E-05	9.96E-05	9.96E-05	9.96E-05	9.96E-05	9.96E-05	9.96E-05	9.96E-05	9.96E-05	9.96E-05	9.96E-05
se-79	2.07E-04	2.07E-04	2.07E-04	2.07E-04	2.07E-04	2.07E-04	2.07E-04	2.07E-04	2.07E-04	2.07E-04	2.07E-04	2.07E-04	2.07E-04
se-80	5.66E-04	5.66E-04	5.66E-04	5.66E-04	5.66E-04	5.66E-04	5.66E-04	5.66E-04	5.66E-04	5.66E-04	5.66E-04	5.66E-04	5.66E-04
br-81	9.41E-04	9.41E-04	9.41E-04	9.41E-04	9.41E-04	9.41E-04	9.41E-04	9.41E-04	9.41E-04	9.41E-04	9.41E-04	9.41E-04	9.41E-04
se-82	1.46E-03	1.46E-03	1.46E-03	1.46E-03	1.46E-03	1.46E-03	1.46E-03	1.46E-03	1.46E-03	1.46E-03	1.46E-03	1.46E-03	1.46E-03
kr-82	2.28E-05	2.28E-05	2.28E-05	2.28E-05	2.28E-05	2.28E-05	2.29E-05	2.29E-05	2.29E-05	2.29E-05	2.29E-05	2.29E-05	2.29E-05
kr-83	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.69E-03	1.69E-03
kr-84	4.85E-03	4.85E-03	4.85E-03	4.85E-03	4.85E-03	4.85E-03	4.85E-03	4.85E-03	4.85E-03	4.85E-03	4.85E-03	4.85E-03	4.85E-03
kr-85	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.02E-03
rb-85	4.46E-03	4.46E-03	4.46E-03	4.46E-03	4.46E-03	4.46E-03	4.46E-03	4.46E-03	4.46E-03	4.46E-03	4.46E-03	4.46E-03	4.46E-03
kr-86	8.13E-03	8.13E-03	8.13E-03	8.13E-03	8.13E-03	8.13E-03	8.13E-03	8.13E-03	8.13E-03	8.13E-03	8.13E-03	8.13E-03	8.13E-03

sr-86	1.35E-05	1.35E-05	1.35E-05	1.35E-05	1.35E-05	1.35E-05	1.35E-05	1.35E-05	1.35E-05	1.36E-05	1.36E-05	1.37E-05	1.38E-05
rb-87	1.07E-02	1.07E-02	1.07E-02	1.07E-02	1.07E-02	1.07E-02	1.07E-02	1.07E-02	1.07E-02	1.07E-02	1.07E-02	1.07E-02	1.07E-02
sr-88	1.50E-02	1.50E-02	1.50E-02	1.50E-02	1.50E-02	1.50E-02	1.50E-02	1.50E-02	1.50E-02	1.50E-02	1.50E-02	1.50E-02	1.50E-02
sr-89	6.60E-04	6.60E-04	6.60E-04	6.60E-04	6.60E-04	6.60E-04	6.59E-04	6.57E-04	6.52E-04	6.34E-04	6.00E-04	5.38E-04	4.38E-04
y-89	1.93E-02	1.93E-02	1.93E-02	1.93E-02	1.93E-02	1.93E-02	1.93E-02	1.94E-02	1.94E-02	1.94E-02	1.94E-02	1.95E-02	1.96E-02
sr-90	2.33E-02	2.33E-02	2.33E-02	2.33E-02	2.33E-02	2.33E-02	2.33E-02	2.33E-02	2.33E-02	2.33E-02	2.33E-02	2.33E-02	2.32E-02
y-90	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.13E-06	6.12E-06	6.12E-06	6.10E-06	6.08E-06	6.01E-06	5.94E-06	5.91E-06	5.90E-06
zr-90	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.45E-03	1.46E-03	1.46E-03	1.46E-03	1.48E-03	1.50E-03
sr-91	6.87E-06	6.87E-06	6.87E-06	6.80E-06	6.64E-06	6.40E-06	4.80E-06	3.35E-06	1.22E-06	3.86E-08	3.86E-11	3.84E-17	2.14E-28
y-91	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.02E-03	1.00E-03	9.55E-04	8.68E-04	7.27E-04
zr-91	2.49E-02	2.49E-02	2.49E-02	2.49E-02	2.49E-02	2.49E-02	2.49E-02	2.49E-02	2.49E-02	2.49E-02	2.50E-02	2.51E-02	2.52E-02
sr-92	2.15E-06	2.15E-06	2.14E-06	2.06E-06	1.89E-06	1.67E-06	5.99E-07	1.67E-07	4.64E-09	2.16E-14	4.69E-25	2.21E-46	0.00E+00
y-92	2.84E-06	2.84E-06	2.84E-06	2.84E-06	2.82E-06	2.78E-06	1.96E-06	9.85E-07	8.96E-08	8.97E-12	6.22E-20	2.93E-36	0.00E+00
zr-92	2.82E-02	2.82E-02	2.82E-02	2.82E-02	2.82E-02	2.82E-02	2.82E-02	2.82E-02	2.82E-02	2.82E-02	2.82E-02	2.82E-02	2.82E-02
y-93	9.56E-06	9.56E-06	9.56E-06	9.52E-06	9.35E-06	9.04E-06	6.88E-06	4.90E-06	1.89E-06	7.19E-08	1.04E-10	2.19E-16	4.95E-27
zr-93	3.10E-02	3.10E-02	3.10E-02	3.10E-02	3.10E-02	3.10E-02	3.10E-02	3.10E-02	3.10E-02	3.10E-02	3.10E-02	3.10E-02	3.10E-02
zr-94	3.38E-02	3.38E-02	3.38E-02	3.38E-02	3.38E-02	3.38E-02	3.38E-02	3.38E-02	3.38E-02	3.38E-02	3.38E-02	3.38E-02	3.38E-02
zr-95	1.74E-03	1.74E-03	1.74E-03	1.74E-03	1.74E-03	1.74E-03	1.73E-03	1.73E-03	1.72E-03	1.68E-03	1.61E-03	1.48E-03	1.26E-03
nb-95	9.51E-04	9.51E-04	9.51E-04	9.51E-04	9.51E-04	9.51E-04	9.51E-04	9.51E-04	9.51E-04	9.50E-04	9.46E-04	9.31E-04	8.82E-04
mo-95	3.06E-02	3.06E-02	3.06E-02	3.06E-02	3.06E-02	3.06E-02	3.06E-02	3.06E-02	3.06E-02	3.07E-02	3.08E-02	3.09E-02	3.12E-02
zr-96	3.52E-02	3.52E-02	3.52E-02	3.52E-02	3.52E-02	3.52E-02	3.52E-02	3.52E-02	3.52E-02	3.52E-02	3.52E-02	3.52E-02	3.52E-02
mo-96	1.75E-03	1.75E-03	1.75E-03	1.75E-03	1.75E-03	1.75E-03	1.75E-03	1.75E-03	1.75E-03	1.75E-03	1.75E-03	1.75E-03	1.75E-03
zr-97	2.00E-05	2.00E-05	2.00E-05	1.99E-05	1.96E-05	1.92E-05	1.63E-05	1.32E-05	7.42E-06	1.02E-06	1.91E-08	6.78E-12	2.30E-18
mo-97	3.53E-02	3.53E-02	3.53E-02	3.53E-02	3.53E-02	3.53E-02	3.53E-02	3.53E-02	3.53E-02	3.53E-02	3.53E-02	3.53E-02	3.53E-02
mo-98	3.62E-02	3.62E-02	3.62E-02	3.62E-02	3.62E-02	3.62E-02	3.62E-02	3.62E-02	3.62E-02	3.62E-02	3.62E-02	3.62E-02	3.62E-02
mo-99	9.06E-05	9.06E-05	9.06E-05	9.05E-05	9.01E-05	8.97E-05	8.60E-05	8.16E-05	7.04E-05	4.25E-05	1.55E-05	2.06E-06	4.70E-08
tc-99	3.51E-02	3.51E-02	3.51E-02	3.51E-02	3.51E-02	3.51E-02	3.51E-02	3.51E-02	3.51E-02	3.51E-02	3.51E-02	3.52E-02	3.52E-02
tc-99m	7.25E-06	7.25E-06	7.25E-06	7.25E-06	7.25E-06	7.24E-06	7.16E-06	6.95E-06	6.15E-06	3.74E-06	1.37E-06	1.82E-07	4.14E-09
mo-100	4.11E-02	4.11E-02	4.11E-02	4.11E-02	4.11E-02	4.11E-02	4.11E-02	4.11E-02	4.11E-02	4.11E-02	4.11E-02	4.11E-02	4.11E-02

ru-100	3.91E-03	3.91E-03	3.91E-03	3.91E-03	3.91E-03	3.91E-03	3.91E-03	3.91E-03	3.91E-03	3.91E-03	3.91E-03	3.91E-03	3.91E-03
ru-101	3.44E-02	3.44E-02	3.44E-02	3.44E-02	3.44E-02	3.44E-02	3.44E-02	3.44E-02	3.44E-02	3.44E-02	3.44E-02	3.44E-02	3.44E-02
ru-102	3.43E-02	3.43E-02	3.43E-02	3.43E-02	3.43E-02	3.43E-02	3.43E-02	3.43E-02	3.43E-02	3.43E-02	3.43E-02	3.43E-02	3.43E-02
ru-103	1.22E-03	1.22E-03	1.22E-03	1.22E-03	1.22E-03	1.22E-03	1.21E-03	1.21E-03	1.20E-03	1.15E-03	1.08E-03	9.34E-04	7.17E-04
rh-103	1.84E-02	1.84E-02	1.84E-02	1.84E-02	1.84E-02	1.84E-02	1.84E-02	1.84E-02	1.84E-02	1.84E-02	1.85E-02	1.87E-02	1.89E-02
ru-104	2.42E-02	2.42E-02	2.42E-02	2.42E-02	2.42E-02	2.42E-02	2.42E-02	2.42E-02	2.42E-02	2.42E-02	2.42E-02	2.42E-02	2.42E-02
pd-104	1.05E-02	1.05E-02	1.05E-02	1.05E-02	1.05E-02	1.05E-02	1.05E-02	1.05E-02	1.05E-02	1.05E-02	1.05E-02	1.05E-02	1.05E-02
ru-105	4.38E-06	4.38E-06	4.38E-06	4.35E-06	4.17E-06	3.86E-06	2.07E-06	9.48E-07	1.07E-07	5.93E-11	1.84E-17	1.77E-30	0.00E+00
rh-105	3.35E-05	3.35E-05	3.35E-05	3.35E-05	3.35E-05	3.35E-05	3.27E-05	3.07E-05	2.40E-05	9.42E-06	1.43E-06	3.33E-08	2.87E-11
pd-105	1.77E-02	1.77E-02	1.77E-02	1.77E-02	1.77E-02	1.77E-02	1.77E-02	1.77E-02	1.77E-02	1.77E-02	1.77E-02	1.77E-02	1.77E-02
ru-106	5.59E-03	5.59E-03	5.59E-03	5.59E-03	5.59E-03	5.59E-03	5.59E-03	5.59E-03	5.58E-03	5.56E-03	5.52E-03	5.44E-03	5.29E-03
pd-106	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.02E-02	1.04E-02
pd-107	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02	1.01E-02
pd-108	6.96E-03	6.96E-03	6.96E-03	6.96E-03	6.96E-03	6.96E-03	6.96E-03	6.96E-03	6.96E-03	6.96E-03	6.96E-03	6.96E-03	6.96E-03
pd-109	4.61E-06	4.61E-06	4.61E-06	4.58E-06	4.50E-06	4.39E-06	3.58E-06	2.78E-06	1.37E-06	1.21E-07	9.40E-10	5.68E-14	7.00E-22
ag-109	3.65E-03	3.65E-03	3.65E-03	3.65E-03	3.65E-03	3.65E-03	3.66E-03	3.66E-03	3.66E-03	3.66E-03	3.66E-03	3.66E-03	3.66E-03
pd-110	2.29E-03	2.29E-03	2.29E-03	2.29E-03	2.29E-03	2.29E-03	2.29E-03	2.29E-03	2.29E-03	2.29E-03	2.29E-03	2.29E-03	2.29E-03
ag-110m	2.27E-05	2.27E-05	2.27E-05	2.27E-05	2.27E-05	2.27E-05	2.27E-05	2.27E-05	2.26E-05	2.25E-05	2.23E-05	2.18E-05	2.09E-05
cd-110	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.43E-03	1.43E-03
ag-111	1.20E-05	1.20E-05	1.20E-05	1.20E-05	1.20E-05	1.20E-05	1.18E-05	1.16E-05	1.10E-05	9.10E-06	6.27E-06	2.98E-06	7.38E-07
cd-111	1.08E-03	1.08E-03	1.08E-03	1.08E-03	1.08E-03	1.08E-03	1.08E-03	1.08E-03	1.08E-03	1.09E-03	1.09E-03	1.09E-03	1.10E-03
cd-112	5.11E-04	5.11E-04	5.11E-04	5.11E-04	5.11E-04	5.11E-04	5.11E-04	5.11E-04	5.11E-04	5.11E-04	5.11E-04	5.11E-04	5.11E-04
cd-113	2.59E-06	2.59E-06	2.59E-06	2.59E-06	2.59E-06	2.59E-06	2.62E-06	2.63E-06	2.65E-06	2.65E-06	2.65E-06	2.65E-06	2.65E-06
cd-114	5.77E-04	5.77E-04	5.77E-04	5.77E-04	5.77E-04	5.77E-04	5.77E-04	5.77E-04	5.77E-04	5.77E-04	5.77E-04	5.77E-04	5.77E-04
in-115	9.82E-05	9.82E-05	9.82E-05	9.82E-05	9.82E-05	9.82E-05	9.83E-05	9.83E-05	9.84E-05	9.85E-05	9.87E-05	9.88E-05	9.89E-05
sn-115	8.00E-06	8.00E-06	8.00E-06	8.00E-06	8.00E-06	8.00E-06	8.00E-06	8.00E-06	8.01E-06	8.02E-06	8.02E-06	8.02E-06	8.03E-06
cd-116	1.94E-04	1.94E-04	1.94E-04	1.94E-04	1.94E-04	1.94E-04	1.94E-04	1.94E-04	1.94E-04	1.94E-04	1.94E-04	1.94E-04	1.94E-04
sn-116	7.46E-05	7.46E-05	7.46E-05	7.46E-05	7.46E-05	7.46E-05	7.46E-05	7.46E-05	7.46E-05	7.46E-05	7.46E-05	7.46E-05	7.46E-05
sn-117	1.75E-04	1.75E-04	1.75E-04	1.75E-04	1.75E-04	1.75E-04	1.75E-04	1.75E-04	1.75E-04	1.75E-04	1.75E-04	1.75E-04	1.75E-04

sn-118	1.45E-04	1.45E-04	1.45E-04	1.45E-04	1.45E-04	1.45E-04	1.45E-04	1.45E-04	1.45E-04	1.45E-04	1.45E-04	1.45E-04	1.45E-04
sn-119	1.49E-04	1.49E-04	1.49E-04	1.49E-04	1.49E-04	1.49E-04	1.49E-04	1.49E-04	1.49E-04	1.49E-04	1.49E-04	1.49E-04	1.49E-04
sn-120	1.50E-04	1.50E-04	1.50E-04	1.50E-04	1.50E-04	1.50E-04	1.50E-04	1.50E-04	1.50E-04	1.50E-04	1.50E-04	1.50E-04	1.50E-04
sn-121m	1.29E-05	1.29E-05	1.29E-05	1.29E-05	1.29E-05	1.29E-05	1.29E-05	1.29E-05	1.29E-05	1.29E-05	1.29E-05	1.29E-05	1.29E-05
sb-121	1.47E-04	1.47E-04	1.47E-04	1.47E-04	1.47E-04	1.47E-04	1.47E-04	1.47E-04	1.47E-04	1.47E-04	1.47E-04	1.47E-04	1.47E-04
sn-122	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04	2.00E-04
te-122	8.69E-06	8.69E-06	8.69E-06	8.69E-06	8.69E-06	8.69E-06	8.69E-06	8.69E-06	8.70E-06	8.72E-06	8.73E-06	8.74E-06	8.74E-06
sn-123	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.82E-06	4.81E-06	4.80E-06	4.74E-06	4.64E-06	4.45E-06	4.10E-06
sb-123	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04	1.89E-04
sn-124	3.43E-04	3.43E-04	3.43E-04	3.43E-04	3.43E-04	3.43E-04	3.43E-04	3.43E-04	3.43E-04	3.43E-04	3.43E-04	3.43E-04	3.43E-04
te-124	6.93E-06	6.93E-06	6.93E-06	6.93E-06	6.93E-06	6.93E-06	6.93E-06	6.93E-06	6.94E-06	6.96E-06	7.00E-06	7.08E-06	7.21E-06
sn-125	2.39E-06	2.39E-06	2.39E-06	2.39E-06	2.39E-06	2.38E-06	2.35E-06	2.32E-06	2.22E-06	1.93E-06	1.44E-06	8.13E-07	2.76E-07
sb-125	2.97E-04	2.97E-04	2.97E-04	2.97E-04	2.97E-04	2.97E-04	2.97E-04	2.97E-04	2.97E-04	2.96E-04	2.96E-04	2.95E-04	2.93E-04
te-125	1.74E-04	1.74E-04	1.74E-04	1.74E-04	1.74E-04	1.74E-04	1.74E-04	1.74E-04	1.74E-04	1.74E-04	1.75E-04	1.77E-04	1.80E-04
te-125m	3.75E-06	3.75E-06	3.75E-06	3.75E-06	3.75E-06	3.75E-06	3.75E-06	3.75E-06	3.75E-06	3.75E-06	3.76E-06	3.77E-06	3.79E-06
sn-126	8.24E-04	8.24E-04	8.24E-04	8.24E-04	8.24E-04	8.24E-04	8.24E-04	8.24E-04	8.24E-04	8.24E-04	8.24E-04	8.24E-04	8.24E-04
te-126	2.30E-05	2.30E-05	2.30E-05	2.30E-05	2.30E-05	2.30E-05	2.30E-05	2.30E-05	2.30E-05	2.30E-05	2.30E-05	2.30E-05	2.31E-05
sb-127	8.81E-06	8.81E-06	8.81E-06	8.81E-06	8.80E-06	8.78E-06	8.58E-06	8.28E-06	7.46E-06	5.21E-06	2.53E-06	6.00E-07	4.03E-08
te-127m	1.94E-05	1.94E-05	1.94E-05	1.94E-05	1.94E-05	1.94E-05	1.95E-05	1.95E-05	1.95E-05	1.97E-05	1.96E-05	1.89E-05	1.73E-05
i-127	1.93E-03	1.93E-03	1.93E-03	1.93E-03	1.93E-03	1.93E-03	1.93E-03	1.93E-03	1.93E-03	1.93E-03	1.94E-03	1.94E-03	1.94E-03
te-128	4.01E-03	4.01E-03	4.01E-03	4.01E-03	4.01E-03	4.01E-03	4.01E-03	4.01E-03	4.01E-03	4.01E-03	4.01E-03	4.01E-03	4.01E-03
xe-128	9.08E-05	9.08E-05	9.08E-05	9.08E-05	9.08E-05	9.08E-05	9.08E-05	9.08E-05	9.08E-05	9.08E-05	9.08E-05	9.08E-05	9.08E-05
te-129m	3.70E-05	3.70E-05	3.70E-05	3.70E-05	3.70E-05	3.70E-05	3.70E-05	3.69E-05	3.65E-05	3.50E-05	3.22E-05	2.73E-05	2.01E-05
i-129	6.45E-03	6.45E-03	6.45E-03	6.45E-03	6.45E-03	6.45E-03	6.45E-03	6.45E-03	6.45E-03	6.45E-03	6.45E-03	6.46E-03	6.46E-03
te-130	1.65E-02	1.65E-02	1.65E-02	1.65E-02	1.65E-02	1.65E-02	1.65E-02	1.65E-02	1.65E-02	1.65E-02	1.65E-02	1.65E-02	1.65E-02
xe-130	3.31E-04	3.31E-04	3.31E-04	3.31E-04	3.31E-04	3.31E-04	3.31E-04	3.31E-04	3.31E-04	3.31E-04	3.31E-04	3.31E-04	3.31E-04
te-131m	6.73E-06	6.73E-06	6.73E-06	6.71E-06	6.67E-06	6.61E-06	6.08E-06	5.48E-06	4.09E-06	1.50E-06	2.03E-07	3.71E-09	2.04E-12
i-131	1.92E-04	1.92E-04	1.92E-04	1.92E-04	1.91E-04	1.91E-04	1.89E-04	1.87E-04	1.79E-04	1.53E-04	1.09E-04	5.48E-05	1.50E-05
xe-131	1.92E-02	1.92E-02	1.92E-02	1.92E-02	1.92E-02	1.92E-02	1.92E-02	1.92E-02	1.92E-02	1.92E-02	1.93E-02	1.93E-02	1.94E-02

xe-131m	3.05E-06	3.05E-06	3.05E-06	3.05E-06	3.06E-06	3.06E-06	3.05E-06	3.05E-06	3.05E-06	3.01E-06	2.81E-06	2.22E-06	1.18E-06
te-132	1.09E-04	1.09E-04	1.09E-04	1.09E-04	1.08E-04	1.08E-04	1.04E-04	9.95E-05	8.77E-05	5.69E-05	2.39E-05	4.24E-06	1.65E-07
i-132	3.34E-06	3.34E-06	3.34E-06	3.34E-06	3.33E-06	3.32E-06	3.21E-06	3.06E-06	2.70E-06	1.75E-06	7.37E-07	1.31E-07	5.09E-09
xe-132	4.73E-02	4.73E-02	4.73E-02	4.73E-02	4.73E-02	4.73E-02	4.73E-02	4.73E-02	4.73E-02	4.74E-02	4.74E-02	4.74E-02	4.74E-02
i-133	4.25E-05	4.25E-05	4.25E-05	4.25E-05	4.23E-05	4.18E-05	3.70E-05	3.14E-05	1.97E-05	3.97E-06	1.62E-07	2.70E-10	1.66E-15
xe-133	2.52E-04	2.52E-04	2.52E-04	2.52E-04	2.52E-04	2.52E-04	2.51E-04	2.50E-04	2.43E-04	2.01E-04	1.22E-04	4.27E-05	5.89E-06
xe-133m	3.34E-06	3.34E-06	3.34E-06	3.34E-06	3.34E-06	3.34E-06	3.31E-06	3.26E-06	3.01E-06	1.90E-06	5.82E-07	4.69E-08	4.06E-10
cs-133	4.98E-02	4.98E-02	4.98E-02	4.98E-02	4.98E-02	4.98E-02	4.98E-02	4.99E-02	4.99E-02	4.99E-02	5.00E-02	5.01E-02	5.01E-02
xe-134	6.71E-02	6.71E-02	6.71E-02	6.71E-02	6.71E-02	6.71E-02	6.71E-02	6.71E-02	6.71E-02	6.71E-02	6.71E-02	6.71E-02	6.71E-02
cs-134	4.88E-03	4.88E-03	4.88E-03	4.88E-03	4.88E-03	4.88E-03	4.88E-03	4.88E-03	4.88E-03	4.87E-03	4.85E-03	4.82E-03	4.75E-03
ba-134	2.53E-03	2.53E-03	2.53E-03	2.53E-03	2.53E-03	2.53E-03	2.53E-03	2.54E-03	2.54E-03	2.55E-03	2.56E-03	2.60E-03	2.67E-03
i-135	1.31E-05	1.31E-05	1.31E-05	1.28E-05	1.24E-05	1.18E-05	7.72E-06	4.55E-06	1.04E-06	6.57E-09	2.62E-13	4.19E-22	1.34E-38
xe-135	5.68E-06	5.69E-06	5.70E-06	5.85E-06	6.16E-06	6.56E-06	8.32E-06	8.29E-06	4.78E-06	1.99E-07	1.53E-10	7.28E-17	1.01E-28
cs-135	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02	2.13E-02
ba-135	1.46E-05	1.46E-05	1.46E-05	1.46E-05	1.46E-05	1.46E-05	1.46E-05	1.46E-05	1.46E-05	1.46E-05	1.46E-05	1.46E-05	1.46E-05
xe-136	9.62E-02	9.62E-02	9.62E-02	9.62E-02	9.62E-02	9.62E-02	9.62E-02	9.62E-02	9.62E-02	9.62E-02	9.62E-02	9.62E-02	9.62E-02
cs-136	2.22E-05	2.22E-05	2.22E-05	2.22E-05	2.21E-05	2.21E-05	2.19E-05	2.17E-05	2.10E-05	1.89E-05	1.53E-05	1.01E-05	4.56E-06
ba-136	9.87E-04	9.87E-04	9.87E-04	9.87E-04	9.87E-04	9.87E-04	9.88E-04	9.88E-04	9.89E-04	9.91E-04	9.94E-04	1.00E-03	1.01E-03
cs-137	5.29E-02	5.29E-02	5.29E-02	5.29E-02	5.29E-02	5.29E-02	5.29E-02	5.29E-02	5.29E-02	5.29E-02	5.29E-02	5.29E-02	5.28E-02
ba-137	2.80E-03	2.80E-03	2.80E-03	2.80E-03	2.80E-03	2.80E-03	2.80E-03	2.81E-03	2.81E-03	2.81E-03	2.83E-03	2.85E-03	2.90E-03
ba-138	5.79E-02	5.79E-02	5.79E-02	5.79E-02	5.79E-02	5.79E-02	5.79E-02	5.79E-02	5.79E-02	5.79E-02	5.79E-02	5.79E-02	5.79E-02
ba-139	2.61E-06	2.61E-06	2.61E-06	2.55E-06	2.26E-06	1.78E-06	2.41E-07	1.97E-08	1.78E-11	6.49E-22	8.63E-43	0.00E+00	0.00E+00
la-139	5.40E-02	5.40E-02	5.40E-02	5.40E-02	5.40E-02	5.40E-02	5.40E-02	5.40E-02	5.40E-02	5.40E-02	5.40E-02	5.40E-02	5.40E-02
ba-140	5.55E-04	5.55E-04	5.55E-04	5.55E-04	5.55E-04	5.54E-04	5.49E-04	5.43E-04	5.26E-04	4.72E-04	3.80E-04	2.46E-04	1.09E-04
la-140	7.72E-05	7.72E-05	7.72E-05	7.72E-05	7.71E-05	7.71E-05	7.68E-05	7.64E-05	7.51E-05	6.95E-05	5.72E-05	3.72E-05	1.65E-05
ce-140	5.41E-02	5.41E-02	5.41E-02	5.41E-02	5.41E-02	5.41E-02	5.41E-02	5.41E-02	5.41E-02	5.42E-02	5.43E-02	5.44E-02	5.46E-02
la-141	6.70E-06	6.70E-06	6.69E-06	6.66E-06	6.47E-06	6.03E-06	3.00E-06	1.24E-06	1.04E-07	2.15E-11	9.12E-19	1.64E-33	0.00E+00
ce-141	1.34E-03	1.34E-03	1.34E-03	1.34E-03	1.34E-03	1.34E-03	1.33E-03	1.33E-03	1.31E-03	1.26E-03	1.16E-03	9.76E-04	7.08E-04
pr-141	4.80E-02	4.80E-02	4.80E-02	4.80E-02	4.80E-02	4.80E-02	4.80E-02	4.80E-02	4.80E-02	4.81E-02	4.82E-02	4.84E-02	4.87E-02

la-142	2.52E-06	2.52E-06	2.52E-06	2.47E-06	2.22E-06	1.79E-06	2.90E-07	2.96E-08	4.96E-11	1.51E-20	1.40E-39	0.00E+00	0.00E+00
ce-142	4.97E-02	4.97E-02	4.97E-02	4.97E-02	4.97E-02	4.97E-02	4.97E-02	4.97E-02	4.97E-02	4.97E-02	4.97E-02	4.97E-02	4.97E-02
nd-142	9.66E-04	9.66E-04	9.66E-04	9.66E-04	9.66E-04	9.66E-04	9.66E-04	9.66E-04	9.67E-04	9.67E-04	9.67E-04	9.67E-04	9.67E-04
ce-143	5.31E-05	5.31E-05	5.31E-05	5.31E-05	5.29E-05	5.24E-05	4.82E-05	4.34E-05	3.23E-05	1.18E-05	1.58E-06	2.81E-08	1.47E-11
pr-143	5.10E-04	5.10E-04	5.10E-04	5.10E-04	5.10E-04	5.10E-04	5.10E-04	5.10E-04	5.06E-04	4.76E-04	3.97E-04	2.65E-04	1.23E-04
nd-143	3.24E-02	3.24E-02	3.24E-02	3.24E-02	3.24E-02	3.24E-02	3.24E-02	3.24E-02	3.24E-02	3.24E-02	3.25E-02	3.27E-02	3.28E-02
ce-144	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.02E-02	1.01E-02	9.88E-03	9.52E-03
nd-144	5.13E-02	5.13E-02	5.13E-02	5.13E-02	5.13E-02	5.13E-02	5.13E-02	5.13E-02	5.13E-02	5.13E-02	5.14E-02	5.16E-02	5.20E-02
pr-145	6.58E-06	6.58E-06	6.58E-06	6.51E-06	6.27E-06	5.92E-06	3.72E-06	2.09E-06	4.12E-07	1.59E-09	2.35E-14	5.16E-24	4.00E-42
nd-145	2.98E-02	2.98E-02	2.98E-02	2.98E-02	2.98E-02	2.98E-02	2.98E-02	2.98E-02	2.98E-02	2.98E-02	2.98E-02	2.98E-02	2.98E-02
nd-146	3.00E-02	3.00E-02	3.00E-02	3.00E-02	3.00E-02	3.00E-02	3.00E-02	3.00E-02	3.00E-02	3.00E-02	3.00E-02	3.00E-02	3.00E-02
nd-147	1.87E-04	1.87E-04	1.87E-04	1.87E-04	1.87E-04	1.86E-04	1.84E-04	1.82E-04	1.76E-04	1.55E-04	1.20E-04	7.25E-05	2.81E-05
pm-147	6.75E-03	6.75E-03	6.75E-03	6.75E-03	6.75E-03	6.75E-03	6.75E-03	6.75E-03	6.75E-03	6.76E-03	6.78E-03	6.79E-03	6.76E-03
sm-147	4.82E-03	4.82E-03	4.82E-03	4.82E-03	4.82E-03	4.82E-03	4.82E-03	4.82E-03	4.82E-03	4.83E-03	4.85E-03	4.89E-03	4.97E-03
nd-148	1.61E-02	1.61E-02	1.61E-02	1.61E-02	1.61E-02	1.61E-02	1.61E-02	1.61E-02	1.61E-02	1.61E-02	1.61E-02	1.61E-02	1.61E-02
pm-148	3.13E-05	3.13E-05	3.13E-05	3.13E-05	3.12E-05	3.11E-05	3.05E-05	2.97E-05	2.75E-05	2.13E-05	1.28E-05	4.65E-06	7.82E-07
pm-148m	3.59E-05	3.59E-05	3.59E-05	3.59E-05	3.59E-05	3.59E-05	3.58E-05	3.57E-05	3.53E-05	3.41E-05	3.19E-05	2.79E-05	2.17E-05
sm-148	5.90E-03	5.90E-03	5.90E-03	5.90E-03	5.90E-03	5.90E-03	5.90E-03	5.90E-03	5.91E-03	5.91E-03	5.93E-03	5.94E-03	5.95E-03
pm-149	3.14E-05	3.14E-05	3.14E-05	3.14E-05	3.13E-05	3.12E-05	3.00E-05	2.82E-05	2.35E-05	1.26E-05	3.59E-06	2.92E-07	2.66E-09
sm-149	6.23E-05	6.23E-05	6.23E-05	6.23E-05	6.25E-05	6.27E-05	6.43E-05	6.62E-05	7.09E-05	8.18E-05	9.08E-05	9.41E-05	9.44E-05
nd-150	7.60E-03	7.60E-03	7.60E-03	7.60E-03	7.60E-03	7.60E-03	7.60E-03	7.60E-03	7.60E-03	7.60E-03	7.60E-03	7.60E-03	7.60E-03
sm-150	1.18E-02	1.18E-02	1.18E-02	1.18E-02	1.18E-02	1.18E-02	1.18E-02	1.18E-02	1.18E-02	1.18E-02	1.18E-02	1.18E-02	1.18E-02
pm-151	6.56E-06	6.56E-06	6.56E-06	6.56E-06	6.52E-06	6.45E-06	5.85E-06	5.18E-06	3.68E-06	1.14E-06	1.10E-07	1.01E-09	1.54E-13
sm-151	5.04E-04	5.04E-04	5.04E-04	5.04E-04	5.04E-04	5.04E-04	5.05E-04	5.05E-04	5.07E-04	5.09E-04	5.10E-04	5.10E-04	5.10E-04
sm-152	5.21E-03	5.21E-03	5.21E-03	5.21E-03	5.21E-03	5.21E-03	5.21E-03	5.21E-03	5.21E-03	5.21E-03	5.21E-03	5.21E-03	5.21E-03
sm-153	2.95E-05	2.95E-05	2.94E-05	2.94E-05	2.92E-05	2.90E-05	2.73E-05	2.54E-05	2.06E-05	1.01E-05	2.41E-06	1.38E-07	6.43E-10
eu-153	5.58E-03	5.58E-03	5.58E-03	5.58E-03	5.58E-03	5.58E-03	5.58E-03	5.58E-03	5.59E-03	5.60E-03	5.60E-03	5.61E-03	5.61E-03
sm-154	1.55E-03	1.55E-03	1.55E-03	1.55E-03	1.55E-03	1.55E-03	1.55E-03	1.55E-03	1.55E-03	1.55E-03	1.55E-03	1.55E-03	1.55E-03
eu-154	1.48E-03	1.48E-03	1.48E-03	1.48E-03	1.48E-03	1.48E-03	1.48E-03	1.48E-03	1.48E-03	1.48E-03	1.48E-03	1.48E-03	1.47E-03

gd-154	1.51E-04	1.51E-04	1.51E-04	1.51E-04	1.51E-04	1.51E-04	1.51E-04	1.51E-04	1.51E-04	1.52E-04	1.53E-04	1.56E-04	1.61E-04
eu-155	1.58E-04	1.58E-04	1.58E-04	1.58E-04	1.58E-04	1.58E-04	1.58E-04	1.58E-04	1.58E-04	1.57E-04	1.57E-04	1.57E-04	1.56E-04
gd-155	2.42E-06	2.42E-06	2.42E-06	2.42E-06	2.42E-06	2.42E-06	2.43E-06	2.45E-06	2.48E-06	2.61E-06	2.86E-06	3.36E-06	4.30E-06
eu-156	9.66E-05	9.66E-05	9.66E-05	9.66E-05	9.65E-05	9.64E-05	9.58E-05	9.49E-05	9.26E-05	8.45E-05	7.04E-05	4.89E-05	2.47E-05
gd-156	2.91E-03	2.91E-03	2.91E-03	2.91E-03	2.91E-03	2.91E-03	2.91E-03	2.91E-03	2.92E-03	2.92E-03	2.94E-03	2.96E-03	2.98E-03
gd-157	3.71E-06	3.71E-06	3.71E-06	3.72E-06	3.72E-06	3.73E-06	3.81E-06	3.89E-06	4.03E-06	4.17E-06	4.19E-06	4.19E-06	4.19E-06
gd-158	7.51E-04	7.51E-04	7.51E-04	7.51E-04	7.51E-04	7.51E-04	7.51E-04	7.51E-04	7.51E-04	7.51E-04	7.51E-04	7.51E-04	7.51E-04
tb-159	1.12E-04	1.12E-04	1.12E-04	1.12E-04	1.12E-04	1.12E-04	1.12E-04	1.12E-04	1.12E-04	1.12E-04	1.12E-04	1.12E-04	1.12E-04
gd-160	5.01E-05	5.01E-05	5.01E-05	5.01E-05	5.01E-05	5.01E-05	5.01E-05	5.01E-05	5.01E-05	5.01E-05	5.01E-05	5.01E-05	5.01E-05
dy-160	7.37E-06	7.37E-06	7.37E-06	7.37E-06	7.37E-06	7.37E-06	7.38E-06	7.38E-06	7.39E-06	7.43E-06	7.50E-06	7.64E-06	7.87E-06
dy-161	1.45E-05	1.45E-05	1.45E-05	1.45E-05	1.45E-05	1.45E-05	1.45E-05	1.45E-05	1.45E-05	1.46E-05	1.46E-05	1.47E-05	1.48E-05
dy-162	1.17E-05	1.17E-05	1.17E-05	1.17E-05	1.17E-05	1.17E-05	1.17E-05	1.17E-05	1.17E-05	1.17E-05	1.17E-05	1.17E-05	1.17E-05
dy-163	8.37E-06	8.37E-06	8.37E-06	8.37E-06	8.37E-06	8.37E-06	8.37E-06	8.37E-06	8.37E-06	8.37E-06	8.37E-06	8.37E-06	8.37E-06
ho-165	2.91E-06	2.91E-06	2.91E-06	2.91E-06	2.91E-06	2.91E-06	2.91E-06	2.91E-06	2.91E-06	2.91E-06	2.91E-06	2.91E-06	2.91E-06
totals	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02	2.06E+02