FORECAST OF WASTE MANAGEMENT REQUIREMENTS OF URANIUM DIOXIDE FUELLED SMALL MODULAR REACTORS USING A MCNP 6.2 MODEL OF THE RMC SLOWPOKE-2 REACTOR

On Small Modular Reactor Spent Fuel Waste Management in Canada's Deep Geological Repository Context

PRÉVISIONS DES EXIGENCES POUR LA GESTION DES DÉCHETS DES PETITS RÉACTEURS MODULAIRES AU DIOXIDE D'URANIUM EN UTILISANT UN MODÈLE MCNP 6.2 DU RÉACTEUR SLOWPOKE-2 AU CMR

De la gestion des déchets nucléaires des petits réacteurs modulaires dans le contexte canadien du dépôt géologique en profondeur

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Abstract

Canada's current long-term high-level radioactive waste management plan, under the auspices of the Nuclear Waste Management Organization (NWMO), involves the construction of a Deep Geological Repository (DGR) where the spent fuel would be interred deep underground. This process follows internationally recognized best practices, but the current planned structure is specifically designed for the spent fuel of Canada Deuterium Uranium (CANDU) reactors. Small Module Reactors (SMR) vary wildly in design and fuel composition, and it is currently unknown if and how the current DGR design will be able to accept SMR fuel for long-term disposal.

The Royal Military College of Canada's (RMC) Safe LOW-Power (K)Critical Experiment-2 (SLOWPOKE-2) reactor was used as a baseline from which SMR spent fuel characteristics can be predicted. The overall goal is to provide insight on decommissioning SMRs and waste management protocols for the NWMO GDR construct. The approach undertaken was subdivided into two major phases: (1) calibrating (or benchmarking) a Monte Carlo N-Particle code, version 6.2 (MCNP 6.2) model for neutron flux mapping using the SLOWPOKE-2 reactor at RMC; and (2) adapting the submodule (CINDER90) within the updated MCNP code to calculate conditions for future SMR fuel disposal.

The first phase, benchmarking of the MCNP 6.2 code, required the updating of the existing MCNP model to reflect changes to the reactor core configuration resulting from the refuelling in Fall 2021. The benchmarking was conducted using neutron activation analysis (NAA) of an aluminum-gold (Al-Au) alloy wire (0.12 wt%) at an inner (no. 2) and outer irradiation (no. 10) sites of the SLOWPOKE-2 at 10 kW(thermal). The MCNP 6.2 model successfully replicates the NAA experiment with an estimated accuracy of 95% for the inner site and 75% for the outer site, improving the existing literature's accuracy.

In the second phase, using the CINDER90 fuel-depletion module MCNP 6.2, a relationship was determined between fuel burnup, spent fuel activity, and decay heat, which was used to predict characteristics of potential SMR spent fuel. Results indicate that SMR spent fuel would output, for a SMR using 20% enriched UO_2 fuel with a burnup of 100 000 $MWd{\cdot}MTHM^{-1}$ (about the average SMR designs burnup) decay heat approximatively eight times higher than the reference CANDU fuel used for the planned DGR design under normal operating conditions, approximately 75 years after discharge.

Required future work includes, amongst others, investigating spent fuel acceptance criteria limits for the DGR and investigating thermal power calibration for the SLOWPOKE-2, which is essential to refine the MCNP 6.2 model further.

Résumé

Le plan canadien de gestion à long terme des déchets radioactifs de haute activité, sous l'égide de la Société de gestion des déchets nucléaires (SGDN), est la construction d'un dépôt géologique en profondeur (DGP) où le combustible nucléaire usé serait enterré profondément sous terre. Ce processus suit les meilleures pratiques reconnues internationalement, mais la structure actuellement prévue est spécifiquement conçue pour la gestion des combustibles issus des réacteurs Canada Deutérium Uranium (CANDU). Les petits réacteurs modulaires (PRM) varient considérablement en termes de conception et de composition de combustible, et il est actuellement inconnu si, et comment, la conception actuelle du GDP sera en mesure d'accepter les combustibles PRM pour leur gestion à long terme.

Le réacteur Safe LOW-Power (K)Critical Experiment-2 (SLOWPOKE-2) du Collège militaire royal du Canada a été utilisé comme base à partir de laquelle les caractéristiques des combustibles usés des PRM peuvent être prédites. L'objectif global est de fournir un aperçu sur la mise hors service des PRM et sur les protocoles de gestion des déchets des PRM dans le contexte du DGP. L'approche est divisée en deux phases : (1) l'analyse comparative d'un code *Monte Carlo N-Particle*, version 6.2 (MCNP 6.2) pour la cartographie du flux neutronique du réacteur SLOWPOKE-2; et (2) l'utilisation d'un sous-module du code MCNP (CINDER90) pour déterminer les conditions de stockage du combustible des PRM.

La première phase, l'analyse comparative du code MCNP 6.2, a nécessité la mise à jour du modèle MCNP existant pour refléter les modifications apportées à la configuration du cœur du réacteur résultant du rechargement du combustible à l'automne 2021. L'analyse comparative a été réalisée en utilisant l'analyse d'activation neutronique (AAN) d'un fil d'alliage aluminium-or (Al-Au) (0,12%mas) aux sites d'irradiation intérieur (n° 2) et extérieur (n° 10) du réacteur SLOWPOKE-2 à 10 kW (thermique). Le modèle MCNP 6.2 a réussi à reproduire avec succès l'expérience d'AAN avec une précision estimée à 95% pour le site intérieur et de 75% pour le site extérieur, améliorant ainsi la précision des données existantes.

Dans la deuxième phase, en utilisant le code d'évolution du combustible nucléaire CINDER90, une relation a été établie entre le taux de combustion, l'activité du combustible usé et la chaleur émise lors de la désintégration radioactive, ce qui a permis de prédire les caractéristiques potentielles des déchets des PRM. Les résultats indiquent que les déchets produits par les PRM produiraient, pour un PRM moyen utilisant du combustible UO_2 enrichi à 20% avec une combustion à 100 000 $MWd \cdot MTHM^{-1}$, environ huit fois plus d'énergie de désintégration que le combustible de référence CANDU utilisé pour la conception du DGP, dans des conditions de fonctionnement normales, approximativement 75 ans après avoir été retiré du réacteur.

Les travaux futurs nécessaires comprennent, entre autres, l'étude des limites des critères d'acceptation des déchets des PRM pour la DGP et l'analyse de la puissance thermique générée par le réacteur SLOWPOKE-2, information qui est essentielle pour affiner davantage le modèle MCNP 6.2.

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List of Acronyms

ABWR	Advanced Boiling Water Reactor
AECL	Atomic Energy of Canada Limited
AGR	Advanced Gas-Cooled Reactor
APM	Adaptive Phase Management
ARIS	Advanced Reactor Information System
BCE	Before Common Era
BWR	Boiling Water Reactor
CANDU	Canadian Deuterium Uranium reactor
CCS	Carbon Dioxide Capture and Storage
CNL	Canadian Nuclear Laboratories
CNSC	Canadian Nuclear Safety Commission
DGR	Deep Geological Repository
EC-JRC	European Commission – Joint Research Centre
ECF	European Climate Foundation
EPR	European Pressurized Water Reactor
ESBWR	Economic Simplified Boiling Water Reactor
FCM	Fully Ceramic Micro-encapsulated
FHR	Fluoride-Salt-Cooled High Temperature Reactor
FHTR	Fluoride-Salt-Cooled High Temperature Test Reactor
GCR	Gas-Cooled Reactor
GFM	Gap Fill Material
GFR	Gas-Cooled Fast Reactor
GHG	Greenhouse Gas
GMFR	Gas Modular Fast Reactor
HALEU	High-Assay Low Enriched Uranium
HCB	Highly Compacted Bentonite
HEU	Highly Enriched Uranium
HLW	High-Level Radioactive Waste
HPGe	High Purity Germanium
HQ	Hydro-Québec
HTGR	High Temperature Gas Reactor
HWR	Heavy Water Reactor
IAEA	International Atomic Energy Agency
ILW	Intermediate-Level Radioactive Waste
IPCC	Intergovernmental Panel on Climate Change
iPWR	Integral Pressurized Water Reactor

ISRW	Integrated Strategy for Radioactive Waste
LBR	Lead-Bismuth Reactor
LDPE	Low density polyethylene
LEU	Low Enriched Uranium
LFR	Lead-Cooled Fast Reactor
LLW	Low-Level Radioactive Waste
LMFR	Liquid Metal Fast Reactor
LWGR	Light Water-Cooled Graphite Moderated Reactor
LWR	Light Water Reactor
MCNP	Monte Carlo N-Particle Transport
MMR	Micro Nuclear Reactor
MNSR	Miniature Neutron Source Reactor
MOX	Mixed Oxide fuel
MSR	Molten Salt Cooled Reactor
NAA	Neutron Activation Analysis
NB Power	New Brunswick Power Corporation
NBT	Neutron Beam Tube
NWMO	Nuclear Waste Management Organization
OPG	Ontario Power Generation
PHWR	Pressurized Heavy Water Reactor
PLNGS	Point Lepreau Nuclear Generating Station
PWR	Pressurized Water Reactor
RBMK	(*Reaktor Bolshoy Moshchnosti Kanalny*), High-Power Channel-type Reactor
RMC	Royal Military College of Canada
SCWR	Supercritical Water-Cooled Reactor
SFBR	Sodium Fast Breeder Reactor
SFR	Sodium-Cooled Fast Reactor
SLOWPOKE	Safe LOW POwer K(C)ritical Experiment
SMR	Small Modular Reactor
SPND	Self-powered neutron detector
SSR-W	Stable Salt Reactor – Wasteburner
TRISO	TRi-structural ISOtropic particle fuel
UFC	Used Fuel Container
UNECE	United Nations Economic Commission for Europe
UNFCC	United Nations Framework Convention on Climate Change
US	United States of America
VDR	Vendor Design Review
VHTR	Very-High Temperature Reactor

VLLW	Very low-level radioactive waste and
VSLLW	Very short-lived low-level radioactive waste
VVER	Water-Water Energetic Reactor
WATSS	Waste to Stable Salt
WISM	Winfrith Improved Multigroup Scheme code
WPu	Waste Plutonium

List of Symbols

A	Mass number, Activity
$A_{S(t)}$	SLOWPOKE-2 Activity at time t
a	Year
A_S	Cadmium shielded sample activity
$A_{SB(t)}$	SLOWPOKE-2 baseline activity at time *t*
$A_{SMR(t)}$	Activity of the simulated SMR at time *t*
A_{US}	Unshielded sample activity
amu	atomic mass unit
Bq	Bequerel
BS	Blank shielded sample
BU	Burnup
BU_S	SLOWPOKE-2 burnup
BU_{SMR}	Simulated SMR burnup
BUS	Blank Unshielded Sample
C	Count
C_S	Cadmium shielded sample count
C_{US}	Unshielded sample count
cm	Centimetre
°C	Degree Celsius
d	Day
E	Energy
Ed	Energy-day
eV	Electron-volt
$\overline{E}_{\alpha i}$	Alpha particle average energy emitted by ith isotope
$\overline{E}_{\beta i}$	Beta particle average energy emitted by i^{th} isotope
$\overline{E}_{\gamma i}$	Gamma photon average energy emitted by i^{th} isotope
f_c	Self-shielding factor
g	Gram
G_{res}	Resonance self-shielding
G_{th}	Thermal shelf-shielding
GWh	Gigawatt-hour
Gy	Gray
h	hour
H_{src}	Shannon entropy
$H_{S(t)}$	SLOWPOKE-2 Decay Heat at time *t*
$H_{SB(t)}$	SLOWPOKE-2 baseline decay heat at time *t*

$H_{SMR(t)}$	Simulated SMR activity at time *t*
I_o	Resonance integral
J	Joule
K	Conversion factor; Kelvin
k_{eff}	Effective neutron multiplication factor
kgU	Kilogram of initial uranium
kW	Kilowatt
kWh	Kilowatt-hour
M	Atomic mass
m	Mass; metre
MeV	Megaelectron-Volt
min	Minute
mk	Milli-k (unit of reactivity equal to 0.001 k)
mm	Millimeter
$m_{U\ or\ HM}$	Mass of uranium or heavy metal
MW	Megawatt
MW_t	Megawatt (thermal)
$MWd{\cdot}MTHM^{-1}$	Megawatts-day per metric tons of heavy metal
$MWd{\cdot}MTU^{-1}$	Megawatts-day per metric tons of uranium
W_e	Watt (electrical)
W_t	Watt (thermal)
n	Neutron
N	Neutron number; Number of histories
N_A	Avogadro's number
$N_m(t)$	Atom density of nuclide *m* at time *t*
P	Reactor power; Gamma probability
P_S	SLOWPOKE-2 Operating Power
p	Sample purity
ppm	Parts per million
Q_i	Total recoverable energy for i^{th} isotope
R	Relative error
r	Radius
R_{Cd}	Cadmium ratio
$R_{th/epi}$	Thermal to epithermal neutron flux ratio
S	Shielded sample
s	Seconds
SF	Scaling Factor
T	Neutron temperature
T_0	Standard temperature

t-CO_2	Tonnes of CO_2
t	Time
$t_{1/2}$	Half-life
t_{decay}	Decay time
t_{detect}	Detection time
t_{irr}	Irradiation time
US	Unshielded sample
v	Neutrons generated per fission
wt%	weight percentage
w_f	Effective energy realeased per fission of ^{235}U
x	isotopic abundance
$\overline{Y_m}$	Additional constant production rate
Z	Atomic number
α	Alpha particle
β	Beta particle
β_m	Total transmutation probability of nuclide *m*
Γ_γ	Resonance width for the (n,γ) reaction
Γ	Total resonance width
γ	Gamma photon, Euler's constant
$\gamma_{k \to m}$	Probability of nuclide *k* transmuting to nuclide *m*
ε	Efficiency
λ^m	Total decay constant of nuclide *m*
λ	Decay constant
Σ_a	Absorption macroscopic cross-section
Σ_s	Scattering macroscopic cross-section
Σ_t	Total macroscopic cross-section
$\Sigma_{tot}(E_{res})$	Macroscopic cross-section at the resonance peak
Σ_{0a}	Macroscopic absorption cross-section for incident neutron at *a* speed of 2200 $m \cdot s^{-1}$
σ	Microscopic cross-section
σ_a^m	Flux-weighted average absorption cross-section of nuclide *m*
σ_{th}	Thermal microscopic cross-section
σ_a	Absorption microscopic cross-section
Φ	Neutron flux; Energy-integrated neutron flux
Φ_{epi}	Epithermal neutron flux
Φ_S	Cadmium shielded sample flux
Φ_{th}	Thermal neutron flux
Φ_{US}	Unshielded sample flux

Chapter 1

Introduction

1.1 Overview

In the past few decades, significant emphasis has been put on human-induced climate change. The preponderance of evidence and consensus in the scientific community on anthropogenic global warming caused by greenhouse gases (GHG) can hardly be easily discredited [1], [2]. The United Nations Framework Convention on Climate Change (UNFCC), with it the Kyoto Protocol and Paris Agreement, have been implemented by the international community to curb, then reduce, the generation of GHG and their impact on climate change [3]–[5]. Likewise, in the Canadian context, the Net-Zero Emission Accountability Act aims to follow the Paris Agreement with an objective of zero emissions by 2025 [6].

From 1990 to 2018, the energy sector, on an international basis, has produced approximately three-quarters of all GHGs. Electricity and heat generation accounted for about 40% of the energy sector's total emissions in the same period [7]. In order to significantly reduce worldwide emissions, a prompt move away from heavily GHG-producing power generation methods (*e.g.,* coal, natural gas) is necessary to have a global impact. However, it does not suffice to change to renewable energies with zero emissions; there remains a GHG cost in producing, manufacturing, operating, and managing each type of energy. A holistic life-cycle approach is therefore required to make an informed decision.

Figure 1 displays the ranges of GHG emissions of the current power generation technologies. Minima and maxima for the GHG emissions for each technology are caused by localization-based variations (*e.g.,* cost of fuel, labour, land) and specific technological approaches used within each technology group.

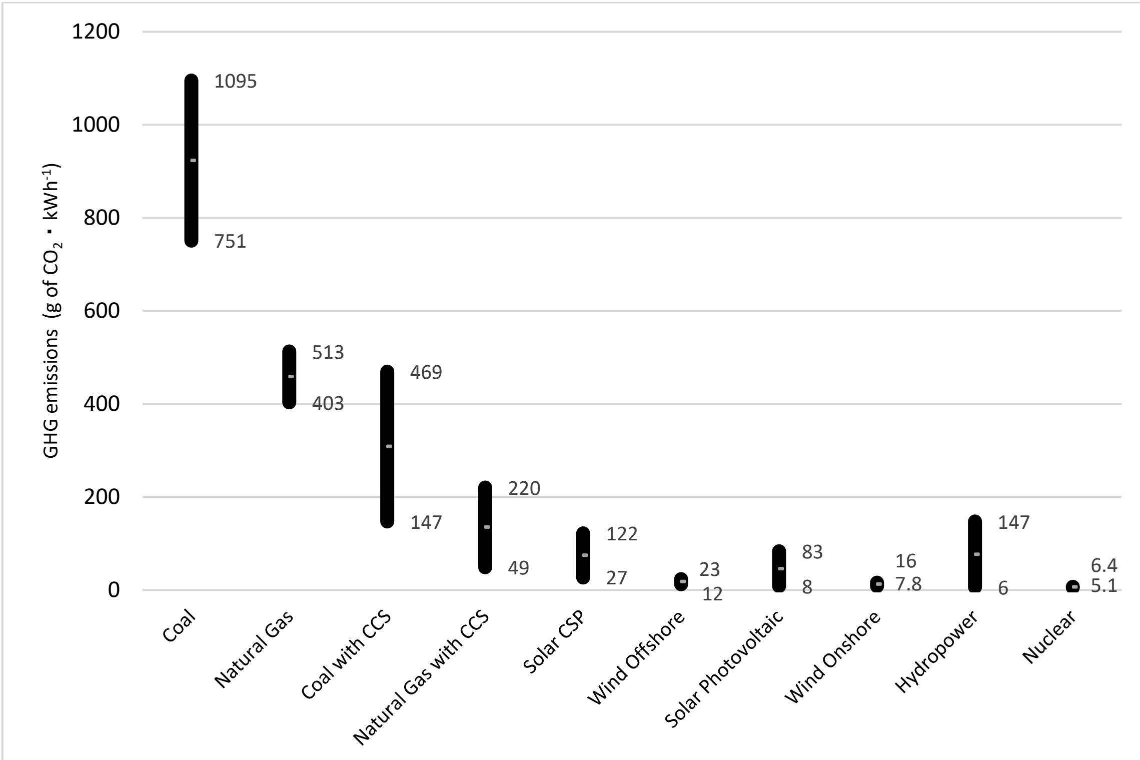

Figure 1. GHG Emissions of Power Generation Technologies (Data From [8])

While GHG emissions for carbohydrate technologies come primarily from the power generation themselves (combustion of the fuel), GHG emissions for renewables energies come, for the vast majority, from the infrastructure required to generate the power, extractions of raw material, installation, *etc*. [8]. Multiple life-cycle studies have been conducted with different results and methodologies. Although not all as optimistic as the United Nations Economic Commission for Europe (UNECE) (Figure 1) concerning the total life-cycle GHG emissions of nuclear power, the findings attest to the nuclear powers' competitiveness with renewable energies [8]–[16]. In particular, most life-cycle studies show nuclear power on par with wind power in emission reduction.

Consequently, the Intergovernmental Panel on Climate Change (IPCC) has long considered nuclear power, in conjunction with other zero or low-GHG power-producing methods (renewables, fossil energy with Carbon Dioxide Capture and Storage (CCS), and bioenergy with CCS) as a "mature low-GHG emission source for baseload power" which could make a significant contribution worldwide to reduce GHGs [16], [17]. While renewable energies must rely on external factors to provide power (wind, solar), nuclear power has constantly available power able to shore the grid against significant demand fluctuations or external resources variations. As such, in four illustrative model pathways simulated to curb global warming at 1.5 °C by 2050, IPCC indicates that nuclear power plays a significant role, with the "middle of the road" scenarios seeing up to 501% worldwide increase in nuclear capacity by 2050, from the level of 2010. Likewise, the European Climate

Foundation (ECF), with a goal to reduce GHG by 80% from the levels of 1990, has included nuclear power as a significant part of the solution for the decarbonisation of the energy sector [18]–[20]. From a legislative perspective, the European Commission's Joint Research Centre (EC-JRC) conducted a technical assessment of the capacity of nuclear power to be assessed as a "green investment" based on the "do no significant harm" criteria, with the proposal entering into force on January 1st 2023 [21]–[23]. Therefore, there appears to be a strong consensus as to the viability of nuclear power as a tool to reduce GHG emissions in the energy sector.

Traditional nuclear power plants with significant electrical capacity, designed at the onset of the Atomic Age (*e.g.,* Pressurized Water Reactors (PWR), Boiling Water Reactors (BWR), Pressurized Heavy Water Reactors (PHWR), Advanced Gas-cooled Reactors (AGR) and Light Water Graphite Reactors (LWGR)) have, for decades supported the brunt of worldwide nuclear power generation, with an average age for the reactor fleet of 30.5 years old [24]. Reactors in operation has also stagnated for years, with the commissionings of new reactors barely offsetting the decommissionings (Figure 2) [25].

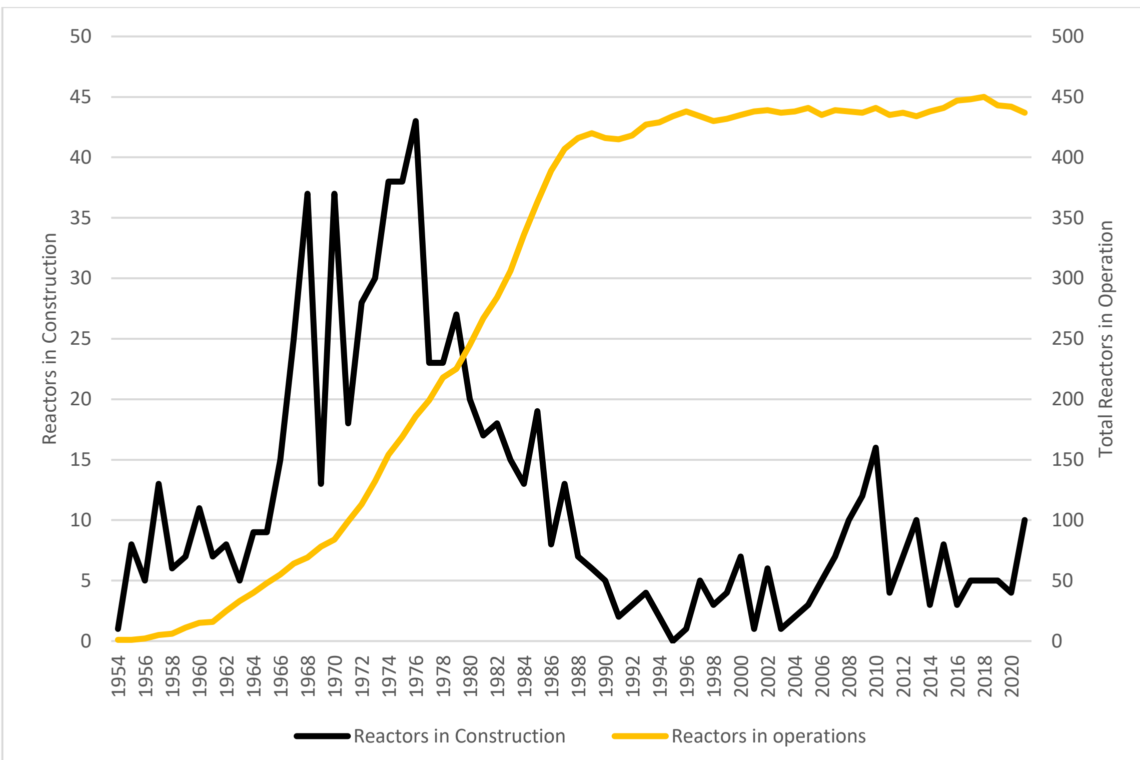

Figure 2. Nuclear Reactors Constructed and Operated (1954-2021) (Data From [25])

If the 501% increase in global nuclear power is to be achieved, much more capacity must be planned and implemented promptly. In response to life-cycle GHG emissions, economic pressures and construction timelines that are characteristics of traditional large capacity nuclear reactors, innovations have been explored in the creation of smaller, cheaper and more flexible reactors. Nian reports that life-cycle GHG emissions decrease with reactor power, thereby favouring smaller reactors from a purely GHG reduction perspective (Figure 3) [12]. Likewise, smaller reactors would cost less to construct and could be brought online on the grid faster than more powerful reactors.

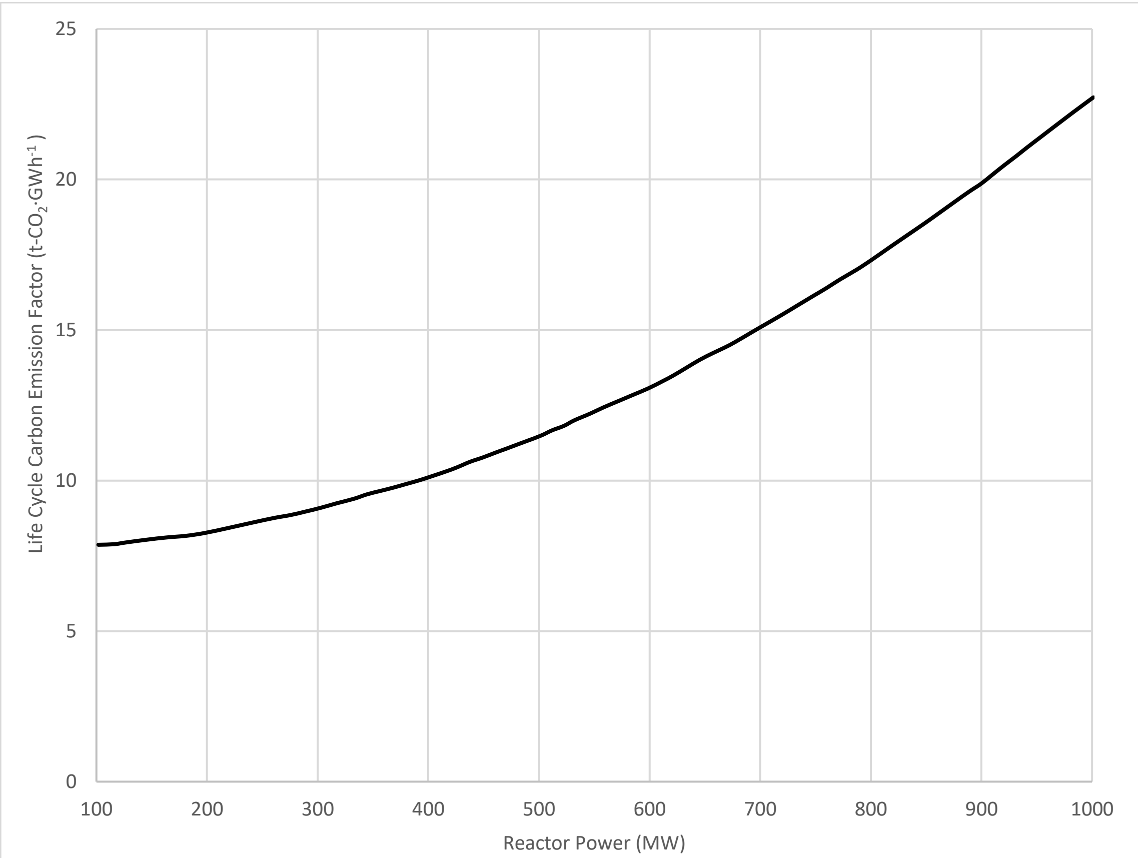

Figure 3. Carbon Emissions Based on Nuclear Reactor Generating Capacity (Data From [12])

Small Modular Reactors (SMR) are nuclear reactors with an electric generating capacity of less than 300 MW, which have the ability to fulfill the niche requirements of being more flexible in applications, cheaper than large reactors, and less susceptible to cost overruns and project delays [26]. A growing number of national and international organizations have been providing roadmaps and plans to support innovation, development and deployments of SMRs, amongst others, the International Atomic Energy Agency (IAEA), the United Kingdom (Nuclear Research and Development Roadmap), Canada (SMR Roadmap) and the United States of America (US) (Foundational Infrastructure for Responsible Use of Small Modular Reactor Technology*)* [27]–[31].

SMRs take their genesis out of the mind and determination of Admiral Hyman G. Rickover, Father of the Nuclear Navy [32]. From 1949 to 1954, he and his team designed the first nuclear reactor to be installed and operated onboard a submarine, USS Nautilus, bringing a revolution in submarine warfare capabilities. In the same spirit, the United States Air Force followed suit with the prototype of a nuclear bomber (NB-36H), which never came to fruition after being cancelled in 1961. The Unites States Army in the 60s and 70s operated eight reactors under the US Army Nuclear Power Program of between 0.5 and 10 MW to power military facilities, often in remote locations (*e.g.,* Antarctica, Greenland, Alaska, Panama) [33]. Likewise, other nations (*e.g.,* United Kingdom, Russia, France, and China) emulated the success of the American military nuclear program and pursued nuclear power on submarines, aircraft carriers, battleships, and icebreakers. Combined with the knowledge gathered from years of operating both sizeable nuclear power plants and small purpose-built nuclear reactors operating on military vessels, they built the foundations of what would become SMRs. The first modern commercially operational SMR, the floating nuclear power plant Akademik Lomonosov, using two KLT-40S, 150 MW_t reactors, was designed based on icebreaker nuclear power plants [34]. It is not by mistake that multiple companies that designed naval nuclear submarines and ships also foray into SMR design and commercialization (*e.g.,* General Dynamics Electric Boat Company, Burns & McDonnells, Westinghouse, Babcock & Wilcox (BWXT), Rolls Royce, TechniAtome, Naval Group) [33], [35]–[38].

Despite their undeniable potential to play a significant role in the fight against GHG emissions from the energy sector and the technical innovations brought by evolving designs, nuclear power, and SMRs in particular, still have challenges to face concerning public acceptance, safety, economics, uranium utilization, proliferation, and waste management [16]. The latter aspect of the SMR deployment equation will be the primary concern of the present thesis.

Radioactive substances, and radioactivity, have multiple beneficial applications for humanity, amongst others: medical imaging, radiation therapy, power generation, non-destructive testing, *etc*. [39]. Those processes use and generate radioactive material that must be responsibly managed once they have rendered their services and until they no longer constitute a potential for harm. Nuclear waste management aims to manage radioactive waste generated by nuclear reaction processes and ensure minimal impact on the environment and biosphere [40]. To safeguard the safety of the public now and for future generations, standards and regulations have been imposed on the nuclear industry for the conduct of nuclear-related activities and subsequent required management of the wastes generated [41]. International and national regulatory organizations ensure that best practices are followed by the operators and support the safety objectives.

In Canada, the Canadian Nuclear Safety Commission (CNSC), under the Nuclear Safety and Control Act, has the mandate to regulate the development, production, and use of nuclear energy and substances to ensure safety, security and reduction of risks associated with their use [42]. When it comes specifically to nuclear waste management, the Government of Canada created, in 2002, the Nuclear Waste Management Organization (NWMO), under the regulatory oversight of CNSC, to investigate, generate and implement a national nuclear waste management plan [43]. As of now, the NWMO, under its Adaptive Phased Management (APM), on approval from the Canadian Government in 2007, has selected the construction of a Deep Geological Repository (DGR) as the preferred method for permanent nuclear waste disposal [44]. The plan consists of burying high-level radioactive wastes (HLW) (*e.g.,* spent fuel) deep underground and sealing them in a purpose-built and designed repository. This process follows the recognized best practices on the international stage [45].

The Canadian nuclear industry is dominated by the Canadian Deuterium Uranium reactor (CANDU) design. Whether operational or decommissioned, all Canadian commercial power-generating reactors have been a CANDU design, producing fairly identical spent fuel bundles of nuclear waste [46]. Research reactors of various designs are operated in Canada, but the rate of their waste production and quantity is minimal compared to the CANDU-produced waste. Therefore, the NWMO has designed the DGR with the CANDU fuel bundle as its baseline waste, building the whole concept and processes around it [47]. However, with SMRs, the types of non-CANDU fuel requiring disposal will potentially increase significantly, such that it cannot be ignored.

1.2 Thesis Context

The potential adoption of SMRs in Canada highlights the need for careful consideration of spent fuel management and disposal strategies. Currently, the planned NWMO DGR is designed to accommodate a single standard of spent fuel (*i.e.*, CANDU), which may pose challenges when dealing with spent fuel from non-traditional streams. This must be addressed to ensure safe, efficient, and flexible management of nuclear waste in the future.

1.3 Research Goals

Using a modelized version of the Royal Military College of Canada (RMC) Safe LOW POwer K(C)ritical Experiment-2 (SLOWPOKE-2) research reactor core as an SMR analog, the present thesis will explore how, and if, the current DGR design and processes are adequate to respond to the large-scale deployment of SMRs in Canada. The Monte Carlo N-Particle (MCNP) Transport Code version 6.2, a nuclear reactor simulation software created by the Los Alamos National Laboratory, will be used for the SLOWPOKE-2 model analysis [48].

The primary and secondary objectives are as follows:

1. Develop and benchmark a MCNP 6.2 model representing the RMC SLOWPOKE-2 (post-refuelling);

   1.1. Calibrate the neutron flux at the inner and outer sites of the new core;

2. Determine the end of operational life characteristics and fissions products inventory of the refuelled core and extrapolate those values through the active design life of the NWMO planned DGR;

3. Assess SLOWPOKE-2 suitability to serve as a scalable model for SMRs' waste management;

   3.1. Identify for which types of SMRs the SLOWPOKE-2 model conforms best;

   3.2. Determine a relationship between SLOWPOKE-2 spent core composition over time and SMR's cores at their end of operational life; and

   3.3. Evaluate the possible impacts of the findings.

1.4 Expected Tasks and Method

Primary Objective 1:

Primary Objective 1 is essential to provide the basis on which the whole thesis analysis will rest. This objective incorporates the following tasks, which will be discussed in Chapter 3 of the thesis (Model Benchmarking – Neutron Flux Mapping):

A. Conduct a Neutron Activation Analysis (NAA) experiment to determine the neutron flux and neutron field characteristics at the inner and outer irradiation sites;

   A.1. Determine the composition and geometry of a neutron detector;

   A.2. Irradiate the detector in the SLOWPOKE-2 and determine the flux at the inner and outer irradiation sites through gamma-spectroscopy;

   A.3. Derive neutron flux characteristics from the obtained results; and,

   A.4. Assess the results in comparison to historical data seen on SLOWPOKE-2 reactors.

B. Generate an updated MCNP 6.2 model representative of the RMC SLOWPOKE-2 (post-refuelling);

   B.1. Identify the differences between the legacy core and the new refuelled core;

   B.2. Update the existing MCNP 6.1 SLOWPOKE-2 model using the new core's characteristics; and, B.3. Where possible, improve on the MCNP code to increase the model's fidelity to the physical state of the reactor at the RMC.

C. Benchmark the updated MCNP 6.2 model;

C.1. Simulate the NAA experiment using the MCNP 6.2 model;

C.2. Compare the simulated results to the NAA experimental results; and,

C.3. Assess the suitability of the updated model to simulate the SLOWPOKE-2 operational characteristics.

Primary Objective 2:

Primary Objective 2 uses the model created at task B and benchmarked at tasks C, finds the end state of SLOWPOKE-2 fuel, and then decays the fission product inventory through the life of the NWMO DGR. This objective will be discussed in Chapter 4 of the thesis (SLOWPOKE-2 Scaling Factors) and incorporate the following tasks:

D. Determine the SLOWPOKE-2 fuel composition and isotope inventory at the end of the core's operational time;

D.1. Using the model, operate the SLOWPOKE-2 new core for a period equivalent to the old core's operational time; and,

D.2. Establish the fuel burnup and isotope inventory at the end of the core's operations.

E. Determine isotope inventory of the spent core through the design life of the NWMO DGR;

E.1. Decay the spent core over the design life of the NWMO GDR and determine spent core activity and decay heat power.

Primary Objective 3:

Primary Objective 3 combines the results obtained from the SLOWPOKE-2 with the DGR design information obtained from the literature, determines a relationship between the SLOWPOKE-2 and SMRs, and operationalize the relationship in the context of the waste management construct in Canada. Chapter 4 of the thesis (SLOWPOKE-2 Scaling Factors) will discuss the possibility of scaling the SLOWPOKE-2 to higher burnups to simulate SMRs. Chapter 5 (Principal Outcomes and Recommendations – SMR Spent Fuel in the DGR) extrapolate SMRs decay heat and activity and assesses the DGR for its ability to receive potential SMR spent fuel. They incorporate the following task:

F. Derive a relationship between the SLOWPOKE-2 spent fuel and SMR spent fuel;

G. Determine for which SMR/SMR type the relationship can be valid; and,

H. Using the predictive relationship, assess selected SMRs designs to establish suitability to be included in the NWMO DGR; and,

I. Analyze the findings and provide insight on future DGR requirements.

1.5 Thesis Limits

The thesis' specific results will be valid solely in a Canadian context as the baseline information for the DGR is taken from the NWMO design.

The analysis is conducted only for high-level radioactive waste, concentrating on reactor cores and spent fuel in the context of their disposal in the planned NWMO DGR. Therefore, the analysis will not be concerned with low-level and intermediate-level nuclear waste.

Chapter 2

Theory and Background

The present chapter provides an overview of theory and background information for this thesis.

Section 2.1 highlights traditional nuclear reactors and SMRs designs and compares them based on their operational burnup. Current SMR projects in Canada are also reviewed to emphasize the extent of expected possible future reactors, which would need to be managed by the NWMO construct.

Section 2.2 reviews the definition and sources of nuclear waste particularly focusing on high-level radioactive waste. As well, the future plan for the NWMO DGR and management of radioactive waste is examined.

Section 2.3 outlines characteristics of the NWMO reference CANDU bundle used as the basis for the GDR design and safety assessments.

Section 2.4 describes the RMC SLOWPOKE-2 research reactor's components and operation as it will be the basis of the MCNP 6.2 simulation model.

The present thesis assumes a working knowledge of basic nuclear reactor theory and radioactivity, which will not be detailed here for the sake of brevity. Readers may wish to refer to *Introduction to Nuclear Engineering* by Lamarre and Baratta *or Fundamentals of Nuclear Engineering* by Lewis, Onder, and Prudil [49], [50] for additional information.

2.1 Nuclear Reactors Burnup

2.1.1 Definition and Impact

Burnup is a measure of the thermal energy released by the nuclear fuel over its time in the reactor. When it comes to average discharge burnup for nuclear reactors, it is generally expressed in Megawatt-days per Metric Tons of Heavy Metal (or Uranium) loaded in the core ($MWd{\cdot}MTHM^{-1}$, or $MWd{\cdot}MTU^{-1}$ (for uranium only fuels)) [51], [52]. Eq. (1) shows the relationship between burnup (BU), the energy produced by the reactor and the mass of fuel loaded in the reactor:

$$BU = \frac{E_d}{m_{U\ or\ HM}} \qquad (1)$$

Where

BU= Burnup ($MWd{\cdot}MTHM^{-1}$, or $MWd{\cdot}MTU^{-1}$)*

E_d = Energy day (MWd)

$m_{U\ or\ HM}$= mass of uranium or heavy metal (t)

Burnup directly impacts nuclear reactors' economics, operational cycles of the reactors, fuel behaviour, and spent fuel characteristics.

The characteristic burnup of a nuclear plant is central to nuclear fuel management [52]. Fuel costs, specifically, return on investment from the manufacturing of the fuel, are impacted by burnup [52]. A fuel designed for higher burnup requires higher enrichment and thus costs more to manufacture. However, this is offset by a longer operational fuel cycle in the reactor. Higher burnup means that more energy can be extracted from the fuel over a more extended period and, therefore, overall, reduces costs. Nuclear power plants' fuel is constantly managed to optimize fuel burnup [52]. Since the beginning of nuclear power usage, for economic reasons, there has been a marked tendency to increase burnup and consequently, enrichment of nuclear fuel [52]. Figure 4 displays that tendency for PWR and BWR in the US from 1968 to 2017. This has been possible with innovations in fuel reliability and reactor design [53].

* Unit of burnup are circumstantial and depend on the agency providing the information. IAEA uses $MWd{\cdot}MTHM^{-1}$ as it deals with reactors with a variety of different nuclear fuels. For agencies dealing with uranium exclusively, $MWd{\cdot}MTU^{-1}$ or $MWh{\cdot}kgU^{-1}$, or variation thereof, are used. $MWd{\cdot}MTU^{-1}$ is generally used here for SLOWPOKE-2 and CANDU comparisons.

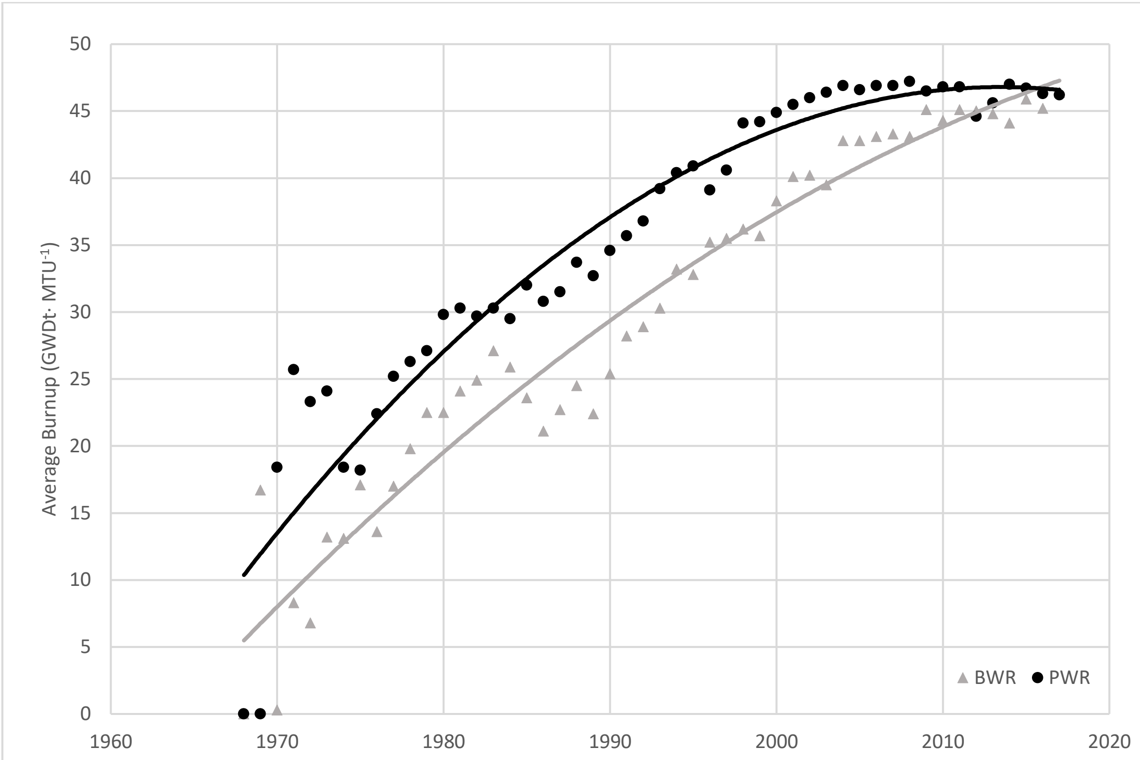

Figure 4. Average Discharge Burnup of BWR and PWR US Nuclear Reactors From 1968 to 2017. (Data From [54])

Burnup affects the physical characteristics of the operational fuel in the reactors. As the fission reactions deplete the fuel, fissions products build up in the fuel pellet structure, increasing pressure, swelling, and causing cracks [52]. However, sudden high-speed overpowered transients can also cause rapid releases of gaseous fissions products and over pressurize the fuel elements, possibly leading to cladding failure [52]. In-reactor corrosion rates of the cladding are also amplified with an increase in burnup [55]. Overall, fuel experiencing higher burnup will see higher failure rates, which could become problematic for waste management systems [52].

The impact of burnup on spent fuel includes the consequences (corrosion, higher failure rates, pressure, *etc.*) of the operational fuel. Thus, a fuel bundle affected by a higher corrosion rate in the reactor will have a weakened cladding barrier that, plays a vital part in the containment of the waste in the DGR. In addition, other characteristics become relevant for nuclear waste management, specifically radioactivity and generated heat from radionuclides decay. Xu *et al*. examined US PWR radioactivity and decay heat: *higher burnup results in higher radioactivity and decay heat even after one million years* [56].

Fission products generation is approximately proportional to the discharge burnup of the fuel [52], [56]. Since spent fuel energy is generated initially, in majority, by fission products, burnup has an impact on the spent fuel thermal energy and therefore on the time it needs to spend in wet storage to dissipate that energy until the spent fuel becomes manageable in dry storage.

Waste management is also affected by the generation of fission products. While the higher burnup reduces the fissile material in the fuel, fission products are generated in increased quantity, creating more significant environmental and biological risks. Those risks must be managed throughout the life of the repository in which the spent fuel will be stored.

2.1.2 Traditional Nuclear Reactor

Since the Chicago Pile-1 in 1942, nuclear technology has seen significant, sustained innovation in fuel, reactor, and plant designs. In 2002, the Generation IV International Forum created a framework outlining the generational evolution of nuclear reactors and highlighted six reactor technologies with the most potential for the future of nuclear power, the so-called "Generation IV" reactors (Figure 5).

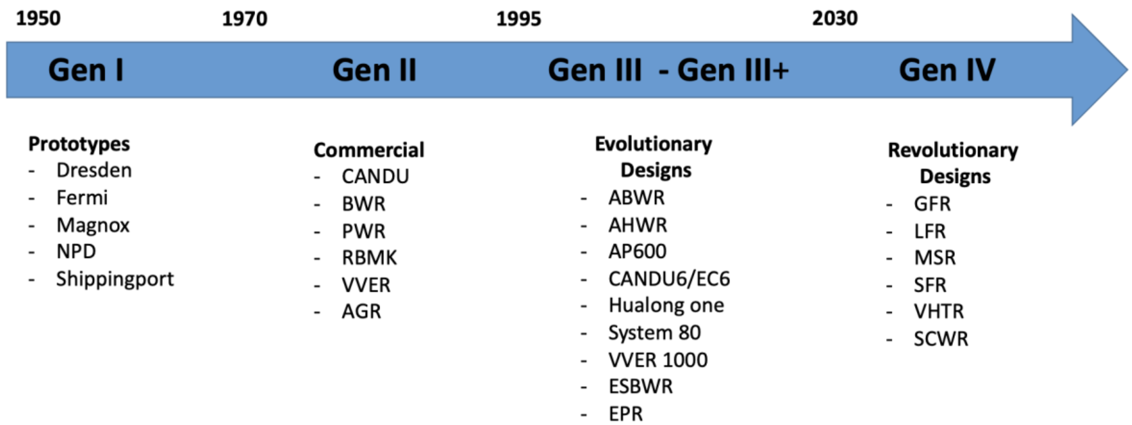

Figure 5. Nuclear Reactors Generational Innovation. (Adapted From [57], [58])

While the current international nuclear power plant fleet is constituted in majority of aging Generation II reactors, internationally, the plants under construction or in the planning phases tend to be Generation III and III+ [25], [59], [60].

Table 1 displays the characteristics of Generation II reactors currently in operation or which design is representative of the reactor types. Of particular interest here are the significant differences in average burnup from the CANDU designs due to their use of natural uranium and operational characteristics, compared to the other types of reactors.

Table 1. Reference Standard Nuclear Reactors

Reactor Type	**Reference reactor**	**Thermal Power** MW_t	**Coolant type**	**Moderator**	**Fuel Type**	**Fuel enrichment** (^{235}U unless otherwise noted) %	**Average Burnup** $MWd \cdot MTHM^{-1}$	**Ref**
BWR	Seabrook	3323	H_2O	H_2O	UO_2	3–5	50 000	[55]
PWR	BWR/5 (NMP2)	3411	H_2O	H_2O	UO_2	3–5	50 000	[55]
LWGR	RBMK-1000	3200	H_2O	Graphite	UO_2	1.8–2.6	~20 000	[61], [62]
PHWR	CANDU 6	2064	D_2O	D_2O	UO_2	Natural Uranium	7 500	[63]
	CANDU (850) (Darlington)	2657	D_2O	D_2O	UO_2	Natural Uranium	7 791	[63]
HTGR	Fulton	3000	He - H_2O	Graphite	UO_2	~7–20	105 000	[55]
AGR	Heysham 2	1551	CO_2 - H_2O	Graphite	UO_2	~3	20 000	[55]
SFBR	Superphenix -1	3000	Liq. Na/ H_2O	None	UO_2/ PuO_2	~15–20 of HM is Pu	110 000	[55]

Similarly, for advanced reactors, the CANDU-based designs (ACR-1000, EC6, IPHWR-100) see a significantly reduced burnup compared to other designs. In fact, they present the lowest burnup of all advanced reactor designs. Annex A presents burnup population data on all advanced reactors with a power over 300 MW_e (non-SMR) reported to the IAEA in the Advance Reactor Information System (ARIS) [64]. Table 2 presents an assessment of the reactors based on their burnups.

Table 2. Burnup Comparison of Advanced Reactor Designs (Data From [64])

	Burnup $MWd \cdot MTHM^{-1}$	**Reactor Model**
Average	58 500	-
Median	56 600	-
Standard Deviation	25 600	-
Highest	120 000	GTHTR300C
Lowest	7 000	IPHWR-100

From a waste management perspective, should Canada entertain the construction of large nuclear reactors other than CANDU, or CANDU based reactors, there is a significant probability that the design assumptions that were made for the construction of the DGR would have to be revaluated, especially if the selected design is using other types of fuel other than solid uranium oxide. As will be seen in the next section, the same logic applies to SMRs.

2.1.3 SMRs

2.1.3.1 ***General Overview of SMRs***

The aptly named Small Modular Reactors are defined and characterized by their small physical size and reduced generated power, and by their designed potential for modularity. It is largely recognized, internationally and in Canada, that SMRs are nuclear reactors with a produced electrical power lower than 300 MW_e [65]–[69]. However, produced electrical power is not the only baseline on which SMRs are assessed. As such, some SMRs have higher electrical power ratings but conform to the modularity inherent to the concept. The modularity of SMRs comes from their capacity to be manufactured mostly in factories and have the capacity to be deployed either as single reactors or as multiple reactor modules [69], [70].

Compared to large-scale nuclear power plants, the expected benefits of SMRs' deployments are multiple. The most relevant here is their inherent proliferation resistance due to most SMR designs having higher burnup, being self-contained, and sealed from manufacture to disposal [71]–[73].

2.1.3.2 ***Current SMR Projects in Canada***

In Canada, the *Roadmap for SMRs* identifies three main thrusts for the potential use of SMR technology: on-grid power generation, heavy industry applications (heat and power), and remote communities' applications [30]. For example, a report prepared for Alberta Innovate by the Pacific Northwest National Laboratory indicates that SMRs could be used in the oil sand industry for power generation in the remote mining facilities, steam generation for usage in the bitumen extraction process and hydrogen production for bitumen upgrading processes [74].

2.1.3.2.1 Regulatory Design Reviews and Ongoing Projects

The CNSC established a "Pre-licensing Vendor Design Review" (VDR) program to provide regulatory support to reactor designers. The process enables the regulator to provide feedback on the design's acceptability for operation in Canada in accordance with applicable laws and regulations. Despite no SMR being fully licenced for operation yet, multiple vendors have commenced the pre-licensing process, demonstrating serious intent for the developers of operating in Canada [75]. Table 3 displays details of the designs under review.

Table 3. CNL and CNSC MMR/SMR Ongoing Projects

Reactor Type	**Reactor Name**	**Thermal Power** MW_t	**Coolant type**	**Moderator**	**Fuel Type**	**Fuel enrichment** (^{235}U unless otherwise noted) %	**Average Burnup** $MWd{\cdot}MTHM^{-1}$	**Ref**
HTGR	U-Battery	10	Helium	Graphite	TRISO	< 20	~80 000	[76]–[78]
	StarCore	35	Helium	Graphite	TRISO	15	60 000	[76], [78]
	MMR	15	Helium	Graphite	FCM TRISO	19.75	> 60 000	[76], [78]
	Xe-100	200	Helium	Graphite	TRISO	15.5	165 000	[75], [76]
MSR	IMSR-400	440	Fluoride Fuel Salt	Graphite	Molten salt (UF_4)	< 5	29 000	[64], [76], [78]
	Moltex SSR-W	750	Molten salt ZrF_4-KF	None	Molten salt	Reactor grade plutonium	120 000 – 200 000	[75], [76]
LMFR	SEALER	8	Lead	Lead	UO_2	19.75	33 000	[75], [76]
	ACR-100	286	Sodium	Sodium	U-Zr alloy	Avg. 13.1	77 000	[75], [76]
PWR	SMR-160	525	H_2O	H_2O	UO_2	4.95 (max)	45 000 (max)	[75], [76]
	NuScale	200	H_2O	H_2O	UO_2	< 4.95	> 30 000	[75], [76]
BWR	BWRX-300	870	H_2O	H_2O	UO_2	3.40 (avg) 4.95 (max)	49 500	[75], [76]
Heat Pipe	eVinci Micro Reactor	7-12	Heat pipes	Metal Hybride	TRISO	5 - 19.75		[75], [76]

All projects under consideration are based on reactors that are currently undergoing CNSC's VDR process:

Chalk River. In 2018, Canadian Nuclear Laboratories (CNL) invited interested SMR designers from around the world to site demonstrations SMRs at the Chalk River, Ontario site. Four projects are in process (MMR, U-Battery, StarCore, IMSR-400). Global First Power's MMR project is the most advanced in the process and expects site preparation and construction in 2023, pending the results of the environmental assessment and regulatory requirements [78].

Darlington. In December 2021, Ontario Power Generation (OPG) announced it had selected the General Electric-Hitachi BWRX-300 SMR for potential deployment at the Darlington site for use as an on-grid power generation plant [79]. The final governmental decision is expected in 2024, with operations potentially starting in 2028 [80], [81].

Bruce Power-Westinghouse. In October 2020, Bruce Power and Westinghouse Electric Company entered into a partnership to deploy the eVinci Micro Reactor in off-grid applications in remote industrial applications and communities [80], [82]. No deployment locations or defined projects have been announced.

Point Lepreau – ARC-100. ARC Clean Energy has developed the ARC-100 and entered into a collaboration in 2020 with NB Power to site a reactor at Point Lepreau Nuclear Generating Station (PLNGS) [83]. The ARC-100 is planned to be operational by 2029 [80].

Point Lepreau – Moltex. The Moltex Stable Salt Reactor – Wasteburner (SSR-W), developed by Moltex Energy is planned to be operational in the early 2030s at PLNGS [80]. Concurrently with the reactor, Moltex is developing a process (Waste to Stable Salt (WATSS)) to take CANDU spent fuel generated at PLNGS and convert it to fuel used in the SSR-W, taking advantage of the SSR-W being co-located with other reactors [84].

2.1.3.3 ***SMR Designs Burnup***

Although the probability that "pre-licensed" designs ultimately operate in Canada is higher than designs that are not on the list, it is not possible to ascertain that only those SMRs will ever operate in Canada. Considering DGRs will be designed as a repository for all HLW generated by nuclear power in Canada for the foreseeable future, it is quite probable that other unlisted designs will operate before the repository is shut. Therefore, as for advanced reactors, SMRs from IAEA's ARIS have been compiled with relevant characteristics at Annex B.

SMR population data information from ARIS shows that due to new designs and technology, the burnup has significantly increased for most types of reactors, a tendency reflected by the standard reactors as well (Table 4) [64]. In all cases, compared to the CANDU spent fuel, any fuel from other designs would certainly have a higher discharge burnup. As well, certain types of advanced and Generation IV designs use exotic fuels compared to CANDU's solid natural uranium oxide. Those exotic fuels would have to be processed before being accepted by the NWMO.

Table 4. Burnup Comparison of SMR Designs. (Data From [64])

	Burnup $MWd{\cdot}MTHM^{-1}$	**Reactor Model**
Average	102 000	-
Median	60 000	-
Standard Deviation	148 000	-
Highest	1 000 000	CA Waste Burner 0.2.5
Lowest	1 000	MoveluX

The quantity of SMR spent fuel to be managed in the next 30 years is estimated to be between 100,000 and 200,000 CANDU bundles-equivalent for an assumed 1,000 MW_e of installed SMR in Canada [46]. Due to the variety of SMRs in development and multiples designs variations, it can be posited that this estimate encompasses multiple types of fuel, and each design might require additional efforts in packaging and processing to meet the waste acceptance criteria before it can be safely disposed of in the DGR [85].

2.2 Nuclear Waste Management

2.2.1 Nuclear Waste Classification and Composition

Regarding nuclear waste classification, the Canadian nuclear regulator, CNSC, generally follows the nomenclature and framework outlined by IAEA [41], [86]. The definitions are based on the activity of the waste, its containment requirements, and the life length of the contained radionuclides. Table 5 displays percentages of waste by volume and radioactivity content.

- **Low-Level radioactive Waste (LLW)**: Includes substances with radionuclides activity above the threshold for exemption under the *Nuclear Safety and Control Act* [87]. This waste contains few long-lived radionuclides and requires containment for up to a few hundred years. This classification encompasses Very Low-Level radioactive Waste (VLLW) and Very Short-Lived Low-Level radioactive Waste (VSLLW) [86].

- **Intermediate-Level radioactive Waste (ILW)**: Contains radionuclides that require containment for several hundred years. Little or no accommodations are needed to be implemented for the heat generated by the waste [86].

- **High-Level radioactive Waste (HLW)**: Includes spent nuclear fuel and associated core components. Requires significant shielding and containment for the disposal of long-lived radionuclides at perpetuity (on a human scale) due to the generated decay heat and radiations [86].

- **Uranium mine and mill tailings**: Waste generated by uranium processing operations containing long-lived radionuclides [86].

Table 5. Composition of Nuclear Waste, by Waste Level Preponderance and Radioactivity (Data From [88])

	Percentage of Produced Waste	Percentage of Radioactivity
LLW	90	1
ILW	7	4
HLW	3	95

Within the reactor core, HLWs are of three main types: fission products, activation products and actinides.

Fission Products. Fission products are the radionuclides directly produced by fission and their transitory radionuclides along their decay chains. As some members of the decay chains are extremely long-lived, they cause the most concerns regarding nuclear waste management [40].

Activation Products. Activation products are created by neutron capture in the material surrounding the core (core structure, fuel element cladding, *etc.*), the fuel itself (*e.g.,* ^{235}U, ^{238}U) and impurities existing within the core and its environment [40].

Actinides. Actinides are very heavy radionuclides produced from the decay chain of uranium, created mostly by neutron capture due to the high neutron flux within the reactors. Actinides generally have high toxicity for the biosphere; some are very long-lived and are susceptible to spontaneous fission [40]. Therefore, actinides must be closely monitored when it comes to waste management.

2.2.2 Nuclear Waste Management

HLW waste management, due to existing constraints, has been divided into a tiered approach: short-term storage, intermediate storage, and disposal. Short-term storage occurs immediately after the removal of the reactor. Fuel is placed in wet storage in pools to allow the fuel to cool to a manageable level. Intermediate storage involves dry storage in purpose-built containers above ground, usually awaiting final permanent disposal. Both wet and dry storage occur on the site of the waste creation, on the nuclear power plant's ground, or in centralized locations [89], [90].

With current technology, regardless of the fuel cycle being employed, in the end, HLWs will remain, although in varying quantities. Reprocessing of waste allows for the extraction of remaining economically valuable fissile materials in the spent fuel for further usage. Some proposed theoretical approaches merit further investigation, for example, the transmutation of nuclear waste. However, even the suggested schemes to reduce waste quantities would still require permanent disposal of some form for the remaining HLWs [40], [91]. There is no substitute for disposal, despite the ability to reduce the total amount of waste [40].

Multiple avenues have been used and abandoned or investigated as disposal methods for nuclear waste. However, deep geological burial is, at the moment of writing, the safest, most achievable and most widely proposed method for permanent disposal [40].

Waste management must contend with four main issues when it comes to nuclear waste, HLWs in particular:

- Timeline of decay of the radionuclides;
- Heat produced from decaying radionuclides;
- Radiation protection; and
- Containment.

Some radionuclides are radioactive for thousands or millions of years and remain problematic. Considering written history started around 3400 BCE, it is difficult to posit where humanity will be in the next few hundred years, let alone thousands or millions of years. Speculations can be made, but no certainty exists as to if it will still be possible, at the time, to keep an organization monitoring nuclear waste over the whole period of its problematic existence. Therefore, permanent disposal is required, which should be able to function independently without required monitoring or necessary activities, in perpetuity.

Decaying spent fuel constantly produces thermal energy. This energy must be considered in the management of the HLWs. Fuel that has been removed from the core is at its hottest, and power subsequently rapidly declines. For example, a CANDU spent fuel bundle goes from 493 kW_t in the reactor to 2.6 kW_t after discharge, and to 4.5 W_t, 10 years later [63]. The typical amount of time spent in wet storage is 6 to 10 years [92].

Radiation management uses time, distance and shielding to ensure minimal exposure, if at all, to the biosphere to prevent negative impacts on future generations. Similarly, containment is used to ensure, as much as possible, that the radionuclides remain in position at the place of disposal. Once contained and shielded, the major threat to the biosphere comes if, and when, containment fails and radionuclides make their way into the environment uncontrolled [40]. Due to the timelines of radionuclides' activity over thousands or millions of years, it is expected that containment will fail at some point due to construction failures of containers or normal material decay. As such, the disposal system design must keep its integrity such that, when radionuclides inevitably leak outside of containment, they will have decayed enough to no longer be a significant biological threat [40].

2.2.2.1 ***NWMO: The Canadian Solution***

In Canada, the quest as to what should be done with HLW has a long history. Starting in 1977 with the Hare Report (EP 77-6), it was mandated by the federal Department of Energy, Mines and Resources to find options for the permanent disposal of HLW. The report recommended a deep geological repository [40]. The Porter report, mandated by the Ontario Royal Commission on Electric Power Planning, concluded with similar recommendations in 1978 [93]. In 1980, the Select Committee on Ontario Hydro Affairs recommended that the province enters a partnership with the federal government to create a nuclear waste management organization. From 1989 to 1998, the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel specifically investigated the technical requirements and feasibility of a DGR in Canada [94]. Finally, in 2002, in accordance with Bill-27, the Nuclear Fuel Waste Act, NWMO was created by nuclear power plant operating companies (OPG, Hydro-Québec (HQ) and New Brunswick Power Corporation (NB Power)) and Atomic Energy of Canada Limited (AECL) to implement the proposed DGR and manage it once the disposal site was operational [95]. As of the time of writing, the final site has yet to be selected but is expected to be confirmed in 2023.

NWMO is managed and financed based on the principle of "polluter pays" [43]. The NWMO has the mandate to offer nuclear waste management services to all nuclear waste owners "without discrimination and at a fee that is reasonable in relation to its costs of managing the nuclear fuel waste of its members or shareholders" [43]. Waste owners contribute to a trust fund based on their waste production rate. The trust fund is expected to cover all costs of the implementation of the DGR plan and its future operation [95].

For the DGR plan implementation, NWMO is using APM, chosen by a process involving public consultation and the Government of Canada in 2007, which includes amongst others: centralized containment of the spent fuel (DGR), transportation, monitoring, and overall management [95]. NWMO has also commenced the Integrated Strategy for Radioactive Waste (ISRW), by request of the federal Minister of Natural Resources, to investigate the long-term storage and management of LLW and ILW [96].

As the only commercial nuclear reactors in Canada are of the CANDU design, the repository is currently only planned for disposal of CANDU fuel bundles. Other types of HLWs in small quantities from hospitals or university research reactors are currently handled under contract by CNL or similar entities [89]. However, at completion of the DGR project, it is expected that the NWMO will be managing all of Canada's HLWs.

2.2.2.1.1 Canadian Deep Geological Repository Overview

The current APM construct is based on all the decisions and assumptions that have been conducted since the Hare Report, mainly that disposal shall be done in deep stable rock, that disposal shall be done in Ontario as most of the waste is created there, and that no reprocessing will be entertained in Canada for the foreseeable future [40]. General regulatory framework includes, amongst other principles, the requirement to have assessments conducted for as long as the waste's maximum impact is expected to occur and that the maximum expected impact, if any, are no greater than the impact that are currently permissible in Canada [97].

At a minimum, the fuel must be solid, durable, and chemically stable in contact with groundwater and should be able to contain its radionuclides without sudden releases [85]. As there are no processing capabilities currently planned for spent fuel, other than the required operations linked with managing received CANDU bundles, any processes needed to make the fuel acceptable to the NWMO must be conducted before the fuel is accepted for internment in the repository [85]. As with CANDU fuel, per CNSC's requirements, waste acceptance criteria require significant information on the characterization of the received fuel: "*physical, mechanical, chemical, biological, thermal and/or radiological properties of the waste, including dominant radionuclide content*" [86]. NWMO specifies further that handling information and time from the removal of the fuel from the reactor will also be needed [85].

2.2.2.1.2 Deep Geological Repository Technical Description

The DGR is designed to keep radionuclides contained as long as possible, ideally until the radionuclides' hazard becomes negligible for the biosphere. The whole DGR concept is designed with a general horizon of 1 million years and a depth of at least 500 m [47]. However, due to the inevitable eventual failure of containment, the DGR system is based on a concept using multiple barriers. Once a barrier is breached, the other ones are present to delay the diffusion of radionuclides in the environment. Figure 6 displays the *five* (5) barriers of the current NWMO DGR system: fuel pellets, fuel bundles (cladding), Used Fuel Container (UFC), clay buffer and surrounding geological formation.

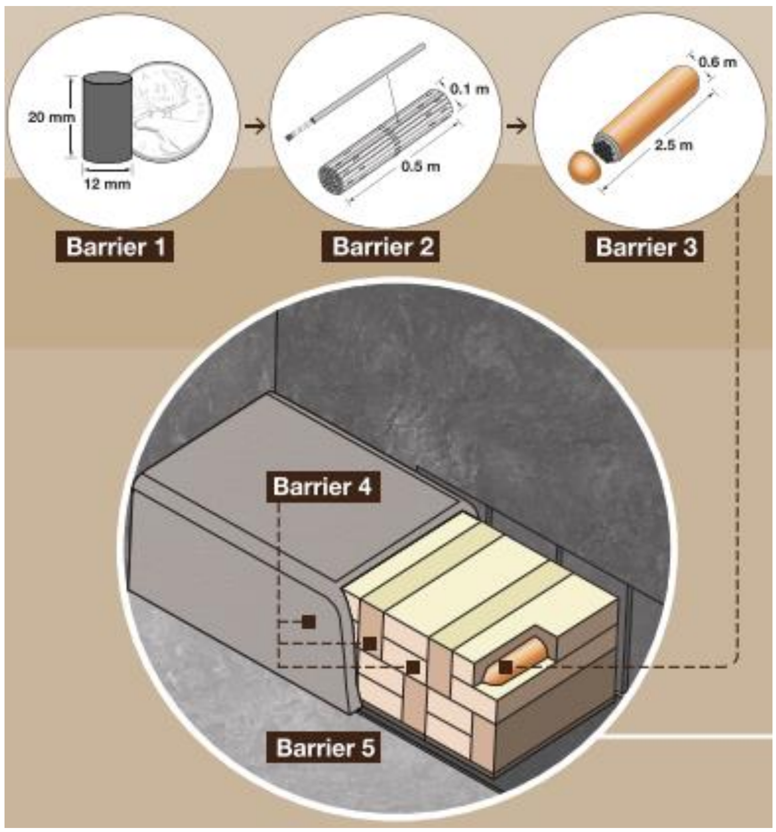

Figure 6. NWMO Deep Repository Multi-Barrier System (Used with Permission [98])

The barriers and location of the repository must be selected purposefully. Due to heat generation and containment requirements, the barriers must be designed such that they have high thermal conductivity, low permeability, low hydraulic gradient, and high sorption capacity [40].

Barrier 1: Fuel Pellets

The majority of fission products (> 90%) remain trapped within the fuel pellets [40], [99]. However, the burnup of the fuel creates changes in the physical structure of the fuel:

the grains of the material change and cracks form. The cracks and internal movements of radionuclides towards the boundaries of the pellets allow fission products to escape the fuel structure. Also, cracks allow water, if present after other boundaries are breached, to infiltrate the pellets and transport radionuclides outside of the barriers, dissolve soluble fission products at the grain boundaries and let fission products in gas forms escape [40]

Radiation emanating from the spent fuel could create, by radiolysis (mostly from α-particles) of the water and water vapour, if present, an environment sufficiently oxidizing to lead to the dissolution of the uranium oxide crystalline lattice [99]. Shoesmith demonstrates that there is a threshold at 20,000-30,000 years after which α-particles radiolysis is not possible due to the radioactive field decay [99]. Passed that threshold, the main dissolution process reverts to chemical dissolution, with extremely low dissolution rates of uranium oxides in water.

Barrier 2: Cladding

CANDU bundle cladding is made of Zircaloy-4. It constants fissions gasses and fission products that have escaped the fuel pellet structure. However, time spent in the reactor does change the cladding's physical properties and weakens its resistance to stresses. Three main failure modes of concern exist for the cladding:

- Hydrogen embrittlement [100], [101];
- Corrosion [40], [102]–[104]; and,
- Mechanical failure [104].

Mechanical failure of the cladding is the most likely failure mode. The UFC could collapse, weakened from corrosion, external pressure, well before corrosion of the zircaloy-4 becomes a concern [104]. The cladding would not be able to sustain the damage of a collapsing UFC and would lead to the release of the contained radionuclides over time.

Barrier 3: Used Fuel Container

The used fuel container (Mark II, CV-HH-4L-12) is designed to store 48 spent fuel bundles in a carbon steel insert assembly protected by a thick corrosion-resistant copper coating (Figure 7). The planned processing of the spent fuel from transport to its sealed position within the UFC is specifically designed for CANDU fuel bundles [47].

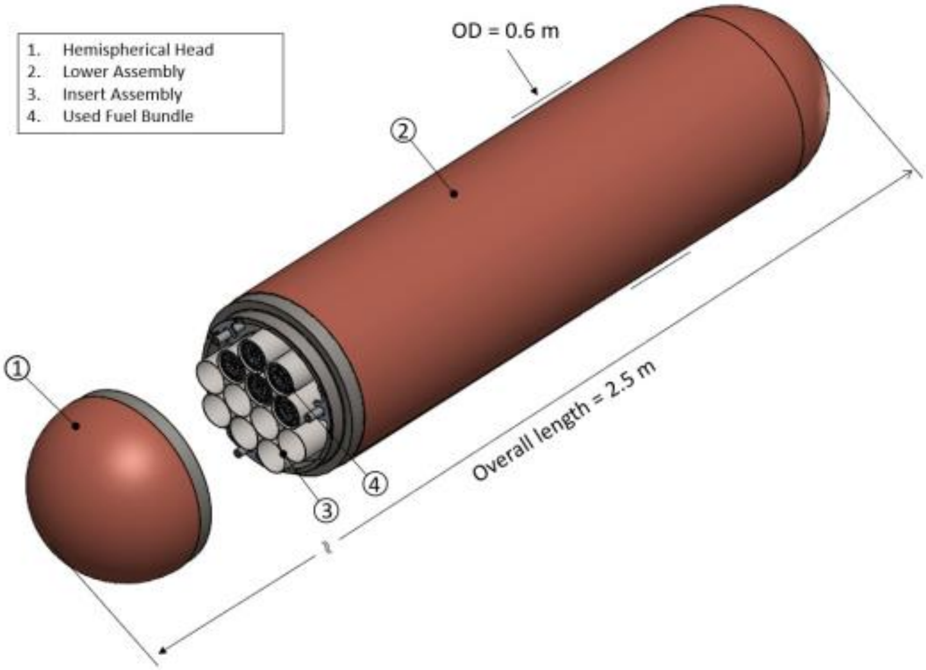

Figure 7. Used Fuel Container (UFC) (Used with Permission [47])

The UFC and cladding have good shielding properties for α and β particles such that only γ radiation would reach its surface [105]. Figure 8 displays γ radiation on the external surfaces of the UFC. The dose rate declines quickly until about 500 years due to the decay of fission products. At that point, actinides decay dominates the γ-rays emission [106].

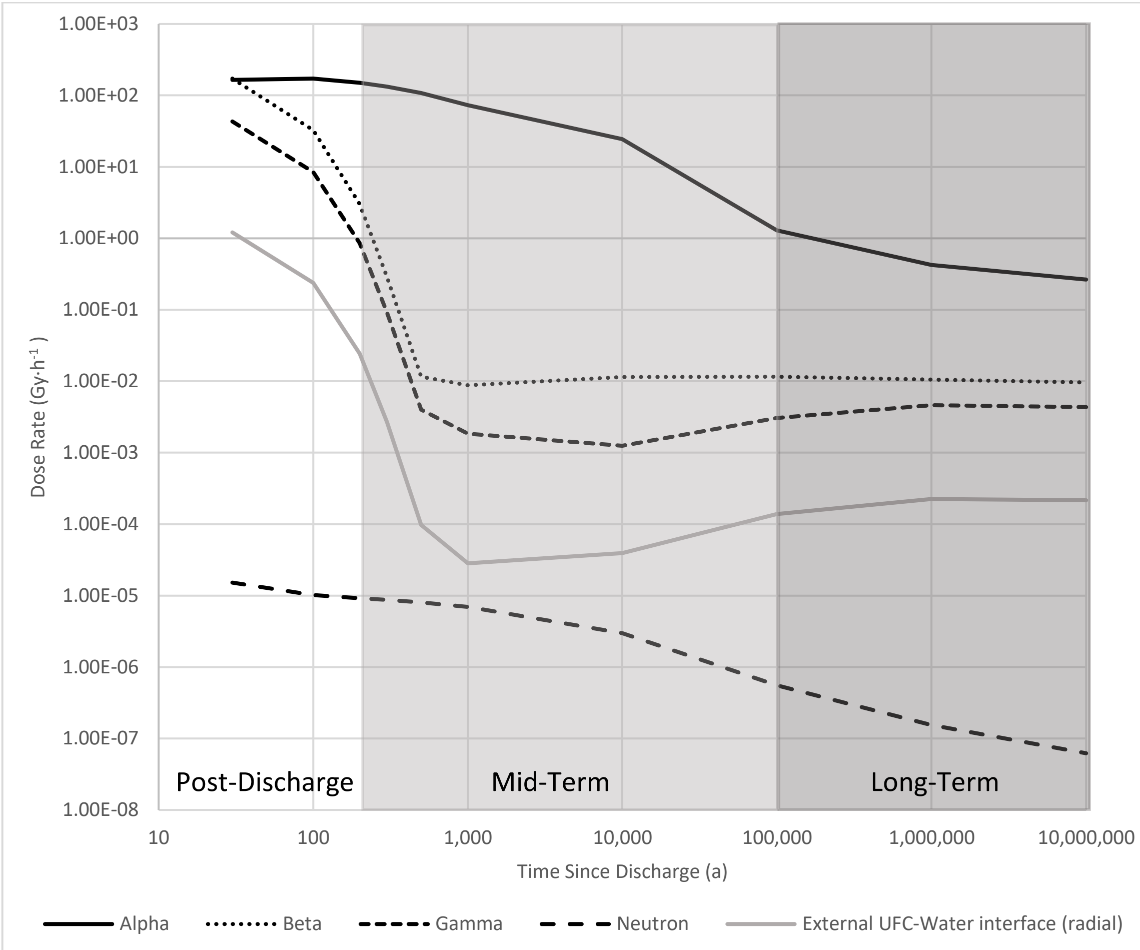

Figure 8. Radiation Dose Generated by CANDU Fuel at 220 $MWh{\cdot}kgU^{-1}$ (~ 9,167 $MWd{\cdot}MTU^{-1}$) (Data From [107])†

Barrier 4: Bentonite Clay

Within the DGR, the UFCs are contained in Highly Compacted Bentonite (HCB) boxes (Figure 9). HCB is also used as filler blocks between the boxes to provide the required separation between UFCs, and less dense pelleted bentonite as an additional filler (Gap Fill Material (GFM)) as needed to fill any gaps and interstices not occupied by UFCs or HCBs [47].

† Errors too small to represent. Maximum error is 1 %.

Figure 9. UFC in HCB Buffer Block (prototypes) (Used with permission [47])

The use of bentonite in nuclear waste management and its characteristics have been extensively studied in Canada and abroad [108]–[110]. The main characteristics of interest, amongst others, are:

- Self-healing and swelling abilities [109];
- Low-permeability [108];
- Cation exchange capacity [40], [110];
- Thermal conductivity;
- Microbial inhibitor [47], [108]; and,
- Radiation resistance [108].

For the present thesis, the thermal conductivity and radiation resistance are the two aspects of interest.

Bentonite's chemical and physical properties are affected by temperatures above 150 °C [40]. At temperatures above this threshold, the bentonite dries up and will start cracking and shifting around the UFC, allowing rapid ingress routes for the fluids to and from the UFC. Therefore, the DGR is designed to have a temperature at the UFC's surface no higher than 100 °C. Bentonite is able to diffuse the energy generated by the fuel's decay without passing the temperature threshold that would affect its properties (Figure 10) [111].

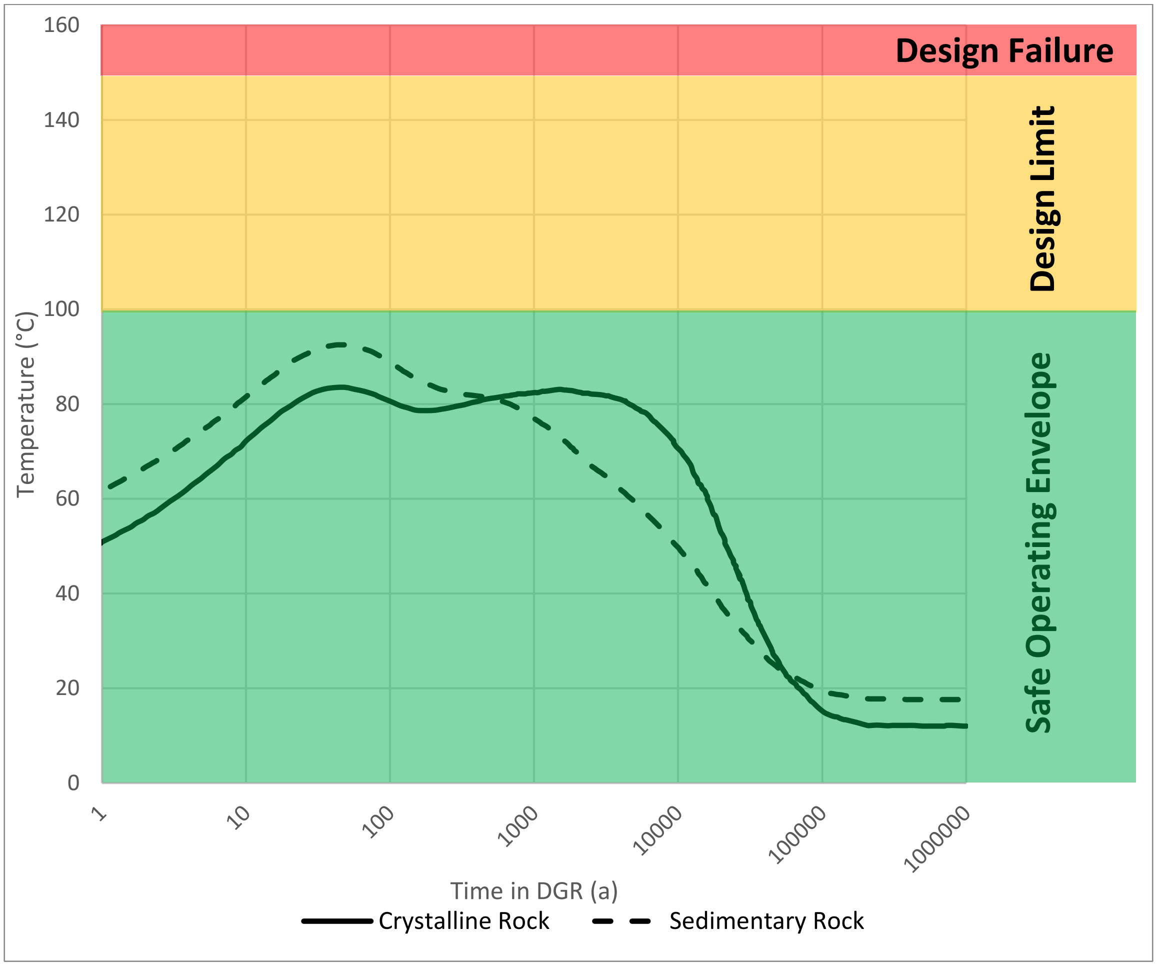

Figure 10. Surface Temperature of a UFC Over Time in the DGR (Crystalline and Sedimentary Rock) (Data From [111], [112])‡

Bentonite itself is not immune to radiation and can, and will, degrade when exposed to high doses of radiation, particularly γ-rays, affecting its swelling and thermal abilities [108], [109].

Barrier 5: Geoshere

The rock in which the DGR is to be excavated must be in a seismically stable region, with rock formation exhibiting minimal fractures and defects and with very low hydraulic conductivity [40]. Similar to the bentonite purpose, the rock formation mechanically supports the DGR system and is chosen to minimize the possibility of radionuclides being transported by water flow to the environment.

‡ Errors not available from references.

2.2.3 SMR in the Context of the DGR

In 2018, the Canadian Small Modular Reactor Roadmap Steering Committee stood up the SMR Waste Management Working Group with the mandate to "*identify waste disposal and storage considerations for Canadian SMR applications*" [30]. Overall, they found that the current legislative, regulatory, and technical framework for waste management for the future SMR fleet is sound and expected to be flexible enough to accommodate a variety of nuclear fuel types. However, significant unknowns remain, the majority stemming from the fact that little is known about the specificities of SMR reactors, their designs, and their fuel contents due to the developing designs being proprietary information of the developers. Amongst others, the biggest items of concern are:

- Characterization of the fuel (development and licensing of new methods or models);
- Processing required to meet the acceptance criteria;
- Cost determination of the whole waste management process;
- The form of the waste (*e.g.,* whole cores, bundles);
- Short term and intermediate repositories' location, designs and duration of storage;
- Transport requirements between temporary and permanent disposal locations; and
- Decommissioning [89].

In general, it is yet not possible to clearly determine all the exact requirements and repercussions of the SMR designs on the NWMO waste management plan for HLW. For example, some SMRs are marketed as having facilitated waste management processes since the whole core is removed and expected to be managed as one entity. However, this practice would go against the principles of waste volume and quantity minimization [89], [113]. Badke and McClellan highlight that plans to dispose of whole cores could lead to LLW and/or ILW being sent to the DGR, adding unnecessary radioactive material to the site, and potentially causing design issues with regard to the UFC [89].

2.3 CANDU Fuel Characteristics

The DGR is specifically and purposefully designed for CANDU fuel bundles. Therefore, if the current NWMO construct is to be used as a waste management system for SMR fuel, the characteristics of the CANDU fuel bundles are a known starting point of reference and comparison.

For ease of discussion, and based on characteristics of the regions, the timeline is divided into three sections:

1- Post-Discharge (5 – 300 a);
2- Mid-term (300 – 100 000 a); and
3- Long-term (100 000 – 10 000 000 a).

Due to the complexity of taking into account very short-lived isotopes that remain immediately after last criticality has been experienced by the fuel in the reactor, but would have little impact on design requirements for a DGR, the timeline of interest has been commenced 5 years after discharge. It is expected, as it is the case now, that SMR fuel would require cooling in a spent fuel pool in the first 10 years post-discharge, the first 5 years having therefore limited impact on waste management overall.

The post-discharge region, from a waste management perspective is the most critical. Assuming no structural failure, the time immediately after discharge, and the subsequent interment of the spent fuel in the GDR will see the highest radiation and decay heat generated by the fuel. Specifically for thermal power decay, recalling Figure 10, the expected maximum temperature at the surface of the UFC is estimated to be at its maximum after approximatively 85 years in the GDR for a CANDU fuel bundle having experience a burnup of 9617 $MWd{\cdot}MTU^{-1}$.

2.3.1 CANDU Reference Bundle

The reference bundle used to design the DGR and make its safety case is the 37-element regular CANDU bundle [114]. As of November 2022, the total projected CANDU waste generated by currently operating reactors and decommissioned reactor show an expected 83% of CANDU spent fuel to be a form of 37-element (regular, long or modified) [115].

All CANDU data presented in this section are obtained or calculated from Appendix E of NWMO report NWMO-TR-2020-05 *Radionuclide Inventory for Reference CANDU Fuel Bundles,* where isotopic activity and total decay heat power were obtained for the 37R bundle [114]. Data were generated using the ORIGEN-S 6.1.3 at burnups of 9167 $MWd{\cdot}MTU^{-1}$ and 12083 $MWd{\cdot}MTU^{-1}$, respectively the highest median burnup seen in any decade of operation of the CANDU design and the highest 95th percentile of burnup seen in any decade of operation.

CANDU fuel is composed of natural uranium in uranium dioxide (UO_2) form. Table 6 displays the isotopic composition of uranium before the fuel enters operation in the reactor.

Table 6. Isotopic Abundance of Natural Uranium [116]

Isotope	Abundance (%)
^{234}U	0.0054 ± 0.0004
^{235}U	0.72041 ± 0.00036
^{238}U	99.27417 ± 0.00036

The fuel bundles are in operation in the CANDU reactor for approximately 18 months, and, once the fuel is depleted, its composition in ^{235}U has fallen to about 0.2% [40].

2.3.2 Activity

Figure 11, Figure 12, and Figure 13 present, respectively, the absolute activity of a CANDU fuel bundle, the overview of relative actinides and non-actinides contribution to total activity and the relative activity contribution of individual isotopes to the total activity.

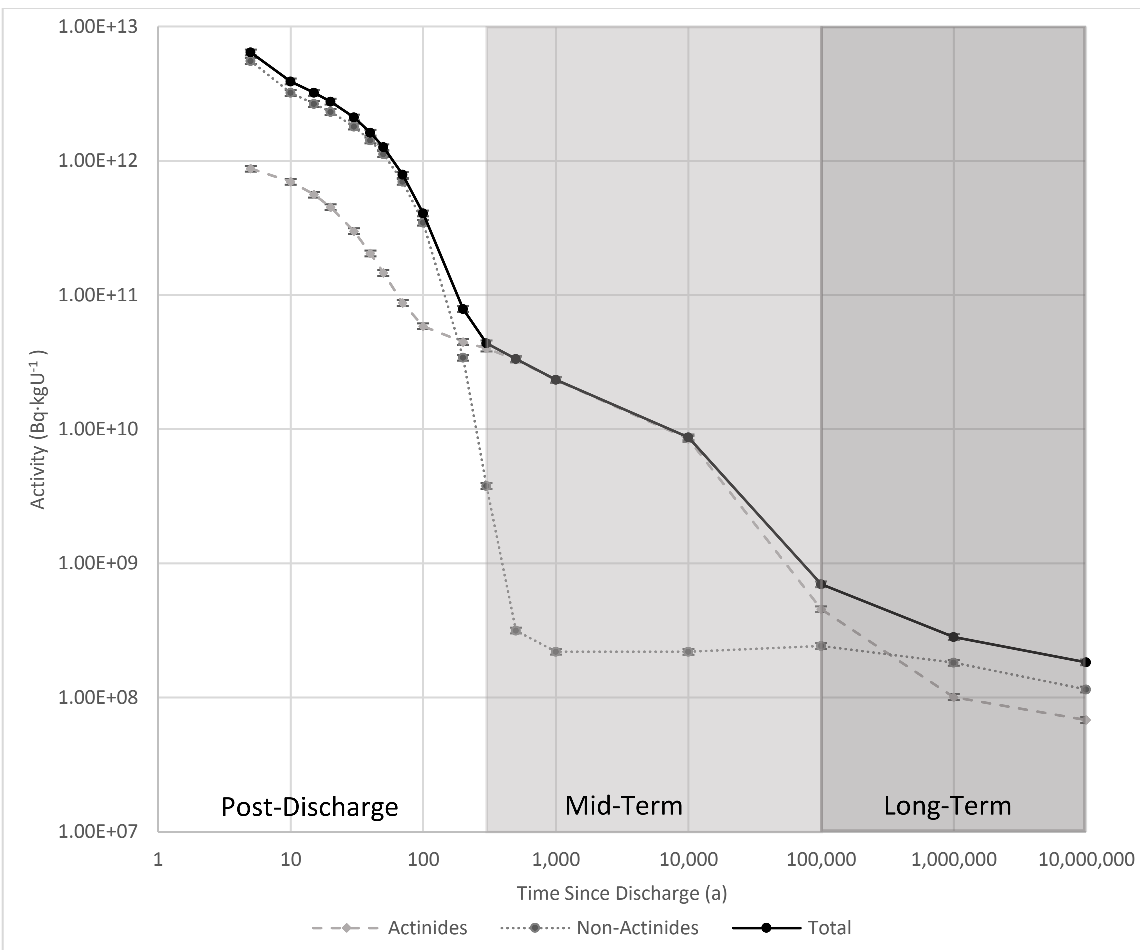

Figure 11. CANDU Actinides and Non-Actinides Activity (9167 MWd·MTU^{-1}) (Data From [114])

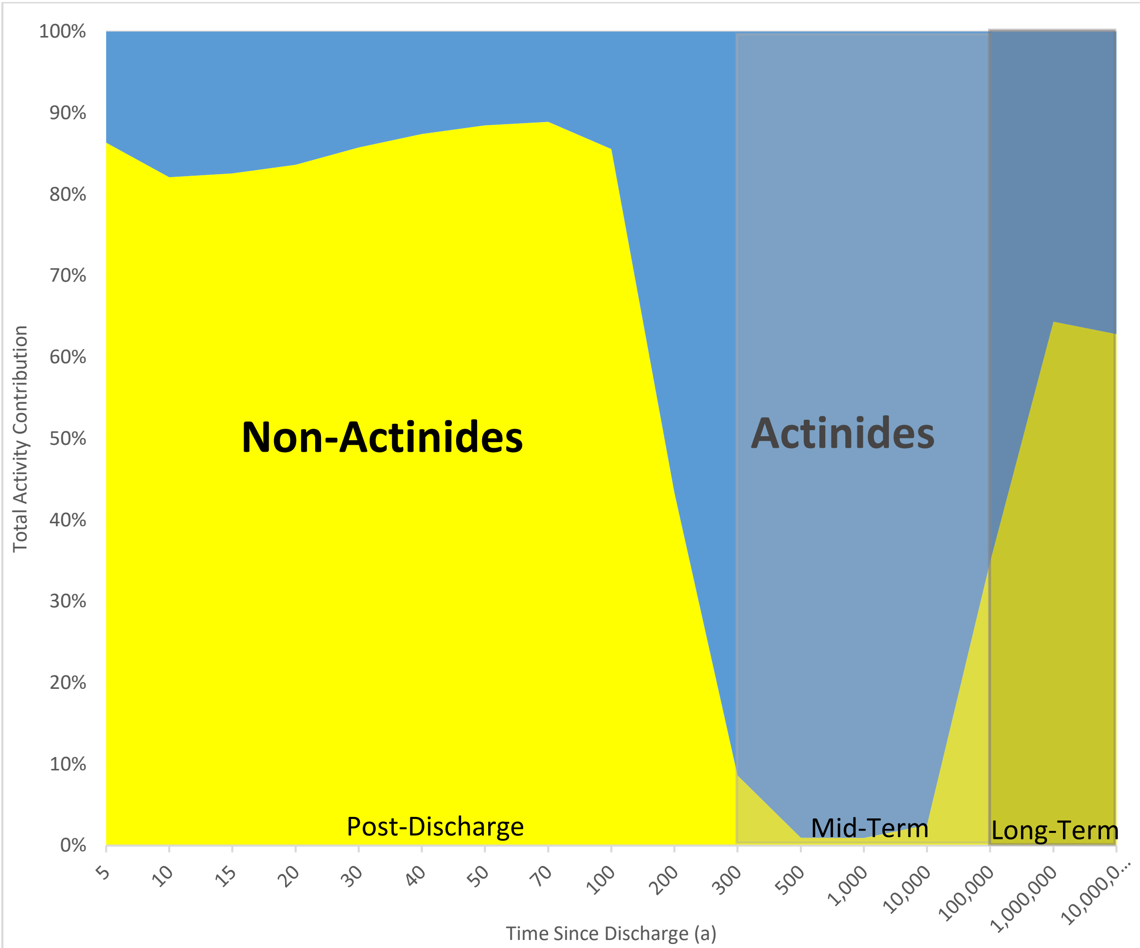

Figure 12. CANDU Relative Activity Contribution of Actinides and Non-Actinides (Data From [114])

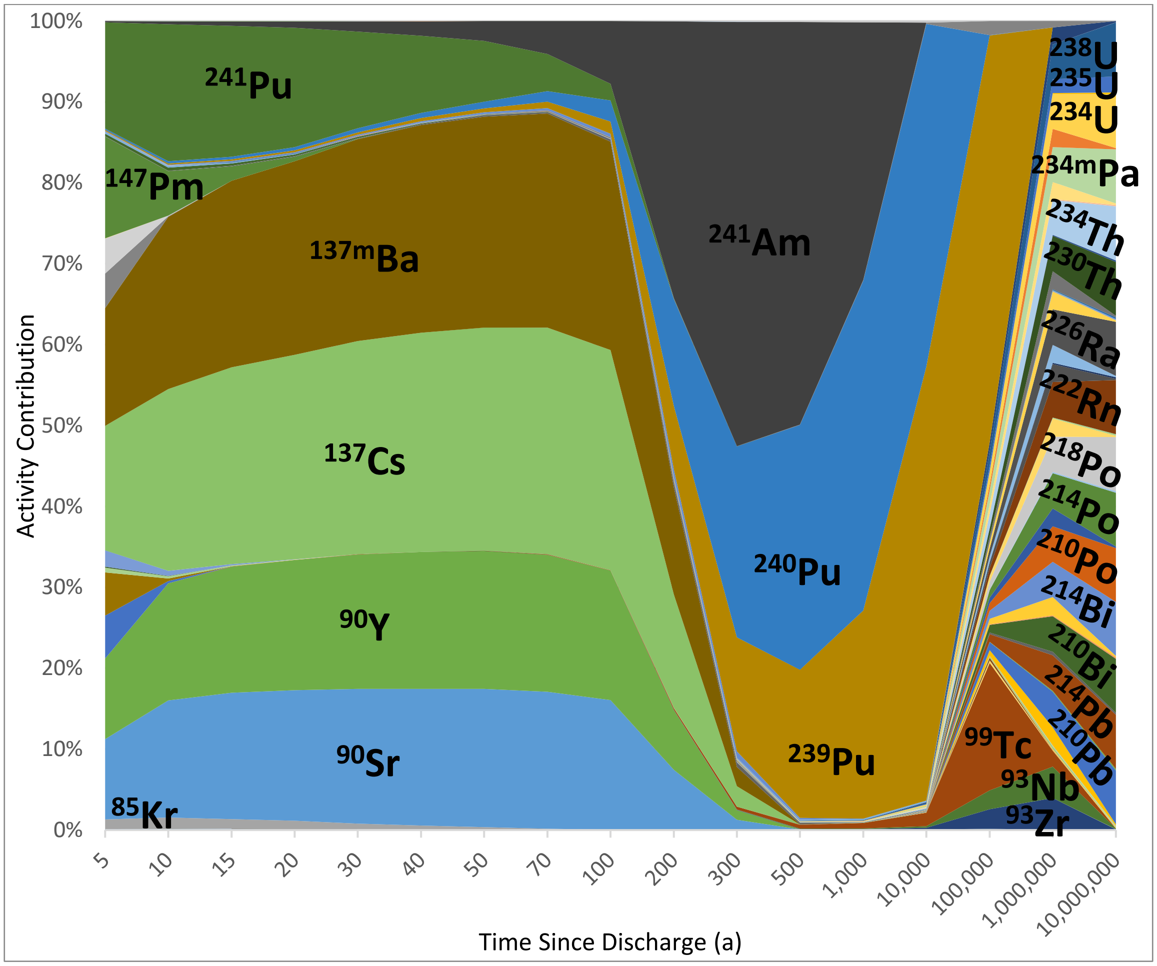

Figure 13. CANDU Relative Isotopic Activity Contribution to Total Activity (Data From [114])

The activity of the post-discharge region is driven by short lived non-actinides fission products: ^{137}Cs, ^{137m}B, ^{90}Sr, and ^{90}Y. Also, a non-negligible portion (10-15%) of the activity being provided by actinides, notably ^{241}Pu. As the fission products decay, the activity, in the mid-term region becomes almost entirely driven by actinides (^{241}Am, ^{240}Pu, ^{239}Pu). The long-term region is shared between various long-lived actinides and non-actinides at approximatively 60:40 ratio.

As burnup will be the main comparison factor throughout the present work, Figure 14 presents the impact of a burnup increase from 9167 MWd·MTU^{-1} to 12083 MWd·MTU^{-1} for the reference CANDU fuel bundle.

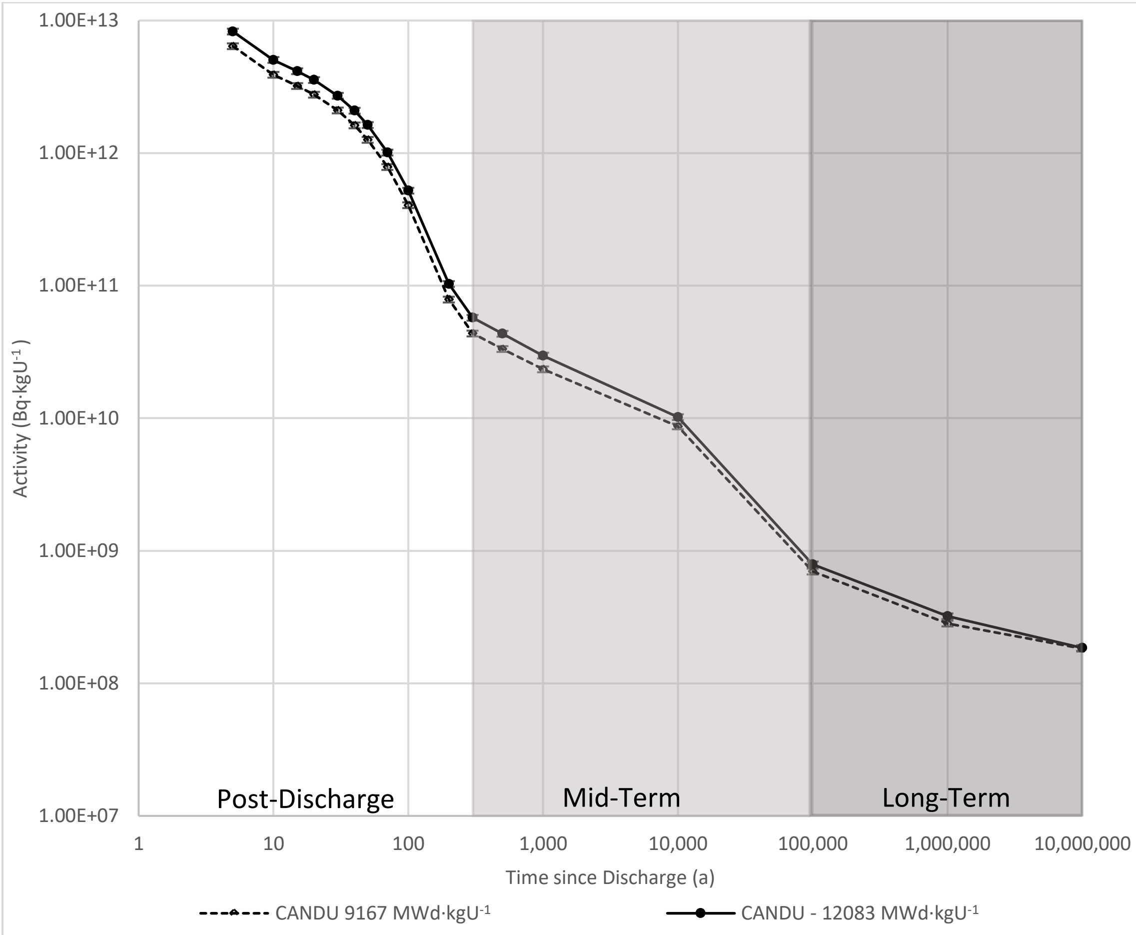

Figure 14. CANDU Spent Fuel Activity *vs.* Burnup Comparison (Data From [114])

2.3.3 Decay Heat

Looking at CANDU spent fuel decay heat, the trends are similar as with activity, which is expected as activity is the main driving factor of spent fuel generated thermal power. Figure 15 presents the decay thermal power of the CANDU reference fuel, per kg of initial uranium at the two available burnups.

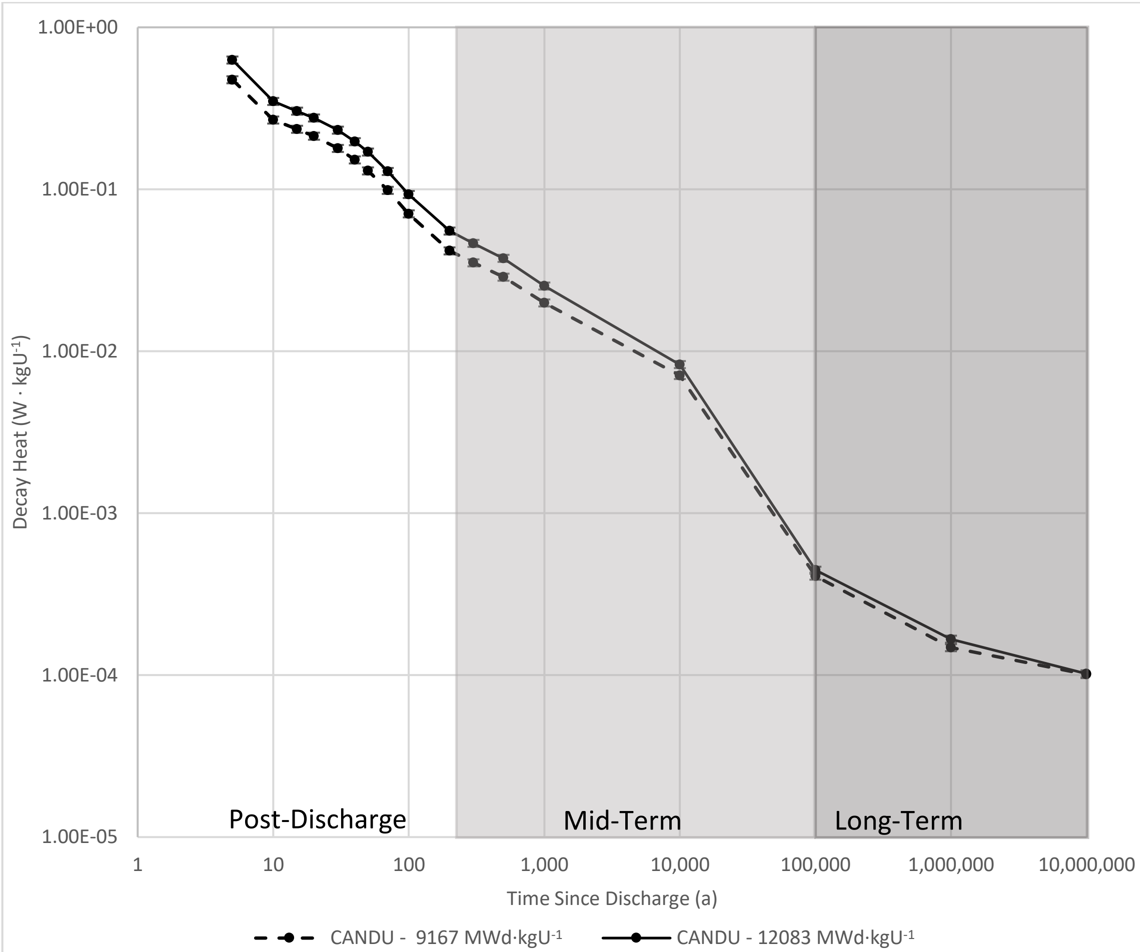

Figure 15. CANDU Decay Heat (Data From [114])

2.4 SLOWPOKE-2

2.4.1 General Overview of SLOWPOKE-2

Technical overview

The RMC SLOWPOKE-2 is a Low Enriched Uranium (LEU) 20 kW_t, undermoderated, light-water- cooled (H_2O), pool type research reactor. Figure 16 displays the general arrangement of the SLOWPOKE-2 facilities at the RMC. Annex C presents technical specifications for the original SLOWPOKE-2 reactor commissioned in 1985. In Fall 2021, the reactor was refuelled with a new core of 195 fuel elements, which is a change from the previous 198 elements, due to higher density of fuel material.

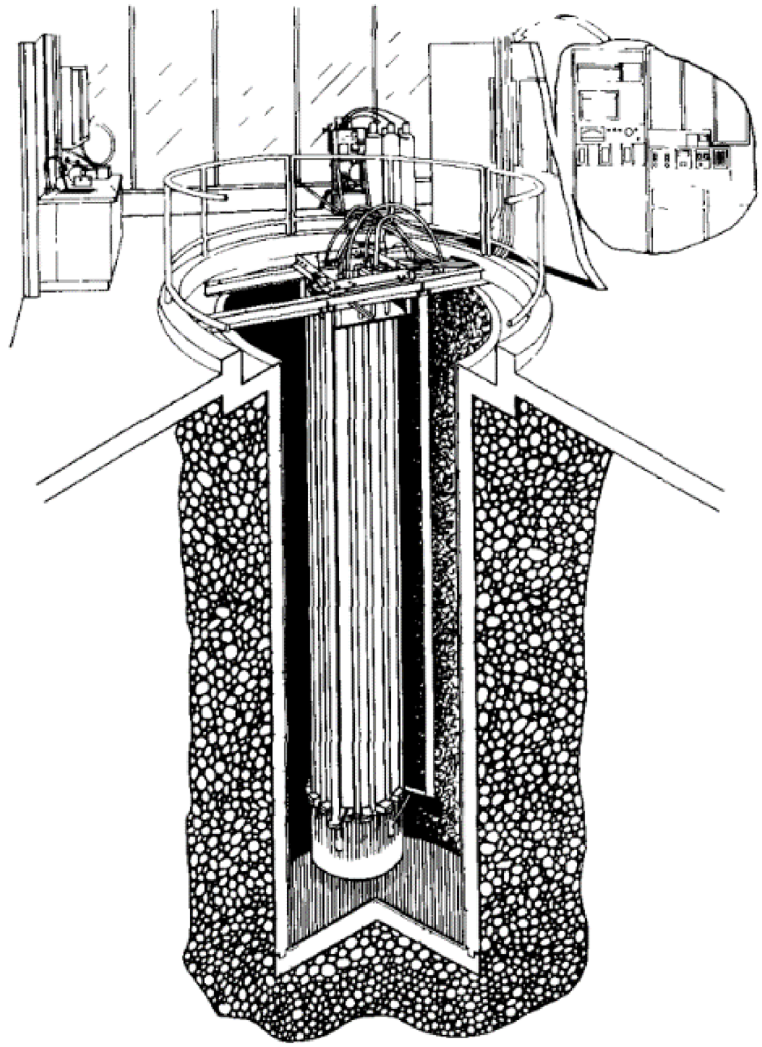

Figure 16. General Arrangement – RMC SLOWPOKE-2 Facility at Installation (1985) [57]

Container/Pool

The reactor pool is a steel-lined concrete construction dug into the lowest level of the reactor facility [57]. The aluminium reactor container is suspended on supporting beams spanning the width of the pool. It hangs off-centre in the light-water pool; its smallest distance from the pool side is 1 m [117]. The reactor container is made of 0.95 cm thick aluminium and is kept bolted and always sealed to prevent users from accessing the core and changing beryllium shims arrangements, as this could cause the reactor to exceed its licenced reactivity limit [117], [118].

The reactor container separates the external shield pool water from the coolant-moderator water internal to the container [118]. Within the container, cooling is provided by natural convection of the light-water passing through the reactor core, with heat propagating to the pool water through the reactor container wall. Heat from the pool is removed by cooling coils connected to the local water supply [118].

Core Assembly

The SLOWPOKE-2's core assembly, located at the bottom of the reactor container, is an approximatively 9 litres zircaloy-4 cylindrical structure with vertical uniformly spaced fuel pins [118], [119]. Figure 17 displays the arrangement of the core assembly and reactor container.

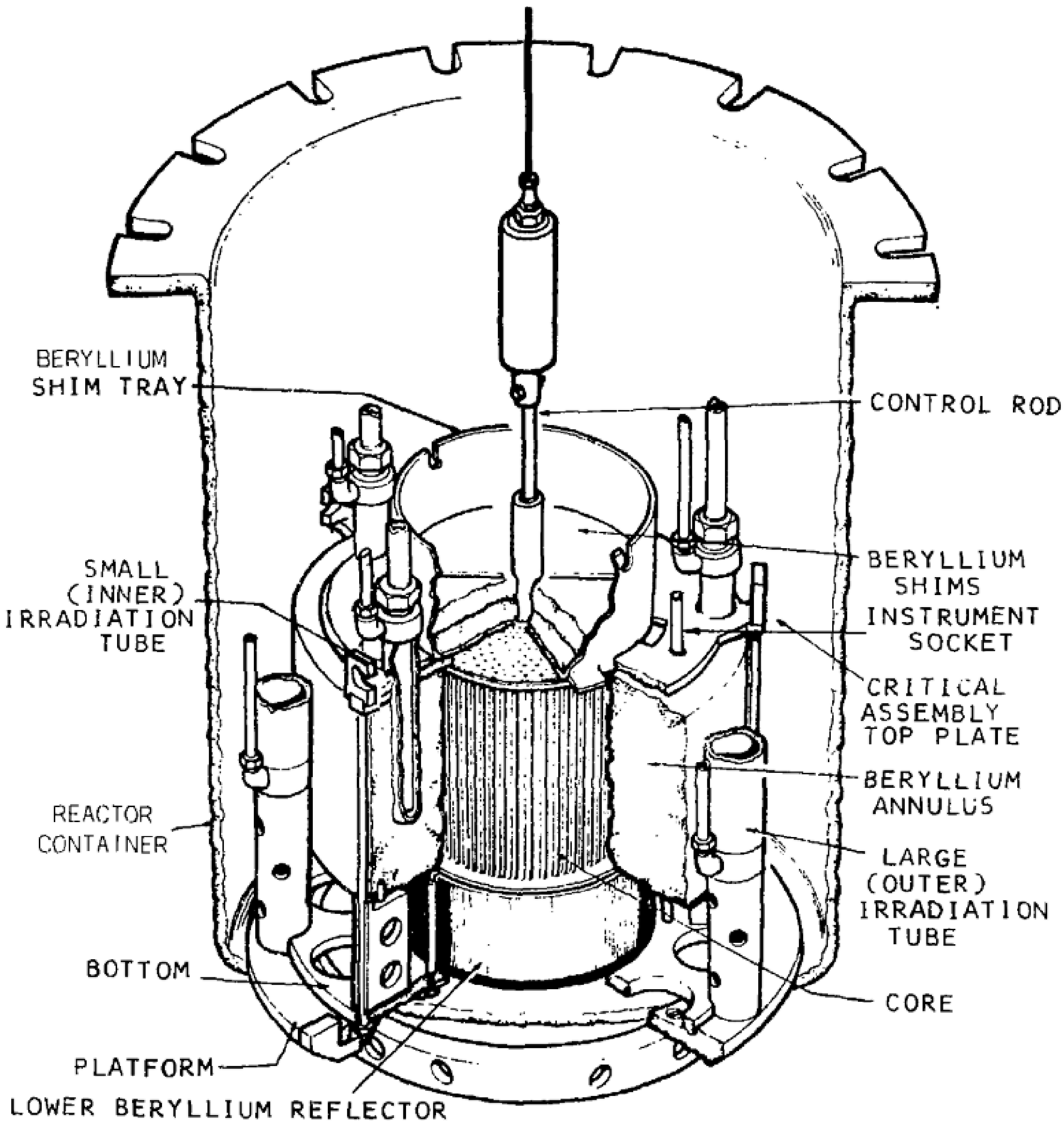

Figure 17. SLOWPOKE-2 Reactor Container's Lower Section [118]

The core is surrounded by beryllium reflectors 10 cm thick below (lower beryllium reflector) and around the core assembly (beryllium annulus) [117]. The reflectors have multiple purposes: to lower the critical mass of fissile material required to operate the reactor, maintain a high ratio of thermal neutron flux to fission power, and moderate fast neutrons leaking from the core to provide high thermal neutron flux to experimental sample sites located within the reflectors [118]. As the fuel is burned up by reactor operation, semi-circular beryllium shims are added to the top of the reactor (in the shim tray), increasing the neutron reflecting ability of the top reflector [119]. The shims allow for extended operational life of the reactor and have been added every few years (approx. 2-4 years) as required to maintain excess reactivity [120]–[123].

On a sector of 45°, a heavy-water (D_2O) thermal column is fitted to moderate neutrons to allow for an adequate thermal neutron flux to the Neutron Beam Tube (NBT) for imaging activities [124]. The thermal neutron flux is 2.7 times higher in the thermal column region, compared to a similar location in the beryllium reflector [57]. For research purposes (*e.g.,* NAA), the core assembly has five inner sample irradiation sites within the beryllium reflector and four outer sample irradiation sites outside of the reflector. Samples in capsules are sent to the core and retrieved through a system of tubes using compressed gas [118]. Figure 18 displays a cross-section of the core and arrangements of the irradiation sites.

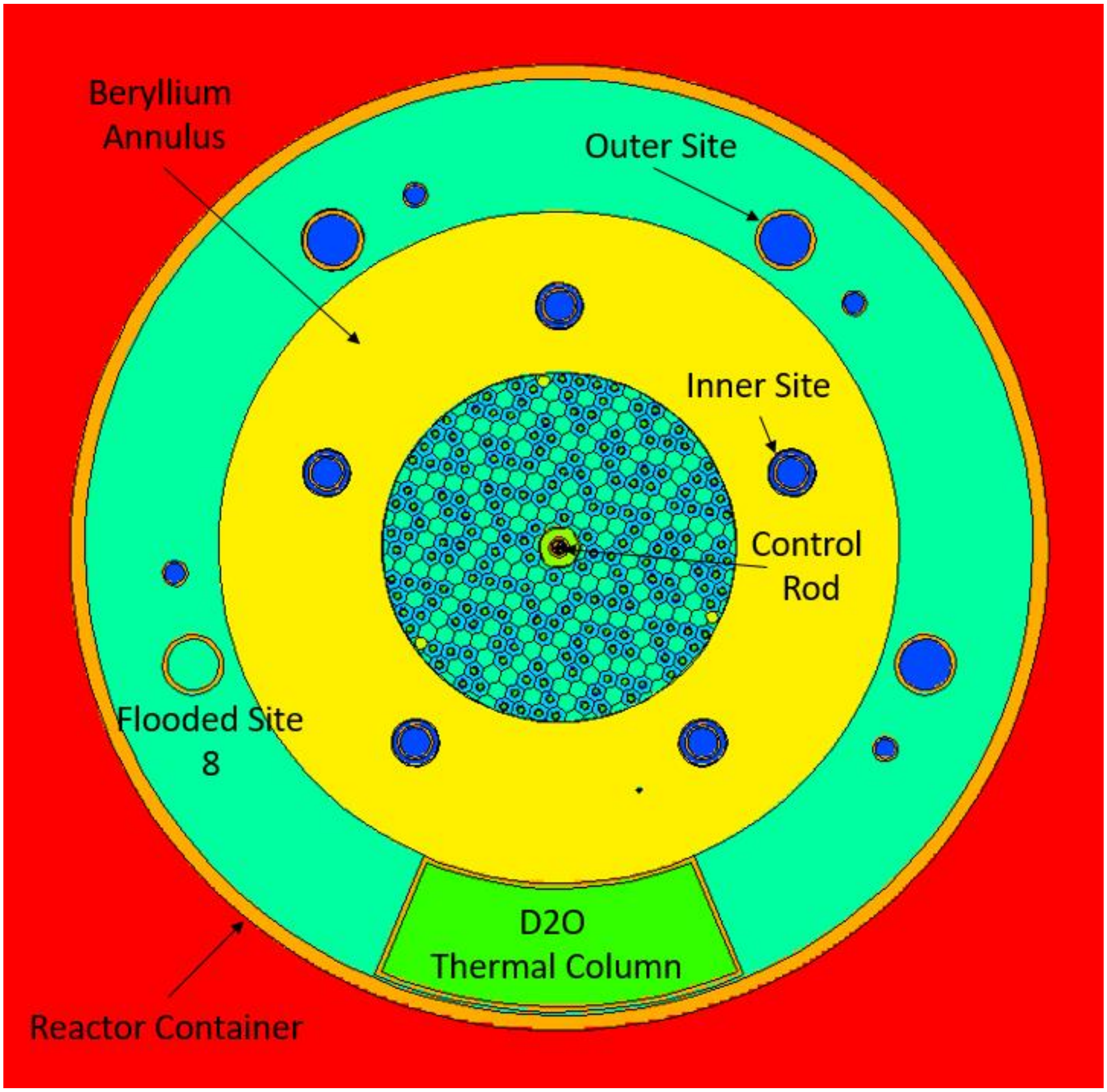

Figure 18. RMC's SLOWPOKE-2 Reactor Core Cross Section (Top View)

Reactor Controls

Inherent safety features and simplicity of operation have been enshrined in the design of the SLOWPOKE-2 from the onset. The primary safety mechanism for the reactor is its negative temperature and void coefficients stemming from its undermoderated design [118]. If a reactivity transient should occur due to loss of the regulation mechanism, the coolant temperature would rapidly increase, leading to a decrease in density of the coolant-moderator. The moderator function of the coolant would then be affected, thereby decreasing reactivity and stabilizing the reactor.

Active reactivity control is done using a cadmium-aluminum absorber rod (5.5 mk). The rod is located at the centre of the core, suspended by a cable to a winch at the top of the reactor container used to control the length of insertion into the core (Figure 16 and Figure 17) [119]. Neutron flux is maintained constant (within 1%) by the reactor control software, and the insertion of the control rod is automatically controlled by information received from a self-powered neutron detector (SPND) located in Inner Site no. 3 [118]. The reactor can be shut down by the full insertion of the control rod or by sending cadmium-filled capsules in the reactor using the sample processing system [118].

2.4.2 SLOWPOKE-2 Fuel

As the main purpose of the SLOWPOKE-2 reactor is as a source of thermal neutron, the core is designed to optimize the thermal neutron flux within the beryllium reflector, specifically at the inner sample irradiation sites [123]. Figure 19 displays the 195 fuel elements pattern within the refuelled LEU SLOWPOKE-2 core.

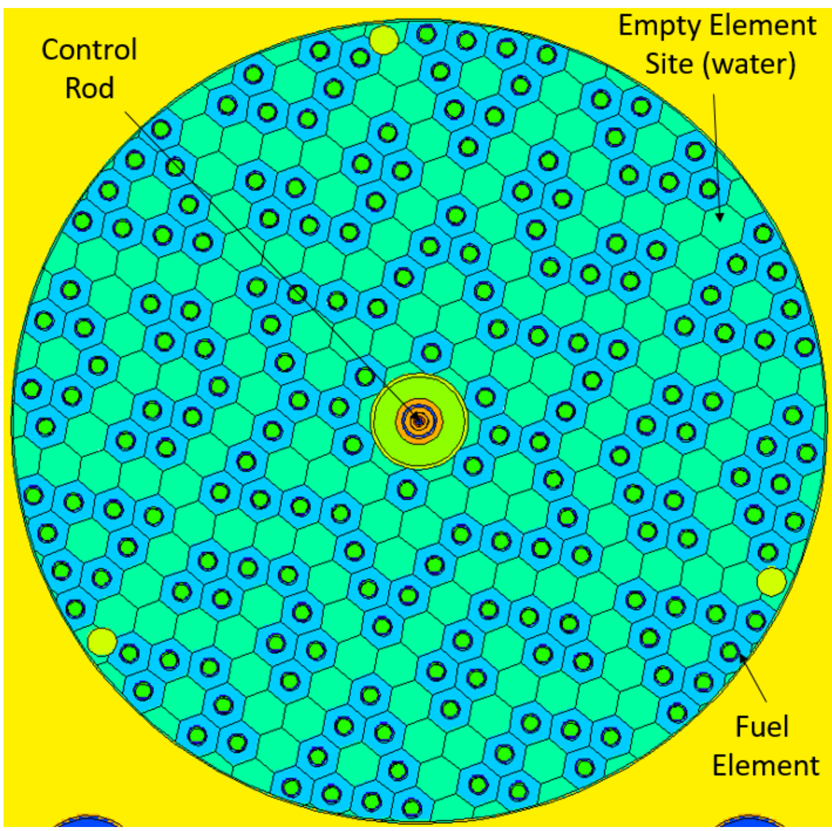

Figure 19. Distribution of Fuel Elements in the new LEU SLOWPOKE-2 Core

The fuel elements of the SLOWPOKE-2 reactor have a similar design as the fuel bundles of the CANDU reactors in both material and general arrangement. The fuel elements are composed of uranium dioxide ceramic pellets similar to CANDU pellets with a ^{235}U enrichment of about 20%. The pellets are contained in a Zirconium-4 cladding and inserted in the fuel cage.

2.4.3 SLOWPOKE-2 Operational History

As it is proposed here to determine the SLOWPOKE-2's spent fuel isotope inventory, it is necessary to understand the reactor's operational history. As discussed above, to maintain the reactor's reactivity, beryllium shims are added to the top of the reactor. From commissioning in September 1985 to the cessation of operations prior to the 2022 refuelling, nine (9) shimming events were required. Figure 20 presents the SLOWPOKE-2 operational history, displaying the shimming events and their impact on reactivity throughout the 1696 days of burnup operations. Annex D presents detailed data on the SLOWPOKE-2 history.

Considering that most experiments conducted at the RMC are at half power for a neutron flux of 5×10^{11} $n \cdot cm^{-2} \cdot s^{-1}$ the definition of a burnup day has been arbitrarily chosen to correspond to flux of 5×10^{11} $n \cdot cm^{-2} \cdot s^{-1}$ at the SPND location for a period of 24 hours. This is consistent with SLOWPOKE-2 operational procedures and methodology employed by Rook [121].

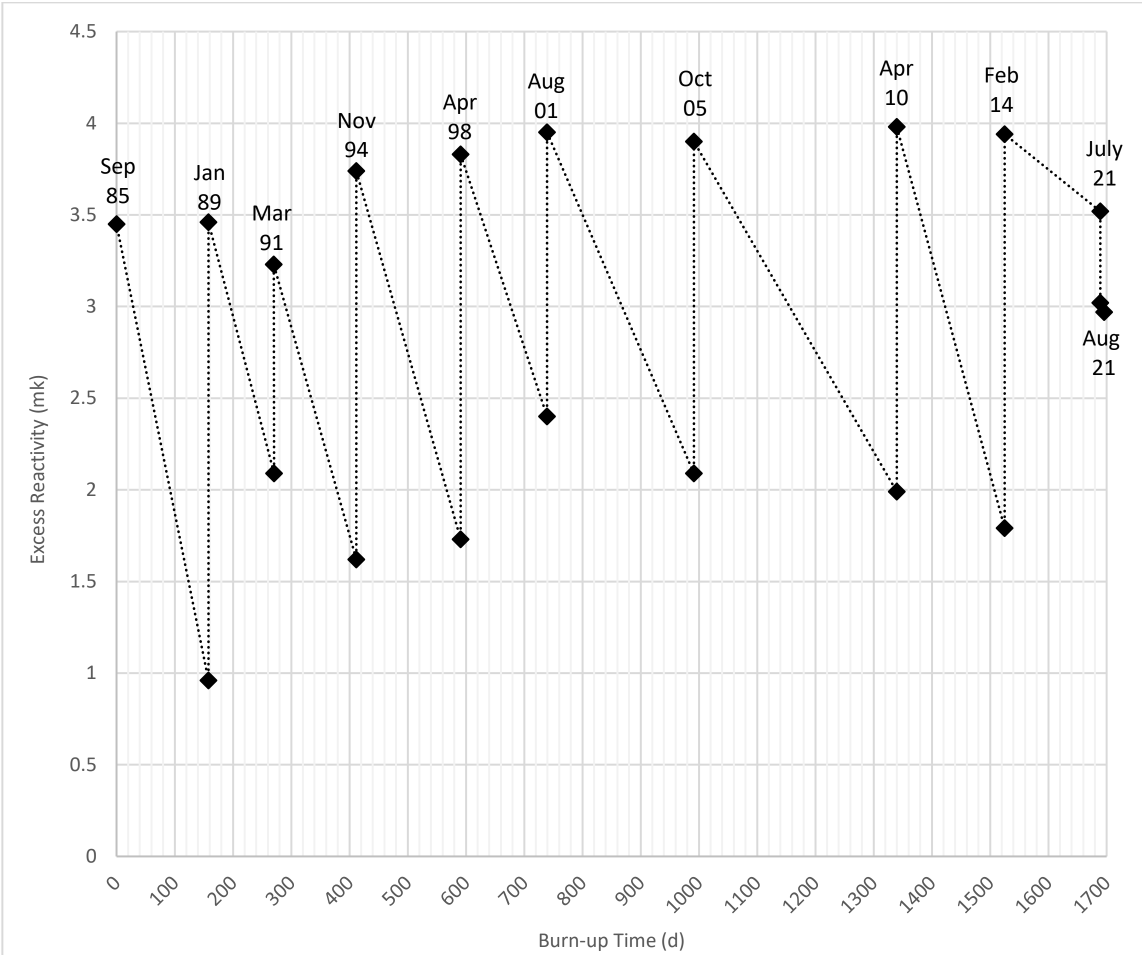

Figure 20. RMC SLOWPOKE-2 Operational History (1985 to 2021)

During assessment of the reactor in July 2021 prior to the refuelling, at 1689 days of burnup, it was noticed that shims were overlapping. Upon discovery, the shims were reinstalled properly. During the 164 days of burnup between the February 2014 and the July 2021 shimming events, it can be seen at Figure 21 that the trend of the shim thickness since the reactor's commissioning was not consistent (red "*X*" indicate the shim thickness from February 2012 to July 2021). However, once the shims were replaced correctly, in July 2021, the trends returned to expected values. The reactor operated for a further *seven* (7) burnup days in this final configuration.

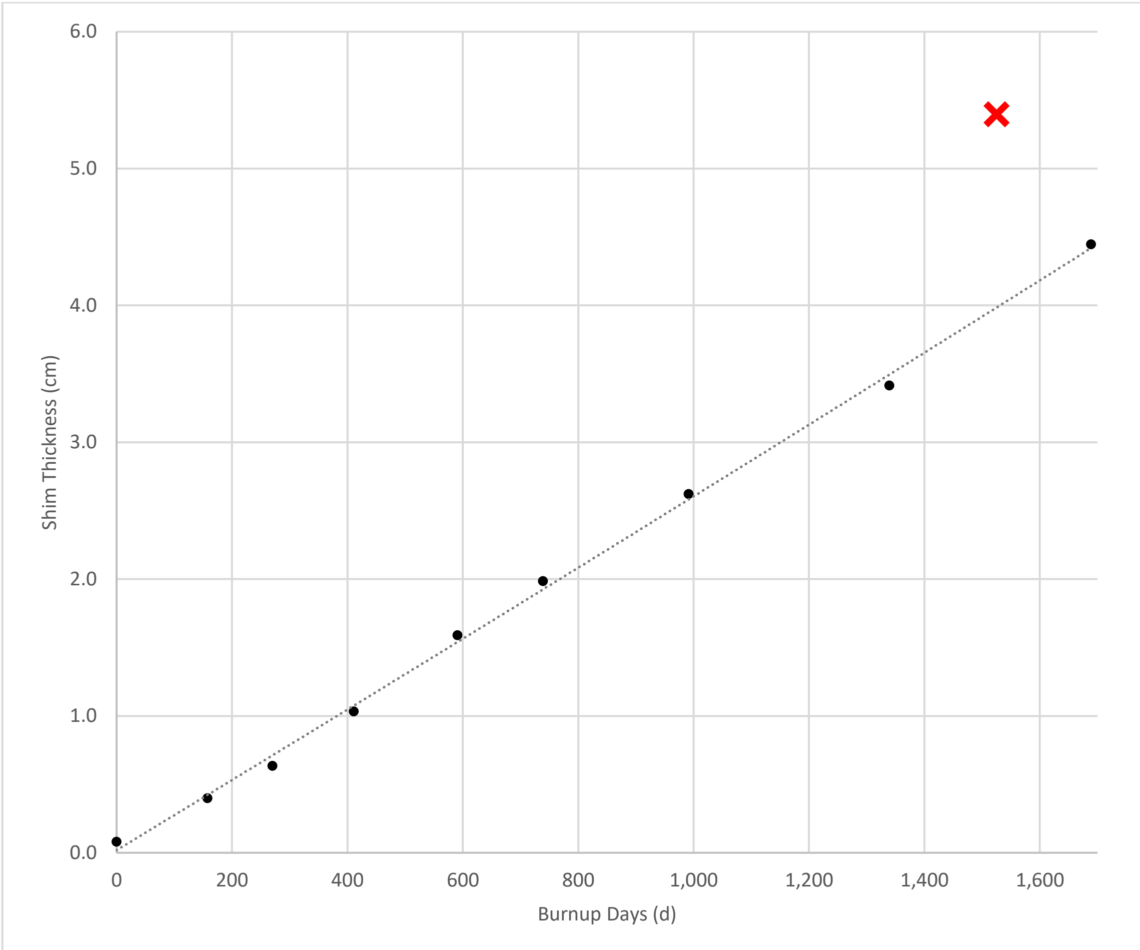

Figure 21. Shim Thickness *vs.* Burnup Days (1985-2021)

Chapter 3

Model Benchmarking – Neutron Flux Mapping

3.1 Introduction

To validate the MCNP model of the SLOWPOKE-2 research reactor at the RMC, an experiment was devised using readily available material and resources. Using a known material and exposing it to the known neutron flux of the reactor, it is determined that it is possible to map the neutron distribution at specific irradiation points in the reactor by neutron activation analysis, both quantitatively and qualitatively, at the irradiation sites. The NAA results are independently confirmed with a comparison with historical NAA values from the literature. Likewise, MNCP simulations results are confirmed with available literature. Finally, NAA experimental data are then compared to the results obtained from the MCNP model for the same reactor locations and operating parameters. This process constitutes the basis of the benchmarking of the model.

This chapter provides the basis for the completion of *Primary Objective 1* and is organized into multiple sections to provide a detailed view of the procedures conducted to benchmark the MCNP model.

Section 3.2 provides an overview of the methods used in the completion of Primary Objective 1: NAA and computational simulation. As well, an overview of select SLOWPOKE-2 neutron flux values from the literature is made and will be used to compare the experimental fluxes obtained from both the NAA method and the MCNP model.

Section 3.3 presents details of the neutron activation analysis experiment conducted on the RMC SLOWPOKE-2 in summer 2022 using a gold-aluminium alloy wire neutron monitor in an inner and an outer radiation site. The validity of the values obtained is assessed based on the existing SLOWPOKE-2 literature reviewed at section 3.2. This section corresponds to task A.

Section 3.4 presents the MCNP 6.2 model generated to mimic the NAA experiment and the associated simulation results in comparison to available literature. This section corresponds to task B.

Finally, section 3.5 discusses the validity of the MCNP model considering the NAA experiment and the existing literature values for neutron flux in the SLOWPOKE-2. This section fulfills task C.

As demonstrated by the end of this chapter, both the experimental results and the simulations agree, and it can be concluded that the model is a good representation of the reactor. Therefore, the predictive model developed by this thesis, may be used to simulate SLOWPOKE-2 spent fuel (Chapter 4) and may be used as the baseline to model SMRs (Chapter 5).

3.2 Neutron Flux Mapping - Overview

A nuclear research reactor's neutron flux can be mapped by experimental methods, computational methods, or a combination of both, using computationally supported experimental processes, which is being done for the present study.

3.2.1 Experimental Method - Neutron Activation Analysis (NAA)

NAA is a method used to determine the elemental composition of a sample based on the conversion of its stable elements to detectable and measurable radioactive elements by exposing the sample to neutrons [125], [126]. The exposure of the sample to the neutron flux of the reactor can cause interaction between the sample matter and the incident neutrons, the most prominent of which is neutron capture, where a neutron is absorbed by the target nucleus, making it heavier and exciting it to an unstable state (reaction (n,γ)). Unstable atoms will attempt to stabilize to a different state through radioactive decay: releasing characteristic photons and alpha or beta particles. The photons can then be detected, and the sample's composition can be determined by comparing the detected photon's energy to known energy values associated with specific isotopes.

While many NAA methods attempt to identify the composition of an unknown sample, flux mapping uses known samples to assess the reactor generated neutron flux. The multi-foil method appears to be the simplest and most used to determine flux in research reactors: multiple foils of high purity are irradiated in the reactor and undergo predictable activation reactions, generally (n,γ). Particular neutron monitor materials are more susceptible to certain particle interactions due to their properties and can therefore be selected based on energies of interest to be analyzed, *e.g.*, thermal neutrons (0 - 0.625 eV), epithermal (0.625 - 4.0 eV), fast (4.0 eV – 10.0 MeV), and total flux [127]–[133].

High Purity Germanium (HPGe) detectors are often used in gamma spectroscopy because of their high resolution. HPGe detectors operate by absorbing the photon energy emitted by a decaying radionuclide displacing an electron and creating a temporary charge. The charge is then collected and organized based on the magnitude of energy into channels allowing subsequent photons absorbed of the same energy to be tabulated, producing distinct "gamma peaks." The number of counts can be used to determine the activity of the irradiated sample based on the efficiency of the detector, which is determined by analysing a radioactive calibration standard of known composition and activity [134].

3.2.2 Computational Methods - Simulations

Computational methods to map a reactor core's neutron flux include codes of both deterministic and stochastic techniques. However, there appears to be a marked preponderance in the use of codes using a stochastic Monte Carlo method to determine the flux of research reactors, the most used of which appears to be the Los Alamos National Laboratory's MCNP transport code in its diverse iterations [128], [130], [135]–[155].

Benchmarking the results of a code with values obtained from other previously validated simulation codes is a common occurrence [139], [144], [147], [148], [152], [153], [156], [157]. However, the computational methods are often conducted concurrently with NAA experiments, which serve as a means to benchmark the simulation model code, as well as qualify and quantify NAA uncertainties [128], [130], [135]–[142], [146], [154], [157]–[160]. Once a model is compared to experimental data, it is part of a validation process, hence simulations can be used with added confidence for further reactor analysis. This is the path chosen for the present work.

Over the years, the modelization capabilities of the codes have significantly improved, going from simple 2D modelization to complex, whole-reactor 3D models. For example, the RMC SLOWPOKE-2 neutron flux was broadly defined in 1989 using a WIMS-CITATION code, in 1999 using a WIMS-AECL 2D model and MCNP 4 simplified 3D model, and in 2020 using a detailed full-core 3D MNCP 6.1 model [117], [123], [145], [161].

3.2.3 Existing SLOWPOKE-2 Literature on Flux Mapping

The following studies existing in the SLOWPOKE-2 literature have either directly been interested in the qualification and quantification of the neutron flux of the SLOWPOKE-2 reactor, or have used the cadmium ratios, epithermal to thermal ratios, and neutron flux for other means while investigating aspects of the reactor. Three SLOWPOKE2s are represented: Dalhousie University (High Enriched Uranium (HEU)), Polytechnique Montréal (LEU) and RMC (LEU). As well, both NAA and computationally assisted simulations are represented, providing a characteristic overview of existing and potential results. The studies retained have been selected to provide comparative values in the power range of interest for the current NAA study, (half-power, approximatively 10 kW_t) as well as using comparable neutron monitoring material.

An overview of values pertinent to the present work is presented at Table 7. Where available, the relevant irradiation sites have been identified (#).

Table 7. SLOWPOKE-2 Neutron Flux Mapping Literature*

		Acharya & Chatt [162]	**Neisiani** [163]	**Kennedy *et al*.** [164]	**Andrews** [161]	**Lamarre** [117]	**Rook** [121]
		Dalhousie University	Polytechnique Montréal	Polytechnique Montréal	RMC	RMC	RMC
Fuel		HEU	LEU	LEU	LEU	LEU	LEU
Method		NAA	NAA	NAA	NAA	Simulation Code: WISM-AECL	Simulation Code: MCNP 6.1
Material		Al-Au wire (wt 0.1073%) and others	Al-Au wire (wt 0.1%)	Al-Au (wt 0.100%) Zr foils (99.9%)	Al-Au wire (wt 0.112%) Pure Co foils Co solution	-	-
Control Neutron Flux ($n \cdot cm^{-2} \cdot s^{-1}$) x$10^{11}$		2.5 to 5		5		5	5
Reactor Power (kW_t)			10		10	10	10
Cadmium Ratio	Inner Site	2.13 ± 0.03 (#2) 2.14 ± 0.04 (#3)			2.1 ± 0.1 (#3) 2.0 ± 0.1 (#4)		
	Outer site	4.58 ± 0.11 (#10)			1.10 ± 0.07 (#9) 4.5 ± 0.3 (#10)		
Thermal to Epithermal Flux Ratio	Inner Site	18.8 ± 0.4 (#2) 18.9 ± 0.4 (#3)	18.1 ± 0.3	19.8±0.4	17.4 ± 1.0 (#3) 15.8 ± 0.9 (#4)	11.8 ± 1.8	Fresh: 10.4 ± 0.6 Depleted: 11.7 ± 0.7 Detailed: 10.9 ± 0.6
	Outer site	57.1 ± 2.2 (#10)		55.4±3.0	1.60 ± 0.09 (#9) 55.3 ± 3.3 (#10)	33.3 ± 3.3	Fresh: 31 ± 2 Depleted: 34 ± 2 Detailed: 32 ± 2
Thermal Flux ($n \cdot cm^{-2} \cdot s^{-1}$) x$10^{11}$	Inner Site		5.3 ± 0.3 to 5.41 ± 0.3		5.7 ± 0.3 (#1) 5.8 ± 0.3 (#3) 5.6 ± 0.3 (#4) 5.5 ± 0.3 (#5)	5.00 ± 0.25	Fresh: 5.19 ± 0.16 Depleted: 5.31 ± 0.16 Detailed: 5.11 ± 0.15
	Outer site				2.8 ± 0.1 (#6) 0.160 ± 0.008 (#9) 2.6±0.1 (#10)	3.01 ± 0.09	Fresh: 2.59±0.09 Depleted: 2.63 ± 0.13 Detailed: 2.50 ± 0.13

*Site numbers in parenthesis when known

3.3 Neutron Flux Mapping - Neutron Activation Analysis

In August 2022, the SLOWPOKE-2 neutron fluxes in the inner and outer irradiation sites were determined using NAA on multiple Au-Al wires both bare and cadmium covered. Calculations were then conducted based on the gamma spectroscopy results to quantify and qualify the neutron field within the reactor. Specifically, the neutron flux, cadmium ratio and thermal-to-epithermal ratios are calculated and then compared to literature values.

3.3.1 Background

The present section reviews the background information required to obtain the values necessary to compare NAA experimental data to the equivalent information obtained from the MCNP simulations of the same NAA experiment (*i.e.,* neutron flux, the cadmium ratio and the thermal to epithermal flux ratio).

3.3.1.1 *Neutron Flux Determination*

The neutron flux is determined by leveraging basic nuclear reactions and decay principles. By irradiating the sample of known composition and known nuclear parameters in a known position of the reactor, for a known duration, with a known rest period between the irradiation and the gamma-detection, and known detection duration, it is possible to derive the total neutron flux experienced by the sample in the reactor and, therefore, map the local neutron flux within the reactor. The total neutron flux seen by the sample in the reactor is given by Eq. (2) [125]:

$$\phi = \frac{C_y M_x \lambda}{\varepsilon_y P_y m p x_x N_A \sigma_a (1 - e^{(-\lambda t_{irr})})\,(e^{-\lambda t_{decay}})(1 - e^{(-\lambda \Delta t_{detect})})} \tag{2}$$

Where

ϕ = Total neutron flux ($n \cdot cm^{-2} \cdot s^{-1}$)
C_y = Counts detected by HPGe detector
M_x= Atomic mass of X (amu)
λ = Decay constant (s^{-1} or min^{-1})
ε_y = Detector efficiency
P_y = Probability of gamma production from isotope Y
σ_a = Microscopic absorption cross-section of the target nuclei X (cm^{-2})
m = Mass of sample (g)
p= Purity of the sample
x_x= Isotopic abundance of X
N_A= Avogadro's number (mol^{-1})
t_{irr} = Irradiation time in the detector (min)
Δt_{detect} = Time of the sample on the HPGe detector (min)
t_{decay} = Decay time between the end of irradiation and the start of detection on the HPGe detector (min)

3.3.1.2 ***Self-Shielding***

Self-shielding is a phenomenon by which a material exposed to a neutron field, as in the case with NAA, will experience a non-uniform distribution of activation [165], [166]. Deeper material within the sample is not activated at the same rate as the peripheral material, it is "shielded" due to neutron absorption and scattering occurring in the periphery. The extent to which a sample is affected by self-shielding depends on the sample's geometry and on its material properties, namely macroscopic absorption and scattering cross-section (Σ_a and Σ_s in cm^{-1}) [125].

Several methods, geometries, and techniques have been developed to combat the impacts of self-shielding on a sample [146], [160]. The effects of self-shielding can be minimized with careful sample designs and selection or compensated by mathematical means (*e.g.,* post-irradiation calculations with a self-shielding factor). Thin and dilute alloys significantly reduce the impact of self-shielding on the neutron flux detected by the material [167]. Computational methods of the self-shielding factor, depending on the monitor's material and geometric characteristics, are available to calculate the impact of self-shielding on the experimental flux obtained from neutron activation.

Four methods have been used to assess the self-shielding factor in the present study, detailed at Annex E : Stewart & Zweifel Method, Universal Sigmoid Curves, ASTM Method and MATSSF Code. In all cases, the calculations of the self-shielding factors assume isotropic neutron fluxes. It is a reasonable simplification due to negligible impact of anisotropic neutron flux on self-shielding in research reactors [165].

In the same manner that self-shielding prevents neutrons from penetrating the material to be activated, gamma self-attenuation impacts the gammas emitted during the decay of the sample. The gammas emitted can be absorbed or scattered within the sample based on the sample geometry, composition, and gamma energy emitted [125]. In the present case however, as all samples are rigorously identical in size and composition, any gamma self-attenuation will be compensated by the application of the efficiency factor of the HPGe detector. It is therefore taken into account, but not explicitly calculated.

3.3.1.3 ***Neutron Field Qualification***

In addition to the purely quantitative neutron flux values, the neutron field in the reactor can be further qualified using calculated values (*i.e.,* cadmium ratios and thermal to epithermal flux ratios). These values allow for a comparison of the neutron field of specific SLOWPOKE-2 with the rest of the reactor fleet.

3.3.1.3.1 Cadmium Ratio

The large absorption cross-section of cadmium can be leveraged to discriminate between thermal and higher energies neutrons by acting as a high-pass filter for neutrons above its cut-off energy. Cadmium's cut-off energy (~0.5 eV) is near the upper limit of the thermal neutron range (0.625 eV). By covering samples to be irradiated with a cadmium shield and comparing to an unshielded sample, a good approximation of the epicadmium neutrons (at energies higher than the cadmium cut-off) can be identified and subtracted from the total flux, thereby allowing for the determination of the thermal flux [49]. The cadmium ratio, presented by Eq. (3), can be used to define the reactor's neutron flux.

$$R_{Cd} = \frac{A_{US}}{A_S} = \frac{\Phi_{US}}{\Phi_S} = \frac{\Phi_{th}\sigma_{th} + \Phi_{epi}I_o}{\Phi_{epi}I_o} \tag{3}$$

Where
R_{Cd} = Cadmium ratio
A_{US} = Activity of the unshielded sample (Bq)
A_S = Activity of the cadmium shielded sample (Bq)
Φ_{US} = Unshielded sample flux ($n \cdot cm^{-2} \cdot s^{-1}$)
Φ_S = Cadmium shielded sample flux ($n \cdot cm^{-2} \cdot s^{-1}$)
Φ_{th} = Thermal neutron flux ($n \cdot cm^{-2} \cdot s^{-1}$)
σ_{th} = Thermal microscopic cross-section (cm^{-2})
Φ_{epi}= Epithermal neutron flux ($n \cdot cm^{-2} \cdot s^{-1}$)
I_o = Resonance integral (barns)

Also, R_{Cd} assists in calculating the thermal and epithermal fluxes, which will be used as a comparison for the experimental sample irradiations [136].

3.3.1.3.2 Thermal to Epithermal Ratio

The cadmium ratio allows for the calculation of the thermal to epithermal flux ratio ($R_{th/epi}$), which informs on the neutron flux energy distribution in the reactor. Also, the ratio will be used as a comparison metric to compare the values obtained from the present study with available historical data. The ratio is defined by Eq. (4) [168]:

$$R_{th/epi} = \frac{\Phi_{th}}{\Phi_{epi}} = (R_{Cd} - 1)\,\frac{I_o}{\sigma_{th}} \tag{4}$$

For the $^{197}Au(n, \gamma)^{198}Au$ reaction, the $\frac{I_o}{\sigma_{th}}$ term has been reported as 15.7 ± 0.3 [167], [168].

3.3.2 Methodology

3.3.2.1 ***Neutron Monitor Selection***

Monitor materials and geometries used in small research reactors to map the neutron field are chosen based on the desired reactions studied and dependent on the material's cross-section spectrum, energy response, environmental conditions, disturbance activity, exposure time, counting method and machining properties. [169].

For the present study, material selection and optimization has been done of the basis of two main parameters (*i.e.,* their availability at the RMC and their ability to provide flux over the whole spectrum of interest (thermal & epithermal)). In addition, factors that can disturb the replicability of the experiment or could affect the sample in unpredictable manners have been eliminated, or if not possible, reduced as far as practically possible.

A non-exhaustive review of literature has revealed several materials that are routinely used to determine neutron flux in research reactors. Of the 30 selected references using neutron activation analysis to map the neutron flux, 13 are using a gold-aluminium alloy [131]–[133], [137], [139], [142], [146], [159], [161], [165], [169]–[171], 12 are using gold [127], [128], [130], [135], [136], [139], [141], [157], [171]–[175]. Other materials are used (*e.g.*, cobalt, copper), but nearly not as prevalent as Al-Au and Au. Table 8 and Figure 22 present a comparison of material properties of interest for the determination of the flux monitor material.

Table 8. Material Properties Comparison [176]

Monitor Material	**Reaction**	**Isotopic Abundance** (%)	**Half-life**	**Emitted Gamma Energy** (main peaks) (keV)
Au	$^{197}Au(n,\gamma)^{198}Au$	100	2.6941 ± 0.0002 d	411.80205 ± 0.00017
Al	$^{27}Al(n,\gamma)^{28}Al$ $^{27}Al(n,p)^{27}Mg$ $^{27}Al(n,\alpha)^{24}Na$	100	2.245 ± 0.002 min 9.458 ± 0.012 min 14.997 ± 0.012 h	1778.987 ± 0.015 843.76 ± 0.10 1368.626 ± 0.005 2754.007 ± 0.011

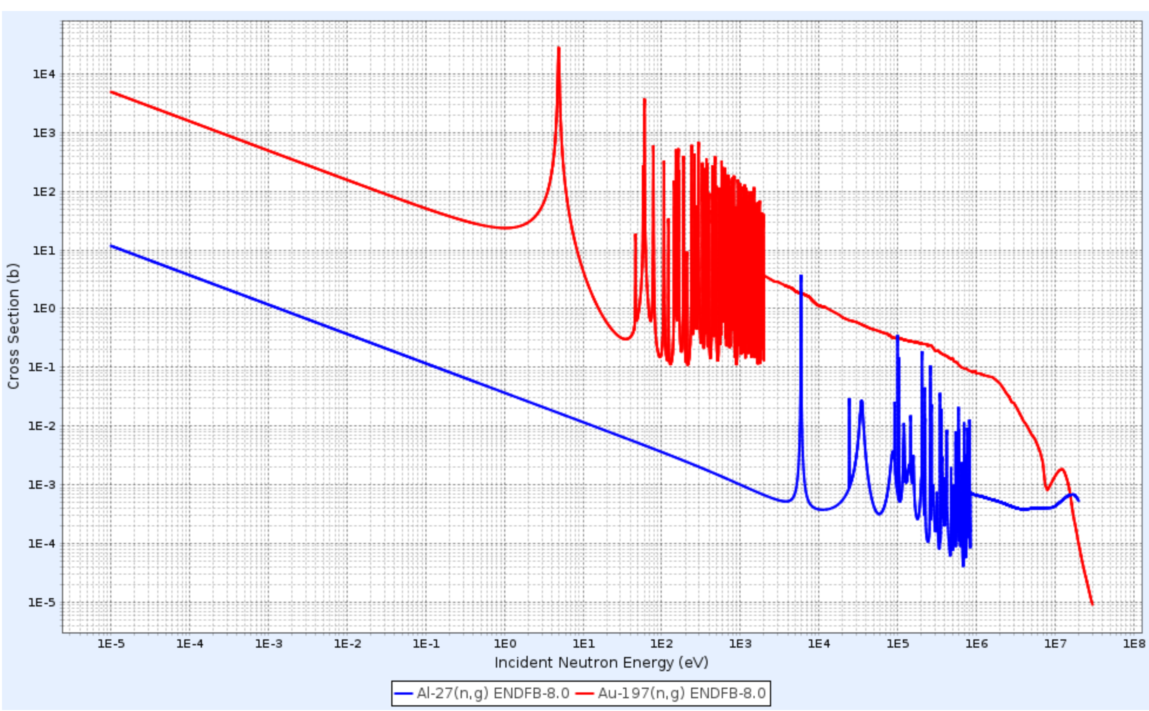

Figure 22. Material Neutron Capture Cross-Section Comparison. (Created from tool at [176])

The four materials considered do not show any resonance over the thermal range of the spectrum and follow a $\frac{1}{v}$ behavior over the whole thermal range for E < 4 eV [49].

Gold, whether in near pure form or in aluminium alloy, is a common material to determine flux in research reactors. Its large neutron capture cross-section (Figure 22) makes it ideal for activation in a reactor and its simple isotopic composition simplifies its use. However, its cross-section also means that long resting periods between irradiation and its analysis by gamma spectroscopy, as well as being more susceptible to self-shielding [177]. This can be partly alleviated by using an Al-Au alloy, effectively diluting the Au in the solid and allowing for longer irradiation [132]. The addition of Al to the monitor also has benefits for the analysis of neutrons in the higher ranges of the energy spectrum. The $^{27}Al(n,\alpha)^{24}Na$ reaction, with a reaction threshold of about 5 MeV, can be used to refine the flux assessment in the higher portion of the neutron spectrum [133].

To mitigate and account for the non-uniform irradiation effects of self-shielding, it is essential to select a material geometry that minimizes its impacts and/or calculate a correction factor. Previous work on the effects of self-shielding with small research reactors (*e.g.,* SLOWPOKE-2 and TRIGA) showed that the flux at the sample sites can be considered nearly isotropic, meaning that there will be a uniform neutron interaction in all directions at a specific location [165]. Based on the near- isotropic neutron flux, and the self-shielding factors' equations at Annex E, the smaller the sample, the less self-shielding there will be regardless of the material's orientation in the irradiation site. Therefore, thin wire was selected as the best geometry, due to its self-shielding reduction capability, its modelling facility and the ability to provide increased experimental consistency, as long as they are maintained longitudinally and centrally located within the sample vials.

Due to its nuclear and geometric properties, based on the objective of diminishing self-shielding, covering a maximum of the neutron spectrum to be assessed and the availability of the monitor material, a 0.12% Au, 99.88% Al, 0.020" wire (from this point identified here as Al-Au wire) was selected as the best choice for the neutron flux mapping of the SLOWPOKE-2.

3.3.2.2 ***Sample Preparation***

Two batches of 12 pieces of wire (20 mm long) were cut and chosen from Al-Au wire stock (Shieldwerx SWX-602D Gold-Aluminum Wire, 99.88% Al, 0.12% Au, 0.020", Lot no. ALAU49019111, Material analysis at Annex F) and weighted on an analytical balance (Mettler Toledo MS104 TS/00). All samples selected were 0.01550 ± o.00005 g. The samples were then prepared for irradiation as per Table 9.

Table 9. Experiment Sample Distribution for the Irradiation in the Reactor

	Inner Site no. 2	**Outer Site no. 10**
Unshielded Blank (BUS)	3	3
Cd-Shielded Blank (BS)	3	3
Cd- Shielded Sample (S)	3	3
Unshielded Sample (US)	3	3

All sample types were prepared in an identical manner for reproducibility with the exceptions that the blanks did not contain an Al-Au wire. The shielded samples were covered in 0.5 ± 0.1 mm cadmium sheets. Figure 23 presents the approximate dimensions and construction of the cadmium shielding. Figure 24 and Figure 25 presents the general arrangement of the samples once assembled.

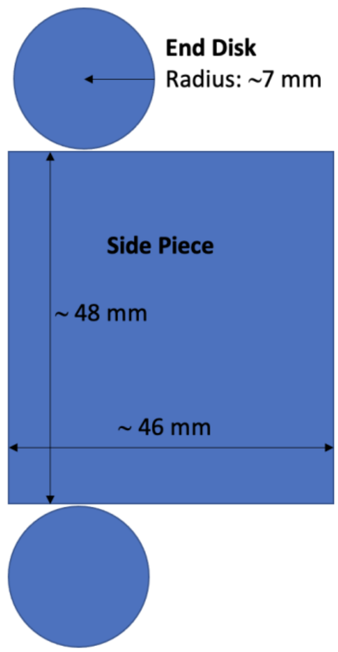

Figure 23. Cadmium Shield Pieces §

§ Not to scale. Showed to display the components of the cadmium shield.

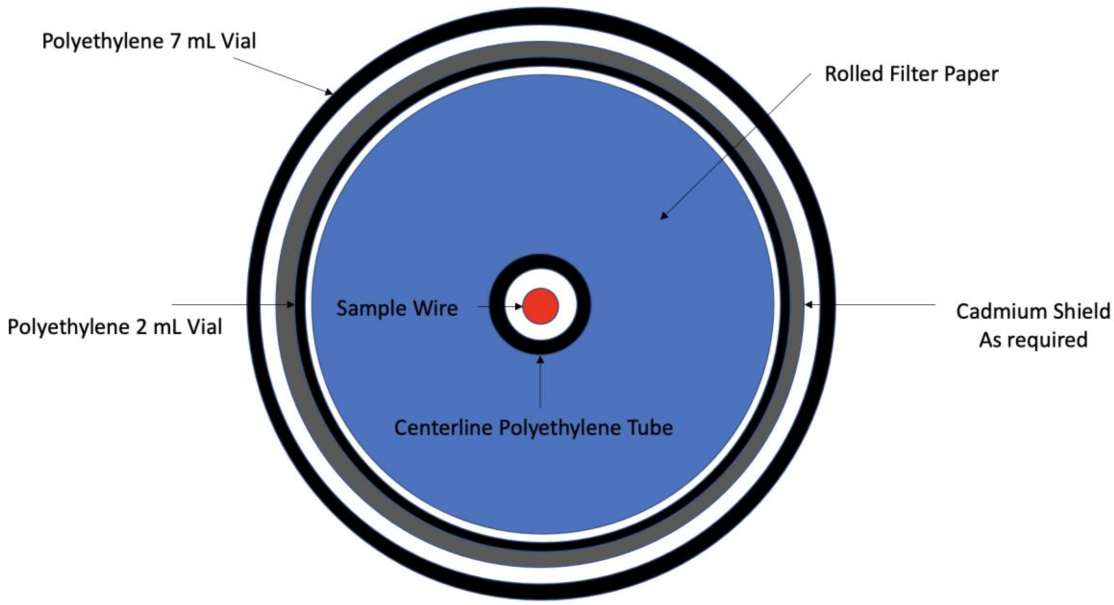

Figure 24. Radial View of the Sample Holder in the 2 mL and 7 mL Vials

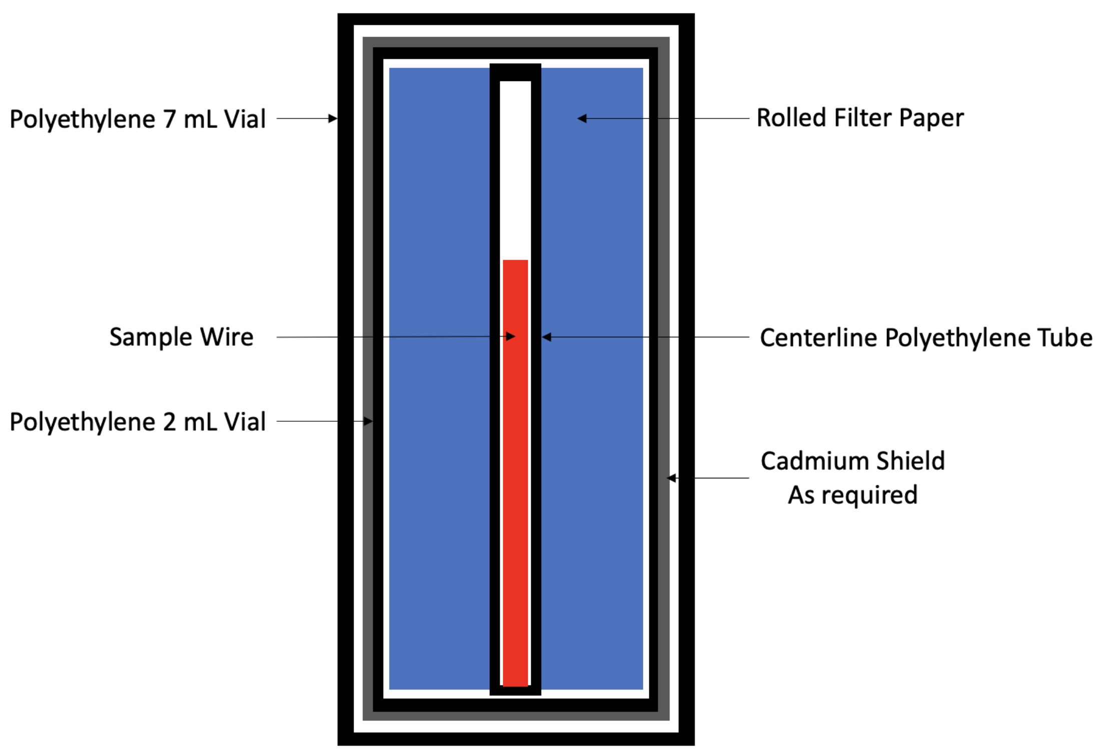

Figure 25. Axial View of the Sample Holder in 2 mL and 7 mL Vials

The Al-Au wire was inserted into a tube (Cole-Parmer Instrument Company, Nat. Polyethylene tubing, Lot 06100-13) tightly wrapped in filter paper (Fiberbrand P4, Cat No. 09-803-6G, Porosity Medium-Fine, Flow rate-Slow) to maintain its vertical orientation at centerline inside the vial. The unshielded samples (US) were then placed inside of a 2 mL vial (Caps: Perfector Scientific, Cryo-Stor Vial Caps, Red, Catalog 2190, Polypropylene; Vials: Perfector Scientific, Cryo-Stor vials 2 mL, Catalog 2190, Polypropylene Copolymer) and 7 mL vial (Polyvial EP-290-NAA Neutron Activation Analysis, Low Density Polyethylene (LDPE)) while the cadmium shielded samples (S) were placed in the 2 mL vial, surrounded in 0.5 mm sheet of cadmium, and then placed in the 7 mL vial. Annex G presents the weighted components of the samples as used for the experiment.

The cadmium shielding material was sourced from sheets available from the RMC SLOWPOKE-2 Laboratory from previous experiments (0.5 mm thick; provenance was not available). The selected cadmium pieces were scrubbed with water to remove surface impurities and then dried using acetone.

Figure 26 and Figure 27 present the sample components prior to assembly. The top of the 7 mL vial was heat sealed to ensure the content remains securely within the vial and bevelled slightly to facilitate movement within the pneumatic tubes during insertion and retrieval from the reactor as per RMC standard procedures.

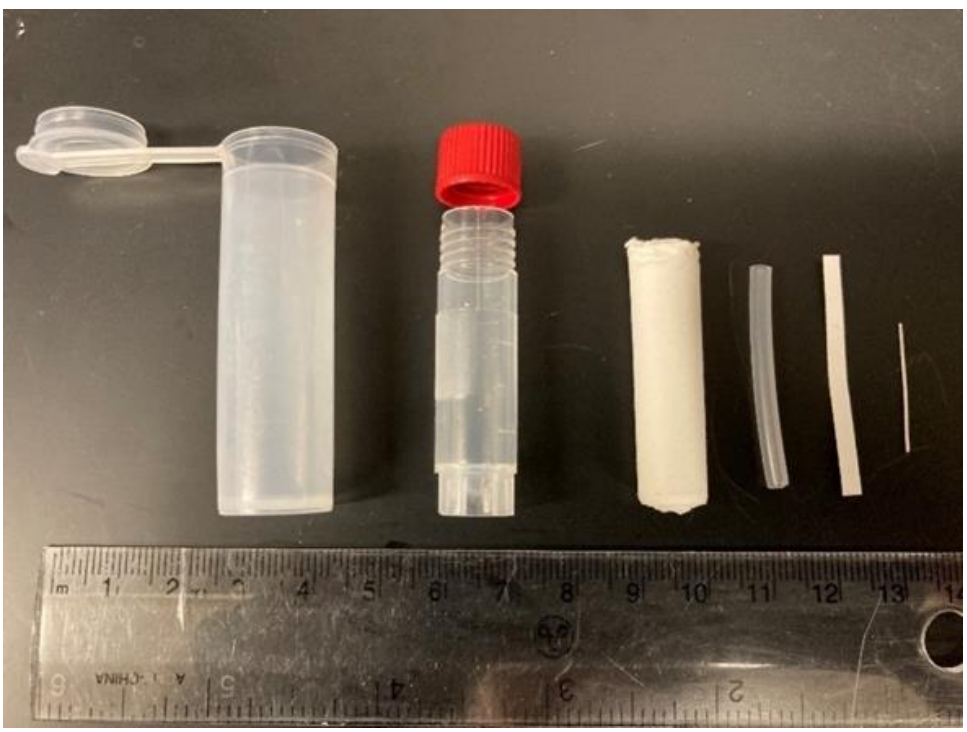

Figure 26. Sample components. Left to Right: 7 mL Vial, 2 mL Vial, Filter Paper Holder, Inner Tube, Filter Paper Piece and Al-Au Wire

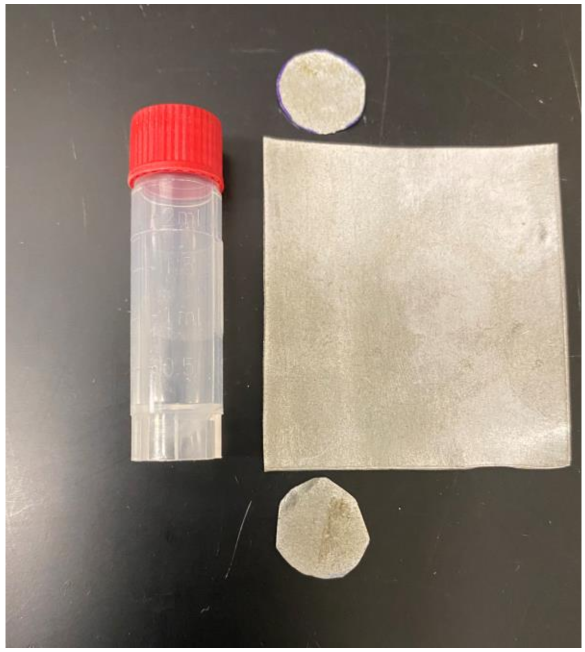

Figure 27. 2 mL Vial (Left) and its Prepared Cadmium Shield (Right)

3.3.2.3 *Irradiation Experimental Method*

Samples were irradiated for 300 ± 1 s with the reactor control set at a neutron flux of 5 x 10 n·cm^{-2}·s^{-1} (half power) and left to decay for approximatively 24 hours before being analyzed on the HPGe detector. A detailed procedure is discussed at Annex H.

3.3.2.4 *Efficiency Determination*

No calibration material containing gold in wire form was available at the RMC, nor was it readily available on the market. Therefore, the Al-Au wire geometry was replicated using a small filter paper strip and laid inside a 1/8" (3.2 mm) polyethylene tube.

The HPGe detector was calibrated for efficiency using the vial and holder structure similar to the samples' construct but changing the wire for a calibration standard (Ecklert & Ziegler, no 7500. Certificate of calibration at Annex I). The calibration solution was inserted in the inner tube of the sample, allowing it to be captured by the filter paper strip in the tube. The vial was then dried in a desiccator until all water had evaporated and weight had stabilized, leaving the radioactive nuclides on the paper strip. The calibration sample was placed on the detector at the same location as all samples and analysed by the HPGe detector. The analysis was conducted in triplicate, with GammaVision providing a calibration curve and associated efficiency equation, which were then applied to the sample results.

3.3.3 Results

Using the developed procedures, in August 2022, the 12 samples and their associated blanks were irradiated in the RMC SLOWPOKE-2 reactor in site 2 (representing the inner irradiation sites) and in site 10 (representing the outer irradiation sites). Timings associated with the experimental processes are available at Annex J.

3.3.3.1 ***Self-Shielding***

Self-shielding factors were calculated using the four methods discussed at Annex K, detailing the methods for the calculations of the self-shielding factors. Annex L presents the output of the MATSSF code.

Table 10. Self-Shielding Factors by Method

Method	Calculated Factor
Stewart & Zweifel	0.999967 ± 0.00003
Universal Sigmoid Curve	G_{Th} = 0.9992 ± 0.0001 G_{Res} = 0.99 ± 0.04
ASTM (William & Gilliam)	G_{Th} = 0.99 ± 0.01
MATSSF**	G_{Th} = 0.9994 ± 0.0001 G_{Res} = 0.9941 ± 0.0001

Based on multiple methods of evaluating the self-shielding factor of the Al-Au sample, and the fact that all results are nearing unity, indicating minimal self-shielding††. It is assessed that self-shielding is not a significant factor affecting the neutron activation analysis conducted due to the geometry of the sample and the dilution of the element of interest (Au) in a matrix of much lesser cross-section (Al) [167]. Therefore, the self-shielding is assessed as negligible, and no correction have been applied to the results.

3.3.3.2 ***Efficiency***

The efficiency curve was calculated by GammaVision version 8.00.03 [178] using the analysed triplicate calibration standard. The report generated by GammaVision on the calibration applied to all samples analyzed is presented at Annex M.

The efficiency curve at Annex M displays the standards' gamma energies detected by the HPGe detector *vs.* its corresponding efficiency.

** MATSSF does not provide error ranges, errors here were selected based on last returned digit.
†† 1 indicating a perfectly uniform activation of the material.

GammaVision's analysis of the efficiency curve returned with Eq. (5) with a computed uncertainty of 4% [179].

$$\varepsilon = e^{\left((-1.1690)+(0.042936)\ln(E)+(-0.0703929)(\ln(E))^2\right)} \quad (5)$$

Where

E = Peak energy of interest (keV)

Evaluated at ^{198}Au's energy peak of 411.8 keV, the HPGE detector efficiency returned from Eq. (5) is 0.031 ± 0.001.

3.3.3.3 ***Total Flux***

The neutron flux detected by each sample was calculated using the known experimental parameters and the sample's characteristics using Eq. (2). An example of the calculations is available at Annex K. The obtained experimental total flux (including thermal, epithermal, and fast neutron fluxes components) and associated data are presented at Table 11.

Table 11. Calculated Flux Using Reaction ^{197}Au(n, γ)^{198}Au at Half Power

			Sample	**Detection Time** (seconds) (± 0.01 s)	**Counts at 411.8 keV** (count)	**Experimental Total Flux** (x10^{11} n·cm^{-2}·s^{-1})
Inner Site (no. 2)	Blanks	Unshielded	USB1	300.00	0	-
			USB2	300.00	0	-
			USB3	300.00	0	-
		Cd Shielded	SB1	3600.00	0	-
			SB2	3600.00	0	-
			SB3	3600.00	0	-
	Samples	Unshielded	US1	300.00	19 820 ± 140	10.1 ± 0.6
			US2	300.00	26 710 ± 170	10.5 ± 0.6
			US3	300.00	25 700 ± 160	10.0 ± 0.6
		Cd Shielded	S1	3600.00	102 760 ± 330	5.3 ± 0.3
			S2	3600.00	157 98 0± 410	5.1 ± 0.3
			S3	3600.00	157 310 ± 410	5.1 ± 0.3
Outer Site (no. 10)	Blanks	Unshielded	USB4	300.00	0	-
			USB5	300.00	0	-
			USB6	300.00	0	-
		Cd Shielded	SB4	3600.00	0	-
			SB5	3600.00	0	-
			SB6	3600.00	0	-
	Samples	Unshielded	US4	300.00	7 770 ± 90	3.9 ± 0.2
			US5	300.00	10 390 ± 100	4.1 ± 0.2
			US6	300.00	10 720 ± 110	4.1±0.2
		Cd Shielded	S4	3600.00	18 160 ± 140	0.95±0.06
			S5	3600.00	30 800 ± 180	0.96±0.06
			S6	3600.00	24 270 ± 160	0.98±0.06

The blanks, both for the shielded and unshielded, revealed no contamination at the 411.8 keV peak. Therefore, no corrections were necessary to compensate for contamination. Samples of GammaVision outputs for samples S1 and US1 are available at Annex N and Annex O respectively.

3.3.3.4 ***Cadmium Ratio and Thermal to Epithermal Ratio***

The cadmium ratios were calculated using Eq. (3) from the experimental ^{198}Au activities computed by GammaVision, using the average activities for each sample groups. The thermal to epithermal ratios were computed using the calculated cadmium ratios as per Eq. (4). Table 12 presents the obtained calculated ratios.

Table 12. Cadmium Ratios and Thermal to Epithermal Ratios

		Sample	**^{198}Au Activity** (Bq)	**Average Activity** (Bq)	**Cadmium Ratio**	**Thermal to Epithermal Ratio**
Inner Site (no. 2)	Unshielded	US1	3 780 ± 150	3 840 ± 90	1.98 ± 0.06	15.4 ± 0.6
		US2	3 960 ± 150			
		US3	3 780 ± 150			
	Cd Shielded	S1	1 990 ± 80	1 940 ± 40		
		S2	1 920 ± 80			
		S3	1 900 ± 80			
Outer Site (no. 10)	Unshielded	US4	1 460 ± 60	1 510 ± 30	4.2 ± 0.1	50 ± 2
		US5	1 520 ± 60			
		US6	1 560 ± 60			
	Cd Shielded	S4	354 ± 14	359 ± 8		
		S5	357 ± 14			
		S6	365 ± 14			

3.3.3.5 ***Thermal, Epithermal/Fast Neutron Fluxes***

Using the total flux and the flux obtained from the cadmium shielded samples, it is possible to obtain an estimate of the thermal flux. Eq. (6) shows the method used to estimate the experimental thermal flux. Table 13 presents the calculated thermal and epithermal/fast fluxes.

$$\Phi_{th} = \Phi_{US} - \Phi_{S} \quad (6)$$

Table 13. Calculated Experimental Thermal, Epithermal/Fast Flux

		Sample	**Experimental Total Flux** ($x10^{11}$ n·cm^{-2}·s^{-1})	**Average Experimental Site Total Flux** ($x10^{11}$ n·cm^{-2}·s^{-1})	**Thermal Flux** ($x10^{11}$ n·cm^{-2}·s^{-1})	**Epithermal/ Fast Flux** ($x10^{11}$ n·cm^{-2}·s^{-1})
Inner Site (no. 2)	Unshielded	US1	10.1 ± 0.6	10.2 ± 0.3	5.0 ± 0.2	5.2 ± 0.3
		US2	10.5 ± 0.6			
		US3	10.0 ± 0.6			
	Cd Shielded	S1	5.3 ± 0.3	5.2 ± 0.2		
		S2	5.1 ± 0.3			
		S3	5.1 ± 0.3			
Outer Site (no. 10)	Unshielded	US4	3.9 ± 0.2	4.0 ± 0.1	3.1 ± 0.1	0.97 ± 0.06
		US5	4.1 ± 0.2			
		US6	4.1 ± 0.2			
	Cd Shielded	S4	0.95 ± 0.06	0.97 ± 0.03		
		S5	0.96 ± 0.06			
		S6	0.98 ± 0.06			

3.3.4 Analysis

As the computational methods (Rook and Lamarre) have significant differences between their obtained values and that seen by the studies using the NAA methods, only the NAA methods (Table 7) have been retained here for direct comparison [117], [121]. Computational methods will be reviewed in section 3.4 in conjunction with the MCNP results of the NAA experiment simulation.

It is expected that the experimental values will not conform perfectly to literature data due to the variety of differences between the studies conducted and the present work. Specifically, the RMC SLOWPOKE-2 reactor has a new core that, even if it should operate similarly as other likewise designed LEU cores, could have unknown differences since no in-depth study has been completed yet on the new fitted core. Rather, the objective of the present analysis section is to confirm general agreements and trends between the literature values and the experimental values, which will be used in turn to benchmark the MCNP model.

3.3.4.1 *Cadmium Ratios*

Unfortunately, not all reviewed studies used the same method to obtain cadmium ratios. Acharya & Chatt at Dalhousie were using the cadmium lined site no. 9, Andrews used a 1.02 mm thick cadmium tubing and Neisiani used a cadmium shield of unspecified thickness [161]–[163]. The cadmium lined irradiation site's thickness is not specified for the Dalhousie SLOWPOKE-2, but the RMC SLOWPOKE-2 legacy MCNP 6.1 model code from Rook specify a cadmium lining of site 9 at 0.508 mm thickness [121].

Table 14 presents the literature cadmium ratios and compare with the obtained experimental values from this work.

Table 14. Cadmium Ratios - Comparison with Literature*

		Present Study RMC	**Acharya & Chatt** [162] Dalhousie	**Andrews** [161] RMC
Cadmium Ratio	Inner Site	**1.98 ± 0.06 (#2)**	2.13 ± 0.03 (#2) 2.14 ± 0.04 (#3)	2.1 ± 0.1 (#3) 2.0 ± 0.1 (#4)
	Outer site	**4.2 ± 0.1 (#10)**	4.58 ± 0.11 (#10)	1.10 ± 0.07 (#9) 4.5 ± 0.3 (#10)

*Site numbers in parenthesis when known

Overall, although the obtained results are not encompassed by the uncertainties of all the literature values, there is a definite agreement with the cadmium ratios experimentally obtained. The experimental values conform best with the other RMC study from Andrews.

3.3.4.2 ***Thermal to Epithermal Flux Ratios***

The thermal and epithermal fluxes calculated from the experiment can be used to determine the flux energy distribution in the RMC SLOWPOKE-2 reactor. The results are overall comparable to previous studies as shown in Table 15.

Table 15. Thermal to Epithermal Flux Comparison*

	Present Study RMC	**Acharya & Chatt** [162] Dalhousie	**Neisiani** [163] Polytechnique	**Kennedy *et al.*** [164] Polytechnique	**Andrews** [161] RMC
Inner Site	**15.4 ± 0.6 (#2)**	18.8 ± 0.4 (#2) 18.9 ± 0.4 (#3)	18.1 ± 0.3	19.8 ± 0.4	17.4 ± 1.0 (#3) 15.8 ± 0.9 (#4)
Outer site	**50 ± 2 (#10)**	57.1 ± 2.2 (#10)		55.4 ± 3.0	1.60 ± 0.09 (#9) 55.3 ± 3.3 (#10)

*Site numbers in parenthesis when known

The trend seen for the cadmium ratio is revisited here. Across the board, the experimental values obtained here are lower than the literature values. Similarly, as with the cadmium ratios, Andrew's results obtained at the RMC are the closest, particularly at the inner site where the experimental results intersect at the periphery of their respective uncertainties for site 2 and 4. [161]. Overall, all results are relatable, although not as convincingly as with the case of the cadmium ratios.

As is, the thermal to epithermal ratio, combined with the cadmium ratio indicate that the contribution of the experimental epithermal flux of is more important here than in the existing literature results. Considering the thermal to epithermal ratio was calculated using the cadmium ratio's values using Eq. (4) it is expected that uncertainties and errors would propagate here as well.

3.3.4.3 *Thermal Flux*

A comparison between the present experimental thermal neutron flux and the available literature is presented at Table 16. Overall, there is a good agreement between the values, particularly with the inner site neutron flux.

Table 16. Experimental Thermal Neutron Flux*

		Present Study RMC	**Neisiani** [163] Polytechnique	**Andrews** [161] RMC
Thermal Flux ($n \cdot cm^{-2} \cdot s^{-1}$) x$10^{11}$	Inner Site	**5.0** ± **0.2** (#2)	5.3 ± 0.3 to 5.41 ± 0.3	5.7 ± 0.3 (#1) 5.8 ± 0.3 (#3) 5.6 ± 0.3 (#4) 5.5 ± 0.3 (#5)
	Outer site	**3.1** ± **0.1** (#10)		2.8 ± 0.1 (#6) 0.160 ± 0.008 (#9) 2.6 ± 0.1 (#10)

*Site numbers in parenthesis when known

3.3.4.4 *Errors and Uncertainties*

All standard errors and uncertainties inherent to neutron activation analysis, extensively presented by Greenberg, Bode & De Nadai Fernandes, apply to the present case: timing errors, nuclear data uncertainties, *etc.* [125]. Errors and uncertainties that are specifically linked to the present study, its protocol, and its results include:

- Cadmium shield thickness (Negligible, investigated at section 3.4.5.3);
- Neutron leaks from improperly shielded samples (Probable);
- Sample components impurities (Negligible); and,
- Reactor time to reach steady state as a significant fraction of irradiation time (Minimal).

Although the above potential errors cannot be wholly dismissed, considering the results are generally in agreement with existing literature, it is assessed that their impact is minimal. Annex P present a detailed analysis of NAA error and uncertainties.

3.3.5 Overall Assessment of NAA Results

Overall, the neutron fluxes, cadmium ratios and thermal to epithermal ratios obtained by NAA relate favorably with the values seen from selected historical literature on the existing SLOWPOKE-2 fleet. It is therefore assessed that the NAA results are valid as the baseline with which to benchmark the updated MCNP 6.2 model.

3.4 MNCP 6.2 NAA Simulation

3.4.1 Overview

The purpose of the present section is to present the MCNP simulation conducted to replicate the NAA experimentation. The results of the simulation will be compared both to NAA experimental results obtained and to literature data for computational methods.

First, an overview of the model will be conducted, both for the original model and for the updated model used for the NAA experiment simulation. Then, the simulation itself and associated results will be presented in the optic of both benchmarking the method, and providing results that can be used as comparison with existing values so that the model itself can be benchmarked as an adequate representation of reality.

3.4.2 Monte Carlo N-Particle Code Overview

The Monte Carlo method is a probabilistic method that has originally been developed to solve neutron transport problems by Los Alamos National Laboratories (LANL) [180]. It remains today, through multiple available codes, one of the main methods of tackling particle transport problems. It is well suited to handle the complexity and probabilistic nature of particle behaviour.

MCNP is a powerful "general-purpose, continuous-energy, generalized-geometry, time-dependent" Monte Carlo particle transport code [181]. Using user-generated input files determining geometry, material, source and tallies defined to return the required results, the code can generate accurate solutions to complex particle transport scenarios. MCNP uses pseudo-random sampling to determine interactions outcomes, following individual neutrons from their creation to their "death" or exit of the area of interest. Throughout their life, the neutrons interact with matter or other particles. Each interaction is assessed and modelled based on probabilities of outcomes determined by physics models or from tabulated nuclear data from libraries. The outcome is a history of the particle conducting a "random walk" in space and colliding with matter. The collision occurrences are tallied, the history is repeated multiple time and the results aggregated.

It is outside of the scope of the present work to cover MCNP's significant complexity and inner workings. However, the technical literature on MCNP's mechanisms and capabilities is plentiful and readily available from LANL, notably, the reader may wish to consult the *MCNP User's Manual* and the *Overview and Theory Manual* for details. [48], [181], [182].

3.4.3 Updated Model

Multiple models were obtained from archives used by Rook, which had previously been benchmarked to represent the original core from the reactor commissioning in 1985 [121]. The "detailed model" was retained and updated to reflect the changes that occurred to the core during refuelling, as well as improving on several aspects to bring the model closer to the reactor as fitted at the RMC. Amongst other, the following were substantially modified:

- Fuel composition;
- Fuel density;
- Core layout (198 to 195 fuel elements); and
- Core alignment.

Modifications and improvements are detailed at Annex Q. A complete updated MCNP input file is presented at Annex R for the no. 2 site shielded sample.

3.4.3.1 ***Samples***

3.4.3.1.1 Geometry

In order to simulate the NAA experiment conducted for section 3.3, the geometry of the sample's components were reproduced as closely as possible to the physical sample irradiated in the reactor, while simplifying the model where necessary to facilitate modelling. Figure 28 and Figure 29 present the geometry of the sample as modelled in MCNP.

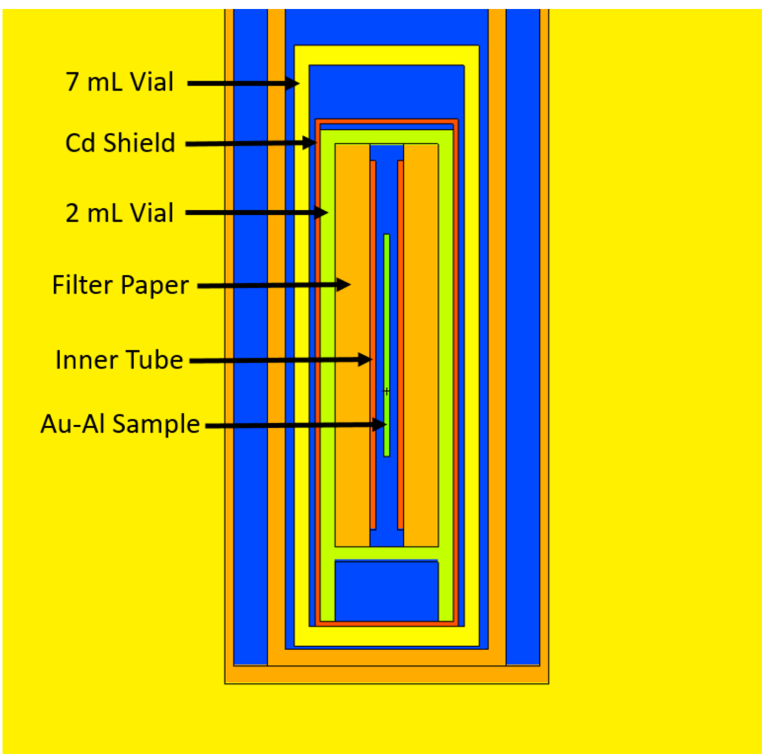

Figure 28. Modelized NAA Sample Axial View (Shielded Sample Displayed)

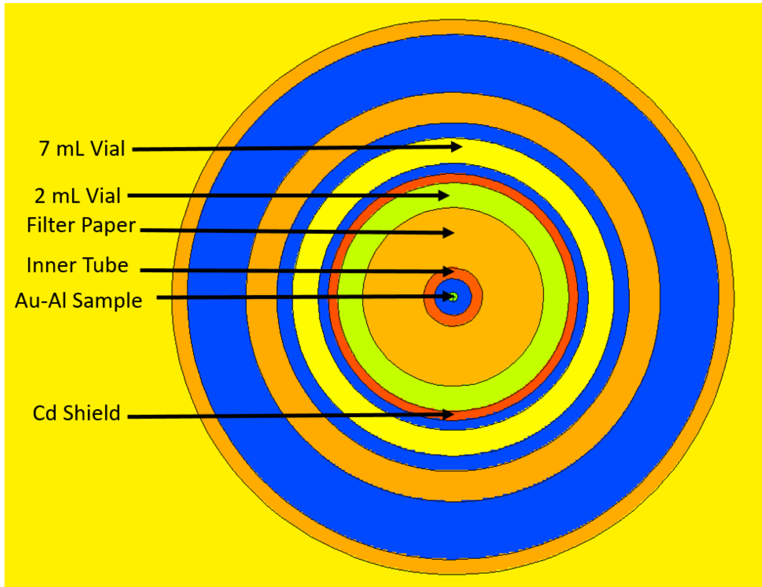

Figure 29. Modelized Sample Radial View (Shielded Sample Displayed)

The geometry of the vials was simplified by assuming perfect cylinders and disregarding the caps. In a similar manner, the 0.5 mm thick cadmium shield was assumed to be "perfect" completely enclosing the 2 mL vial without gaps. The rolled filter paper around the inner tube was assumed to be tight enough to be modelled as one solid block of filter paper rather than attempting to model a rolled up piece of paper.

One discrepancy from the physical sample is the apparent gap between the 7 mL vial and the cadmium shield. In reality, the cadmium shield fitted very tightly between the 2 mL vial and the 7 mL vial without, as far as could be seen, gaps.

3.4.3.1.2 Materials

The only material with known composition and available analysis is the Al-Au sample (Annex G). However, considering the approximate nature of the impurities and their proportion compared to the Au and Al material, the wire was modelled as a "perfect" sample. Likewise, all components of the sample arrangement were modelled as ideal materials.

Despite searches on the nature of the material involved, it was often only possible to get an approximation of the density of the material used. Table 17 presents the ideal materials' compositions used in the MCNP model and their respective densities. Where densities were uncertain and provided in a possible range, an average of densities' limits were used.

Table 17. MCNP Sample Material Composition and Density

Component	Material	Ideal Composition	Density ($g \cdot cm^{-3}$)	Model Material Density ($g \cdot cm^{-3}$)
7mL Vial	LDPE	C_2H_4	0.917-0.930 [183]	0.92
2 mL Vial	Polypropylene Copolymer	C_3H_6	0.905 [183]	0.905
Filter Paper	Cellulose	$C_6H_{10}O_5$	0.69 (measured)	0.69
Inner Tube	Polyethylene	C_2H_4	0.917-0.930 [183]	0.92
Cd Shield	Cadmium	^{106}Cd – 1.25% ^{108}Cd – 0.89% ^{110}Cd – 12.49% ^{111}Cd – 12.8% ^{112}Cd – 24.13% ^{113}Cd – 12.22% ^{114}Cd – 28.73% ^{116}Cd – 7.49% [176]	8.65 [50]	8.65
Al-Au Sample	Al-Au alloy	^{198}Au – 0.12% ^{27}Al – 99.88%	2.719 (Calculated)	2.719

3.4.3.2 ***Library***

The codes typically require other inputs either from other supporting codes or from particles and elements data libraries, most notably to provide cross-section information. The libraries provide the underlying material information which is used in the simulation, notably nuclear and atomic data used to resolve particle interactions. For MCNP models, the default nuclear data libraries are of the ENDF/B series released by the Cross-Section Evaluation Working Group of the IAEA [184].

The original MCNP model used ENDF/B-VII.1 for all material and cross-section data required by MCNP [121]. To use the latest available nuclear data, the model was updated to the ENDF/B-VIII.0 based library *Lib80x* downloaded from LANL's nuclear data libraries website [185].

Unless changes have been explicitly identified, composition of existing material and densities have not been altered from the original model, only the library identifiers have been updated to allow MCNP to select the latest data available [121].

3.4.4 Methodology

Throughout the MCNP simulation, it has been endeavoured to use best practices as listed in the *MCNP User's Manual* [236]. Details of the simulation parameters and methodology are available at Annex S. Assessment of the MCNP's 10 statistical checks of results and the evaluation of the Shannon entropy have been conducted to ensure statistically relevant results obtained through the simulations.

MCNP's parameters were selected to optimize the code to obtain minimal results' errors and minimize computational resources requirements.

3.4.5 Results and Analysis

3.4.5.1 *Results' Statistical Confirmation*

The Shannon entropy method ascertained that the Monte Carlo system converges for all simulation runs, and an appropriate number of cycles are disregarded before tallies are aggregated. As well, that all statistical checks automatically conducted by MCNP were confirmed passed on all tallies. This provides confidence that the results and their associated error will cover the "true" value [181].

3.4.5.2 *NAA Experiment Simulation*

The neutron flux at the sample was determined using a F4 tally encompassing the whole simulated Al-Au wire sample. Table 18 presents the results from the NAA experiment replication and associated ratios. The results showed are computed using the "Duchesne" scaling factor (Annex U). Fluxes' errors are computed by MCNP and taken from the output file (one standard deviation).

Table 18. NAA Replication MCNP Results

	Neutron Groups	Neutron Flux Unshielded Sample ($x10^{11}$ $n \cdot cm^{-2} \cdot s^{-1}$)	Neutron Flux Shielded Sample ($x10^{11}$ $n \cdot cm^{-2} \cdot s^{-1}$)	Thermal to Epithermal Ratio	Cadmium Ratio
Inner Site (no. 2)	Thermal	4.88 ± 0.03	0.271 ± 0.009	10.8 ± 0.3	1.83 ± 0.02
	Epithermal	0.45 ± 0.01	0.43 ± 0.01		
	Fast	5.15 ± 0.04	5.03 ± 0.04		
	Total	10.48 ± 0.05	5.73 ± 0.04		
Outer Site (no. 10)	Thermal	2.38 ± 0.02	0.049 ± 0.003	33 ± 2	4.7 ± 0.1
	Epithermal	0.071 ± 0.004	0.077 ± 0.004		
	Fast	0.54 ± 0.01	0.51 ± 0.01		
	Total	2.99 ± 0.02	0.64 ± 0.01		

As with the NAA experimental results which were compared to historical NAA experimental results, data obtained from the MCNP simulation will be compared with other computationally supported studies, namely Lamarre and Rook.

Considering the reactor refuelled in September 2021 is simulated here, with added details to the code, the aim is not to obtain identical data nor to replicate previous studies. However, general trend lines are expected to remain similar, namely the thermal flux, as the reactor is controlled by thermal neutron flux detection, and the new core has been designed to retain the same thermal flux characteristics as the legacy core.

3.4.5.2.1 Neutron Flux

The neutron flux was evaluated by using a F4 tally, using the wire sample as the tally cell. The obtained results are highlighted at Table 19. The energy bins for the thermal neutron flux were identical to both Lamarre and Rook (Annex S) [117], [121].

Table 19. Simulated Neutron Flux Comparison with Literature

		Present Study	**Lamarre** [117]	**Rook** [121] RMC		
		RMC	RMC	Fresh Fuel	Depleted Fuel	Detailed Fuel
Thermal Flux (n·cm^{-2}·s^{-1}) x10^{11}	Inner Site	**4.88 ± 0.03**	5.00±0.25	5.19 ± 0.16	5.31 ± 0.16	5.11 ± 0.15
	Outer site	**2.38 ± 0.02**	3.01 ± 0.09	2.59 ± 0.09	2.63 ± 0.13	2.50 ± 0.13
Epithermal Flux (n·cm^{-2}·s^{-1}) x10^{11}	Inner Site	**0.45 ± 0.01**	0.424 ± 0.021	0.497 ± 0.025	0.454 ± 0.023	0.471 ± 0.024
	Outer site	**0.071 ± 0.004**	0.0905 ± 0.0045	0.0805 ± 0.0040	0.0783 ± 0.0039	0.0779 ± 0.0040
Fast Flux (n·cm^{-2}·s^{-1}) x10^{11}	Inner Site	**5.15 ± 0.04**	-	5.44 ± 0.15	5.57 ± 0.15	5.42 ± 0.15
	Outer site	**0.54 ± 0.01**	-	0.548 ± 0.027	0.580 ± 0.029	0.558 ± 0.028

In the case of the comparison with Rook, considering the current core has new fuel and the NAA experimentations were conducted on the reactor core with very few burnup days since refuelling, the best comparison would be with the "fresh fuel" model, as well as with the "detailed fuel" model which also uses fresh fuel. It is also to be considered that the current model used here was updated and modified from the detailed fuel model, from which it retains its general geometry and construct.

Across the board, the thermal flux obtained for the present study are markedly lower than the values obtained by both Rook and Lamarre, even when accounting for errors. Of both Rook and Lamarre, Rook's model is the most detailed, using more modern code, and therefore a likely better direct comparison subject. Lamarre's model using WIMS-AECL in two dimensions does not consider the control rod position, and the effect of the upper and lower beryllium reflectors. As well, the WIMS-AECL code provides relative neutron fluxes. The SPND detected flux was used to convert the relative values to absolute neutron fluxes by assigning the SPND value to the SPND location.

It is posited that the discrepancy might be due, amongst other potential sources of errors, to the reactor power used for the simulation and, in the case of Rook specifically, to the scaling factor used to calculate the tallies in MCNP (*i.e.,* 9.6 kW_t scaling factor used for this work *vs.* 10 kW_t used in past studies). As well, physical differences between the legacy core and the new core should not be discounted. However, the general trends remain similar and consistent throughout the results.

3.4.5.2.2 Thermal to Epithermal Ratios

The thermal to epithermal ratios obtained from the simulations are presented at Table 20. Being a ratio, the thermal to epithermal ratio can go beyond the discrepancy in absolute flux values and highlight the specificities of the neutron field in the reactor. This is particularly important when it comes to comparing the difference studies done on the

SLOWPOKE-2 with regard to the potential for operating power discrepancies between the studies.

Table 20. MCNP Simulation's Thermal to Epithermal Ratios Comparison with Literature

	Present Study	**Lamarre** [117]	**Rook**[121] RMC		
	RMC	RMC	Fresh Fuel	Depleted Fuel	Detailed Fuel
Inner Site	**10.8** ± **0.3**	11.8 ± 1.8	10.4 ± 0.6	11.7 ± 0.7	10.9 ± 0.6
Outer site	**33** ± **2**	33.3 ± 3.3	32 ± 2	34 ± 2	32 ± 2

The values obtained with the MCNP 6.2 simulations are statistically similar to both Lamarre and Rook's values when taking the errors into account. It is important to note that thermal to epithermal ratios are not provided directly by Rook, but the ratio was computed using the thermal and epithermal values from the MCNP 6.1 runs in the same manner as it was done for the MCNP 6.2 values.

Despite the geometric changes to the core's orientation, the material changes and inclusion of impurities in the fuel, the neutron field has remained similar for both the legacy and new cores. This result was to be expected considering that the new core was designed to operate with similar neutron field characteristics as the old core, specifically for the thermal neutron portion of the energy spectrum.

3.4.5.3 *Cadmium Thickness Impact on NAA Experiment*

Section 3.3.4.1 highlighted a possible issue with regard to the cadmium shield thickness being inconsistent between literature experiments. In order in investigate the impact of the cadmium shield thickness on the NAA experimental and MCNP simulation results, a model was created from the MCNP shielded samples, increasing the cadmium shield from 0.5 mm to 1 mm.

Figure 30 presents the neutron flux experienced at a sample simulated in site 2 of the reactor with a shield of 1 mm and 0.5 mm. As a point of comparison, unshielded data have been added.

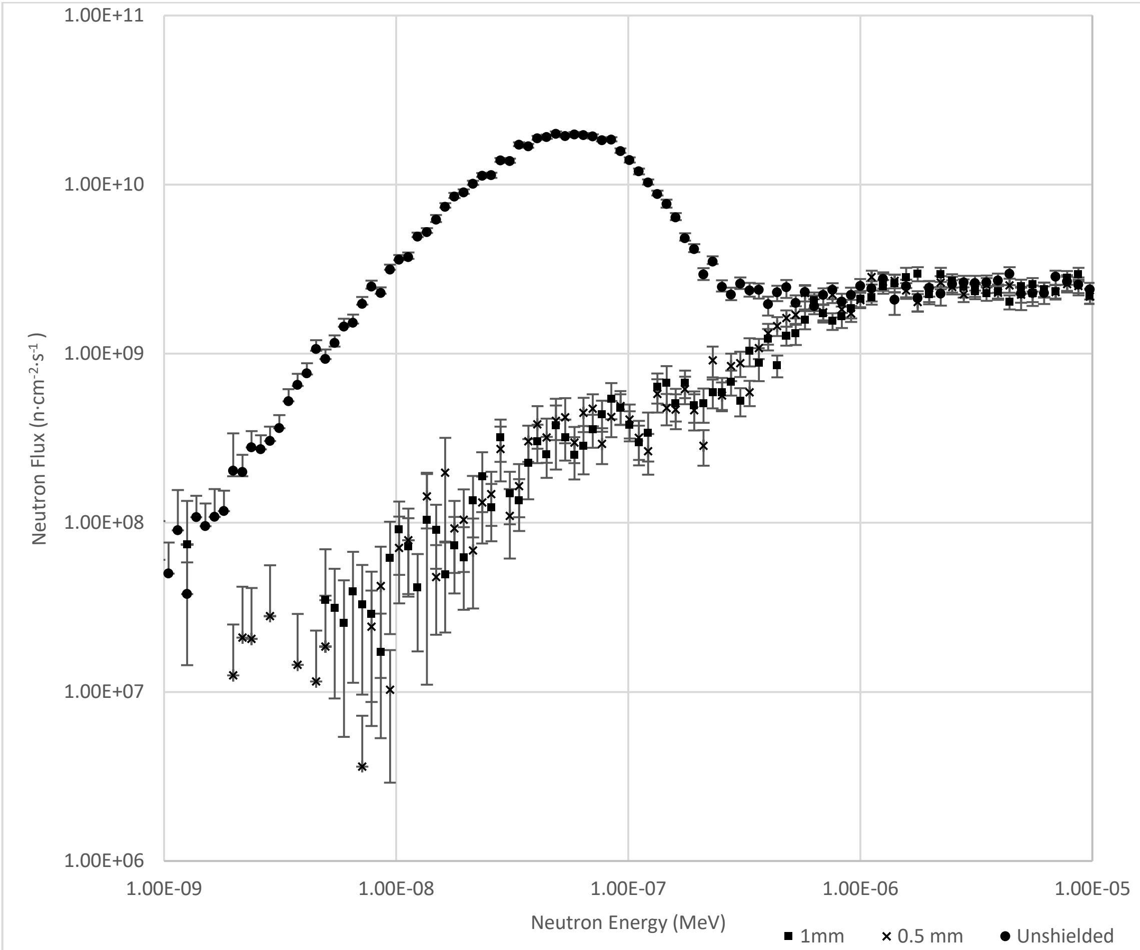

Figure 30. Comparison of Cadmium Shields of 0.5 mm and 1 mm Thickness at Site 2

When compared to the unshielded sample neutron flux, both the 0.5 mm and 1 mm shielded sample are behaving as expected from a sample covered in cadmium. The cadmium's high cross-section shields the sample, although imperfectly, from the incident neutrons up to the cadmium cut-off region around the 1×10^{-6} MeV region of the graph, where the neutron flux returns to similar levels as for the unshielded sample.

A paired *t*-test conducted on the two distributions from 1×10^{-9} MeV to 6.25×10^{-7} MeV (thermal flux limit) indicate support for the null hypothesis: both the 0.5 mm and 1 mm neutron flux distributions are statistically similar ($t(70)=-1.672$, $p=0.099$, $a=0.05$) [186]. Overall, there is no discernible significant difference between the two flux distributions for the shielded samples. It is also not possible to see a significant difference for the cadmium cut-off.

Table 21 presents the inner site's binned neutron flux for the 0.5 mm and 1 mm shielded samples and the unshielded sample.

Table 21. Impact of Cadmium Shield Thickness on Neutron Flux (Inner Site 2)

	Unshielded	0.5 mm Shield	1 mm Shield
Thermal Flux ($n \cdot cm^{-2} \cdot s^{-1}$) x$10^{11}$	4.88 ± 0.03	0.271 ± 0.009	0.245 ± 0.008
Epithermal Flux ($n \cdot cm^{-2} \cdot s^{-1}$) x$10^{11}$	0.45 ± 0.01	0.43 ± 0.01	0.43 ± 0.01
Fast Flux ($n \cdot cm^{-2} \cdot s^{-1}$) x$10^{11}$	5.15 ± 0.04	5.03 ± 0.04	5.07 ± 0.04
Total Flux ($n \cdot cm^{-2} \cdot s^{-1}$) x$10^{11}$	10.48 ± 0.05	5.73 ± 0.04	5.75 ± 0.04

Results show a marked decrease in neutron flux for the thicker cadmium shield, which is to be expected. However, since the cadmium ratio is computed from the total flux using Eq. (3), the difference of 0.02 x 10^{11} $n \cdot cm^{-2} \cdot s^{-1}$ between the 0.5 mm and the 1 mm would not affect the ratio significantly.

The investigation of the cadmium shield thickness using the MCNP 6.2 model has demonstrated that, for the purpose of determining the cadmium ratio in the SLOWPOKE-2, a 0.5 mm cadmium shield around the sample was of a similar efficiency as a 1 mm cadmium shield, therefore, the ratio obtained remains valid as long as the actual thickness of the cadmium shield is between 0.5 and 1 mm.

3.4.5.4 ***Neutron Energy Distribution***

The energy distribution of the neutron field generated by the SLOWPOKE-2 reactor, for both the inner and outer irradiation sites is presented at Figure 31. Across the energy spectrum, the inner site displays a higher flux than the outer site. Overall, the energy distribution is behaving as would be expected for a reactor designed as a thermal neutron generator. The vast majority of the created neutrons are being moderated to energies within the thermal range. By the time neutrons reach the outer site, they have encountered more moderating material than the neutrons reaching the inner site, therefore, proportionally more of the neutron field has been moderated to the thermal region. Computationally, this is seen by the significant increase in thermal to epithermal ratio from the inner to the outer site.

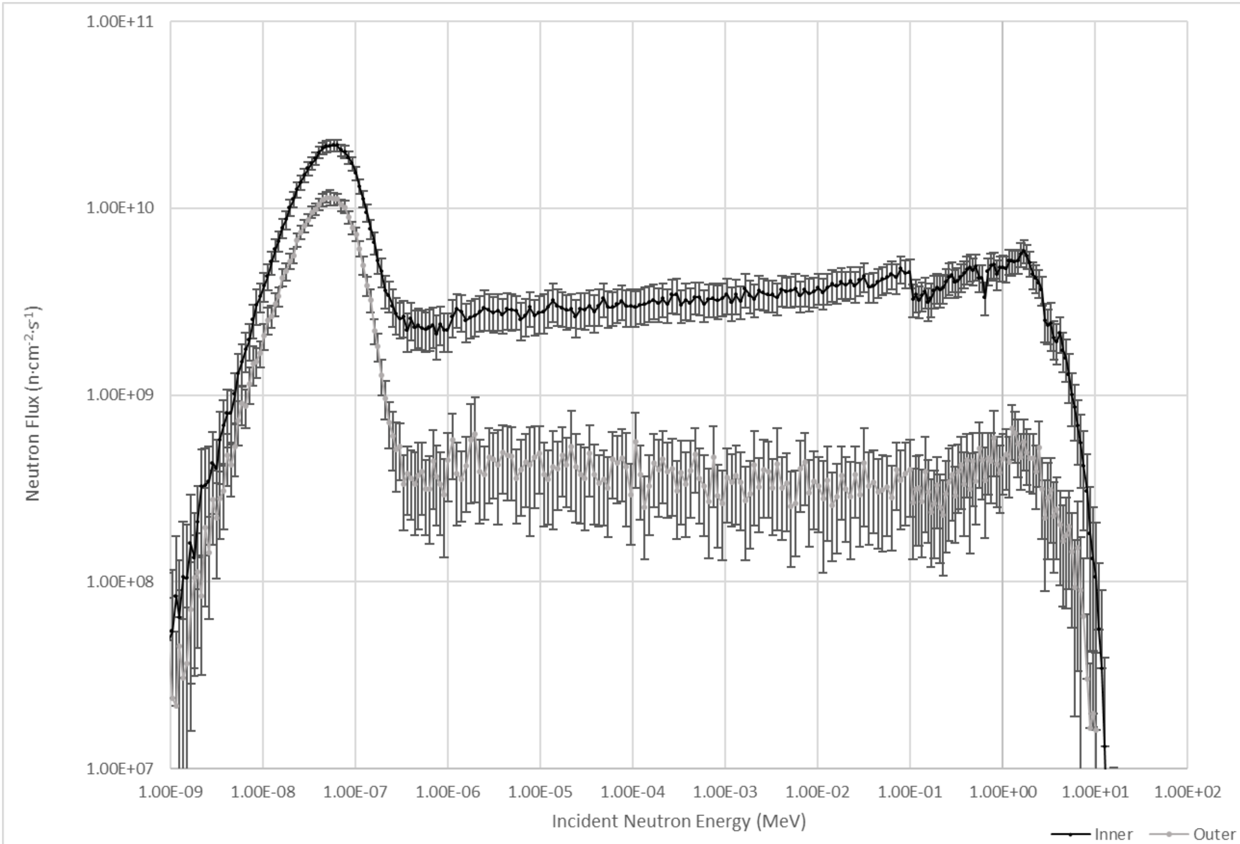

Figure 31. Neutron Flux Distribution at the Inner and Outer Irradiation Sites

Figure 31 was generated by averaging the sample's neutron flux for all inner and outer sites, with the exception of the cadmium lined site 9. Although the raw data are not available to provide a numerical comparison between the neutron distributions generated by Rook and here, both can be assessed visually to be identical in shape with the major scale difference stemming from the scaling factor used to determine the F4 tallies for the samples [121].

3.4.6 Errors and Uncertainties

Potential sources of errors and uncertainties are explored at Annex P. Errors and uncertainties include amongst others:

- Model geometry (probable);
- Tally setup (minimal);
- Material composition and impurities (probable);
- Core material evolution (probable);
- MCNP limitations (probable);
- Human errors (probable).

Overall potential errors and uncertainties are assessed as having a probable significant impact on the end results, specifically the neutron flux values, considering it was not possible to perfectly replicate existing literature. However, changes from the old core to the new core could potentially explain the differences, which would require further analysis to ascertain.

3.4.7 Overall Assessment of NAA Results

Overall, through comparisons of the MCNP model with literature on SLOWPOKE-2 models, namely Rook and Lamarre, it has been demonstrated that the results, for neutron flux, cadmium ratios and thermal to epithermal ratios are comparable. Therefore, it is assessed that the updated MCNP 6.2 model is consistent with existing models of the SLOWPOKE-2, and can consequently be used with increased confidence as the basis for the benchmarking process.

3.5 Model Benchmarking

The model benchmark will be conducted on the basis of the ability of the updated model to represent the reality of the NAA experimental results.

3.5.1 Results

Rook, using MCNP 6.1 and comparing the results to cobalt wire neutron activations experiment in the SLOWPOKE-2 estimate that the legacy model returns results 30% lower than the experimental values for a reactor operated at 10 kW_t [121]. Table 22 presents a comparison between the NAA results (section 3.3) and the MCNP results from the updated model (section 3.4). The difference allows to benchmark the model to the experimental values and provide an estimate of the accuracy of the model to represent the experiment, and therefore, the reactor's operation. As is, the greatest difference between the NAA results and the MCNP results are with the outer site neutron flux and the thermal to epithermal ratios.

Table 22. Experimental NAA and MCNP Model Comparison

			NAA Results (This work)	MCNP 6.2 (This work)	Difference %
Inner Site (no. 2)	Neutron Flux Unshielded Sample ($n{\cdot}cm^{-2}{\cdot}s^{-1}$) x$10^{11}$	Thermal	5.0 ± 0.2	4.88 ± 0.03	-2 ± 4
		Epithermal	0.34 ± 0.02	0.45 ± 0.01	32 ± 8
		Fast	4.8 ± 0.2	5.15 ± 0.04	7 ± 5
		Total	10.2 ± 0.3	10.48 ± 0.05	3 ± 3
	Neutron Flux Shielded Sample ($n{\cdot}cm^{-2}{\cdot}s^{-1}$) x$10^{11}$	Thermal	-	0.271 ± 0.009	-
		Epithermal	-	0.43 ± 0.01	-
		Fast	-	5.03 ± 0.04	-
		Total	5.2 ± 0.2	5.73 ± 0.04	10 ± 4
	Thermal to Epithermal Ratio		15.4 ± 0.6	10.8 ± 0.3	-30 ± 2
	Cadmium Ratio		1.98 ± 0.06	1.83 ± 0.02	-8 ± 1
Outer Site (no. 10)	Neutron Flux Unshielded Sample ($n{\cdot}cm^{-2}{\cdot}s^{-1}$) x$10^{11}$	Thermal	3.1 ± 0.1	2.38 ± 0.02	-23 ± 3
		Epithermal	0.064 ±0.003	0.071 ± 0.004	11 ± 8
		Fast	0.90 ± 0.04	0.54 ± 0.01	-40 ± 3
		Total	4.0 ± 0.1	2.99 ± 0.02	-25 ± 2
	Neutron Flux Shielded Sample ($n{\cdot}cm^{-2}{\cdot}s^{-1}$) x$10^{11}$	Thermal	-	0.049 ± 0.003	-
		Epithermal	-	0.077 ± 0.004	-
		Fast	-	0.51 ± 0.01	-
		Total	0.97 ± 0.03	0.64 ± 0.01	-34 ± 2
	Thermal to Epithermal Ratio		51 ± 1	33 ± 2	-35 ± 4
	Cadmium Ratio		4.22 ± 0.06	4.7 ± 0.1	11 ± 3

3.5.2 Discussion

It was demonstrated at sections 3.3 and 3.4 that NAA results obtained are consistent with literature NAA values and that the MCNP 6.2 updated model results are consistent with known RMC SLOWPOKE-2 model results. However, in the case of the MCNP model, while the thermal to epithermal ratios are consistent between the updated model and literature, the obtained neutron flux results are lower than the literature models. During the investigation, while comparing with Rook's results, it was highlighted that the power used to calculate the scaling factor necessary to obtain the neutron flux results from MCNP was different, for identical neutron flux selected at the reactor's control system. Further investigation is required on that subject to ascertain an accurate way to compute reactor power.

3.5.2.1 *Inner site*

Overall, there is a good agreement between NAA results and the MCNP results at the inner site for the thermal and total flux within the margin of errors. The biggest difference is when it comes to the epithermal flux and the thermal to epithermal ratios. While MCNP simulates each neutron and associates it with the appropriate energy bins once it is tabulated at the sample, the NAA experimental method relies on mathematical relationships between the ratios and the energy bins. As such, a small difference in the ratios are compounded and amplified to the calculated flux. The total fluxes of the NAA experiment are the only values obtained without relationships to the other fluxes and ratios, as they are calculated using experimental information on the sample or obtained from GammaVision. The total fluxes, or activities from GammaVision, are then used to calculate the thermal flux (as per Eq. (6)), cadmium ratio (as per Eq. (3)), which in turn is used to compute the thermal to epithermal ratio using Eq. (4). The epithermal flux is calculated using the thermal to epithermal ratio and the thermal flux, while the fast flux is calculated as the remainder. Therefore, there exist definite potential, on the NAA side, for significant uncertainty margins compared to the direct flux computation of MCNP.

Considering fission occurs primarily in the thermal region of the incident neutrons, that the epithermal region has approximatively one order of magnitude less neutron flux in both the MCNP simulation and the NAA experiment and that the thermal flux and total flux are comparable between the NAA and MCNP results, it is assessed that the MCNP model is an adequate representation of reality for the reactor up to the inner site and should provide accurate simulated information for the purpose of finding the burnup of the core and fuel composition.

3.5.2.2 ***Outer Site***

There remain significant differences for the outer site results. Something, within the MCNP code, is impeding neutrons from reaching the sample, or the scaling factor is site specific and cannot be used at all locations of the reactor.

While an issue with the code's handling of neutron path within the beryllium annulus or the material aging since commissioning might explain some of the discrepancies between the NAA and the MCNP results, it seems unlikely to explain as much as the approximatively 25% difference seen at the thermal and total fluxes.

An idealized MCNP scaling factor for the model to reach the NAA experimental data for the outer site would be approximatively $(10.5 \pm 0.4) \times 10^{14}$ $n \cdot s^{-1}$, compared to the idealized scaling factor for the inner site at $(8.3 \pm 0.3) \times 10^{14}$ $n \cdot s^{-1}$. The significant difference between the two seems to point towards the need of a distance dependant scaling factor.

Rook's model went beyond the outer site and determined that the neutron flux was stable between 10 cm and 20 cm from the centre of the core, the area where the inner site is located (at 15.24 cm in the MCNP models [121]. At the edge of the beryllium annulus (~21 cm), the flux decreases according to the inverse square law. Andrews experimental results from irradiations in the pool support that rate of decrease [161]. Considering the outer sites are outside of the beryllium annulus (~21 cm), it is possible that the same scaling factor would not apply for the outer site as for the inner site due to a change in the local conditions. Further investigation is warranted.

3.6 Chapter Conclusion

As part of developing a benchmarked MCNP 6.2 model to simulate the operating conditions of the SLOWPOKE-2 research reactor at the RMC, the following conclusions were derived:

1. The refuelled core's neutron field's characteristics are similar to the old core's (Task A);

2. The update of the reactor's geometry to include updated pool geometry, core elements arrangement, orientation and fuel composition did not significantly change the raw values of the MCNP F4 tallies compared to the legacy code used by Rook (Task B) [121];

3. The scaling factor to be used by MCNP requires an accurate determination of the reactor's operating power (Task B);

4. The model was improved from an estimated overall 30% estimated error by Rook, to an estimated 5% for the inner site and 25% for the outer site's thermal and total flux (Tasks B and C);

Overall, the updated MCNP 6.2 model is assessed as being suitably benchmarked to adequately represent the SLOWPOKE-2 core's neutron flux characteristics and therefore suitable to be used as the basis for a simulation of the fuel's burnup over the time of the core's operational life, and subsequent storage in repository conditions.

Chapter 4

SLOWPOKE-2 Scaling Factors

4.1 Introduction

To generate discharged fuel inventory, determine the reactor's burnup, and provide the basis on which to build a case for a relationship between the SLOWPOKE-2's spent fuel and SMRs', the benchmarked model and the MCNP fuel depletion module CINDER90 were used [48]. Specifically, CINDER90 provided computed fuel burnup and isotopic activities of the decaying isotopes contained in the spent fuel, which are used to calculate decay heat.

This chapter provides the basis for the completion of *Primary Objective 2* and *Primary Objective 3* and is organized into multiples sections to discuss the use of the model to generate the scaling factor which will be used at Chapter 5 to estimate SMR spent fuel evolution within the GDR (*i.e.,* activity and decay heat).

Section 4.2 presents the methodology that will be used to proceed from the benchmarked model to the SLOWPOKE-2 scaling factors for activity and decay heat, and how the CINDER90 module was used to achieve these values.

Section 4.3 demonstrate how the simulation of the core was conducted to obtain the reactor's operational burnup and the fuel's isotopic inventory at the end of its operational life.

Section 4.4 presents the values obtained, for both activity and decay heat, from the decay of the fuel over a simulated period of 10 million years after it has been discharged from the reactor.

Section 4.5 establishes the basis for a relationship between the burnup of the core at different power levels and the resulting spent fuel's activity and decay heat.

Section 4.6 develops the scaling relationship that allows the SLOWPOKE-2 to be scaled up, with regards to activity and decay heat, to simulate reactors at higher burnups.

Finally, section 4.7 determines the limitations that exists with the use of the proposed scaling method.

4.2 Methodology

4.2.1 Approach Overview

The general approach to creating a relationship between the SLOWPOKE-2 and SMR will be passing through the assessment of three main parameters of spent fuel: burnup, activity, and decay heat. The steps taken to create that relationship are as follows:

1. Determine the operational burnup of the SLOWPOKE-2 at different power levels;
2. Assess how the burnup increases based on power levels;
3. Determine the isotopic content of spent fuel at the end of the SLOWPOKE-2 operating cycle;
4. Decay the spent core over 10 million years and determine activity and decay heat generated by the spent fuel;
5. Assess how activity and decay heat changes over time;
6. Relate the burnup changes to the activity and decay heat changes;
7. Determine the relationship between burnup and activity and decay heat that allow the scaling of the SLOWPOKE-2 to any burnup level; and,
8. Determine the limitations of the defined relationship.

Ultimately, what will remain is a scaling relationship that will allow the use of the modelled SLOWPOKE-2 activity and decay heat as the preliminary baseline values to generate estimated activity and decay heat for SMR spent fuel with known operational burnups.

4.2.2 CINDER90– Fuel Depletion Module

For the determination of operational burnup, spent fuel isotopic inventory at the end of the SLOWPOKE-2 operational cycle, and spent fuel activity as the fuel decays over time in the DGR is conducted using the CINDER90 fuel depletion module of MCNP applied to the benchmarked model from Chapter 3.

CINDER90 is a transmutation nuclide inventory computing code originally created as a standalone code, which has been imbedded within MCNP to provide fuel depletion and burnup calculation capabilities [48], [187]. The code uses Markovian chains to solve the probabilistic Bateman equation governing the rate of change of atom density of a particular nuclide as per Eq. (7) and Eq. (8) [187].

$$\frac{\mathrm{d}N_m(t)}{\mathrm{dt}} = -N_m(t)\beta_m + \overline{Y_m} + \sum_{k\neq m} N_m(t)\gamma_{k\rightarrow m} \tag{7}$$

$$\beta_m = \lambda^m + \Phi\sigma_a^m \tag{8}$$

Where

$N_m(t)$ = Atom density of nuclide m at time t

β_m = Total transmutation probability of nuclide m

Φ = Energy-integrated neutron flux

λ^m= Total decay constant of nuclide m

σ_a^m= Flux-weighted average absorption cross-section of nuclide m

$\overline{Y_m}$ = Additional constant production rate

$\gamma_{k\to m}$ = Probability of nuclide k transmuting to nuclide m

The CINDER module uses its own nuclear data library generated from ENDF/B-VI of 3400 nuclides ($1 < Z < 103$), 63 neutron groups and 25 photon groups. MCNP calculates the fluxes, reaction rates, fission multiplicity, and recoverable energy per fission, and feeds it to the CINDER module, which generates the new atom densities of the fuel material at the steps requested by the operator. The new atom densities are fed back to MCNP to process the next time step [48].

For the present thesis, the values of interest provided by the CINDER90 module are the isotopic activity and the total core operational burnup.

4.2.3 Decay Heat Calculations

While the CINDER module of MCNP provides activities directly in the output file for individual isotopes, it does not provide decay heat power ($\mathrm{H}_{(t)}$). Those values therefore require calculations based on the isotope's activities using the decay heat summation method. Given the activity (A) at time (t) after the fuel has been discharged from the reactor (Eq. (9)), it is possible to estimate the decay heat generated by the decaying spent fuel by using its generated radiation energy (Eq. (10) and Eq.(11)) [188]–[190].

$$\mathrm{A}_{(t)} = \sum_{i=1}^{n} N_{i(t)}\lambda_i \tag{9}$$

$$\mathrm{H}_{(t)} = \sum_{i=1}^{n} N_{i(t)}\lambda_i Q_i \approx \sum_{i=1}^{n} N_{i(t)}\lambda_i\left(\bar{E}_{\alpha i} + \bar{E}_{\beta i} + \bar{E}_{\gamma i}\right) \tag{10}$$

$$\mathrm{H}_{(t)} \approx \sum_{i=1}^{n} A_{i(t)}\left(\bar{E}_{\alpha i} + \bar{E}_{\beta i} + \bar{E}_{\gamma i}\right) \tag{11}$$

Where

$A_{i(t)}$ = Activity of isotope i at time t (Bq·kgU^{-1})
H$_{(t)}$ = Total Decay Heat at time t (W·kgU^{-1})
$N_{i(t)}$ = Number of isotope i at time t
λ_i = Decay constant of isotope (s^{-1})
Q_i= Total recoverable energy for isotope i (J)
$\bar{E}_i$= Average generated energy of isotope i by radiation α, β or γ (J)

Average energies were taken from the ENDF/B.VIII.0 library from the IAEA Nuclear Data Services Evaluated Nuclear Data File database [191].

4.3 Burnup and Spent Fuel Isotopic Inventory: The SLOWPOKE-2 at the End of its Operational Cycle

Considering the new core has not operated enough to surmise as to its end-of-life operational burnup, an assumption has to be made as to its expected operational life. Since the new core has been designed to operate within identical parameters as the old core, it is posited that the shimming events' relationship to burnup days, as described at Figure 20, will remain similar for the new core. Therefore, the simulated operational burnup of the new core is based on the premise that it will have an identical operational history as the old core, and therefore, will experience a similar amount of burnup days throughout its operational life.

A complete simulated duplicate of all the SLOWPOKE-2 old core shimming events listed at Figure 20 would be necessary to obtain an exact isotopic inventory of the fuel at the end of its operational life. However, it is computationally prohibitive. Also, considering the area of interest for GDR is after the time where the spent fuel has cooled in wet storage, it is unnecessary to have minute fidelity on very short-lived isotopes immediately at discharge.

Casper has demonstrated that the SLOWPOKE-2 core could be simulated in a bulk burnup run on MCNP without having to simulate all individual shimming events of the operating cycle, resulting in statistically similar results for isotope inventory of the spent fuel after the 1696 days of burnup [192]. As such, the operational burnups of the new core were conducted here in one single burnup step of 1696 days.

Annex T presents the CINDER90 module code details used to conduct the simulated burnups of the reactor fuel.

4.3.1 Operational Cycle Simulation – Model Control Parameters

To determine operational burnup and isotopic inventory at the end of the 1696 days the model requires a control rod height and a beryllium shim height (Annex T). The control rod heights were determined based on the experimental values from the NAA experiment but, in the case of the shim heights, further evaluations were necessary. Due to the overlapping shims from February 2014 to September 2021, shims heights just before the reactor's refuelling cannot be used to conduct a bulk burnup simulation as the reactor operated 164 burnup days with a significantly higher shim thickness (5.40 cm) than the end state of the reactor (4.45 cm).

The theoretical highest effective shim height, the limit at which additional shims do not have an additional impact on the reactivity or the reactor, was estimated at 5.07 cm by quadratic regression on a shim thickness *vs.* total reactivity plot (Figure 32, *red "X"* indicating the reactivity and shim height of the problematic overlapping shims).

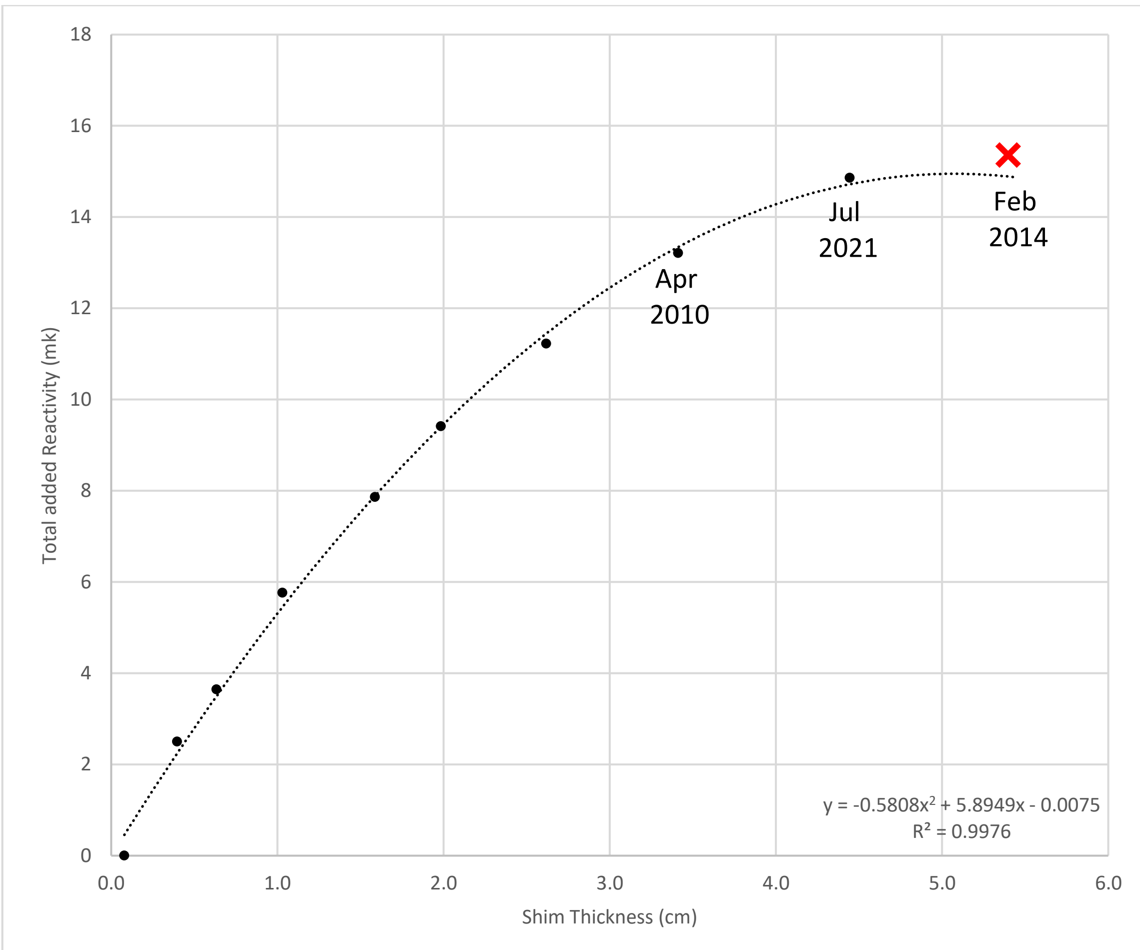

Figure 32. Shim Thickness *vs.* Total Added Reactivity (1985-2021)‡‡

‡‡ Information presented as is without error bars as obtained from the SLOWPOKE-2 operating logs.

To determine the shim height to be used in burnup simulations, two bulk burnup MCNP runs, one at the final shim height of 4.45 cm and one at the theoretical highest effective shim height (*i.e.,* 5.07 cm) were conducted for an operational burnup of 1696 days. The atomic fractions of the resulting spent fuel isotopes were compared using a paired *t*-test ($t(170)= 2.704$, $p=0.0075$, $a=0.05$) [186]. The two shim heights were assessed to be statistically similar and a selection of either would yield similar results. As a decision had to be made for the code, of the two potential shim height, the 5.07 cm was retained for MCNP bulk run simulations.

4.3.2 Operational Burnup and Isotopic Inventory Results

Operational burnup using the benchmarked model was conducted at 10 kW_t (half power), 15 kW_t (three-quarter power) and 20 kW_t (full power), for the 1696 burnup days, using the MCNP 6.2 fuel depletion module (CINDER90). Table 23 presents the obtained operational burnup from the three simulations.

Table 23. Operational Burnup

Simulated Power (kW_t)	**Burnup** ($MWd{\cdot}MTU^{-1}$)
10	3035
15	4552
20	6070

For the SLOWPOKE-2, the relationship between the reactor power and fuel burnup appears to be directly proportional: specifically, *a doubling of the power doubles the fuel burnup* (Eq. (12)):

$$P_S \propto BU_S \tag{12}$$

Where

P_S = SLOWPOKE-2 Operating Power (kW_t)
BU_S = SLOWPOKE-2 Burnup ($MWd{\cdot}MTU^{-1}$)

The complete isotope inventory and burnup results for the half and full power MCNP burnup runs are presented at Annex V. The three-quarter power data were used to determine the burnup direct proportionality relationship but have been omitted from further inclusion in data to reduce computational resources required to conduct the analysis.

4.4 Decay to 10 000 000 Years

The isotope inventory generated by the 1696 days of burnup was decayed in steps corresponding to the steps used by NWMO to assess the isotope inventory of a decaying CANDU fuel bundle to allow direct comparison at each time steps [114]. The steps cover *five* (5) years after the fuel has been discharged to 10 million years.

The complete isotope inventory MCNP output for the decay steps for the half and full power runs are presented at Annex W and Annex X, respectively. Considering the direct proportionality of the burnup, only the half power and full power spent fuels were fully decayed to 10 million years to save on data processing and analysis time.

4.4.1 Activity

Activity is obtained directly from the CINDER90 output file and converted from curies (Ci) to becquerels (Bq). The value is then normalized based on the initial content of uranium of the fuel prior to its operational cycle in the reactor. This allows for a direct comparison to NWMO values from the CANDU reference bundle [114].

The activity of the fuel, in Bq per kg of initial uranium ($Bq{\cdot}kgU^{-1}$), obtained from decaying the spent fuel over 10 million years, is presented at Figure 33. Both the half power and full power runs have similar behaviour over the whole timeline of interest.

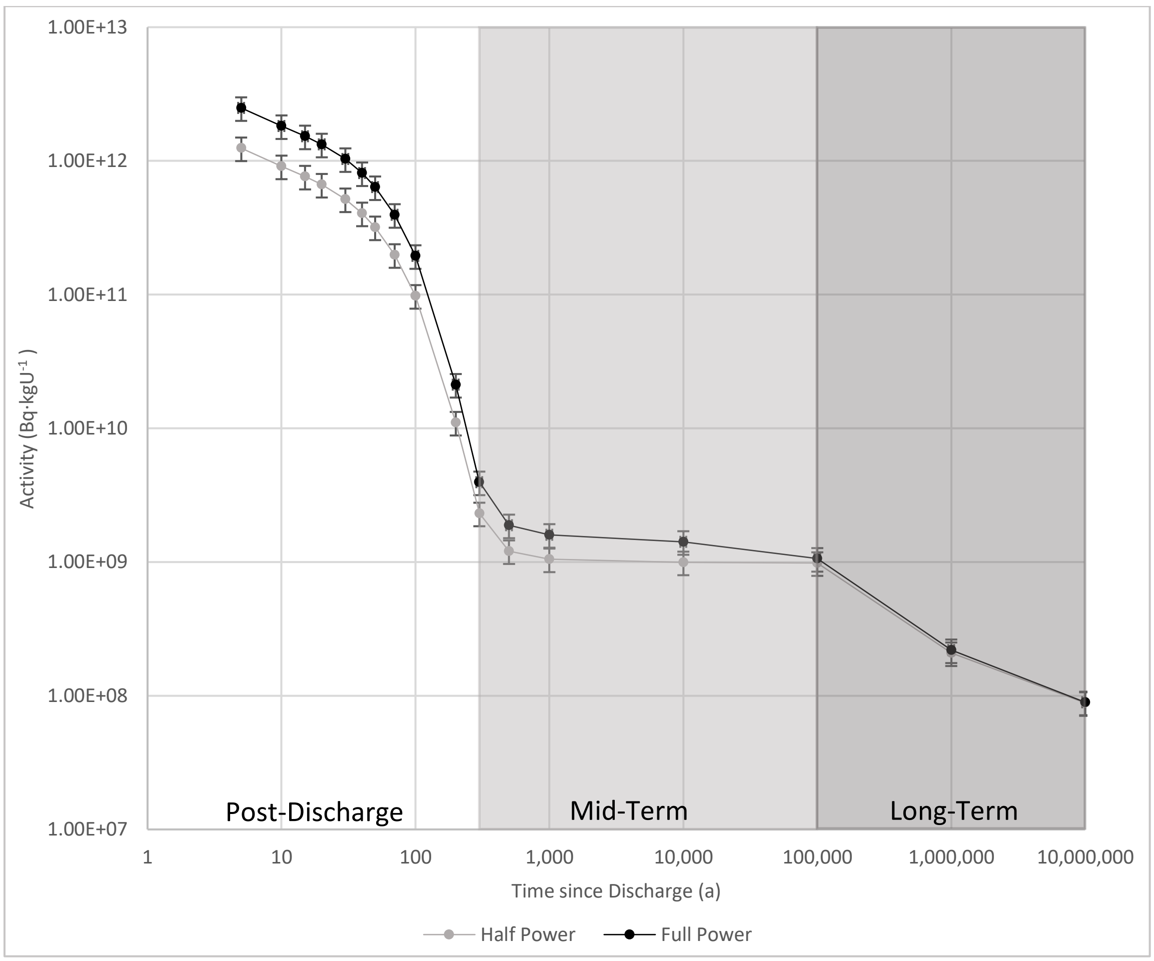

Figure 33. SLOWPOKE-2 Activity (Half (10 kW_t) and Full Power (20 kW_t))

The post-discharge phase is characterised by very high activity that rapidly declines once it enters the mid-term region. The activity in the post-discharge region is almost entirely due to non-actinide fission products. Figure 34 presents the relative contribution of actinides and non-actinides to the total activity of the spent fuel for the half power MCNP run. Figure 35 presents individual relative isotopes contribution to the total activity. The full power simulation results (not shown) display an identical behaviour.

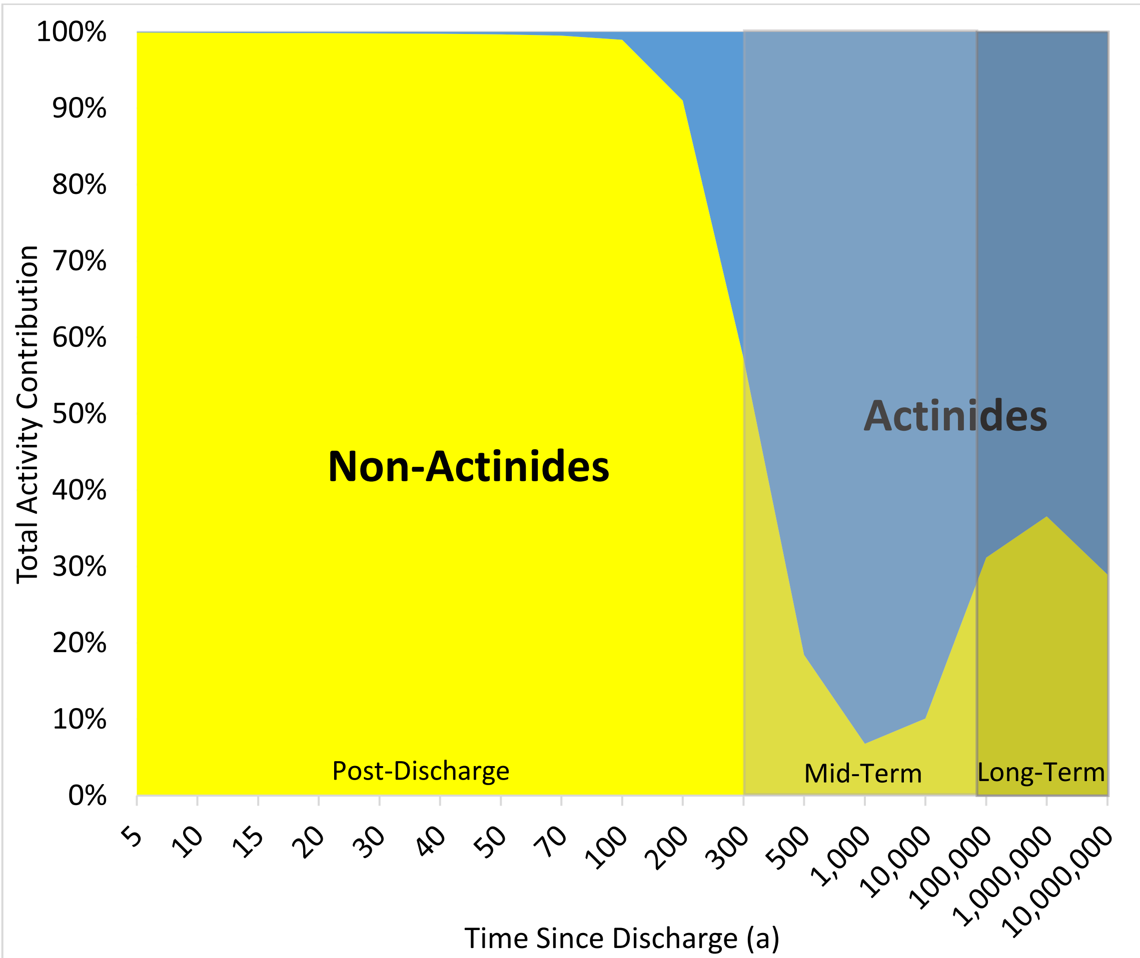

Figure 34. Relative Contribution of Actinides and Non-Actinides to Total Activity (Half-Power – 10 kW_t)

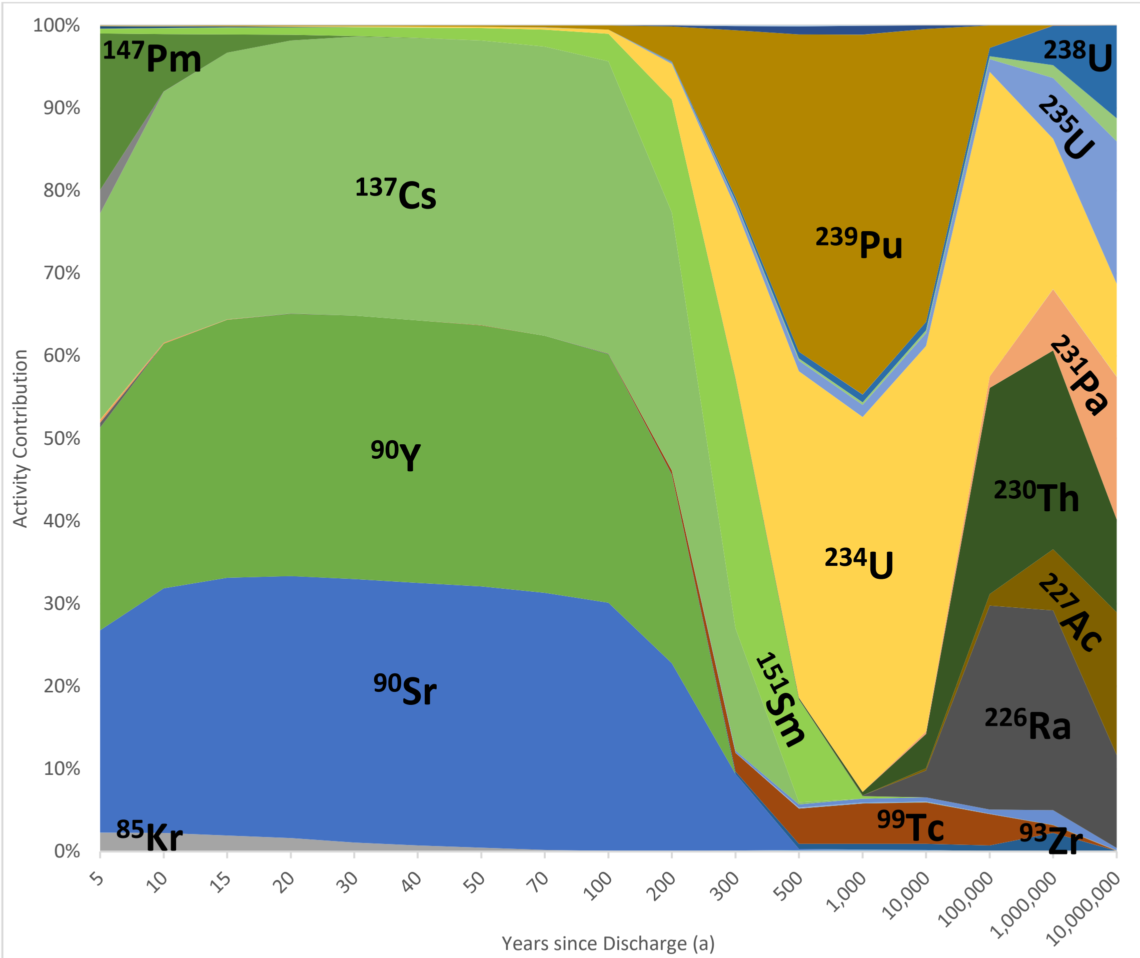

Figure 35. SLOWPOKE-2 Relative Activity Contribution of Major Isotopes (Half-Power – 10 kW_t)

The post-discharge region is dominated by a few short-lived fission products, produced at high yields from ^{235}U fission, most notably ^{137}Cs ($t_{1/2} = 30.08 \pm 0.09$ a), and the β^- decay relationship from ^{90}Sr ($t_{1/2} = 28.91 \pm 0.03$ a) to ^{90}Y ($t_{1/2} = 64.05 \pm 0.05$ hr) [191].

The lower presence of actinides in the SLOWPOKE-2 spent fuel, when compared to the higher preponderance of actinides in the CANDU spent fuel (Figure 11, Figure 12 and Figure 13), is explained by the use of natural uranium in CANDU fuel. Whilst the SLOWPOKE-2 uses ^{235}U almost exclusively as principal fuel, the CANDU reactor relies heavily on the generation of actinides by neutron capture, which are then used as fuel. Therefore, the unburnt fuel from CANDU reactors generated actinides including members of their decay chains and are taking a relatively more important contribution to the total activity in the post-discharge and mid-term regions.

For the SLOWPOKE-2 spent fuel, the mid-term region sees a plateauing of the generated activity dominated by actinides contribution, notably from ^{239}Pu and ^{234}U. The absolute activity contribution of the actinides steadily decreases but remains dominant in the post-discharge region, due to the decaying of short-lived fission products. The same logic applies to the remaining fission products ^{151}Sm and ^{99}Tc. The mid-term regions sees and absolute increase of non-actinide activity (Figure 36). This is driven almost exclusively by the creation of ^{226}Ra through α decay of ^{230}Th ($t_{1/2}$ = (7.54 ± 0.03) x 10^4 a), itself generated by neutron capture through the ^{238}U decay chain during the reactor's operation [191].

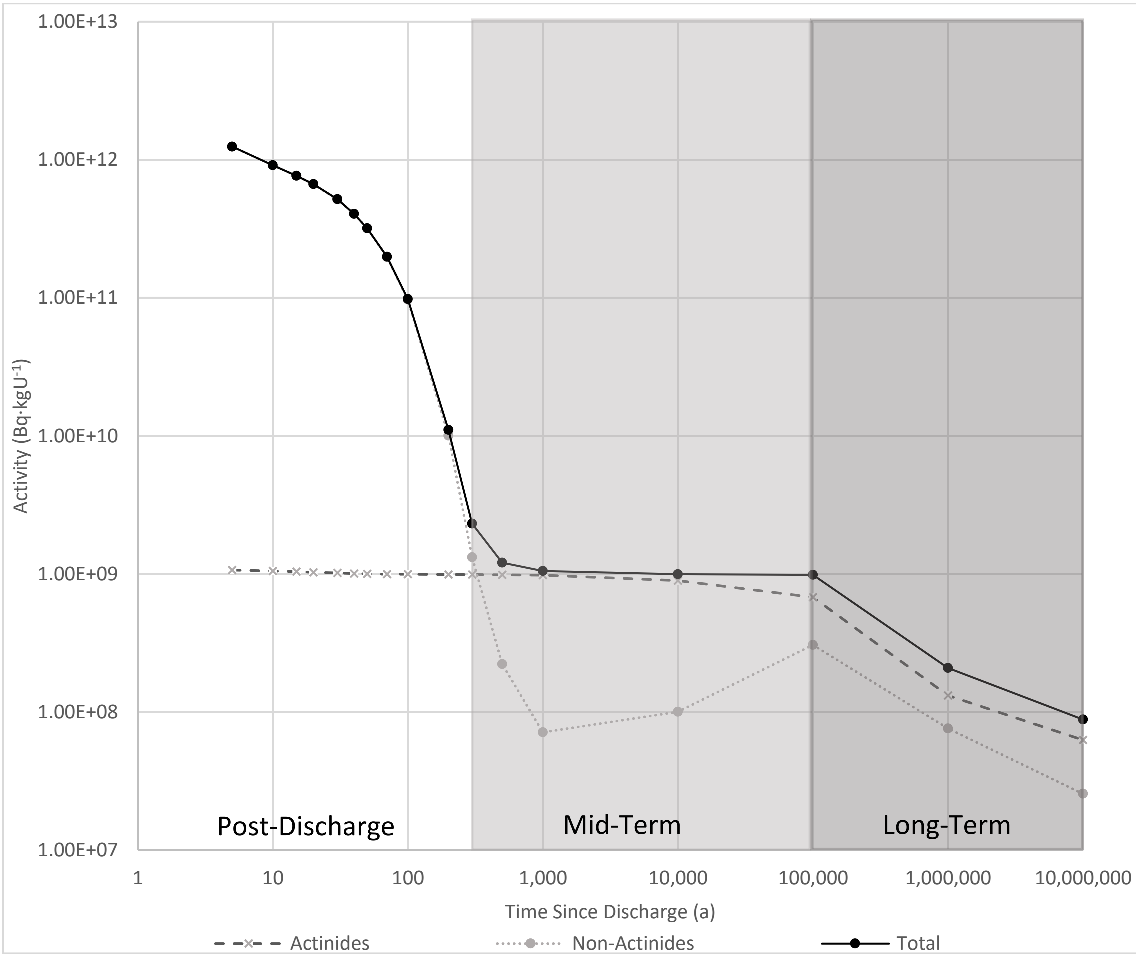

Figure 36. SLOWPOKE-2 Absolute Activity Contribution (Half-Power – 10 kW_t)[§§]

The long-term region sees the generation of active isotopes, ^{227}Ac and ^{229}Th, from the α decay of ^{231}Pa ($t_{1/2}$ = (3.276 ± 0.011) x 10^4 a) and ^{233}U ($t_{1/2}$ = (1.5919 ± 0.0015) x 10^4 a) respectively [191]. However, most of the long-term activity is contributed by extremely long-lived isotopes, both actinides and non-actinides, and the rate of activity decrease is fairly constant for the whole region.

§§ 20% error bars removed to unclutter the plot.

4.4.2 Decay Heat

Decay heat for the half power and full power isotope inventories were calculated using Eq. (11) and the activities obtained from the MCNP runs from section 4.4.1. Results are presented at Figure 37. The overall shape of the decay heat curves (Figure 37) follows that of the activity curves (Figure 36). It naturally follows that the activity ($A_{i(t)}$) is the driving factor of heat generation rather than the individual isotopes' generated energies ($\bar{E}_i$) in Eq. (11).

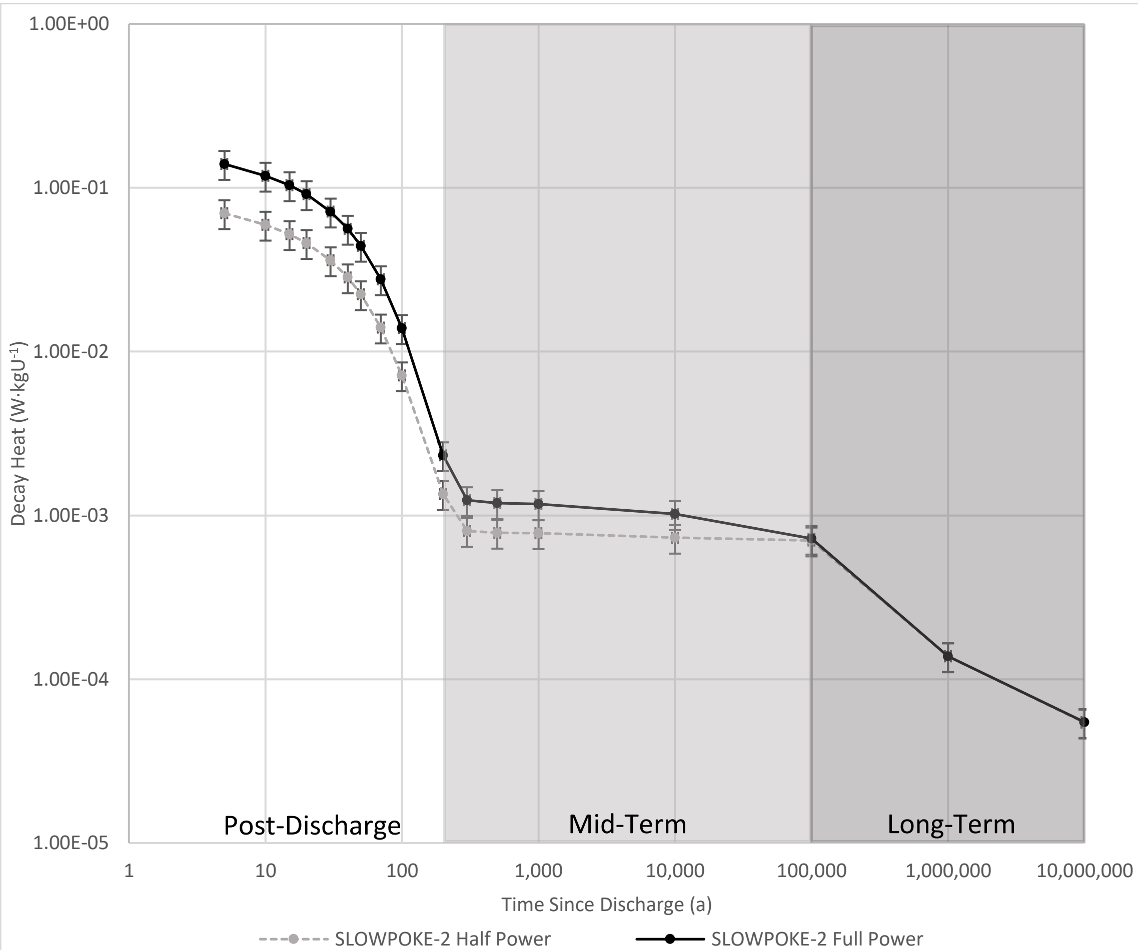

Figure 37. Decay Heat of Half Power (10 kW_t) and Full Power (20 kW_t) Spent Fuel

4.5 Relationship Between Half Power and Full Power

The burnup of SLOWPOKE-2 is directly proportional to the power, where doubling the power results in doubling the burnup. This section aims to show that this directly proportional relationship also holds true for activity and decay heat when comparing spent fuels from half power and full power such that Eq. (13) and Eq. (14) remain true:

$$\mathrm{P}_S \propto \mathrm{BU}_S \propto A_{S(t)} \tag{13}$$

$$\mathrm{P}_S \propto \mathrm{BU}_S \propto H_{S(t)} \tag{14}$$

Where

P_S = SLOWPOKE-2 Operating Power ($\mathrm{kW_t}$)
BU_S = SLOWPOKE-2 Burnup ($\mathrm{MWd \cdot kgU^{-1}}$)
$A_{S(t)}$ = SLOWPOKE-2 Activity at time t ($\mathrm{Bq \cdot kgU^{-1}}$)
$H_{S(t)}$ = SLOWPOKE-2 Decay Heat at time t ($\mathrm{W \cdot kgU^{-1}}$)

Half and full power data are compared by plotting the full power values over the half power values obtaining the trend line on each region. Figure 38 demonstrates the relationship existing between the half power and full power activity curves and Figure 39 presents the scaling factors for the thermal power decay curves.

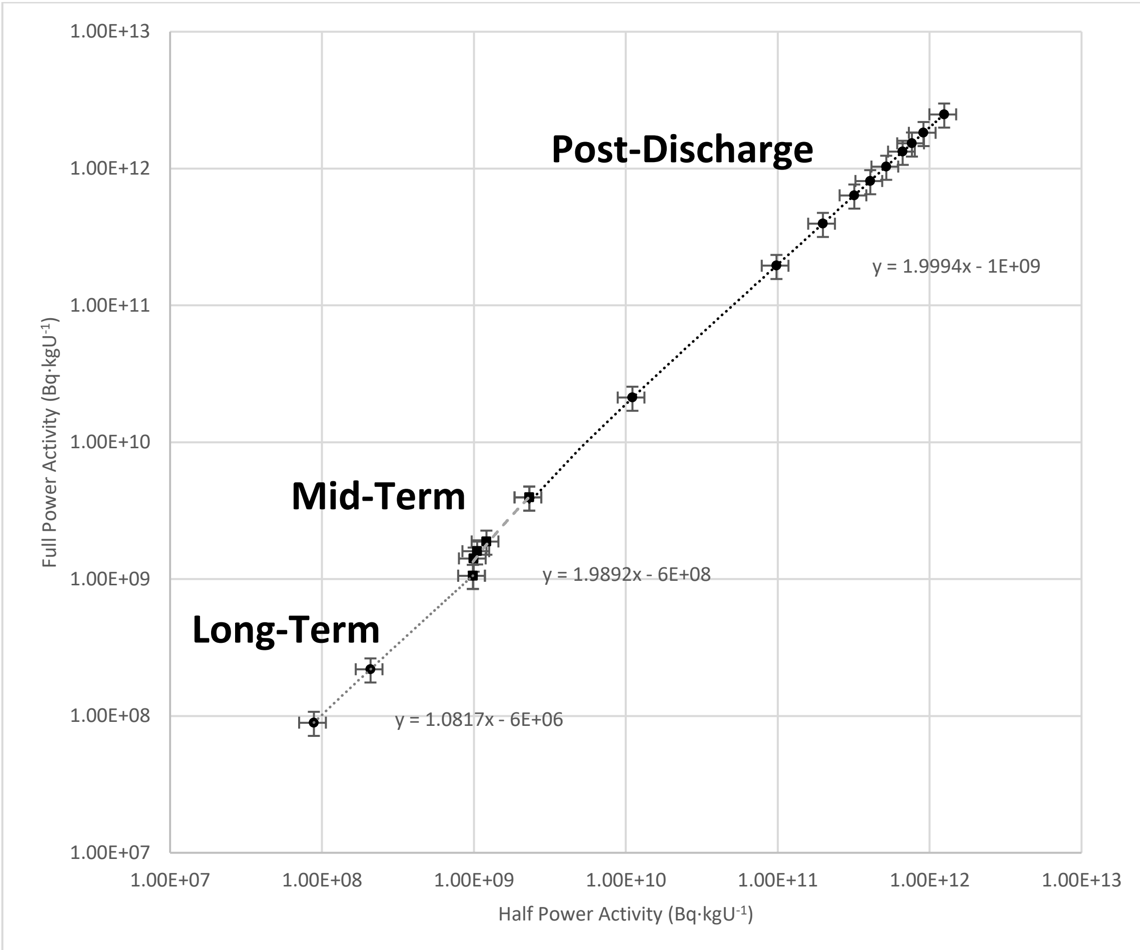

Figure 38. Scaling Factor between Half Power (10 kW_t) and Full Power (20 kW_t) Activities

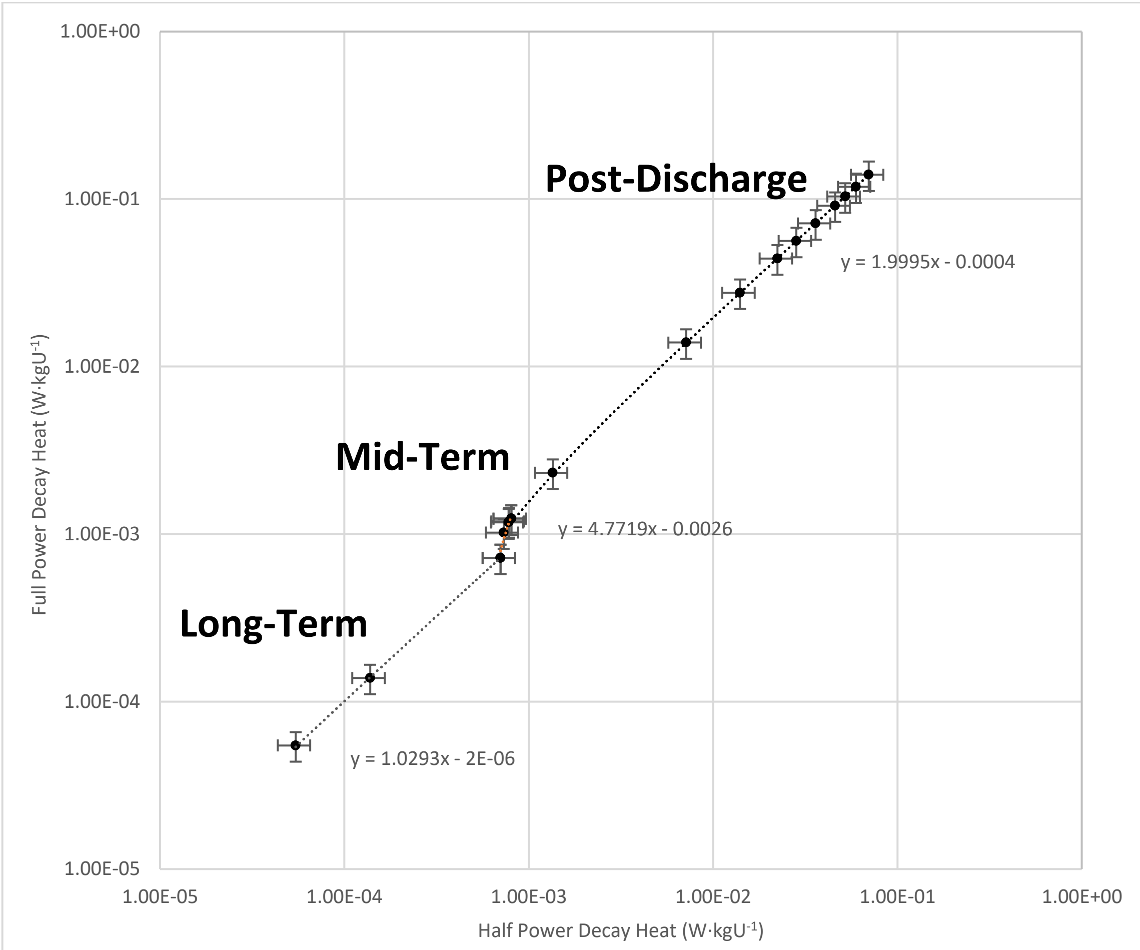

Figure 39. Scaling Factor between Half Power (10 kW_t) and Full Power (20 kW_t) Decays

In both cases, doubling the half power values results in the full power values, within errors, as displayed by the linear regression equations for the post-discharge region, showing a proportionality constant (slope) of *two* (2), as per Eq. (15) where the proportionality constants for both burnups and activities at 10 kW_t and 20 kW_t is identical (decay heatequation not shown but with identical results).

$$\frac{\mathrm{BU}_{S\ (20\ kW)}}{\mathrm{BU}_{S\ (10\ kW)}} = \frac{A_{S(20\ kW)(t)}}{A_{S(10\ kW)(t)}} = 2, \text{for } 5\ \mathrm{a} < \mathrm{t} < 300\ \mathrm{a} \qquad (15)$$

The direct proportional relationships are due to the preponderance of fission products generated activity and decay heat, nearly 100%, in the post-discharge region compared to the negligible contribution of actinides (see Figure 34 and Figure 35). Actinides are created in the reactor by neutron capture, and their subsequent decay, while fission products are directly related to the burnup of fuel. For the mid-term and long-term regions, no such proportionality relationship can be directly made with the burnup, due to the opposite situation: actinides are driving the activity and decay heat curves. The proposed relationship is therefore limited in time to the post-discharge region from 5 years to 300 years. Xu, Kazimi & Driscoll similarly highlighted the burnup-fission products and proportionality for PWR reactors, bringing credence to the relationship found here [56].

Therefore Eq. (13) and Eq. (14) remain true if 5 a < t < 300 a, yielding Eq. (16) and Eq. (17):

$$\mathrm{P}_S \propto \mathrm{BU}_S \propto A_{S(t)} \text{ for } 5\text{ a} < \text{t} < 300\text{ a} \tag{16}$$

$$\mathrm{P}_S \propto \mathrm{BU}_S \propto H_{S(t)} \text{ for } 5\text{ a} < \text{t} < 300\text{ a} \tag{17}$$

Ultimately, the intent is to find a constant (x) between the SLOWPOKE-2 activity and decay heat values and a simulated SMR at a higher level burnup such that it fulfills the relationship at Eq. (18) and Eq. (19).

$$A_{SMR(t)} = x \cdot A_{S(t)}, \text{for } 5\text{ a} < \text{t} < 300\text{ a} \tag{18}$$

$$H_{SMR(t)} = x \cdot H_{S(t)}, \text{for } 5\text{ a} < \text{t} < 300\text{ a} \tag{19}$$

Where

$A_{SMR(t)}$ = Activity of the simulated SMR at time t ($\mathrm{Bq{\cdot}kgU^{-1}}$)
$H_{SMR(t)}$ = Decay heat of the simulated SMR at time t ($\mathrm{W{\cdot}kgU^{-1}}$)
x = scaling factor

4.6 Scaling Factors SLOWPOKE-2 to SMRs

The aim of the following section is to identify the components of the scaling factor (x) that will allow the gathered information (*i.e.,* burnup, activity and decay heat) on the SLOWPOKE-2 to serve as the basis for the simulation of SMRs.

The two main differences between the SLOWPOKE-2 and reference CANDU spent fuel used as the GDR design basis are the burnup and enrichment. In order to reduce the factors of differentiations, the values obtained at Figure 33 and Figure 37 were normalized based on the burnup of each curves for both the activity and decay thermal power. This leaves the only one major difference between the two distributions, *i.e.*, the initial ^{235}U content, which will be discussed at section 4.7 below as a limitation to the proposed relationship.

The normalization allows for the scaling of the SLOWPOKE-2 to higher burnups. Figure 40 indicates that the burnup-activity relationship starts to degrade at 300 years post-discharge, which further support the timeline limitations found for Eq. (16) and (17).

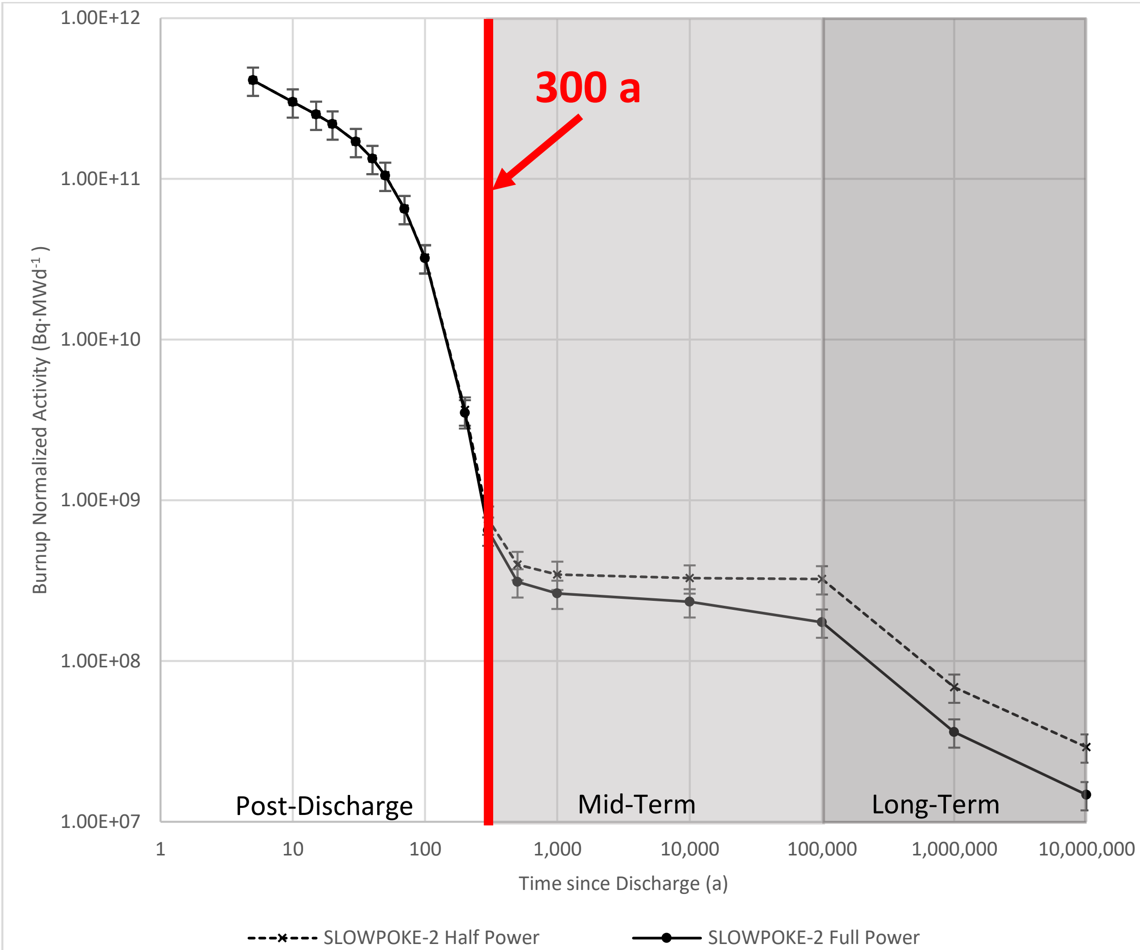

Figure 40. Burnup Normalized Activity (SLOWPOKE-2 Baseline Activity)

From Eq. (18) for the activity, the normalization gives Eq. (20), simplified to Eq. (21) where the scaling factor becomes the burnup normalized curve from Figure 40:

$$\frac{A_{SMR(t)}}{BU_{SMR}} = \frac{A_{S(t)}}{BU_S}, \text{for } 5 \text{ a} < \text{t} < 300 \text{ a} \qquad (20)$$

$$A_{SMR(t)} = \mathrm{A}_{\mathrm{SB(t)}} \cdot BU_{SMR}, \text{for } 5 \text{ a} < \text{t} < 300 \text{ a} \qquad (21)$$

Where

BU_{SMR} = Simulated SMR burnup (MWd·kgU^{-1})

$\frac{A_{S(t)}}{BU_S}$ = $A_{SB(t)}$ = SLOWPOKE-2 baseline activity at time *t* (Bq·MWd^{-1})

$A_{SMR(t)}$ = Activity of the simulated SMR at time *t* (Bq·kgU^{-1})

The extrapolation of the SLOWPOKE-2 activity to higher burnup, for the timeline of 5 to 300 years after discharge can therefore be calculated using Eq. (21).

4.6.1.1 ***Burnup Normalized Decay Heat***

Burnup normalized activity for CANDU and SLOWPOKE-2 is presented at Figure 41.

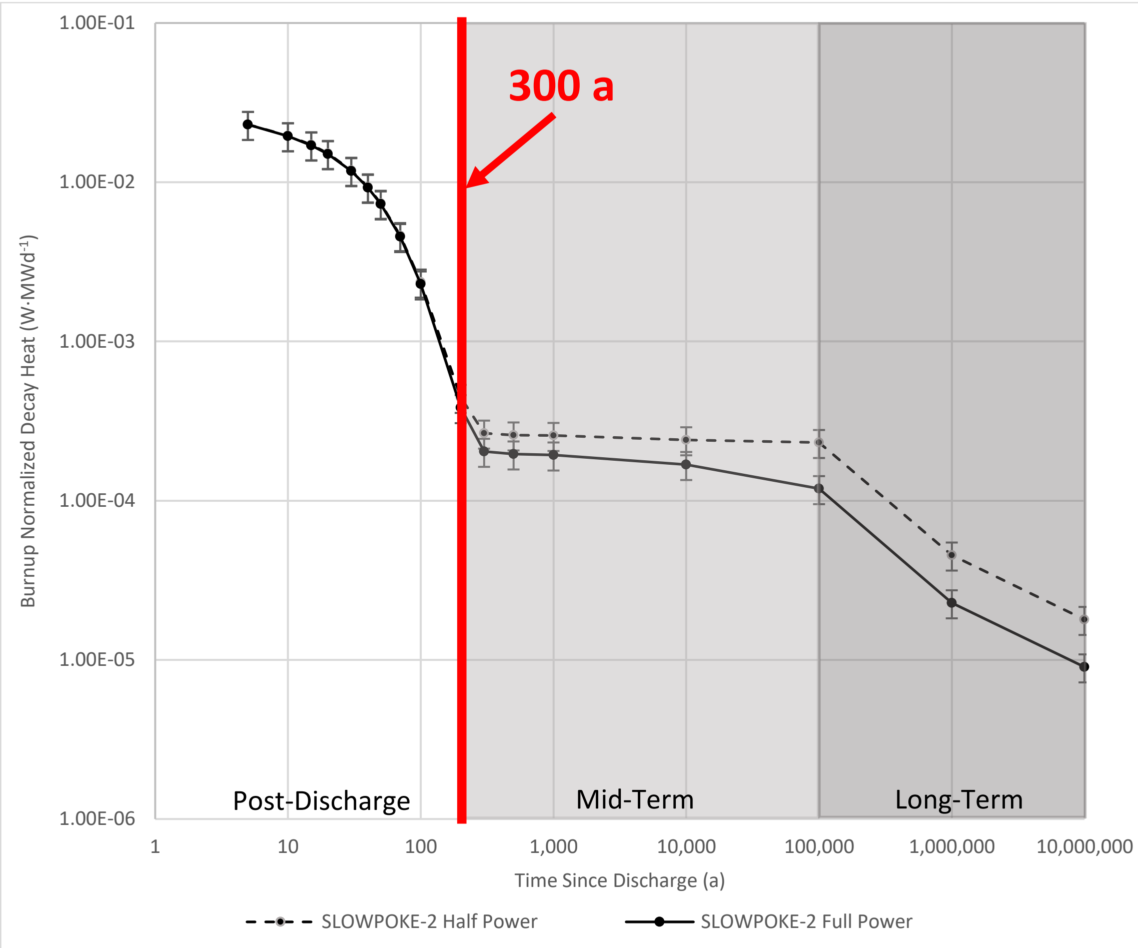

Figure 41. Burnup Normalized Decay Heat (SLOWPOKE-2 Baseline Decay Heat)

Extrapolation of a reactor's decay heat to higher burnup, for the timeline of 5 to 300 years after discharge is calculated using Eq. (22), using the same principle as with Eq. (20) and Eq. (21).

$$\mathrm{H}_{SMR(t)} = \mathrm{H}_{SB(t)} \cdot \mathrm{BU}_{SMR}, \text{for } 5\text{ a} < \text{t} < 300\text{ a} \qquad (22)$$

Where

$\mathrm{H}_{SMR(t)}$ = Simulated SMR decay heat at time t (Bq·kgU^{-1})
$\mathrm{H}_{SB(t)}$ = SLOWPOKE-2 baseline decay heat at time t (Bq·MWd^{-1})
BU_{SMR} = Simulated SMR burnup (MWd·kgU^{-1})

4.7 Scaling Limitations

The SLOWPOKE-2, with its low burnup, cannot by itself be directly compared to SMRs when it comes to spent fuel characteristics over time, an extrapolation of expected activity and generated decay heat must be conducted by scaling the SLOWPOKE-2 to SMR burnup levels using Eq. (21). and Eq. (22). However, the scaled values are not valid for all higher burnup reactors.

Three (3) limitations are put on the proposed relationship based on fuel type, enrichment, and simulated time after discharge:

Fuel Types

Considering simulations on the SLOWPOKE-2 has only been conducted with its current actual fuel composition and arrangement, the scaling is only valid for reactors operating with a UO_2 solid ceramic fuel. Other more exotic fuel would require further analysis due to their potential of creating different fission and activation products that could potentially affect the balance of the defined relationships.

Enrichment

For similar reasons as with the fuel type, the enrichment for which the relationship at Eq. (21). and Eq.(22) is valid is that of the SLOWPOKE-2: ~19.6%.

Due to proliferation concerns, SMR fuel designs have generally a 20% ceiling limit with most of the UO_2 reactor fuel designs having an enrichment between 5 and 15%. As discussed at section 4.5, the direct proportionality between activity and burnup, and decay heat and burnup, is reasonable because of the relatively small actinides contribution to the total activity compared to the fission products' contribution. The higher ^{235}U concentration in SLOWPOKE-2 fuel reduces the generation of actinides. As well, the simulation of higher burnup reactors would further reduce the actinides contribution since higher burnups would see a higher utilization of the actinides during the reactors' operational cycle. Low enrichment, or no enrichment in the case of the CANDU, would see a greater contribution of actinides to the total spent fuel activity, which could affect the identified burnup-activity and burnup-decay heat relationships.

Time after Discharge

The preponderance of fission products driving the total activity is only seen in the post-discharge region, supporting the activity-burnup relationship. Such a relationship cannot be clearly delineated for the mid-term and long-term regions. The proposed process is therefore limited to spent fuel characteristics estimations in the 5 to 300 years post-discharge timeline.

4.8 Errors and Uncertainties

Potential sources of errors and uncertainties are highlighted at Annex P. Overall, an estimated error of 20% was estimated for all CINDER90 generated activities. Errors and uncertainties include amongst others:

- Omitted isotopes from simulations (Moderate); and,
- Simulation run discontinuities (Minimal).

Overall, potential error and uncertainties are assessed as having a probable moderate impact on the results. Particularly, the inability of MCNP to provide error margins for the isotopic inventory simulated and operational burnup tends to push for the selection of a conservative estimated error. It is posited that the actual errors obtained from simulations is much lower than the used 20% error.

4.9 Chapter Conclusion

The spent fuel isotopic composition, generated activity and decay heat have been obtained from the benchmarked MCNP 6.2 SLOWPOKE-2 model using the integrated CINDER90 depletion code module. A relationship was determined between the burnup and the SLOWPOKE-2 model results which allows for the scaling of the SLOWPOKE-2 activities and decay heat to SMR burnup levels. The following conclusions were derived:

1. SLOWPOKE-2 burnup is directly proportional to its operating power (Task D);

2. SLOWPOKE-2 burnup is significantly lower than most currently designed SMRs (Task D);

3. Decay heat is driven by the fuel's activity (Task E);

4. Burnup and spent fuel activity, and decay thermal power have a directly proportional relationship for the SLOWPOKE-2 MCNP results valid from 5 to 300 years after the spent fuel has been discharged from the reactor (Task F);

5. Using the SLOWPOKE-2 model's burnup-normalized activity and decay heat as baseline scaling factor, it is possible to estimate SMR reactors' activity and decay thermal power (Task F); and,

6. The derived relationship is only valid for reactors using UO_2 fuel with ~19.6% enrichment for a period of 5 to 300 years after discharge (Task G).

Overall, a relationship has been established between SLOWPOKE-2 operational burnup and the resulting spent fuel's activity and decay heat. It is now possible to estimate SMR spent fuel characteristics, within limitations, to assess the GDR's ability to manage them in its current design.

Chapter 5

Principal Outcomes and Recommendations – SMR Spent Fuel in the GDR

5.1 Introduction

The GDR, as currently intended, is designed specifically to handle CANDU fuel bundles, used here as the reference design. This design range is used as a comparison factor against which SMR designs are compared for their suitability to be included in the GDR waste management process.

This chapter provides the basis for the completion *Primary Objective 3* and is organized into two sections to extrapolate on the SMR spent fuel management within the DGR context.

Section 5.2 presents six SMR designs selected as a representation of SMRs spent fuel to be compared with the reference spent fuel. Decay heat and activity are assessed as the main comparison characteristics, with potential impacts of their values on the GDR.

Section 5.3 presents possible areas for investigation and future work required to properly assess higher burnup and enriched SMR fuel.

5.2 SMR Comparison to GDR Design

5.2.1 Methodology

The SLOWPOKE-2 results from MCNP 6.2 were scaled up using Eq. (21) and Eq. (22), respectively for activity and decay heat. The results were compared to NWMO published CANDU reference fuel activity and decay heat for the post-discharge time range (5-300 years) [114].

A selection of SMR design fitting the limitations of the model have been selected for the application of Eq. (21) and Eq. (22) (converted to $MWd{\cdot}MTU^{-1}$) and comparison with the DGR reference.

Any results passing beyond the threshold of the reference bundle does not in itself indicate that the GDR safety limits have been breached. It does indicate however, that there is a possibility that assumptions made during the design of the GDR for CANDU spent fuel do not hold any more in the case of SMR spent fuel and that further analysis and design changes are required.

5.2.2 Selected SMRs

SMRs within the limitations of the model have been selected as a comparison point with the reference CANDU fuel bundle. The selection was made from the IAEA ARIS database for SMRs (see Annex B), based on their use of UO_2 fuel with enrichment near that of the SLOWPOKE-2 [64]. As SMRs were not designed exactly to the same fuel specification as the SLOWPOKE-2, the selection was narrowed using SMRs with a fuel enrichment of 19.6 ± 0.5%. Table 24 presents the selected SMRs for direct comparison with the DGR design.

Table 24. Selected SMR Designs for Comparison

Reactor Type	**Reactor Name**	**Thermal Power** MW_t	**Coolant type**	**Moderator**	**Fuel Type**	**Fuel enrichment** (^{235}U unless otherwise noted) %	**Average Burnup** $MWd{\cdot}MTU^{-1}$
LMFR	SEALER	8	Lead	Lead	UO_2	19.75	33 000
	LFR-TL-X	15/30/60	Lead	None	UO_2	19.75	40 000
	SVBR	280	Lead-bismuth eutectic alloy	Lead-bismuth eutectic alloy	UO_2	< 19.3	60 000
	Westinghouse LFR	950	Lead	Fast Spectrum	UO_2, with provision to transition to UN	≤ 19.75	≥ 100 000
PWR	SHELF	28.4	H_2O	H_2O	UO_2	19.7	Up to 160 000
	RITM-200	165	H_2O	H_2O	UO_2	19 - 19.6	68 400

Considering the median SMR burnup is approximatively 60 000 $MWd{\cdot}MTU^{-1}$ and the average burnup of approximately 100 000 $MWd{\cdot}MTU^{-1}$ (see Table 4), the selected SMRs for comparison are estimated as a good representation of actual possible SMRs. Of particular interest is the SEALER design, which is in the pre-licensing process at CNSC but was unfortunately the only reactor project in Canada meeting the limitations of the proposed relationship.

5.2.3 Discussion

The estimated activities and decay heat of the sample SMRs, calculated using Eq. (21) and Eq. (22), are presented at Figure 42 and Figure 43, respectively.

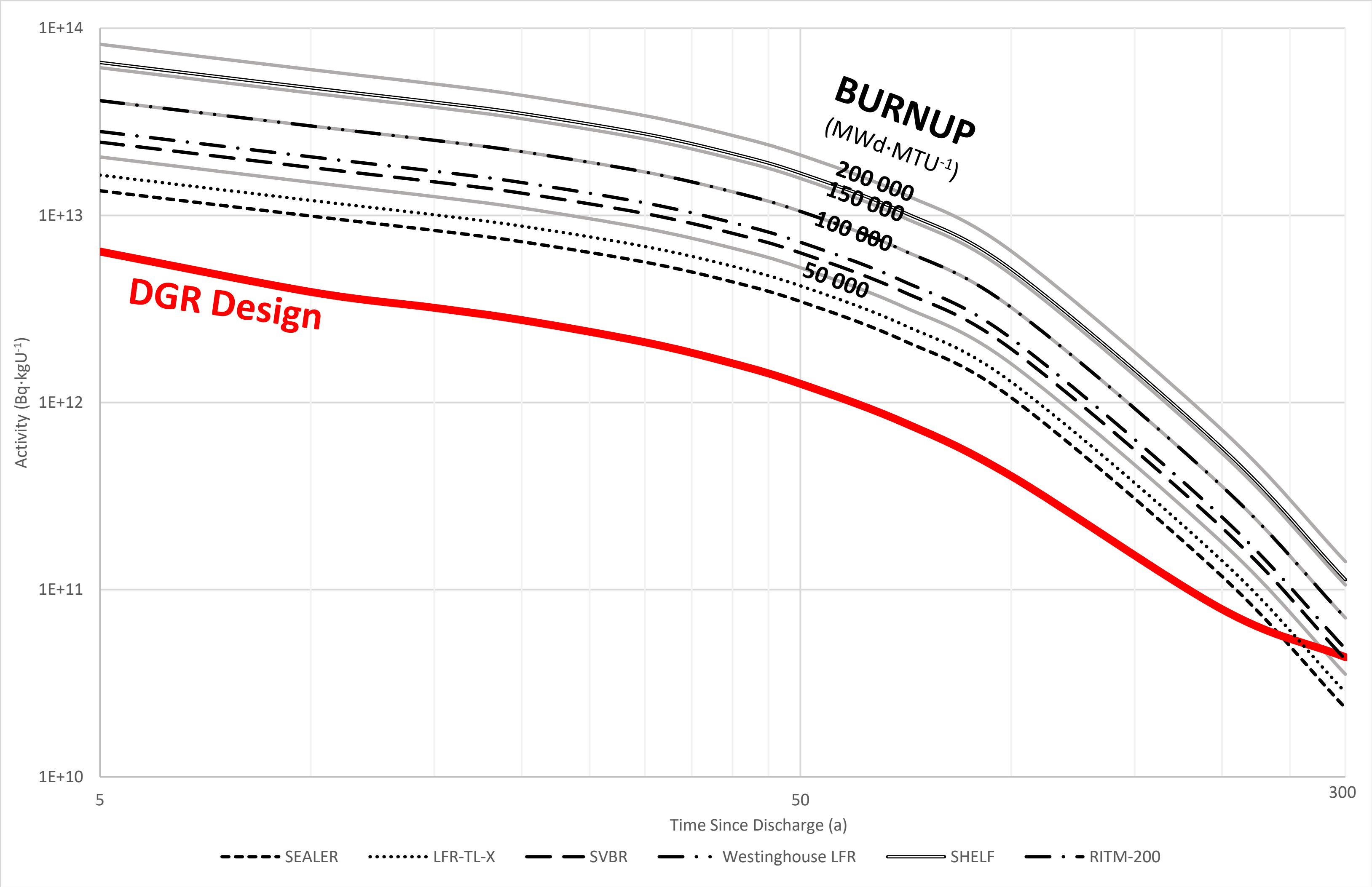

Figure 42. Estimated SMR Activity 5 to 300 Years Post-Discharge (~19.6% enrichment, UO_2)

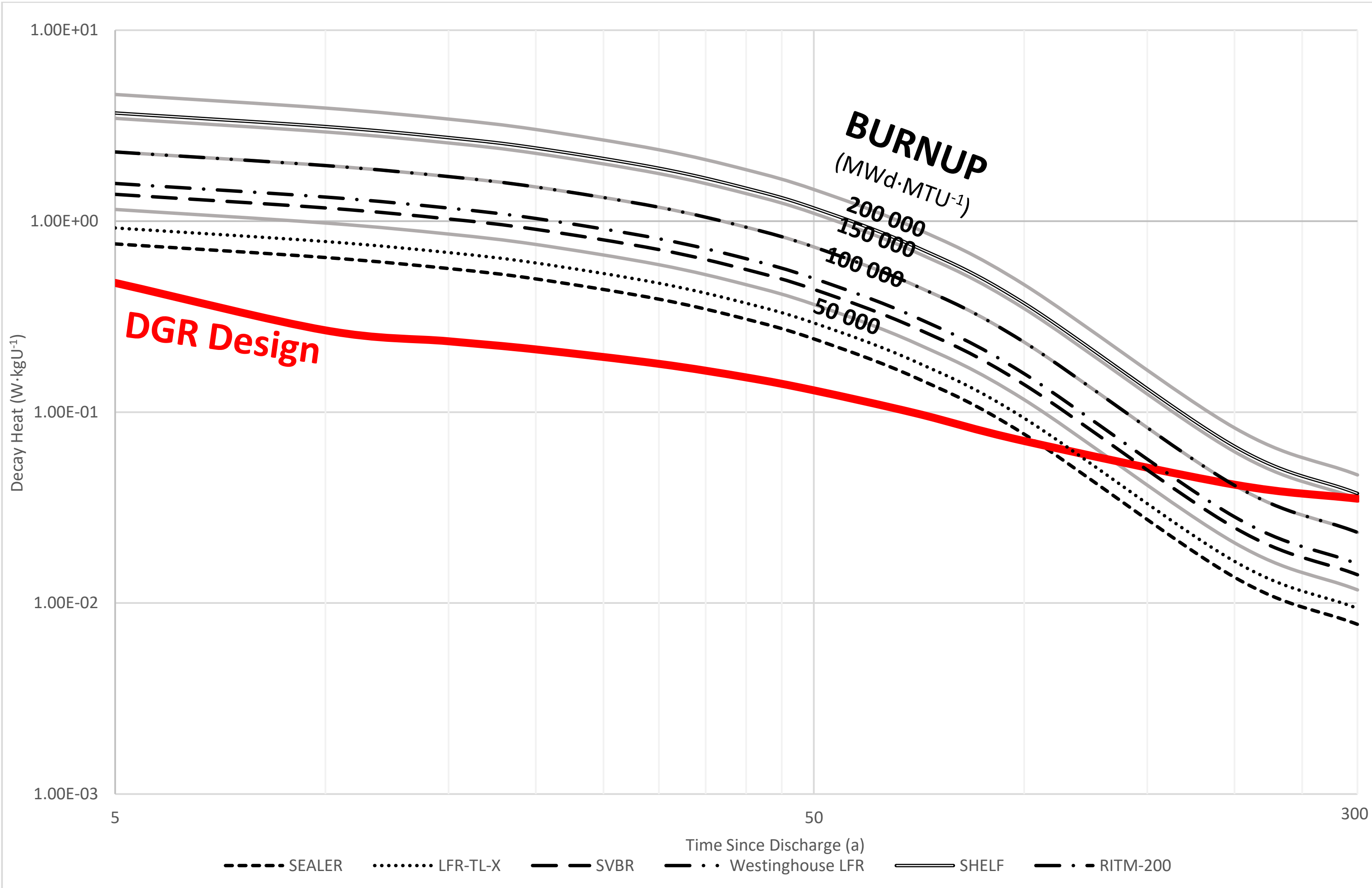

Figure 43. Estimated SMR Decay Heat 5 to 300 Years Post-Discharge (~19.6% enrichment, UO_2)

Across the timeline of interest (5-300 years post-discharge), both the activity and decay thermal power of SMR designs are consistently above the DGR reference spent fuel design, with the exception of the tail end of the timeline of interest (Figure 42 and Figure 43).

It is to be noted that the assessment has been conducted on the spent fuel only and does not include cladding or supporting structure which would invariably increase the overall absolute activity and decay heat generated within the GDR.

5.2.3.1 *Activity*

As the general trend is equally valid for the SLOWPOKE-2 simulated fuel (Figure 36) as it is for the CANDU spent fuel (Figure 11), it can be posited that the higher fission products generation at higher burnups would produce proportionally greater doses at higher burnups for the post-discharge regions. Figure 44 present the effective dose rate of a reference CANDU bundle (near contact) and of a reference bundle filled UFC (near contact).

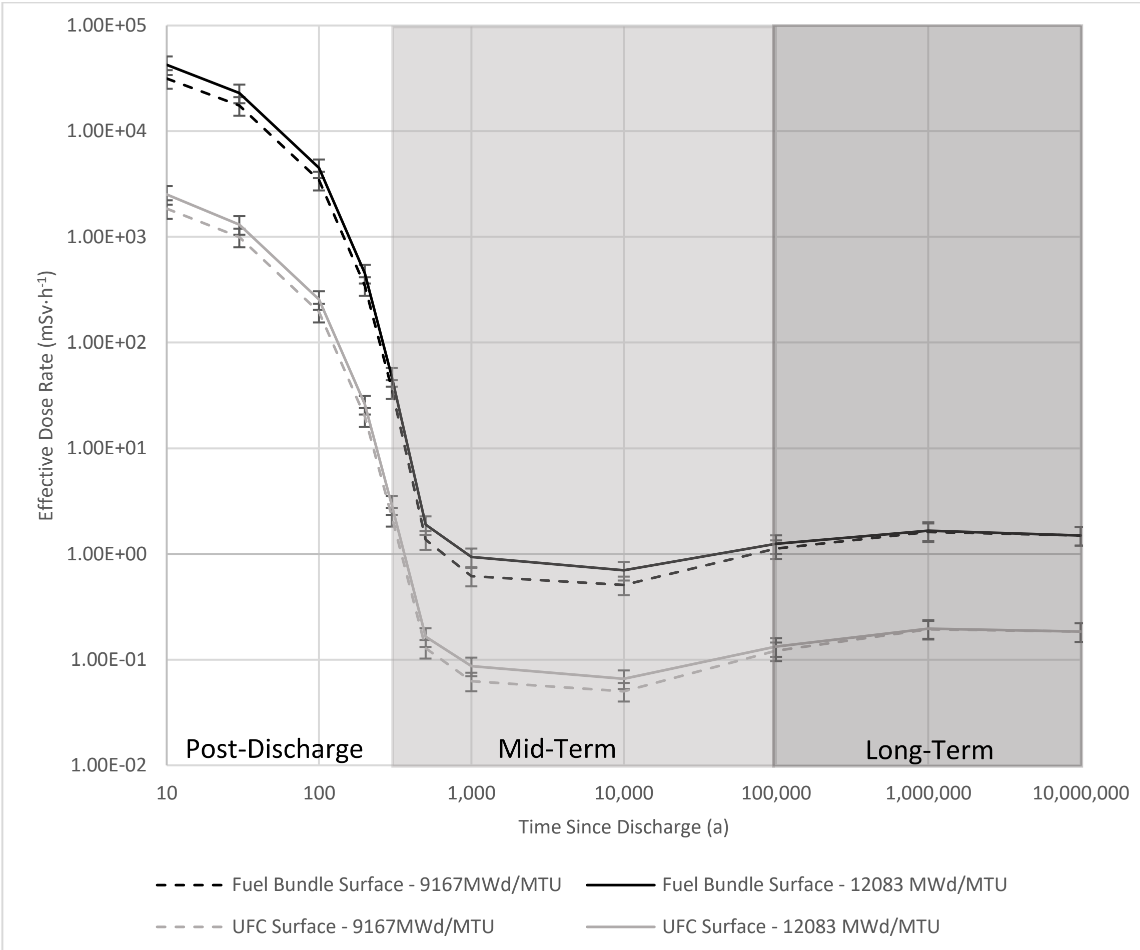

Figure 44. Effective Dose Rate of a Reference Bundle and UFC (Data From [193] using ICRP 2010)

If the UFC retains its structural integrity, α and β particles are retained within the fuel matrix and the UFC structure and have no discernible impact to emitted radiation to the UFC's exterior. Gamma photons, and neutrons to a much lesser extent, are the only significant radiation making it to the outside of the UFC [193].

An increase in radioactivity dose within the confines of an intact GDR does not in itself constitute a significant concern. The increase in activity within the UFC would, however, contribute to the increase in radiolysis of water vapour within the UFC and water surrounding the UFC, which in turn contribute to the production of oxidizing and reducing products which could potentially hasten the corrosion of the UFC's steel structure and of the UFC's copper coating to an unknown extent [194], [195]. Similarly, the added production of hydrogen by radiolysis could contribute to an increase in zircaloy cladding failure [194], [195].

The effective dose rate trends generally follow that of the CANDU activity curve (Figure 11) first being driven by rapidly decaying fission products in the post-discharge region (from 5 to 300 year), then being driven by actinides (300 years and beyond). Ariani highlights ^{137m}Ba as being the principal gamma source for the 10-to-200-year period, which relates back to its activity contribution in CANDU spent fuel (Figure 13) [193].

In the event of a UFC failure, the added fission products and activation products from a higher burnup would produce more of the mobile radionuclides (*e.g.*, ^{129}I, ^{36}Cl, and ^{14}C) than anticipated with the reference fuel and therefore increase the potential exposure of the geosphere to radiation.

5.2.3.2 ***Decay Heat***

For a normally operating DGR, the peak temperature is reached within the first 100 years of operation (Figure 10) [111]. The system is designed for a temperature of less than 100 °C with a safety margin to the 150 °C threshold affecting the surrounding bentonite clay [40]. Considering the maximum temperature of 84 °C (crystalline rock) and 93°C (sedimentary rock) at the container surface occurring at approximatively 45 years of GDR time (75 years post-discharge with 30 years wet/dry storage prior to internment), as calculated by Guo, a 20% enriched reactor operating at 60 000 MWd·MTU^{-1}, the median SMR burnup (Table 4), would have a decay thermal power generated by the spent fuel approximatively *five* (5) times superior as that of the reference CANDU spent fuel for the same timeline [111]. Similarly, at 100 000 MWd·MTU^{-1}, approximatively the average SMR burnup, the decay thermal power would be approximatively *eight* (8) times superior to the reference CANDU spent fuel.

Decay heat has an impact on several critical DGR design factors, amongst others:

- UFC properties (Corrosion rate, mechanical);
- Bentonite properties (mechanical, sorption, water saturation rates);
- GDR surrounding rock properties (mechanical, dissolution rates,); and,
- Microbial processes [194], [195].

A significant increase in decay heat produced by the spent fuel would invariably have a negative effect on those aspects. Should the increase be sufficient to affect bentonite properties significantly, it could have a compounding effect: as drying bentonite cracks and allows rapid water movement to the UFC surface, leading to accelerated UFC corrosion due to the presence of water, and therefore possible premature failure.

5.3 Recommendations and Future Work on GDR Design

Two preliminary post closure safety assessments have been conducted by NWMO, one for the GDR constructed in crystalline rock, the other in sedimentary rock. Multiple scenarios involving single or multiple failures of DGR components, or sudden increase or decrease of critical DGR parameters. However, in all cases, the reference spent fuel, remains unchanged [194], [195].

Considering the initial foundations on which the assessments are conducted cannot be used to assess the viability of accepting SMR spent fuel within the current design of the GDR, and considering the demonstrated extent, using simulated SLOWPOKE-2 spent fuel, at which SMR spent fuel can diverge from the reference design fuel for both activity and decay heat generated, it is therefore recommended that an extensive review be conducted on the design and parameters of the GDR.

Unfortunately, the current model cannot be used to extrapolate on the behaviour of the higher burnup and higher enrichment spent fuel within the confines of a DGR. Significant assessments and modelization of fuels other than the reference spent fuel must be conducted to validate the GDR design fully and properly for use by higher burnup SMR spent fuel. Therefore, only qualitative, and generic recommendations can be provided, with several avenues for future work to be explored.

Acceptance Criteria and Limit Definitions

The acceptance criteria for the spent fuel at NWMO is, at the time of writing, undefined. The parameters governing all aspects of the operating GDR behaviour are well understood and documented, with limits identified (*e.g.,* temperature limit of 100 °C for the container cover and bentonite clay buffer). However, the GDR has only been extensively researched for CANDU spent fuel bundles. For all known and identified limits, a corresponding acceptance criterion ensuring that the limit is not breached according to the safety assessment should be investigated and promulgated. It is not possible to control the DGR once the UFCs are in position, but it is possible to control what exactly are loaded in the UFCs.

Geometry

The interior of the UFC is specifically designed for CANDU bundles. The management of SMR waste would require the redesign of the UFC's interior to accommodate different type of fuel geometry. Likewise, the automatic handling system managing the spent fuel from the transport vessel to the UFC would have to be modified to handle the new fuel. One avenue to investigate further is the creation of a standardized fuel bundle of dimensions similar to that of the CANDU bundle that could be taken into the current UFC interior design.

Quantity

Considering the temperature limit of 100 °C to the UFC's surface, a limit to the generated thermal power within the UFC could be established based on the reference fuel. For example, assuming the limit is set to the current reference fuel, for a 20% enriched fuel at 60 000 $MWd \cdot MTU^{-1}$, the amount of spent fuel in a single UFC would need to be reduced by approximatively *five* (5) times to reach the same decay thermal power level.

Consequently, a GDR would have to be *five* (5) times as voluminous to accommodate the additional UFCs needed to manage the same amount of fuel, changing the original design significantly and requiring a greater area of operation for the GDR.

UFC Placement within the GDR

If a standard load limit is not established, it is possible to position UFCs farther away from each other to reduce the compounding effects on temperature and radioactivity that they have on one another. Again, this would most assuredly require a GDR greater than originally designed.

Decay Time Prior to Permanent Disposal

Keeping the spent fuel in wet or dry storage for longer periods of time until they become manageable within the construct of the current GDR design is possible, but impractical as it could take hundreds of years possibly to reach levels similar to that of the reference fuel. For example, it would take approximately 100 years for RITM-200 spent fuel to reach a generated decay heat commensurate to the reference fuel at the start of its time in the GDR (10 years post-discharge) (Figure 43).

5.4 Chapter Conclusion

Using the scaling factor defined in Chapter 4, the DGR reference design was compared to SMR designs. It was determined that for the post-discharge region from 5 to 300 years, the decay heat generated by the spent fuel, a characteristic critical for DGR integrity, for an SMR of average burnup of 100 000 $MWd \cdot MTU^{-1}$ could potentially reach levels approximatively *eight* (8) times superior to the reference CANDU spent fuel. The following conclusions were derived:

1. The current model cannot determine if, and when, the SMR spent fuel would breach the limits of the GDR (Task I); and,

2. Significant further investigations are required to support a safety assessment of the new spent fuel in the GDR. Specifically, spent fuel acceptance criteria must be identified and confirmed (Task I).

Chapter 6

Conclusion and Future Work

The main goal of the present work was to explore (using the RMC SLOWPOKE-2 as a baseline) how, and if, the current GDR design are adequate to respond to large-scale deployment of SMRs in Canada. Overall, the main objective has been partially achieved based on the three objectives identified at the onset.

6.1 Conclusion

Primary Objective 1: Develop and benchmark a MCNP 6.2 model representing the RMC SLOWPOKE-2 post-refuelling

A NAA experiment was used to benchmark the SLOWPOKE-2 MCNP 6.2 model using Al-Au wires, with and without cadmium shielding, in inner site no. 2 and outer site no. 10 of the RMC SLOWPOKE-2. The NAA experiment was modelled in MCNP and compared to the experimental values (*i.e.*, neutron fluxes, cadmium ratios and thermal-to-epithermal ratios). Both the NAA experiment and MCNP model compared favorably with existing literature. It was assessed that the model was an adequate representation of the SLOWPOKE-2. The benchmarked model has an estimated departure, when compared to the NAA experiment, of 5% for the inner site and 25% for the outer site (for both the thermal and total neutron fluxes). This represents a marked improvement from previous RMC SLOWPOKE-2 model iteration, the last of which had an estimated departure from experimental values of 30% [121].

Primary Objective 2: Determine the SLOWPOKE-2 post-discharge characteristics and fissions products inventory of the refuelled core

The CINDER90 fuel depletion module of MCNP 6.2 was used on the benchmarked model to generate the fuel isotopic inventory at the end of its operational life and calculate its operational burnup. The discharged fuel was then decayed over 10 million years and assessed based on its activity and generated decay heat.

Primary Objective 3: Assess the suitability of SLOWPOKE-2 to serve as a scalable model for SMRs' waste management.

A relationship was derived for the post-discharge time from 5 years to 300 years of decay, where the burnup of the reactor increased at the same rate as its power rating and at the same rate as the spent fuel's activity and decay heat. Therefore, using the SLOWPOKE-2 activity and decay heat normalized on its burnup, it is possible to use the SLOWPOKE-2 as the baseline and scale it up to SMR burnup levels. The defined relationship has been limited to reactors with fuel enriched to about 20% ^{235}U and of a similar composition as the SLOWPOKE-2's fuel (*i.e.*, uranium dioxide).

Applying the simulated SLOWPOKE-2 relationship to existing SMR designs demonstrated that potential SMRs had activity and decay heat levels that were significantly higher than the reference fuel used for the GDR design. However, the limits of the current design must be clearly delineated to properly assess if SMR spent fuel are manageable with the current DGR design and provide actionable recommendations.

Overall, the contribution of the present work to science includes the confirmation that SLOWPOKE-2 can, within limits, be used as a predictive baseline for SMRs spent fuel. More importantly, this work created the first benchmarked SLOWPOKE-2 simulation model of the newly refuelled reactor, which is already being used in other studies in the advancement of the SLOWPOKE-2 knowledge [196].

6.2 Future Work

6.2.1 Neutron Activation Analysis

Holistic Reactor Approach

The present experimental approach only looked at site no. 2 and no. 10 of the RMC SLOWPOKE-2 reactor. The prevailing assumption was that both sites would be an adequate representation for all inner and outer sites. However, there could exist significant differences between the neutron fluxes of each site as presented by Andrews [161]. Similarly, further investigation of the neutron field could be conducted by using multiple materials and investigating multiple reactions, for example $^{27}Al(n,\alpha)^{24}Na$ to characterise parts of the fast neutron field as conducted by Tiyapun *et al*. and Chiesa *et al*. [146], [171].

It is therefore recommended to conduct neutron flux assessments with multiple materials, in all sites and within the reactor pool to expand knowledge of the new core beyond the confines of the reactor container. As well, more experimental data for the reactor could support further benchmarking and improvements of the MNCP model.

Reactor Power

The method to calculate the SLOWPOKE-2 reactor power has not been revised since the commissioning of the reactor in 1985. Data obtained by this work as well as preliminary MCNP assessments (Annex U) seem to point towards the need to re-evaluate the power factor used, or the method itself.

Knowing the actual power of the reactor is essential to allow comparison with known literature values as well as being critical to properly conduct simulations of the reactor in MCNP (both for burnup simulations and flux tallies). Therefore, it is recommended that further investigation be conducted on the determination of power for the SLOWPOKE-2 new core installed in Fall 2021, and if warranted revisit the updated MCNP model benchmarking process.

Evaluation of the SLOWPOKE-2 reactor's thermal power is currently being conducted by CNL and Di Giovanni using computational fluid dynamics and data analysis of SLOWPOKE-2 logs. One of the expected outcomes of the CNL / Di Giovanni assessment is an updated power conversion factor linking the reactor's thermal power to the detected neutron flux at the SPND [197].

Reactor Reaction Time vs. Steady State

The irradiation time of 5 minutes were selected specifically to reduce exposure to the operators while allowing for adequate neutron capture reactions in the sample. However, as shown at Annex P, that short of an irradiation time has the sample experience varying fluxes due to the time required for the reactor to reach steady state. Considering it is most likely not easily feasible to fasten the control reaction time of the reactor itself to compensate for neutron field disruptions in the core brought by the insertions of samples, lengthening the irradiation time should be investigated to increase the percentage of stable neutron flux time for the sample irradiation.

6.2.2 MCNP Simulation of NAA Experiment

Model Code Review

Due to the way the model code was reconstructed from an MCNP 6.1 output file, several notes and information on the way the code works have been removed or are incomplete. As well, due to the number of iterations to the code and several changes, a "master code" should be created by comparing the model with the original SLOWPOKE-2 blueprints and confirming measurements of the reactor as installed at the RMC.

Material Evolution and Beryllium Poisoning Impact

The current model does not consider beryllium poisoning, and more generally material evolution of the SLOWPOKE-2 reactor components that are irradiated over the lifetime of the reactor. As most reactor components, other than the core refuelled in September 2021, have been in use since commissioning in 1985, and expect to remain in place until at least the end of the new core's operating life, material evolution within the core might have an increasing impact on the core's operating conditions.

Investigating material composition changes over time would allow for an anticipation of the future impact on results and reactor operating conditions and provide modelling results that are better representative of reality.

6.2.3 Burnup and Decay Simulations

Cladding and Activation products

The present work only considers the spent fuel. Expanding to include the cladding and activation products of the core material would provide a better estimate of the overall activity and decay heat of the SLOWPOKE-2 core, which could potentially be used to improve the proposed relationship.

Benchmarking with other Codes and Reactors

It is recommended that a purpose designed depletion code in the likes of ORIGEN or SERPENT be used to ascertain the spent fuel burnup, decay heat and isotopic activity values obtained from the MCNP CINDER90 module [198], [199]. Similarly, the MCNP model should also be benchmarked against full reactor simulation codes for example the DONJON/DRAGON codes which have been successfully used to simulate the SLOWPOKE-2 research reactor [200], [201].

Further investigations should be conducted to refine the relationship found based on the SLOWPOKE-2 values. Benchmarking the proposed process with known existing reactor burnup and isotopic composition values and adjusting it, if required, would strengthen the relationship, and increase the accuracy of the predictions. As well, exploring other fuel enrichment, burnups and fuel type would contribute to strengthening the proposed relationship.

Expanding Knowledge

Ultimately, the logical conclusion of any future work relating to the inclusion of SMR spent fuel to the NWMO GDR would be the creation of a reference SMR fuel which would be representative of the SMRs that could be used in Canada. The reference fuel could be used to build the DGR safety case for the safe inclusion of SMR spent fuel in the DGR and, if required affect changes to the current design. The reference fuel would not need to be an actual operational design but would need to encompass the potential risks and exposure limits of all possible spent fuel.

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Annex A

Advanced Reactors (ARIS)

Table A-1. Advanced Reactors [A1]

Reactor Type	**Reactor**	**Thermal Power** MW_t	**Coolant**	**Moderator**	**Fuel**	**Fuel enrichment** (^{235}U unless otherwise noted) %	**Average Burnup** $MWd \cdot THM^{-1}$
BWR	ABWR	3926	H_2O	H_2O	UO_2	4	50 000
	ABWR-II	4960	H_2O	H_2O	UO_2	5.2	60 000
	ESBWR	4500	H_2O	H_2O	UO_2	-	-
	KERENA	3370	H_2O	H_2O	UO_2 and MOX	4.95	60 000
	RMWR	3926	H_2O	H_2O	UO_2 and MOX	11.4	50 000
GCR	GTHTR300C	600	Helium	Graphite	UO_2 and MOX	14.3	120 000
	Prismatic HTR	350	Helium	Graphite	UO_2	15.5	117 000
GFR	KAMADO FBR	3000	Carbon Dioxide	None	UO_2 and MOX	18	100 000
HWR	ACR-1000	3200	H_2O	D_2O	UO_2	2.4	20 000
	EC6	2084	D_2O	D_2O	UO_2	0.7	7 500
	IPHWR-700	2166	D_2O	D_2O	UO_2	0.7	7 000
iPWR	IMR	1000	H_2O	H_2O	UO_2	4.8	46 000
LFR	ELFR	1500	Lead	None	MOX	-	-
	W-LFR	950	Lead	None	Oxide (UO2 or MOX) (prototype) Advanced fuel	-	100 000
MSR	LFTR	600	Fluoride Salts	Graphite	Molten salt with thorium and uranium	-	-
	MSFR	3000	Molten Salt	None	LiF-(U,Pu)F3-ThF4	-	-
PWR	AP 1000	3400	H_2O	H_2O	UO_2	4.8	60 000
	AP-600	1940	H_2O	H_2O	UO_2	4.8	55 000
	APR+	4290	H_2O	H_2O	UO_2	4.26	45 600
	APR1000	2815	H_2O	H_2O	UO_2	4	54 100
	APR1400	3983	H_2O	H_2O	UO_2	4.65	46 500
	APWR	4466	H_2O	H_2O	UO_2	-	55 000-65 000 [202]
	ATMEA1	3150	H_2O	H_2O	UO_2 and MOX	5	-
	EPR	4590	H_2O	H_2O	UO_2 and MOX	4.95	60 000
	OPR1000	2815	H_2O	H_2O	UO_2	4	54 000
	UK-SMR	1276	H_2O	H_2O	UO_2	4.95	57 500
	VVER-1000 (V-466B)	3000	H_2O	H_2O	UO_2	4.45	52 800
	VVER-1200 (V-392M)	3200	H_2O	H_2O	UO_2	4.79	60 000
	VVER-1200 (V-491)	3200	H_2O	H_2O	UO_2	4.79	60 000
	VVER-1500 (V-448)	4250	H_2O	H_2O	UO_2	4.92	57 200
	VVER-600 (V-498)	1600	H_2O	H_2O	UO_2	-	56 600

	VVER-640 (V-407)	1800	H_2O	H_2O	UO_2	3.18	47 380
SCWR	CSR1000	2300	H_2O	H_2O	UO_2	6.2	45 000
	HP-LWR	2300	H_2O	H_2O	UO_2	9	60 000
	JSCWR	3681	H_2O	H_2O	UO_2	7.2	45 000
SFR	ASTRID	1500	Sodium	None	MOX	20	-
	BN-1200	2800	Sodium	None	Nitride or MOX	-	-
	CFR-600	1500	Sodium	None	UO_2 and MOX	-	100 000
	FBR-1 & 2	1250	Sodium	None	MOX	-	-
	JSFR	3530	Sodium	None	MOX	-	-
	PRISM	840	Sodium	None	U-Pu-Zr	26	-
	TWR-P	1475	Sodium	None	U-Zr	-	-

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Annex B

Small Modular Reactors, Research Reactors, Demonstrators and Prototypes

Table B-1. Small Modular Reactors, Research Reactors, Demonstrators and Prototypes [B1], [B2]

Reactor Type	**Reactor**	**Thermal Power** MW$_t$	**Coolant type**	**Moderator**	**Fuel Type**	**Fuel enrichment** (^{235}U unless otherwise noted) %	**Average Burnup** MWd·THM^{-1}
BWR	BWRX-300	870	H_2O	H_2O	UO_2	3.40 (avg) / 4.95 (max)	49 500
	DMS	840	H_2O	H_2O	UO_2	< 5	< 60 000
	KARAT-100	360	H_2O	H_2O	UO_2	4	45 900
	KARAT-45	180	H_2O	H_2O	UO_2	4.5	45 900
	VK-300	750	H_2O	H_2O	UO_2	4	41 400
FHR	Mk1 PB-FHR	236	Li2BeF4	Graphite	TRISO particles in graphite pebble matrix	19.9	180 000
FHTR	Energy Well	20	Molten Salt FLiBe	Molten Salt FLiBe	TRISO	15	70 000
FR	Aurora	4	Liquid Metal	None	Metal fuel		
GCR	PBMR	400	Helium	Graphite	UO_2	-	92 000
	Prismatic HTR	350	Helium	Graphite	UO_2	15.5	117 000
GFR	ALLEGRO	75	Helium	None	MOX	-	-
GMFR	EM2	500	Helium	None	UC	~14.5	~130 000
Heat Pipe	MoveluX	10	Sodium heat-pipe	Calcium hydride (CaH2)	Silicide (U3Si2)	4.8 - 5.0	1 000
	Westinghouse eVinci	7-12	Heat pipes	Metal hydride	TRISO or another encapsulati on	5 - 19.75	
HTGR	A-HTR-100	100	Helium	Graphite	Pebble bed with coated particle fuel	LEU or WPu	86 000
	GTHTR300	<600	Helium	Graphite	UO_2 TRISO	14	120 000
	GTHTR300C	600	Helium	Graphite	UO_2 and MOX	14.3	120 000
	GT-MHR	600	Helium	Graphite	Coated particle fuel	14-18 or WPu	100 000 720 000 (Depend on fuel type)
	HTMR-100	100	Helium	Graphite	TRISO particles in pebbles: LEU, Th/LEU, Th/HEU or Th/Pu	Depending on selected fuel	80 000 – 90 000
	HTR-10	10	Helium	Graphite	TRISO (UO_2 kernel)	17	80 000
	HTR-PM	500	Helium	Graphite	UO_2	8.5	90 000
	HTTR-30	30	Helium	Graphite	TRISO (UO_2 kernel)	3 – 10 (6 avg.)	22 000 33 000 (max)
	MHR-100	215	Helium	Graphite	Coated particle fuel	< 20	

	MHR-T	600	Helium	Graphite	Coated particle fuel	< 20	125 000
	MMR	15	Helium	Graphite	FCM or TRISO graphite	19.75	> 60 000
HTGR	PBMR-400	400	Helium	Graphite	Pebble bed with coated particle fuel	9.6 or WPu	
	RDE	10	Helium	Graphite	Spherical elements with coated particle fuel	17	80 000
	SC-HTGR	625	Helium	Graphite	UCO TRISO	14.5 average 18.5 max	165 000
	StarCore	35, 50, 150	Helium	Graphite	TRISO	15	60 000
	U-Battery	10	Helium	Graphite	TRISO	< 20	~ 80 000
	Xe-100	200	Helium	Graphite	UCO TRISO, pebbles	15.5	165 000
HWR	AHWR	920	H_2O	D_2O	MOX	3.25	38 000
	IPHWR-220	754	D_2O	D_2O	UO_2	0.7	9 000
	TEPLATOR	50	D_2O	D_2O	Spent fuel	<1.2	2 300
LBR	Micro-URANUS	60	Pb-Bi (45-55 wt.%) eutectic alloy	Pb-Bi (45-55 wt.%) eutectic alloy	UO_2	3 radial zones; 8, 10, 12	60 000
LFR	ALFRED	300	Lead	None	MOX	-	-
	CLEAR-I	10	Lead Bismuth Eutectic alloy	None	UO_2	-	-
	ELECTRA	0.5	Lead	None	(Pu,Zr)N	-	-
	G4M	70	Lead Bismuth Eutectic alloy	None	Uranium nitride	19.75	-
	MYRRHA	100	Lead Bismuth Eutectic alloy	None	MOX	-	-
	PEACER	850	Lead Bismuth Eutectic alloy	None	U-TRU-Zr	-	-
	SVBR-100	280	Lead Bismuth Eutectic alloy	None	UO_2	16.5	-
LMFR	4S	30	Sodium	None	U-Zr alloy	< 20	34 000
	ARC-100	355	Sodium	Sodium	U-Zr alloy	Avg. 13.1	77 000
	BREST-OD-300	700	Lead	None	Mixed uranium plutonium nitride	up to 14.5	61 450
	LFR-AS-200	480	Lead	None	MOX	19 max. 23.2 in Pu	100 000
	LFR-TL-X	15/30/60	Lead	None	UO_2	19.75	40 000
	SEALER	8	Lead	None	UO_2	19.75	33 000
	SEALER	140	Lead	None	UN	11.8	60 000

	SUPER-STAR	300	Lead	None	Particulate-based U-Pu-Zr metallic fuel with weapons Pu	< 12	55 (mean) 84 (peak)
	SVBR	280	Lead-bismuth eutectic alloy	Lead-bismuth eutectic alloy	UO_2	< 19.3	60 000
	Westinghouse LFR	950	Lead	Fast Spectrum	UO_2, with provision to transition to UN	≤ 19.75	≥ 100 000
LWR	DHR400	400	H_2O	H_2O	UO_2	< 5.0	30 000
MSR	ThorCon	557	Molten Salt	Graphite	UF4, ThF4	19.7	509 000
	CA Waste Burner 0.2.5	100	Fuel Salt	D_2O	LiF-ThF4	Inventory of spent nuclear fuel	900 000 – 1 000 000
	FUJI	450	Molten fluoride	Graphite	Molten salt with Th and U	2.0 (0.24%U233 + 12.0%Th). Pu or LEU can be used	No mechanical limit for burnup
MSR	Integral MSR	440	Fluoride fuel salt	Graphite	Molten salt fuel UF4	< 5	29 000
	LFTR	600	$LiF-BeF_2-UF_4$ Fuel Salt	Graphite	LiF-BeF2-UF4	N/A, ^{233}U derived from Thorium	-
	MCSFR	125/500/1000/3000	NaCl-XClv-YClz-UCl_3/4-$PuCl_3$-FPCly fuel salt	None	Molten Chloride Salt	10% Pu fissile/(Pu+U total) or ~15% enriched HALEU	300 000-500 000
	MkI PB-FHR	236	Fluoride Salts	Graphite	UCO	19.8	180 000
	MSTW	270	Molten Salt	Graphite	Eutectic Sodium-actinide fluoride salt mixture	-	250 000
	SmAHTR	125	Fluoride Salts	Graphite	UCO	8	69 000
	smTMSR-400	400	$LiF-BeF_2-ZrF_4-ThF_4-UF_4$ fuel salt	Graphite	Molten salt fuel	19.75	~300 000
	Stable Salt Reactor – Waste-burner	750	molten salt ZrF_4-KF	None	Molten salt fuel	Reactor grade plutonium	120 000 – 200 000
	ThorCon	557	Molten salts	Graphite	UF4, ThF4	5.0 minimum / 19.7 maximum	12 400
Pebble-bed salt cooled Reactor	KP-FHR	320	Li2BeF4	Graphite	TRISO particles in graphite pebble matrix	19.75	-
PHWR	CANDU SMR	960	D_2O	D_2O	UO_2	Natural Uranium	5 800
PWR	ABV-6E	38	H_2O	H_2O	UO_2	<20	N/A
	ACP100	385	H_2O	H_2O	UO_2	<4.95	< 52 000

	ACPR50S	200	H_2O	H_2O	UO_2	< 5	< 52 000
	CAP200	660	H_2O	H_2O	UO_2	4.2	35 000
	CAREM	100	H_2O	H_2O	UO_2	3.1	24 000
	ELENA	3.3	H_2O	H_2O	UO_2 / MOX	15.2	57 600 / 27 390
	FBNR	218	H_2O	H_2O	CERMET	5	15 300
	HAPPY200	200	H_2O	H_2O	UO_2	2.76 avg / 4.45 max	40 000
	IMR	1000	H_2O	H_2O	UO_2	4.8	46 000
	IRIS	1000	H_2O	H_2O	UO_2	4.95	65 000 (max)
	KLT-40S	150	H_2O	H_2O	UO_2	18.6	45 400
	mPower	575	H_2O	H_2O	UO_2	< 5	< 40 000
	NuScale	200	H_2O	H_2O	UO_2	< 4.95	> 30 000
	NUWARD	2x540	H_2O	H_2O	UO_2	<5	
	RITM-200	165	H_2O	H_2O	UO_2	19 - 19.6	68 400
	RUTA-70	70	H_2O	H_2O	Cermet (0.6 UO_2+ 0.4 Al alloy)	3.0	25 000 – 30 000
	SHELF	28.4	H_2O	H_2O	UO_2	19.7	Up to 160 000
	SMART	365	H_2O	H_2O	UO_2	< 5	< 54 000
	SMR-160	525	H_2O	H_2O	UO_2	4.95 (maximum)	45 000 (maximum, initial design)
	UK SMR	1276	H_2O	H_2O	UO_2	4.95 (max)	55 000 – 60 000
	UNITHERM	30	H_2O	H_2O	UO_2 in metallic silumin or Zr matrix, metal-ceramic	19.75	1 150
	VBER-300	917	H_2O	H_2O	UO_2	4.95	50 000
	VVER-300 (V-478)	850	H_2O	H_2O	UO_2	4.79	65 000
	Westinghouse -SMR	800	H_2O	H_2O	UO_2	< 5	> 62 000
SCWR	CSR1000	2300	H_2O	H_2O	UO_2	6.2	45 000
SFR	MBIR	150	Sodium	None	MOX	-	-
	PGSFR	150	Sodium	None	U-Zr and U-TRU-Zr	-	-
	PRISM	840	Sodium	None	U-Pu-Zr	26	-

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Annex C

RMC SLOWPOKE-2 Technical Specifications

Table C-1. Technical Specification for SLOWPOKE-2 [C1], [C2]

General	Reactor type	Pool
	Thermal Power output	20 kW_t
Fuel	Fuel Material	Uranium Dioxide
	Fuel Enrichment	19.89%
	Subassembly Form	Rods
	Subassembly Dimension	4.2 mm dia. x 227 mm
	Cladding	Zircaloy-4
	Cladding thickness	0.5 mm
	Subassembly rating	0.7 kW/m
	Assemblies	198 rods
	Assembly Fissile Content	1.12 kg
	Assembly Heat Transfer Area	0.74 m^2
	Maximum Surface Heat Flux	0.03 MW/m^2
Core	Reactor Vessel	Aluminium
	Vessel Dimensions	0.6 m dia. X 4.3 m
	Core Dimensions	230 mm dia. X 227 mm
	Core Volume	9.4 L
	Number of Fuel Sites	1
	Coolant	H_2O (deionized)
	Peak Thermal Flux	0.01 x 10^{18} $n \cdot m^{-2} \cdot s^{-1}$
	Peak Fast Flux	0.01 x 10^{18} $n \cdot m^{-2} \cdot s^{-1}$
Reactivity Control	Reactor regulation	1x Cd-Al rod
	Maximum excess reactivity	3.4 mk
	Prompt Neutron lifetime	0.07 ms
	Shutdown System	None
Reflector	Material	Beryllium
	Thickness (Axial)	0-100 (Top), 100mm (Bottom)
	Thickness (Radial)	100 mm
	Number of vertical Sites	4x Be, 5x H_2O, 1x Thermal column
	Peak Thermal Flux	0.01 x 10^{18} $n \cdot m^{-2} \cdot s^{-1}$
Biological Shielding	Material	H_2O
	Thickness	4.2 m
	Pool Dimensions	2.46 m dia. X 5.87m

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Annex D

SLOWPOKE-2 Operational History

Table D-1. SLOWPOKE-2 Operational History

	Neutron Flux Hours ((x 10^{11} $n \cdot m^{-2} \cdot s^{-1}$)·hr)	**Total Burnup Days**	**Inserted Reactivity** (mk)	**Total Inserted Reactivity** (mk)	**Excess Reactivity Before and After Shimming** (mk)	**Shim Height** (cm)
Sep-85		Commissioning			3.45	0.08
Jan-89	18 964	158	2.5	2.5	0.96 3.46	0.40
Mar-91	32 446	270	1.14	3.64	2.09 3.23	0.64
Nov-94	49 383	412	2.12	5.76	1.62 3.74	1.03
Apr-98	70 926	591	2.1	7.86	1.73 3.83	1.59
Aug-01	88 719	739	1.55	9.41	2.4 3.95	1.98
Oct-05	118 978	991	1.81	11.22	2.09 3.90	2.62
Apr-10	160 764	1340	1.99	13.21	1.99 3.98	3.41
Feb-14	183 003	1525	2.15	15.36	1.79 3.94	5.40
Jul-21	202 673.35	1689	-0.5	14.86	3.52 3.02	4.45
Sep-21	203 521.56	1696			2.97	

Note. Data is taken directly from SLOWPOKE-2 logs. Logs were provided without margin of errors and are therefore presented here as is.

Annex E

Self-Shielding Factors

Stewart & Zweifel Method [E1]

The Steward & Zweifel method was selected by Andrews as the self-shielding correction used for the flux calculations of the neutron activation analysis [E2]. It was used here as to have a comparison point with Andrew's results for the RMC SLOWPOKE-2. The method assumes an isotropic incident neutron field for a cylinder (wire). The self-shielding factor (f_c) is provided by (E–1):

$$f_c = 1 - \frac{4}{3} N \sigma_a r \qquad \text{(E–1)}$$

Where

N = Nuclei density (nuclei·cm^{-3})

σ_a = Absorption cross section (cm^2)

r = Wire radius (cm)

Universal Sigmoid Curves [E3],[E4]

The universal sigmoid curves method was empirically developed by Martinho, Salgado and Gonçalves using MCNP (code version not mentioned) calculated self-shielding factors and allows the computation of the thermal self-shielding factor (G_{th}) and the resonance self-shielding factor (G_{res}) based on material composition and a single geometric parameter. For the thermal region self-shielding factor, G_{th}, the curve is defined by (E–2):

$$G_{th} = \frac{1}{1 + \left(\frac{z}{1.029}\right)^{1.009}} \qquad \text{(E–2)}$$

Where the factor z is defined by (E–3), with the geometric and macroscopic parameters:

$$z = 2r\Sigma_t \left(\frac{\Sigma_a}{\Sigma_t}\right)^{0.85} \qquad \text{(E–3)}$$

Where

r = Wire radius (cm)

Σ_t= Total macroscopic cross-section (cm^{-1}) averaged over the thermal neutron spectrum at room temperature

Σ_a= Absorption macroscopic cross-section (cm^{-1}) averaged over the thermal neutron spectrum at room temperature

For G_{res}, the curve is defined by (E–4):

$$G_{res} = \frac{0.94}{1 + \left(\frac{z}{2.70}\right)^{0.82}} + 0.06 \qquad \text{(E–4)}$$

Where the factor z is defined by (E–5):

$$z = \Sigma_{tot}(E_{res})(2r)\left(\frac{\Gamma_\gamma}{\Gamma}\right)^{1/2} \quad \text{(E–5)}$$

Where,

r = Wire radius (cm)

$\Sigma_{tot}(E_{res})$= Macroscopic cross-section at the resonance peak (cm^{-1})

Γ_γ = Resonance width for the (n,γ) reaction (eV)

Γ= Total resonance width (eV)

ASTM Method [E5], [E6]

The ASTM standard for the determination of thermal neutron flux uses various tabled data to evaluate the self-shielding factors. However, the included information is for pure elements and does not present information for alloys. For geometries and materials not included in the tables, the ASTM points to William & Gilliam for self-shielding correction factors [E6].

For a wire geometry in an isotropic Maxwellian incident neutron field, the self-shielding factor (f) is defined by (E–6):

$$f = 1 - \frac{8}{3\sqrt{\pi}}\left(\Sigma_{0a}\sqrt{\frac{T_0}{T}}\right) + \left(\Sigma_{0a}\sqrt{\frac{T_0}{T}}\right)^2\left(\ln\left(\frac{1}{\Sigma_{0a}}\sqrt{\frac{T}{T_0}}\right) + \frac{5}{4} - \frac{3}{2}\gamma\right) \quad \text{(E–6)}$$

Where,

Σ_{0a}= Macroscopic absorption cross-section (cm^{-1}) for incident neutron at a speed of 2200 $m \cdot s^{-1}$

T_0 = Standard temperature (293.6 K)

T = Neutron temperature (K)

γ = Euler's constant: 0.577 2156

MATSSF Code [E7], [E8]

The MATSSF Code, developed by Trkov *et al*. as part of a Coordinated Research Project of IAEA, given chemical composition, component weight fraction, diameter, mass, and length of the wire samples to be irradiated, returns both the thermal and resonance self-shielding factors [E8]. The code was validated by comparison with the more complex and computationally intensive MCNP5 model and various experimental NAA studies [E7], [E9]-[E11]. MATSSF is recognized as a valid self-shielding factor evaluation method and is routinely used in NAA studies [E12]-[E18].

MATSSF uses two different approaches for the determination of self-shielding factors. The thermal self-shielding factor is calculated using a method taking its roots in processes described by de Corte, an evolution of the Zweifel & Stewart method [E19]. The resonance self-shielding factor's determination is built on an NJOY code structure designed to handle nuclear data files in the standard ENDF format. The resonance self-shielding factor is interpolated from the code's internal tables.

MATSSF was obtained from the IAEA's Nuclear Data Section website [E8]. The present work's code is the latest version (2018/11) using the ENDF/B-VII library.

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Annex F

Al-Au Wire Material Analysis

shieldwerx™

Material Analysis

Wire: Gold-Aluminum (Lot # ALAU49019111)

Diameter: 0.020"
Gold: 0.12 %
Aluminum: 99.88 %

Impurity Analysis

B	0.00107
Be	<0.00001
Bi	<0.00006
Ca	<0.00002
Cd	<0.00005
Co	<0.00006
Cr	<0.00004
Cu	0.00036
Fe	0.00121
Ga	<0.00002
Li	<0.00002
Mg	0.00022
Mn	<0.00002
Na	<0.00001
Ni	0.00008
Pb	<0.00007
Si	0.00359
Sn	<0.00003
Sr	<0.00001
Ti	<0.00005
V	0.00003
Zn	<0.00015
Zr	<0.00005

Shieldwerx
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Figure F-1. Au-Al Material Analysis

Annex G

Sample Composition Data

Table G-1. Sample Composition Data

			Wire Weight (g) ±0.00005	**Paper Holder Weight** (g) ±0.00005	**Central Paper Weight** (g) ±0.00005	**Tube Holder Weight** (g) ±0.00005	**Cd-Shield Weight** (g) ±0.00005	**Paper Cap** (g) ±0.00005	**2 mL Vial Weight (vial +cap only)** (g) ±0.00005	**Total 2 mL vial (vial +content)** (g) ±0.00005	**Total Weight (vial + content)** (g) ±0.00005
Inner Site No. 2	Unshielded Blank	USB1	0.01150	1.01450	0.01200	0.07450	-	-	1.99350	3.19100	6.40700
		USB2	0.01150	1.04400	0.01200	0.17550	-	-	1.99900	3.22700	6.50350
		USB3	0.01150	1.05400	0.01250	0.17650	-	-	1.95150	3.19200	6.45950
	Unshielded Sample	US1	0.01150	1.03550	0.01250	0.17250	-	-	2.00500	3.23350	6.50600
		US2	0.01150	1.05800	0.01150	0.17200	-	-	1.93500	3.18800	6.46050
		US3	0.01150	1.02700	0.00950	0.17600	-	-	1.93400	3.15800	6.43100
	Shielded Blank	SB1	0.01150	1.02400	0.01250	0.17250	10.89100	0.10900	1.99300	3.20150	17.46500
		SB2	0.01150	1.04950	0.01150	0.17350	10.60100	0.12500	2.02450	3.25650	17.24750
		SB3	0.01150	1.04100	0.01150	0.17700	10.65550	0.12450	2.00100	3.23000	17.27950
	Shielded Sample	S1	0.01150	1.02000	0.01200	0.17150	11.25250	0.11450	2.00800	3.22250	17.84500
		S2	0.01150	1.03300	0.01050	0.17300	11.04100	0.11100	2.00400	3.23300	17.65400
		S3	0.01150	1.04600	0.01350	0.17050	10.64850	0.10300	1.95050	3.19050	17.21600
Outer Site No. 10	Unshielded Blank	USB4	0.01150	1.01400	0.01000	0.17350	-	-	1.99850	3.19350	6.40900
		USB5	0.01150	1.00250	0.00950	0.17250	-	-	1.95150	3.13300	6.40150
		USB6	0.01150	1.02850	0.01150	0.17350	-	-	1.95400	3.16550	6.43300
	Unshielded Sample	US4	0.01150	1.01400	0.00900	0.17250	-	-	2.01350	3.22150	6.43250
		US5	0.01150	1.00450	0.01150	0.17350	-	-	1.99350	3.19300	6.45950
		US6	0.01150	0.99200	0.01050	0.17650	-	-	1.95050	3.13800	6.40650
	Shielded Blank	SB4	0.01150	1.01350	0.00850	0.17450	10.63450	0.11850	1.94750	3.14300	17.15650
		SB5	0.01150	1.03750	0.01000	0.17300	11.46100	0.11750	1.93850	3.15850	18.00300
		SB6	0.01150	1.04800	0.01000	0.17350	11.42450	0.10000	1.99850	3.22800	17.95350
	Shielded Sample	S4	0.01150	1.01900	0.01200	0.17400	11.54600	0.11250	1.95550	3.17350	18.03700
		S5	0.01150	1.00850	0.01200	0.17400	11.07350	0.11950	1.94750	3.14850	17.61600
		S6	0.01150	1.03100	0.01250	0.17600	11.39650	0.10750	1.93650	3.16450	17.93850

Annex H

Irradiation Method Irradiation
and Sample Analysis

The irradiation procedure was adapted from the RMC's *Method ASG084, Low Level Detection of Elements by Neutron Activation Analysis* and from ASTM International's standard *E262-17 Standard Test Method for Determining Thermal Neutron Reaction Rates and Thermal Neutron Fluence Rates by Radioactivation Techniques* [H1], [H2].

Sample Activation

The samples were each irradiated for 5 minutes (300 ± 1 s) and left to decay for approximatively one day in a lead container to allow short-lived radionuclides to decay, and to reduce radiation exposure during the detection phase for operators. The samples were irradiated in the reactor with the controls being set at $5 \times 10^{11}\ n{\cdot}cm^{-2}{\cdot}s^{-1}$ at the inner site. The reactor control system maintained the flux level automatically.

Site 2 had an automatic timer linked to the pneumatic system that automatically recovered the sample when the time had lapsed. Site 10's samples had to be ejected manually (Figure H-1).

Figure H-1. Sample Transfer System Controller

Gamma Spectroscopy

Once the decay wait time had elapsed, the 2 mL vials were extracted from the 7 mL vials, removing the cadmium shielding as required. The 2 mL vials were inserted into a fresh 7 mL vial for analysis. The vials were then scanned with a HPGe detector and analyzed by an ORTEC electronic spectroscopy system (High Performance Portable Digital MCA, model DigiDART, serial no. 09071056 rev K; Software: GammaVision for Windows version

8.00.03 UMCBI kernel version 8.04 connection version 8.04) [H3]-[H5]. The general laboratory arrangement and DigiDARTt detector are displayed at Figure G-2.

Figure G-2. General Arrangement of the HPGe Detector and Associated Equipment at the RMC

The unshielded samples underwent gamma ray spectroscopy for 5 minutes (300.00± 0.01 s) while the shielded samples were scanned for 60 minutes (3600.00± 0.01 s) to compensate for the expected reduction in thermal neutrons reaching the Al-Au sample. The sample was placed on the first step of the detector sample holder, 0.8 ± 0.1 cm above the HPGe detector surface (Figure H-3).

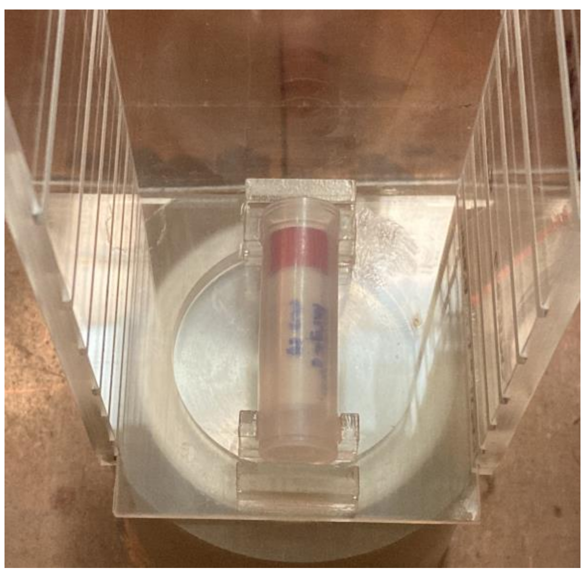

Figure H-3. Sample on the Detector Sample Holder's First Step Undergoing Detection on the HPGe

GammaVision was set up to focus on the $^{197}Au(n, \gamma)^{198}Au$ reaction through the assigned analysis library. The integrated software functions analyzed the spectrum automatically and compensated for decay time from the irradiation to the gamma detection on the HPGe. The analysis settings used are the standard settings used at the RMC for routine NAA. A complete list of the GammaVision analysis parameters is at Table H-1:

Table H-1. GammaVision Analysis Parameters

Tab	Parameter	Status
Sample	Analysis Range	From 0 to 16000
	Background Type	3 Points
	Nuclide Library	^{198}Au
	Calibration	See Annex I
System	MDA Type	Reg. Guide 4.16 Method
	Peak Search Sensitivity	3
	Library	
	Match Width	0.5000
	Fraction Limit	0.0000
	File for suspected nuclides	Standard RMC library
	Units	Bq
	Multiplier	1.0000
	Divisor	1.0000
	Activity	Bq
	Size	1.000
	±	0.00
Decay	Decay Correction	Depending on the sample according to Annex J
	During acquisition	Unchecked
	Sample collection	Unchecked
Report	Reporting Options:	Checked
	Unknown Peaks	Checked
	Library peak list	Checked
	Library peak matrix	Checked
	Nuclide abundance	Checked
	ISO NORM	Unchecked
	Uncertainty Reporting	Percent, Total
	Confidence level	1
Analysis	Analysis method Program	NPP32 Analysis
	Additional Error	
	Systematic	1.00000%
	Random	1.00000%
	Analysis	
	Peak Cutoff	30.0000%
	True Confidence Correction	Unchecked
	Directed Fit	Unchecked
Corrections	No input, No change from default	
Isotopes	No input, No change from default	
Uncertainty	No input, No change from default	

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[H4] Advanced Measurement Technology Inc, “GammaVision - Gamma Ray Spectrum Analysis and MCA Emulator for Microsoft Windows 7, 8.1, and 10 Professional,” *ORTEC Part No. 783620*, no. Revision K. ORTEC, Oak Ridge, TN.

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Annex I

Calibration Standard Certificates

Eckert & Ziegler
Isotope Products

24937 Avenue Tibbitts
Valencia, California 91355

Tel 661•309•1010
Fax 661•257•8303

CERTIFICATE OF CALIBRATION
MULTINUCLIDE STANDARD SOLUTION

Customer:	STUART HUNT & ASSOCIATES	**Source No.:**	2291-42
P.O. No.:	0015825	**Reference Date:**	1-Mar-22 12:00 PST
Catalog No.:	7500	**Contained Radioactivity:**	1.059 μCi 39.18 kBq

Physical Description:

A. Mass of solution: 5.22605 grams in 5 mL flame-sealed ampoule
B. Chemical form: Multinuclide in 2M HCl
C. Carrier content: See attached sheet
D. Density: 1.033 g/mL @ 20°C

Gamma-Ray Energy (keV)	Nuclide	Half-life	Branching Ratio (%)	Conc. (nCi/g)	Gammas per second per gram	Total Uncert.
88	Cd-109	462.6 ± 0.7 days	3.63	57.04	76.61	3.1 %
122	Co-57	271.79 ± 0.09 days	85.6	2.203	69.77	3.1 %
159	Te-123m	119.7 ± 0.1 days	84.0	2.963	92.09	3.1 %
320	Cr-51	27.706 ± 0.007 days	9.86	72.24	263.5	3.0 %
392	Sn-113	115.09 ± 0.04 days	64.9	10.70	256.9	3.0 %
514	Sr-85	64.849 ± 0.004 days	98.4	13.57	494.1	3.0 %
662	Cs-137	30.17 ± 0.16 years	85.1	9.830	309.5	3.0 %
898	Y-88	106.630 ± 0.025 days	94.0	22.03	766.2	3.0 %
1173	Co-60	5.272 ± 0.001 years	99.86	11.99	443.0	3.0 %
1333	Co-60	5.272 ± 0.001 years	99.98	11.99	443.5	3.0 %
1836	Y-88	106.630 ± 0.025 days	99.4	22.03	810.2	3.0 %

Method of Calibration:

This source was prepared from a weighed aliquot of solution whose concentrations in μCi/g were determined by gamma spectrometry.

Notes:

- See reverse side for leak test(s) performed on this source.
- EZIP participates in a NIST measurement assurance program to establish and maintain implicit traceability for a number of nuclides, based on the blind assay (and later NIST certification) of Standard Reference Materials (as in NRC Regulatory Guide 4.15).
- Nuclear data was taken from IAEA-TECDOC-619, 1991.
- Overall uncertainty is calculated at the 99% confidence level.
- This source has a recommended working life of 1 year.

Daniel James Van Dalsem
Quality Control

16-Mar-22
Date

EZIP Ref. No.: 2291-42

ISO 9001 CERTIFIED

Medical Imaging Laboratory
24937 Avenue Tibbitts Valencia, California 91355

Industrial Gauging Laboratory
1800 North Keystone Street Burbank, California 91504

Figure I-1. Calibration Standard Solution Certificate - 1

Eckert & Ziegler
Isotope Products

24937 Avenue Tibbitts
Valencia, California 91355

Tel 661•309•1010
Fax 661•257•8303

Carrier Concentrations

20 µg Co/mL
10 µg Cs/mL
50 µg Sr/mL
500 µg Cd/mL
50 µg Y/mL
50 µg Sn/mL
50 µg Te/mL
10 µg Cr/mL

ISO 9001 CERTIFIED

Medical Imaging Laboratory
24937 Avenue Tibbitts Valencia, California 91355

Industrial Gauging Laboratory
1800 North Keystone Street Burbank, California 91504

Figure I-2. Calibration Standard Solution Certificate - 2

Annex J

Sample Irradiation Data

Table J-1. Sample Irradiation Data

			Irradiated Time In	**Irradiated Time Out**	**Irradiation Time** (seconds) (± 1 s)	**Decay Time to Detector Start** (Minutes) (± 10 min)	**Detector Time Start**	**Detector Time Stop**	Time on the Detector (seconds) (± 0.01 s)
Inner Site No. 2	Unshielded Blank	USB1	2022-08-10 13:41	2022-08-10 13:46	300	2950	2022-08-12 14:56	2022-08-12 15:01	300.00
		USB2	2022-08-10 14:29	2022-08-10 14:34	300	1522	2022-08-11 15:56	2022-08-11 16:01	300.00
		USB3	2022-08-10 14:12	2022-08-10 14:17	300	1578	2022-08-11 16:35	2022-08-11 16:40	300.00
	Unshielded Sample	US1	2022-08-10 13:49	2022-08-10 13:54	300	2955	2022-08-12 15:09	2022-08-12 15:14	300.00
		US2	2022-08-10 14:36	2022-08-10 14:41	300	1522	2022-08-11 16:03	2022-08-11 16:08	300.00
		US3	2022-08-10 15:52	2022-08-10 15:57	300	1484	2022-08-11 16:41	2022-08-11 16:46	300.00
	Shielded Blank	SB1	2022-08-10 14:06	2022-08-10 14:11	300	1174	2022-08-11 9:45	2022-08-11 10:45	3600.00
		SB2	2022-08-10 14:20	2022-08-10 14:25	300	1378	2022-08-11 13:23	2022-08-11 14:23	3600.00
		SB3	2022-08-10 16:47	2022-08-10 16:52	300	1436	2022-08-11 16:48	2022-08-11 17:48	3600.00
	Shielded Sample	S1	2022-08-12 14:51	2022-08-12 14:56	300	4087	2022-08-15 11:03	2022-08-15 12:03	3600.00
		S2	2022-08-10 14:26	2022-08-10 14:31	300	1399	2022-08-11 13:50	2022-08-11 14:50	3600.00
		S3	2022-08-10 16:47	2022-08-10 16:52	300	1436	2022-08-11 16:48	2022-08-11 17:48	3600.00
Outer Site No. 10	Unshielded Blank	USB4	2022-08-10 14:40	2022-08-10 14:45	300	2910	2022-08-12 15:15	2022-08-12 15:20	300.00
		USB5	2022-08-10 15:14	2022-08-10 15:19	320***	1491	2022-08-11 16:10	2022-08-11 16:15	300.00
		USB6	2022-08-10 15:51	2022-08-10 15:56	300	1467	2022-08-11 16:23	2022-08-11 16:28	300.00
	Unshielded Sample	US4	2022-08-10 14:47	2022-08-10 14:52	300	2911	2022-08-12 15:23	2022-08-12 15:28	300.00
		US5	2022-08-10 15:28	2022-08-10 15:33	300	1484	2022-08-11 16:17	2022-08-11 16:22	300.00
		US6	2022-08-10 16:13	2022-08-10 16:18	300	1451	2022-08-11 16:29	2022-08-11 16:34	300.00
	Shielded Blank	SB4	2022-08-10 14:58	2022-08-10 15:03	300	2910	2022-08-12 15:33	2022-08-12 16:33	3600.00
		SB5	2022-08-10 15:21	2022-08-10 15:26	300	1180	2022-08-11 11:06	2022-08-11 12:06	3600.00
		SB6	2022-08-10 15:59	2022-08-10 16:04	300	2607	2022-08-12 11:31	2022-08-12 12:31	3600.00
	Shielded Sample	S4	2022-08-12 15:01	2022-08-12 15:06	300	4139	2022-08-15 12:05	2022-08-15 13:05	3600.00
		S5	2022-08-10 15:42	2022-08-10 15:47	300	1226	2022-08-11 12:13	2022-08-11 13:13	3600.00
		S6	2022-08-10 16:06	2022-08-10 16:11	300	2695	2022-08-12 13:06	2022-08-12 14:06	3600.00

*** The sample was irradiated 20 additional seconds due to operator error.

Annex K

Sample Calculations

Atoms of ^{197}Au in the Wire Sample

$$N_x = \frac{mpx_x N_A}{M_x} \quad (K–1)$$

Where

m = mass of sample (g) = 0.0115 g
p= purity of the sample = 0.12%
x_x= isotopic abundance of ^{197}Au = 100%
N_A= Avogadro's number (mol^{-1}) = 6.02214076 x 10^{23} mol^{-1} [K1]
M_x= Atomic mass of ^{197}Au ($g{\cdot}mol^{-1}$) = 196.966568786 $g{\cdot}mol^{-1}$ [K2]

$$N_{^{197}Au} = \frac{0.0115g \cdot 0.0012 \cdot 100\% \cdot \; 6.02214076 \text{ x } 10^{23} \; \frac{atoms}{mol}}{196.966568786 \; \frac{g}{mol}} \quad (K–2)$$

$$N_{^{197}Au} = 4.2192715 \; x \; 10^{19} \; atoms \; of \; ^{197}Au \quad (K–3)$$

Self-Shielding Factors

Zweifel & Stewart

$$f_c = 1 - \frac{4}{3} N \sigma_a r \quad (K–4)$$

Where

σ_a = absorption cross section (cm^2) = 98.6822 barns = 9.86822 x 10^{-23} cm^{-2} [K2]
r = wire radius = 0.0254 cm
N = nuclei density ($nuclei{\cdot}cm^{-3}$)

$$N = \frac{Number \; of \; ^{197}Au \; atoms}{Volume \; of \; Sample \; Wire} = \frac{4.2193 \; x \; 10^{16} \; ^{197}Au \; atoms}{4.2564 \; x \; 10^{-3} \; cm^3} \quad (K–5)$$

$$N = 9.9127 \; x \; 10^{18} \; \frac{atoms \; of \; ^{197}Au}{cm^3} \quad (K–6)$$

$$f_c = 1 - \frac{4}{3} \cdot \; 9.9127 \; x \; 10^{18} \; \frac{atoms \; of \; ^{197}Au}{cm^3} \cdot \; 9.86822 \text{ x } 10^{-23} \text{ cm}^2 \cdot 0.0254 \text{ cm} \quad (K–7)$$

$$f_c = 0.999966871 \quad (K–8)$$

Universal Sigmoid Curves

Thermal Self-Shielding Factor

$\Sigma_{t\,Au}$= ^{197}Au Total macroscopic cross-section (cm^{-1}) averaged over the thermal neutron spectrum at room temperature = 95.05 barns = 9.505 x 10^{-23} cm^{-1} [K3]
$\Sigma_{a\,Au}$ = ^{197}Au Absorption macroscopic cross-section (cm^{-1}) averaged over the thermal neutron spectrum at room temperature = 88.19 barns = 8.819 x 10^{-23} cm^{-1} [K3]
$\Sigma_{t\,Al}$= ^{127}Al Total macroscopic cross-section (cm^{-1}) averaged over the thermal neutron spectrum at room temperature = 1.617 barns = 1.617 x 10^{-24} cm^{-1} [K3]
$\Sigma_{a\,Al}$ = ^{127}Au Absorption macroscopic cross-section (cm^{-1}) averaged over the thermal neutron spectrum at room temperature = 1.414 barns = 1.414 x 10^{-24} cm^{-1} [K3]
x_{Al} = wire Al composition = 0.9988
x_{Au} = wire ^{197}Au composition = 0.0012

$$\Sigma_t = x_{Al}\Sigma_{t\,Al} + x_{Au}\Sigma_{t\,Au} \quad \text{(K–9)}$$

$$\Sigma_t = 0.9988 \cdot 9.505 \text{ x } 10^{-23} cm^{-1} + 0.0012 \cdot 1.617 \text{ x } 10^{-24}\, cm^{-1} \quad \text{(K–10)}$$

$$\Sigma_t = 9.8334\, x\, 10^{-2}\, cm^{-1} \quad \text{(K–11)}$$

$$\Sigma_a = x_{Al}\Sigma_{a\,Al} + x_{Au}\Sigma_{a\,Au} \quad \text{(K–12)}$$

$$\Sigma_a = 0.9988 \cdot 8.819 \text{ x } 10^{-23} cm^{-1} + 0.0012 \cdot 1.414 \text{ x } 10^{-24}\, cm^{-1} \quad \text{(K–13)}$$

$$\Sigma_a = 1.3101\, x\, 10^{-2}\, cm^{-1} \quad \text{(K–14)}$$

Z Factor

$$z = 2r\Sigma_t \left(\frac{\Sigma_a}{\Sigma_t}\right)^{0.85} \quad \text{(K–15)}$$

Where

r = Wire radius (cm) = 0.0254 cm
Σ_t= Total macroscopic cross-section (cm^{-1}) averaged over the thermal neutron spectrum at room temperature
Σ_a= Absorption macroscopic cross-section (cm^{-1}) averaged over the thermal neutron spectrum at room temperature

$$z = 2 \cdot 0.0254 \text{ cm} \cdot 9.8334\, x\, 10^{-2}\, cm^{-1} \left(\frac{1.3101\, x\, 10^{-2} \text{ cm}^{-1}}{9.8334\, x\, 10^{-2}\, cm^{-1}}\right)^{0.85} \quad \text{(K–16)}$$

$$z = 9.0048245 \text{ x } 10^{-4} \quad \text{(K–17)}$$

Thermal self-shielding factor

$$G_{th} = \frac{1}{1 + \left(\frac{z}{1.029}\right)^{1.009}} \qquad (K–18)$$

$$G_{th} = \frac{1}{1 + \left(\frac{9.0048245 \times 10^{-4}}{1.029}\right)^{1.009}} \qquad (K–19)$$

$$G_{th} = 0.999179305 \qquad (K–20)$$

Resonance Self-Shielding Factor

$$G_{res} = \frac{0.94}{1 + \left(\frac{z}{2.70}\right)^{0.82}} + 0.06 \qquad (K–21)$$

Z Factor

$$z = \Sigma_{tot}(E_{res})(2r)\left(\frac{\Gamma_\gamma}{\Gamma}\right)^{\frac{1}{2}} \qquad (K–22)$$

Where,

r = wire radius (cm) = 0.0254 cm

$\Sigma_{tot}(E_{res})$= macroscopic cross-section at the resonance peak (cm^{-1})

= $\sigma_{tot}(E_{res}) \cdot N =$ 3.0770 x 10^{-20} cm^2 · 9.9127 x 10^{18} atom·cm^{-3} = 0.30501 cm^{-1} [K4]

Γ_γ = resonance width for the (n,γ) reaction (eV) = 0.1225 eV [K4]

Γ= total resonance width (eV) = 0.1377 eV [K4]

$$z = 0.30501\ \text{cm}^{-1}\ (2 \cdot 0.0254\ cm)\left(\frac{0.1225\ eV}{0.1377\ eV}\right)^{\frac{1}{2}} \qquad (K–23)$$

$$z = 1.4614328 \times 10^{-2} \qquad (K–24)$$

Resonance Self-Shielding Factor

$$G_{res} = \frac{0.94}{1 + \left(\frac{1.4614328 \times 10^{-2}}{2.70}\right)^{0.82}} + 0.06 \qquad (K–25)$$

$$G_{res} = 0.98716029 \qquad (K–26)$$

ASTM Method

$$f = 1 - \frac{8}{3\sqrt{\pi}}\left(\Sigma_{0a}\sqrt{\frac{T_0}{T}}\right) + \left(\Sigma_{0a}\sqrt{\frac{T_0}{T}}\right)^2\left(\ln\left(\frac{1}{\Sigma_{0a}}\sqrt{\frac{T}{T_0}}\right) + \frac{5}{4} - \frac{3}{2}\gamma\right) \qquad \text{(K–27)}$$

Where,

Σ_{0a}= Macroscopic absorption cross-section (cm^{-1}) for incident neutron at a speed of 2200 m/s = 1.3101 x 10^{-2} cm^{-1}

T_0 = standard temperature (K) = 293.6 K

T = neutron temperature (K) = 313 K (estimated by averaging the pool temperature over the time of the experiment)

γ = Euler's constant: 0.5772156 [K5]

$$f = 1 - \frac{8}{3\sqrt{\pi}}\left(1.3101 \text{ x } 10^{-2}\sqrt{\frac{293.6}{313}}\right) + \left(1.3101 \text{ x } 10^{-2}\sqrt{\frac{293.6}{313}}\right)^2 \left(\ln\left(\frac{1}{1.3101 \text{ x } 10^{-2}}\sqrt{\frac{293.6}{313}}\right) + \frac{5}{4} - \frac{3}{2}0.5772156\right) \qquad \text{(K–28)}$$

$$f = 0.999515994 \qquad \text{(K–29)}$$

Experimental Flux

Sample calculation conducted for sample S1, shielded sample no 1.

$$\phi = \frac{C_y M_x \lambda}{\varepsilon_y P_y m p x_x N_A \sigma_a (1 - e^{(-\lambda t_{irr})})\,(e^{-\lambda t_{decay}})(1 - e^{(-\lambda \Delta t_{detect})})} \qquad \text{(K–30)}$$

Where

C_y= Count at 411.8 keV peak = 19820

M_x= Atomic Mass of ^{197}Au = 196.966568786 g·mol^{-1} [K2]

λ= Decay constant (min^{-1}) = Ln2·$t_{1/2}^{-1}$ = 0.000178623 min^{-1} = 0.000002977 s^{-1} [K2]

ε_y = efficiency of the HPGe detector = 0.031

P_y= Probability of gamma production from ^{198}Au decay = 0.9562 [K2]

m= sample mass (g) = 0.0115 g

p= ^{197}Au sample composition = 0.0012

x_x= Isotopic abundance of ^{197}Au = 1

N_A = Avogadro's number (mol^{-1}) = 6.02214076 x 10^{-23} mol^{-1} [K1]

σ_a= ^{197}Au absorption cross-section (cm^{-2}) = 9.86822 x 10^{-23} cm^{-2}

t_{irr} = irradiation time (min) = 5 min

t_{decay} = decay time (min) = 4087 min

Δt_{detect} = time on the HPGe detector (min) = 60 min

$$\phi = \frac{19820 \cdot 196.966568786 \frac{\text{g}}{\text{mol}} \cdot 0.000002977\ \text{s}^{-1}}{0.031 \cdot 0.9562 \cdot 0.0115\ g \cdot 0.0012 \cdot 1 \cdot 6.02214076\text{x}10^{23}\text{mol}^{-1} \ldots} \qquad (\text{K–31})$$

$$\cdot\, 9.86822\text{x}10^{-23}\text{cm}^{-2}\left(1 - e^{(-0.000178623\ \text{min}^{-1} \cdot 5\ min)}\right) \ldots$$

$$\left(e^{-0.000178623\ \text{min}^{-1} \cdot 4087\ min}\right)\left(1 - e^{(-0.000178623\ \text{min}^{-1} \cdot 60\ min)}\right)$$

$$\phi = 1.01\ \text{x}\ 10^{12}\ \frac{n}{cm^2 \cdot s} \qquad (\text{K–32})$$

MCNP Scaling Factor

$$\text{SF}\left(\frac{\text{neutron}}{s}\right) = \frac{\text{P}\left(\frac{\text{J}}{s}\right) \cdot \text{v}\left(\frac{\text{neutron}}{Fission}\right)}{1.6022x10^{-13}\left(\frac{J}{MeV}\right) \cdot k_{eff} \cdot w_f\left(\frac{MeV}{Fission}\right)} \qquad (\text{K–33})$$

Where

P = reactor power (W) = 8850 W

v = neutrons generated per fission (neutron/fission) = 2.434 neutron/fission (from MCNP output)

k_{eff}= effective multiplication factor = 1 (for steady state reactor)

w_f= effective energy realeased per fission of ^{235}U = 180.88 $\frac{MeV}{Fission}$ (from MCNP output)

$$\text{SF}\left(\frac{\text{neutron}}{s}\right) = \frac{8850\left(\frac{\text{J}}{s}\right) \cdot 2.434\left(\frac{\text{neutron}}{Fission}\right)}{1.6022x10^{-13}\left(\frac{J}{MeV}\right) \cdot 1 \cdot 180.88\left(\frac{MeV}{Fission}\right)} \qquad (\text{K–34})$$

$$\text{SF} = 7.432870526\ \text{x}10^{14}\,\frac{\text{neutron}}{s} \qquad (\text{K–35})$$

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[K5] J. G. Williams and D. M. Gilliam, "Thermal neutron standards," *Metrologia*, vol. 48, no. 6, pp. S254–S262, Dec. 2011, doi: 10.1088/0026-1394/48/6/S03.

Annex L

MATSSF Results

```
MATSSF - Element & isotope composition
 -------------------------------------

 Enter components terminated by blank
$      Component chemical composition :
Al-27
$Enter component fraction       [w/o] :
99.88

$      Component chemical composition :
Au-197
$Enter component fraction       [w/o] :
0.12

$      Component chemical composition :

$Enter sample mass               [mg] :
11.5
$Enter sample diameter           [mm] :
0.508
$Enter sample length/thickness   [mm] :
21
 Neutron source definitions:
 ISRC  Description
   0 = Isotropic
   1 = Wire flat in a channel
   2 = Foil or wire along channel axis:
 Default irradiation channel data
 CHD   Irradiation channel diameter [mm]
 CHT   Channel active height [mm]

$Enter ISRC (0, 1, or 2)              :
0
 Default Bell factor                  :     1.1600
$         Enter new value to redefine :


 Scanning the cross section library ...
 zgT0,Zga0,Zge0  0.104384169       1.67847835E-02   8.75993893E-02
 N          3
 XI,GTH,GCP,WGT   2.61967257E-03  0.999438822      0.809506416       1.00000000
    GLS  0.991002202      0.998542130
    GWI  0.996507108      0.999436677
    GSF  0.997052848      0.999524891

 MATSSF - Element & isotope composition
 ======================================

 Component chemical composition         weight %
 ------------------------------------------------
 Al-27
                                         99.8800
 Au-197
                                          0.1200
 ------------------------------------------------
                                 Total  100.0000

 Mass, abundance & SSF library        : MATSSF.DAT
 Cross sections library               : MATSSF_XSR.TXT

 Material density     2.7019 [g/cm3]
 Mass                11.5000 [mg]
 Diameter             0.5080 [mm]
```

Length/thickness	21.0000	[mm]
Volume	0.0043	[cm^3]
Mean chord length	0.0502	[cm]
Escape x.sect.	23.1108	[1/cm]
Potential x.sect.	0.1146	[1/cm]

Neutron source Isotropic

G-thermal 0.9994

Isotope	weight input	[%] norm.	number density [x 1.E24 i/cm3]	SigB [barn]	SSF	G-fast
13-Al- 27	99.88000	99.88000	6.0232E-02	3.837E+02	0.9792	0.9791
79-Au-197	0.12000	0.12000	9.9129E-06	2.343E+06	0.9941	0.9939
Total	100.00000	100.00000	6.0241E-02			

Annex M

HPGe Calibration Output File

and

Calibration Curve

```
Calibration Data from file:    Aug 1, Nov 1, Nov 2 Merged.Clb
       Energy Calibration Date: 2022-12-19  Time: 4:12:08 PM
   Efficiency Calibration Date: 2023-01-23  Time: 3:52:46 PM

Calibration Description:
  PE Tube 1 August and PEtube 1 and 2 November calibration


Energy Calibration Fit
    Energy =  -0.0471 +0.820770*Channel +1.38919e-007*Channel**2
 FWHM (ch) =   2.1408 +0.000515*Channel +2.81573e-008*Channel**2
```

Energy/FWHM Table

Channel	Energy(keV)	Fit(keV)	Delta	FWHM(keV)	Fit(keV)	Delta
107.24	88.03	87.98	0.06%	1.79	1.80	-0.86%
148.76	122.07	122.06	0.01%	1.84	1.82	0.84%
193.82	159.00	159.04	-0.03%	1.86	1.84	0.84%
477.30	391.71	391.74	-0.01%	1.95	1.96	-0.87%
626.29	514.00	514.05	-0.01%	2.00	2.03	-1.71%
806.11	661.66	661.67	-0.00%	2.15	2.11	1.76%
1093.90	898.02	897.96	0.01%	2.25	2.25	0.04%
1429.09	1173.24	1173.19	0.00%	2.42	2.41	0.31%
1623.15	1332.50	1332.55	-0.00%	2.49	2.51	-0.48%
2236.60	1836.38	1836.38	-0.00%	2.82	2.82	0.05%

```
Efficiency Calibration Fit
  Knee Energy =    80.00 keV
  Above the Knee: Quadratic         Uncertainty = 3.9490 %
    Ln(Eff) =  -1.1690  +0.042936*Ln(Eng) -0.0703929*(Ln(Eng))**2
  Below the Knee: None          Uncertainty = 0.0000 %
```

Efficiency Table

Energy	Efficiency	Fit	Delta
80.00	============== Knee ==============		
87.91	8.9806E-002	9.1881E-002	-2.31%
88.03	8.9510E-002	9.1806E-002	-2.57%
88.03	9.3540E-002	9.1803E-002	1.86%
122.06	7.8967E-002	7.5200E-002	4.77%
122.07	7.8967E-002	7.5196E-002	4.77%
122.07	8.2026E-002	7.5196E-002	8.33%
159.08	6.5444E-002	6.3271E-002	3.32%
159.14	5.2349E-002	6.3254E-002	-20.83%
159.19	6.4365E-002	6.3241E-002	1.75%
319.92	3.8810E-002	3.8260E-002	1.42%
391.69	3.3226E-002	3.2651E-002	1.73%
391.71	3.2835E-002	3.2649E-002	0.57%
391.74	3.2836E-002	3.2647E-002	0.57%
513.81	2.8022E-002	2.6160E-002	6.65%
513.99	2.9078E-002	2.6152E-002	10.06%
514.00	2.8022E-002	2.6152E-002	6.68%
661.62	2.0554E-002	2.1081E-002	-2.57%
661.66	2.0675E-002	2.1080E-002	-1.96%
661.66	2.1640E-002	2.1080E-002	2.58%
898.02	1.5060E-002	1.6048E-002	-6.56%
898.02	1.5686E-002	1.6048E-002	-2.31%
898.03	1.5060E-002	1.6048E-002	-6.56%
1173.23	1.2333E-002	1.2505E-002	-1.39%
1173.24	1.2769E-002	1.2505E-002	2.07%
1173.24	1.2333E-002	1.2505E-002	-1.39%
1332.50	1.1074E-002	1.1065E-002	0.08%

1332.50	9.8379E-003	1.1065E-002	-12.47%
1332.51	1.1074E-002	1.1065E-002	0.08%
1836.00	8.4044E-003	8.0497E-003	4.22%
1836.01	8.4043E-003	8.0496E-003	4.22%
1836.01	8.7895E-003	8.0496E-003	8.42%

Calibration Certificate Table

Isotope	Energy	Pct	Halflife	Activity	GPS	Error	Date & Time
Cd-109	88.03	3.61	4.63E+002	664.27	23.98	1.50%	2022-03-01 12:00:00 PM
Co-57	122.07	85.59	2.71E+002	25.52	21.84	1.50%	2022-03-01 12:00:00 PM
Te-123m	159.19	84.00	1.20E+002	34.31	28.82	1.50%	2022-03-01 12:00:00 PM
Sn-113	391.71	64.17	1.15E+002	125.31	80.41	1.50%	2022-03-01 12:00:00 PM
Sr-85	513.81	98.40	6.48E+001	157.16	154.65	1.50%	2022-03-01 12:00:00 PM
Cs-137	661.66	85.21	1.10E+004	113.68	96.87	1.50%	2022-03-01 12:00:00 PM
Y-88	898.02	95.00	1.07E+002	252.44	239.82	1.50%	2022-03-01 12:00:00 PM
Co-60	1173.24	99.90	1.93E+003	138.80	138.66	1.50%	2022-03-01 12:00:00 PM
Co-60	1332.50	99.98	1.93E+003	138.84	138.82	1.50%	2022-03-01 12:00:00 PM
Y-88	1836.01	99.35	1.07E+002	255.25	253.59	1.50%	2022-03-01 12:00:00 PM
Cd-109	87.91	3.61	4.63E+002	664.27	23.98	1.50%	2022-03-01 12:00:00 PM
Co-57	122.06	85.59	2.71E+002	25.52	21.84	1.50%	2022-03-01 12:00:00 PM
Te-123m	159.08	84.00	1.20E+002	34.31	28.82	1.50%	2022-03-01 12:00:00 PM
Cr-51	319.92	9.90	2.77E+001	833.13	82.48	1.50%	2022-03-01 12:00:00 PM
Sn-113	391.74	64.17	1.15E+002	125.31	80.41	1.50%	2022-03-01 12:00:00 PM
Sr-85	514.00	98.40	6.48E+001	157.16	154.65	1.50%	2022-03-01 12:00:00 PM
Cs-137	661.62	85.21	1.10E+004	113.68	96.87	1.50%	2022-03-01 12:00:00 PM
Y-88	898.03	95.00	1.07E+002	252.44	239.82	1.50%	2022-03-01 12:00:00 PM
Co-60	1173.23	99.90	1.93E+003	138.80	138.66	1.50%	2022-03-01 12:00:00 PM
Co-60	1332.51	99.98	1.93E+003	138.84	138.82	1.50%	2022-03-01 12:00:00 PM
Y-88	1836.00	99.35	1.07E+002	255.25	253.59	1.50%	2022-03-01 12:00:00 PM
Cd-109	88.03	3.61	4.63E+002	598.34	21.60	1.50%	2022-03-01 12:00:00 PM
Co-57	122.07	85.59	2.71E+002	22.99	19.68	1.50%	2022-03-01 12:00:00 PM
Te-123m	159.14	84.00	1.20E+002	30.92	25.97	1.50%	2022-03-01 12:00:00 PM
Sn-113	391.69	64.17	1.15E+002	112.90	72.45	1.50%	2022-03-01 12:00:00 PM
Sr-85	513.99	98.40	6.48E+001	141.61	139.34	1.50%	2022-03-01 12:00:00 PM
Cs-137	661.66	85.21	1.10E+004	102.43	87.28	1.50%	2022-03-01 12:00:00 PM
Y-88	898.02	95.00	1.07E+002	227.44	216.07	1.50%	2022-03-01 12:00:00 PM
Co-60	1173.24	99.90	1.93E+003	125.20	125.07	1.50%	2022-03-01 12:00:00 PM
Co-60	1332.50	99.98	1.93E+003	125.09	125.07	1.50%	2022-03-01 12:00:00 PM
Y-88	1836.01	99.35	1.07E+002	229.97	228.48	1.50%	2022-03-01 12:00:00 PM

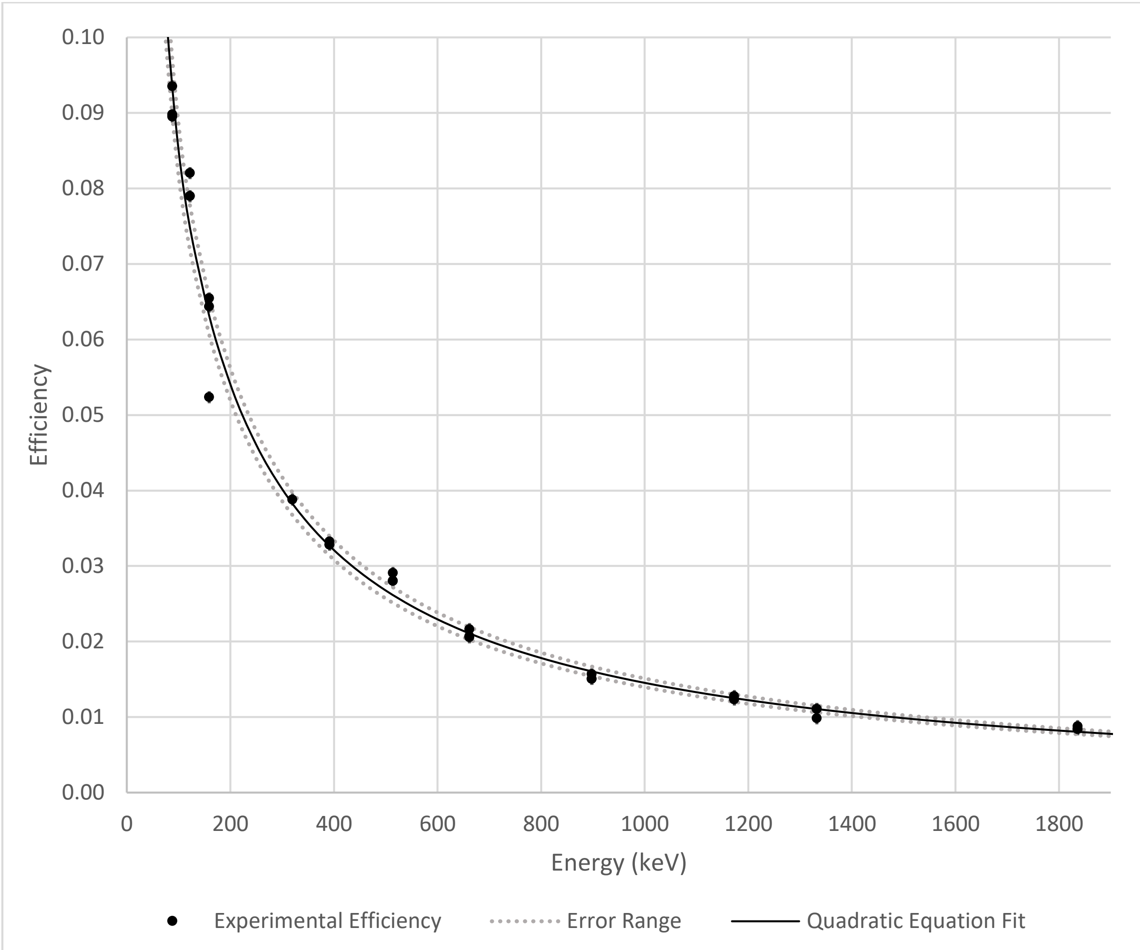

Figure M-1. HPGe Efficiency Curve

Annex N

GammaVision Output
Unshielded Sample US1

```
Sample description
     11Aug2022-Neilsen S1 US1


Spectrum Filename: E:\SLOWPOKE Data\Combined Efficiency\US1 - Shelf 1
                   .An1

Acquisition information
       Start time:                 2022-08-12 3:18:35 PM
       Live time:                297
       Real time:                300
       Dead time:                  0.94 %
       Detector ID:                    2

Detector system
     NIELSEN 49-TN22644A with Digidart 09071056


Calibration
       Filename:                   Aug 1, Nov 1, Nov 2 Merged.Clb
     PE Tube 1 August and PEtube 1 and 2 November calibration


       Energy Calibration
            Created:               2022-12-19 4:12:08 PM
            Zero offset:          -0.047 keV
            Gain:                  0.821 keV/channel
            Quadratic:             1.389E-07 keV/channel^2

       Efficiency Calibration
            Created:               2023-01-23 3:52:46 PM
            Knee Energy:          80.00 keV
            Above the Knee:        Quadratic        Uncertainty =   3.95 %
            Log(Eff):             -1.168979E+00 + ( 4.293551E-02*Log(E) ) +
                                   ( -7.039291E-02*Log(E)^2 )
            Below the Knee:        None             Uncertainty =   0.00 %

Library Files
       Main analysis library:      Au198.Lib
       Library Match Width:        0.500
       Peak stripping:             Library based

Analysis parameters
       Analysis engine:            Npp32   G702W050
       Start channel:             20 (    16.37keV )
       Stop channel:            4048 (  3324.71keV )
       Peak rejection level:      30.000%
       Peak search sensitivity:    3
       Sample Size:                1.0000E+00 +/- 0.000E+00%
       Activity scaling factor:    1.0000E+00/(  1.0000E+00*  1.0000E+00) =
                                   1.0000E+00
       Detection limit method:     Reg. Guide 4.16 Method
       Random error:               1.0000000E+00
       Systematic error:           1.0000000E+00
       Fraction Limit:             0.000%
       Background width:           average of three points.
```

Half lives decay limit: 12.000
Activity range factor: 2.000
Min. step backg. energy 0.000
Multiplet shift channel 2.000

Corrections	Status	Comments
Decay correct to date:	YES	2022-08-10 1:54:00 PM
Decay during acquisition:	NO	
Decay during collection:	NO	
True coincidence correction:	NO	
Peaked background correction:	NO	
Absorption (Internal):	NO	
Geometry correction:	NO	
Random summing:	NO	

Energy Calibration
Normalized diff: 1.0000

***** S U M M A R Y O F P E A K S I N R A N G E *****

Peak Energy	Area	Uncert	FWHM	Corrctn Factor	Nuclide Energy	Brnch. Ratio	Act. Bq	Nuc
69.69	1115.	6.47	3.73	0.000E+00	68.89	0.810	0.000E+00	AU198
					70.82	1.380	0.000E+00	AU198
80.29	296.	18.35	2.03	9.685E-02	80.30	0.610	2.863E+03	AU198
409.87	19819.	0.72	2.61	3.149E-02	411.80	95.580	3.777E+03	AU198
672.58	101.	13.47	2.82	2.078E-02				
1361.95	337.	5.77	3.28	1.083E-02				
1453.71	40.	16.96	2.38	1.016E-02				
2741.56	215.	6.82	2.70	5.298E-03				

************ U N I D E N T I F I E D P E A K S U M M A R Y ************

Peak Channel	Centroid Energy	Background Counts	Net Area Counts	Efficiency * Area	Uncert 1 Sigma %	FWHM keV	Suspected Nuclide	
497.93	408.67	142.	998.	3.164E+04	3.59	1.974	-	D
499.29	409.87	3252.	16526.	5.249E+05	0.92	1.974	-	D
819.13	672.58	40.	86.	4.125E+03	15.04	2.119	-	D
1658.95	1361.95	13.	337.	3.111E+04	5.77	3.281	-	s
1770.68	1453.71	2.	40.	3.936E+03	16.96	2.377	-	s
3338.40	2741.56	0.	215.	4.058E+04	6.82	2.704	-	

s - Peak fails shape tests.
D - Peak area deconvoluted.
L - Peak written from unknown list.
C - Area < Critical level.

*************** D I S C A R D E D I S O T O P E P E A K S ***************

Nuclide	Centroid Energy	Background Counts	Net Area Counts	Intensity Cts/Sec	Uncert 1 Sigma %	Activity

P - Peakbackground subtraction

This section based on library: Au198.Lib

************** I D E N T I F I E D   P E A K   S U M M A R Y **************

Nuclide	Peak Channel	Centroid Energy	Background Counts	Net Area Counts	Intensity Cts/Sec	Uncert 1 Sigma %	FWHM keV
AU-198	84.00	68.89	1674.	455.	1.530	13.56	1.793D
AU-198	86.34	70.82	1346.	603.	2.028	9.53	1.794D
AU-198	97.88	80.29	1062.	296.	0.996	18.35	2.032s
AU-198	501.74	411.80	16009.	2502.	8.418	7.43	1.975D

s - Peak fails shape tests.
D - Peak area deconvoluted.
A   Derived peak area.

***** S U M M A R Y   O F   L I B R A R Y   P E A K   U S A G E *****

- Nuclide - Name	Code	Average Activity Bq	Peak Energy keV	Peak Activity Bq	Code	MDA Value Bq	COMMENTS		
AU-198	F	4.7679E+02					2.70E+00		
			411.80	4.768E+02	(	1.129E+02	7.43E+00	9.56E+01	G
			70.82	0.000E+00	-	0.000E+00	9.53E+00	1.38E+00	X
			68.89	0.000E+00	-	0.000E+00	1.36E+01	8.10E-01	X
			675.88	0.000E+00	%	1.564E+03	1.56E+02	8.04E-01	G
			80.30	2.863E+03	+	1.495E+03	1.84E+01	6.10E-01	X
			1087.68	0.000E+00	%	6.666E+03	1.34E+02	1.59E-01	G

(- This peak used in the nuclide activity average.

* - Peak is too wide, but only one peak in library.
! - Peak is part of a multiplet and this area went negative during deconvolution.
? - Peak is too narrow.
@ - Peak is too wide at FW25M, but ok at FWHM.
% - Peak fails sensitivity test.
$ - Peak identified, but first peak of this nuclide failed one or more qualification tests.
\+ - Peak activity higher than counting uncertainty range.
\- - Peak activity lower than counting uncertainty range.
= - Peak outside analysis energy range.
& - Calculated peak centroid is not close enough to the library energy centroid for positive identification.
P - Peakbackground subtraction
} - Peak is too close to another for the activity to be found directly.

Nuclide Codes:	Peak Codes:
T - Thermal Neutron Activation	G - Gamma Ray
F - Fast Neutron Activation	X - X-Ray
I - Fission Product	P - Positron Decay
N - Naturally Occurring Isotope	S - Single-Escape
P - Photon Reaction	D - Double-Escape
C - Charged Particle Reaction	K - Key Line
M - No MDA Calculation	A - Not in Average
R - Coincidence Corrected	C - Coincidence Peak

H - Halflife limit exceeded

- -

***** S U M M A R Y O F N U C L I D E S I N S A M P L E *****

Nuclide	Time of Count Activity Bq	Time Corrected Activity Bq	Uncertainty Counting	1 Sigma Total	MDA
AU-198	2.8079E+02	4.7679E+02	7.4269E+00%	7.5289E+00%	1.129E+02

< - MDA value printed.
A - Activity printed, but activity < MDA.
B - Activity < MDA and failed test.
C - Area < Critical level.
F - Failed fraction or key line test.
H - Halflife limit exceeded

----------------------------- S U M M A R Y ----------------------------

Total Activity (16.4 to 3324.7 keV) 2.808E+02 Bq
Total Decayed Activity (16.4 to 3324.7 keV) 4.7678650E+02 Bq

Analyzed by: ____
Lt(N) B. Casper & LCdr S.P.J. Parent

Reviewed by: ____
Supervisor

Laboratory: RMC

Annex O

GammaVision Output
Shielded Sample S1

```
Sample description
     12Aug2022-Neilsen S1 S1

Spectrum Filename: E:\SLOWPOKE Data\Combined Efficiency\S1 - Shelf
                   1.An1

Acquisition information
       Start time:                2022-08-15 11:12:32 AM
       Live time:              3583
       Real time:              3600
       Dead time:                 0.47 %
       Detector ID:                   2

Detector system
     NIELSEN 49-TN22644A with Digidart 09071056


Calibration
       Filename:                  Aug 1, Nov 1, Nov 2 Merged.Clb
     PE Tube 1 August and PEtube 1 and 2 November calibration


       Energy Calibration
            Created:              2022-12-19 4:12:08 PM
            Zero offset:         -0.047 keV
            Gain:                 0.821 keV/channel
            Quadratic:            1.389E-07 keV/channel^2

       Efficiency Calibration
            Created:              2023-01-23 3:52:46 PM
            Knee Energy:         80.00 keV
            Above the Knee:       Quadratic        Uncertainty =   3.95 %
            Log(Eff):            -1.168979E+00 + ( 4.293551E-02*Log(E) ) +
                                  ( -7.039291E-02*Log(E)^2 )
            Below the Knee:       None             Uncertainty =   0.00 %

Library Files
       Main analysis library:     Au198.Lib
       Library Match Width:       0.500
       Peak stripping:            Library based

Analysis parameters
       Analysis engine:           Npp32   G702W050
       Start channel:            20 (    16.37keV )
       Stop channel:           4048 (  3324.71keV )
       Peak rejection level:     30.000%
       Peak search sensitivity:   3
       Sample Size:               1.0000E+00 +/- 0.000E+00%
       Activity scaling factor:   1.0000E+00/(  1.0000E+00*  1.0000E+00) =
                                  1.0000E+00
       Detection limit method:    Reg. Guide 4.16 Method
       Random error:              1.0000000E+00
       Systematic error:          1.0000000E+00
       Fraction Limit:            0.000%
       Background width:          average of three points.
       Half lives decay limit:   12.000
       Activity range factor:     2.000
       Min. step backg. energy    0.000
       Multiplet shift channel    2.000
```

Corrections	Status	Comments
Decay correct to date:	YES	2022-08-12 2:56:00 PM
Decay during acquisition:	NO	
Decay during collection:	NO	
True coincidence correction:	NO	
Peaked background correction:	NO	
Absorption (Internal):	NO	
Geometry correction:	NO	
Random summing:	NO	

Energy Calibration
Normalized diff: 1.0000

***** S U M M A R Y   O F   P E A K S   I N   R A N G E *****

Peak Energy	Area	Uncert	FWHM	Corrctn Factor	Nuclide Energy	Brnch. Ratio	Act. Bq	Nuc
23.84	1489.	8.76	2.67	0.000E+00				
69.73	5905.	2.90	3.73	0.000E+00	68.89	0.810	0.000E+00	AU198
					70.82	1.380	0.000E+00	AU198
80.28	1244.	10.52	3.39	9.686E-02	80.30	0.610	1.222E+03	AU198
334.82	2382.	3.81	2.76	3.694E-02				
409.89	102757.	0.32	2.90	3.148E-02	411.80	95.580	1.988E+03	AU198
490.43	305.	10.50	3.45	2.719E-02				
508.51	143.	18.87	2.64	2.639E-02				
525.34	914.	4.75	2.82	2.568E-02				
672.59	525.	5.82	3.01	2.078E-02				
1082.15	101.	19.73	2.93	1.350E-02				
1361.97	290.	7.37	3.25	1.083E-02				
1453.78	383.	5.79	3.30	1.016E-02				
2741.58	161.	7.88	3.96	5.298E-03				

************ U N I D E N T I F I E D   P E A K   S U M M A R Y ************

Peak Channel	Centroid Energy	Background Counts	Net Area Counts	Efficiency * Area	Uncert 1 Sigma %	FWHM keV	Suspected Nuclide	
29.10	23.84	6207.	1489.	0.000E+00	8.76	2.666	-	s
407.96	334.82	1958.	2382.	6.448E+04	3.81	2.759	-	s
498.12	408.83	1110.	4981.	1.579E+05	1.70	1.974	-	D
499.26	409.89	24524.	79321.	2.519E+06	0.45	1.974	-	D
597.52	490.43	240.	305.	1.122E+04	10.50	3.452	-	s
619.55	508.51	218.	143.	5.407E+03	18.87	2.644	-	s
640.04	525.34	278.	914.	3.558E+04	4.75	2.816	-	s
819.36	672.59	187.	436.	2.098E+04	6.53	2.119	-	D
1318.54	1082.15	88.	79.	5.871E+03	20.14	2.355	-	D
1658.97	1361.97	48.	290.	2.673E+04	7.37	3.246	-	s
1770.76	1453.78	27.	383.	3.769E+04	5.79	3.300	-	s
3338.43	2741.58	0.	161.	3.039E+04	7.88	3.957	-	s

s - Peak fails shape tests.
D - Peak area deconvoluted.
L - Peak written from unknown list.
C - Area < Critical level.

*************** D I S C A R D E D   I S O T O P E   P E A K S ***************

Nuclide	Centroid Energy	Background Counts	Net Area Counts	Intensity Cts/Sec	Uncert 1 Sigma %	Activity

P - Peakbackground subtraction

This section based on library: Au198.Lib

************* I D E N T I F I E D   P E A K   S U M M A R Y *************

Nuclide	Peak Channel	Centroid Energy	Background Counts	Net Area Counts	Intensity Cts/Sec	Uncert 1 Sigma %	FWHM keV
AU-198	84.00	68.89	8438.	2472.	0.690	5.63	1.793D
AU-198	86.34	70.82	8076.	2713.	0.757	5.06	1.794D
AU-198	97.86	80.28	6354.	1244.	0.347	10.52	3.389s
AU-198	501.74	411.80	76931.	17944.	5.008	2.31	1.975D

s - Peak fails shape tests.
D - Peak area deconvoluted.
A   Derived peak area.

***** S U M M A R Y   O F   L I B R A R Y   P E A K   U S A G E *****

- Nuclide - Name	Code	Average Activity Bq	Peak Energy keV	Activity Bq	Code	MDA Bq	Value	COMMENTS	
AU-198	F	3.4717E+02						2.70E+00	
			411.80	3.472E+02	(	2.506E+01	2.31E+00	9.56E+01	G
			70.82	0.000E+00	-	0.000E+00	5.06E+00	1.38E+00	X
			68.89	0.000E+00	-	0.000E+00	5.63E+00	8.10E-01	X
			675.88	0.000E+00	%	3.499E+02	8.91E+01	8.04E-01	G

ORTEC g v - i (1087) Npp32 G702W050 2023-01-24 12:47:07 PM Page 4
RMC   Spectrum name: S1-2 - Shelf 1.An1

Nuclide	Ave activity	Energy	Activity	Code	Peak MDA	Comments		
		80.30	1.222E+03	+	3.674E+02	1.05E+01	6.10E-01	X
		1087.68	0.000E+00	%	1.284E+03	2.47E+02	1.59E-01	G

(- This peak used in the nuclide activity average.

* - Peak is too wide, but only one peak in library.
! - Peak is part of a multiplet and this area went negative during deconvolution.
? - Peak is too narrow.
@ - Peak is too wide at FW25M, but ok at FWHM.
% - Peak fails sensitivity test.
$ - Peak identified, but first peak of this nuclide failed one or more qualification tests.
\+ - Peak activity higher than counting uncertainty range.
\- - Peak activity lower than counting uncertainty range.
= - Peak outside analysis energy range.
& - Calculated peak centroid is not close enough to the library energy centroid for positive identification.
P - Peakbackground subtraction
} - Peak is too close to another for the activity to be found directly.

Nuclide Codes:
T - Thermal Neutron Activation
F - Fast Neutron Activation
I - Fission Product
N - Naturally Occurring Isotope
P - Photon Reaction
C - Charged Particle Reaction
M - No MDA Calculation
R - Coincidence Corrected
H - Halflife limit exceeded

Peak Codes:
G - Gamma Ray
X - X-Ray
P - Positron Decay
S - Single-Escape
D - Double-Escape
K - Key Line
A - Not in Average
C - Coincidence Peak

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- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

 *****   S U M M A R Y   O F   N U C L I D E S   I N   S A M P L E   *****
          Time of Count  Time Corrected  Uncertainty  1 Sigma
 Nuclide     Activity       Activity       Counting     Total         MDA
                Bq             Bq
 _____________________________________________________________________________
 AU-198       1.6703E+02    3.4717E+02   2.3100E+00%   2.6195E+00% 2.506E+01
   < - MDA value printed.
   A - Activity printed, but activity < MDA.
   B - Activity < MDA and failed test.
   C - Area < Critical level.
   F - Failed fraction or key line test.
   H - Halflife limit exceeded
 -----------------------------   S U M M A R Y   ----------------------------
 Total Activity (   16.4 to  3324.7 keV)     1.670E+02  Bq
 Total Decayed Activity (   16.4 to  3324.7 keV) 3.4717102E+02  Bq


 Analyzed by: ________________________________________
                    Lt(N) B. Casper & LCdr S.P.J. Parent

 Reviewed by: ________________________________________
                    Supervisor

Laboratory:  RMC
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Annex P

Error and Uncertainties

NAA

Alloy Concentration and Impurities

All calculations assume that the Al-Au wire is an ideally mixed alloy with Au evenly distributed in the aluminium supporting matrix [P1]. Considering the small size of the samples, any significant change in the Au distribution could impact the samples' results. Likewise, it is assumed that potential impurities in the Al-Au wire would be evenly distributed, which is most likely not the case. For instance, the material analysis of the Al-Au wire material (Annex F) indicates potential impurities of high absorption cross-section: bismuth (<0.00006%), cadmium (<0.00005%) and lithium (<0.00002%) [P2]. If the impurities are concentrated at a location within the wire, it would disturb the activation distribution in the wire by increasing local shielding or gamma absorption, which, considering the small size of the sample, could have repercussions on the results. The impact of uneven Au distribution should be redressed using triplicate samples repeating the same experiment, considering the effect would be randomized within the selected wire sections.

Other than the material analysis report of the sample material, no further information is currently available regarding impurity distribution in the sample material. The material, however, was sourced from a reputable manufacturer (Shieldwerx) providing wires designed explicitly for flux mapping of reactors, increasing the confidence that the material was manufactured to a high standard and therefore reducing the potential for significant impact coming from composition uncertainties [P3].

Auxiliary Material Impurities

Similarly, as for the sample alloy, impurities and their distributions within the auxiliary materials (*i.e.* vials, inner tubing and filter paper) are unknown, and no material analysis is available from the manufacturer. As the manufacturers are well established, reputable companies, it can be posited that the impurities are low, especially where it is explicitly highlighted that the parts are "laboratory grade." However, the impact of impurities on the results cannot be entirely ascertained unless further analysis is conducted on the materials in question, which would be outside the scope of the present study. If the impurities are randomly distributed in the material, it would be possible to statistically diminish their impact by conducting further experimental runs under identical conditions. If the impurities are systematically evenly distributed, it would be possible to compensate for them in the equations if their nature and quantities are known, or they would become irrelevant in the calculations of the ratios as they would affect all samples equally, cancelling each other out.

While the auxiliary material impurities' impact cannot be wholly dismissed, they have not been considered and are assumed negligible in the calculations conducted here.

Irradiation timings

Irradiation timings were mandated by the need to keep post-irradiation exposure to a workable level to allow for the necessary manipulations to remove the samples from the original irradiation vials and transfer them to the detector vials. As such, the duration of all irradiations was limited to 5 minutes. This short interval in the reactor, combined with a drastic fluctuation in the control rod and flux, may not be enough time to statistically compensate for major operating behaviour variance. Any significant change could be a source of uncertainty exacerbated by the time required to re-achieve steady state compared to longer durations where fluctuations are proportionally less significant. This was apparent when the cadmium-shielded samples were examined at the inner site. The neutron flux drastically dropped when the strong neutron absorber (cadmium) was inserted. Figure P-1 displays the reactor response and control rod position during the irradiation of the unshielded sample US2. Changes in the rod position to keep the flux steady at 5×10^{11} $n \cdot cm^{-2} \cdot s^{-1}$ in the inner irradiation sites affects the neutron flux, and the reactor does not reach an actual steady state of operation during the time of the irradiation.

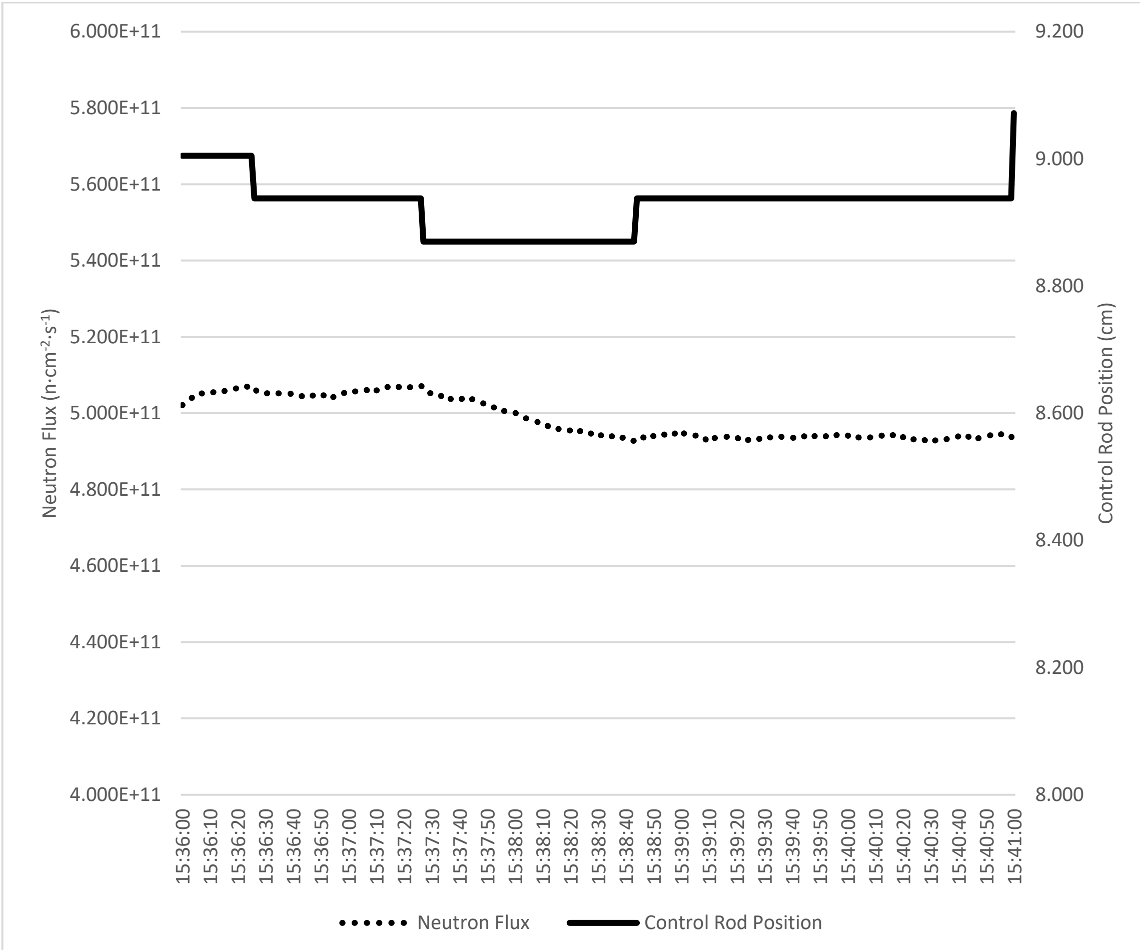

Figure P-1. US2 Incident Neutron Flux and Control Rod Position

The rod position and neutron flux fluctuations are much more pronounced for shielded samples as the reactor must compensate for the high absorption cross-section of the inserted cadmium. Figure P-2 presents the neutron flux response of the reactor to inserting a shielded sample in manual mode (control rod held at a constant 9 cm). The drop in thermal neutron flux is immediate and continuous over the whole irradiation time.

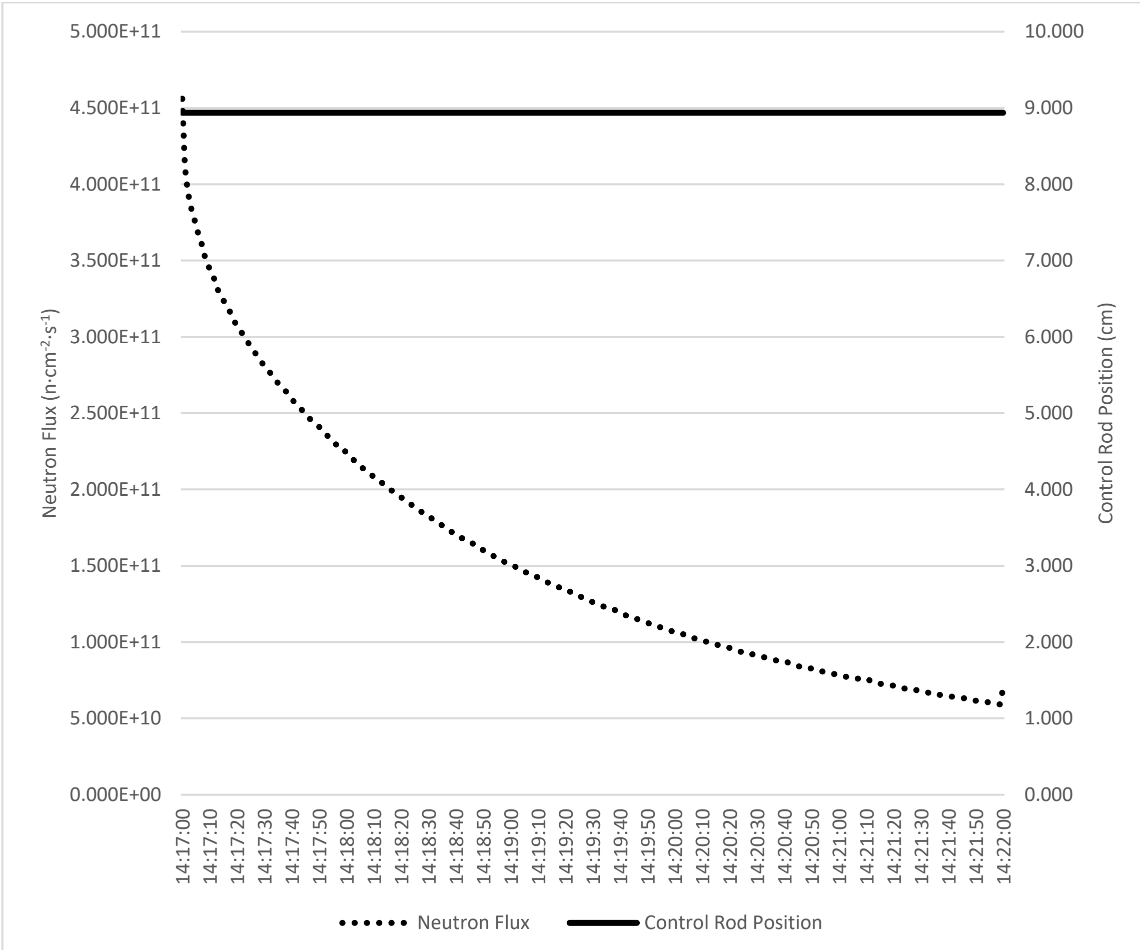

Figure P-2. SLOWPOKE-2 Behaviour During Cd Shielded Sample Irradiation – Manual Mode

In automatic mode, the control rod compensates for the rapid drop in detected thermal neutron flux for the reactor to maintain its setting at 5 x 10 n·cm^{-2}·s^{-1}. Figure P-3 presents the shielded sample S3. As soon as the sudden drop of thermal neutron flux is detected by the SPND, the control rod shoots up to compensate and increase the neutron flux back to the set point. However, the control system overcompensates and takes time to stabilize the rod position. The last data point at 16:52:00 is due to the reactor's response to removing the sample from the irradiation site.

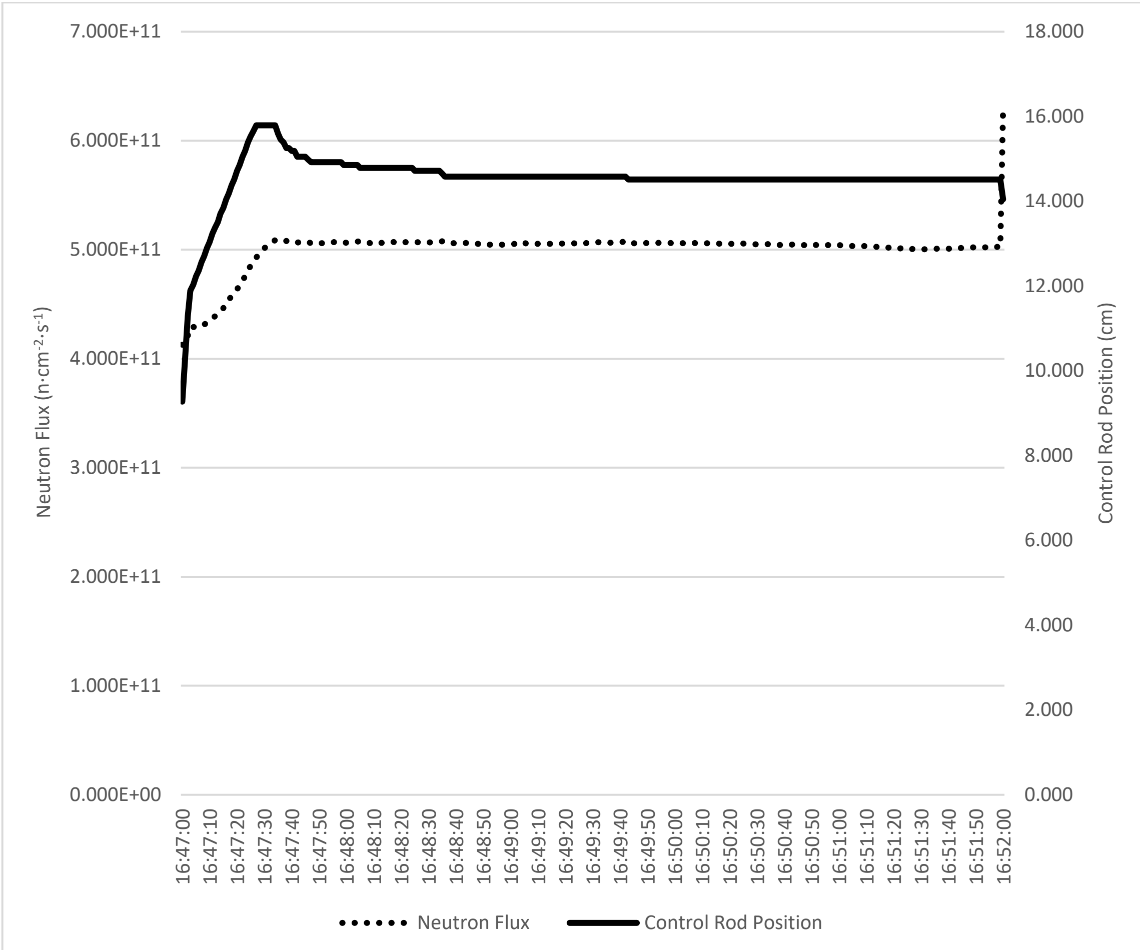

Figure P-3. S3 Incident Neutron Flux and Control Rod Position

It took approximately 36 s for the reactor to reach steady state and compensate for the insertion of the cadmium shield, or 12% of the whole irradiation time. The sample, therefore, saw only a portion of the expected neutron flux in the first 36 s. If the same sample had been in the reactor for 1 hour, for example, assuming the only perturbation was the sample entering and leaving the irradiation site, the 36 s of rapid control rod movements at the start would have accounted for 1% of the total irradiation time.

Therefore, by choosing a short irradiation time to allow for manipulation post-irradiation, possible uncertainties were introduced regarding the actual flux the sample experienced.

Standard Calibration Solution – Efficiency

Due to the short half-life of ^{198}Au, standard solutions are usually not readily available. Therefore, another standard needed to be used to ascertain the efficiency of the HPGe detector. Since the standard calibration solution did not contain the ^{198}Au-generated gammas at 411.8 keV, it was necessary to use the quadratic curve generated by GammaVision to find the efficiency at that particular energy. With an uncertainty of 3.95%, the efficiency is the highest uncertainty of the total flux calculation.

Likewise, since the standard was only available in aqueous form, getting an identical geometry as the sample wires was impossible. However, significant efforts were made to mimic the geometry of the wires using the filter papers in the calibration standard samples. Uncertainties are known to have been generated by the geometric difference between the wire and calibration samples. No attempts were made to quantify the uncertainty between the two sample types. Considering the experimentally calculated fluxes and their close relationship with the existing literature, the impact, if any, is not significant enough to impede the experimental aims of validating the MCNP model.

Also, only one calibration standard was evaluated simultaneously with the samples in August 2021. The two remaining calibration standards were evaluated on the HPGe detector in November 2021. The three calibrations returned similar values, and the effect, if any, is likely minimal. The only significant difference was that ^{51}Cr had decayed entirely between August and November due to its short half-life.

Quantitative Error Analysis

Errors are deviations from the “true” value of the element to be measured and can be classified based on the nature of the measurement error:

- *Gross errors*: generally generated by operator mistakes or using erroneous procedures;
- *Systematic errors*: errors which remain constant or have predictable and stable behaviour. They are generally produced by equipment and procedures employed; and
- *Random errors*: errors varying randomly in direction and degree of importance for repeated measurements. Their behaviour is unpredictable [P4].

Although not completely unavoidable, gross errors can be minimized as much as possible by using rigorous experimental procedures. All samples were prepared simultaneously, using the same source material and techniques. One gross error was detected in the conduct of the experiment. During the irradiation of USB5, the sample was in the reactor for 5 minutes and 20 seconds rather than the expected 5 minutes. As the sample was a blank and was used to ascertain the absence of contamination with a radionuclide emitting gammas at 411.8 keV, the error had no impact on the results, considering no gammas were detected at this energy for any of the blank samples. The successful comparison with the existing literature values also points towards a minimal impact of gross errors on the results.

Systematic and random errors are much more difficult to control, but they can usually be calculated based on known published quantities or estimated based on the experimental procedure. Considering all results are derived from the calculations of the total flux experienced by the sample, Table P-1 presents all errors related to the flux calculations with the corresponding reference or substantiation. Depending on the type of error and how it was provided or evaluated, the error is presented either in absolute form or relative (identified by a %).

Table P-1. Systematic and Random Error is Total Flux Calculations

	Unit	Uncertainty	Reference and Notes
Sample mass	g	0.00005	Half of the smallest digit provided on the balance
Sample purity	%	0.00005	Half of the last digit on the sample material analysis sheet (Annex F)
Isotopic abundance	-	Nil	[P5]
^{197}Au Atomic Mass	amu	0.000000705	[P6]
^{198}Au Half-life	days	0.0012	[P6]
^{198}Au Absorption Cross-Section at 0.00253 keV	barn	0.0001	[P6]
Avogadro's constant	mol^{-1}	Nil	[07]
Efficiency	-	3.95%	Computed by GammaVision (Annex M)
Probability of gamma production	-	0.0006%	[P6]
Irradiation time	s	1	Approximated to 1 s due to human reaction time, recovery system time and clock time
Decay time	min	10	Clock discrepancies between reactor time and HPGe clock time.
Detector time	s	0.01	0.01 s, estimated computer accuracy [P8]
Gamma Count	-	Depends on sample	Computed by GammaVision (Annex N, Annex O)

Irradiation Time

Most of the uncertainties are self-explanatory, provided from literature, or computed by GammaVision. However, the irradiation time and the decay time warrant a particular look.

The irradiation time was calculated by the automatic pneumatic sample handling system for samples irradiated in the inner site no. 2. For the sample irradiation in the outer site no. 10, the laboratory clock was used (Marathon atomic wall clock). The clock uncertainty is estimated at 0.5 seconds, but to this number needs to be added the operator's reaction time and the pneumatic system's response to commands. Therefore, the irradiation time's uncertainty is estimated to be approximately 1 s. Considering the automatic handling system is the same design as the original commissioning system, the 1 s uncertainty was also applied to inner site no. 2 samples.

For the decay time, it was noticed that the laboratory wall clock and the time on the computer associated with the HPGe detector running GammaVision had a time difference of slightly less than 10 minutes. The uncertainty was, therefore, conservatively approximated to 10 minutes.

Overall, those uncertainty approximations have minimal impact on the overall uncertainty, the calculated uncertainties for the total flux of samples being driven by the HPGe detector efficiency.

MCNP

Quantitative Errors – Tallies

All errors for the simulated neutron flux results are computed automatically by MCNP 6.2. The code returns relative errors corresponding to an equivalent one standard deviation [P9]. For a standard tally, the relative error is related to the total number of histories as per (P–1):

$$R \propto \frac{1}{\sqrt{N}} \qquad \text{(P–1)}$$

Where

N = Number of histories

R = Relative error

The MCNP computed error is indicative only of the precision of the obtained result, not of its accuracy concerning its ability to represent the true values of the physical reactor correctly. All of the F4 tallies for the neutron flux have relative errors below 0.03 for the inner site and below 0.08 for the outer site which, both being less than 0.10, are assessed as "generally reliable" by MCNP, the best possible assessment for tallies [P9]. It assumes that the physical geometry of the model is accurate, that the tally has been adequately set up and that the tally is sampling the region of interest appropriately.

Throughout the present section, the reported errors are the absolute values of the errors computed using the MCNP provided relative errors.

Systematic Errors – Geometry and Legacy Model

For the present study, due to the complexity and time requirements necessary to generate an MCNP model from scratch, Rook's MCNP models, from which the MCNP 6.1 detailed model was used as the basis for the present updated MCNP 6.2 model, were assumed to be an accurate representation of the legacy core SLOWPOKE-2 as installed at the RMC. Consequently, only the areas discussed at Annex Q were modified to represent the new core within the legacy reactor construct. Any errors in the original code, whether in geometry or materials' definitions, in areas that were not explicitly modified, have been carried to the updated model.

Systematic Errors – Material

Unless specified, the material used in the reactor was not changed from the legacy code. Therefore, those materials' uncertainties are considered similarly, as discussed above. For the new material, specifically for the sample and vial, several assumptions had to be made to allow MCNP to consider the material's presence. The assumptions themselves have been discussed in more detail in Annex Q. Most assumptions were necessary due to a lack of exact information on the material being used: densities were often estimated, and materials were modelled without impurities.

Considering the materials used in the NAA experimentation have been repeatedly used as standard components at the RMC, it was posited that impurities would most likely be minimal, or if there were significant impurities, they would have minimal interactions with the neutron field of interest. This, however, can only be confirmed with further investigations into the materials.

Systematic Errors – MCNP Code Limitations

The results are as good as the model created and the parameters selected for the Monte Carlo simulations. The results here assume that the tallies were defined adequately, that there were sufficient histories and cycles to obtain representative results, and that reactions of interest were adequately sampled. An oversampling of a particular area or reaction of low impact, or an undersampling of an essential factor could have skewed the results.

The physical size of the cell to be tallied significantly impacts the ability of MCNP to obtain good sampling results. For example, compared to Rook's sample cell, which used a liquid solution in a 2.5 mL vial, the Al-Au wire used here had a significantly smaller volume and, therefore, a smaller area available for incident neutrons interaction with the material. This was particularly evident when looking at the incident neutrons energy distribution: when using the same history numbers as Rook, several energy bins were reported empty by MCNP when there were expectations of obtaining results in those particular bins.

Attempts were made to diminish the impact of that particular type of error by ensuring a high number of cycles (970) was used to compute the tallies after a high number of dismissed cycles (30) to ensure convergence before the tallying of results. Also, neutron histories were raised to 500 000 to increase the probability of neutrons of all available energies interacting with the sample material.

The successful comparison of results with existing studies, both with MCNP 6.1 and with WIMS-AECL, increases confidence that the sampling and computation parameters selection were conducted adequately but cannot by themselves ascertain to that situation.

Gross Errors – Human Factors

Considering the complexity of the MCNP input files and the constant tinkering and modifications that have been required throughout the thesis, it is quite probable that a modification has been made, either by mistake or willingly, that has unforeseen consequences for the results, but with an impact moderate enough that it is not immediately apparent when the results are assessed. To reduce those types of errors, regular verifications as to the geometry being modified were conducted using the MCNP visual editor (Visual Editor 6.1). Still, the whole reactor cannot be routinely and entirely reviewed for defects [P10]. Unless the code was not running to completion (*e.g.,* lost particles, geometric failures, tally failures) or provided impossible results, it was assumed that the code was behaving as expected. However, any small changes (additional spaces, removal, or addition of digits to numbers could be virtually impossible to find unless a line-by-line evaluation was conducted on the code, which was not undertaken in the present case.

Material Evolution

The model assumes that the reactor operates as if it were a new reactor. While it could be estimated that the core (fuel and cage) is new due to the few days of burnup from the refuelling in September 2021 to the NAA experimentation in August 2022, the rest of the reactor has remained unchanged. Therefore, the code, as is, does not consider changes in the material due to exposure to radioactivity over time.

Most of the reactor's volume comprises the beryllium annulus, bottom reflector, and upper shims. However, the code assumes the beryllium remains as built in 1984 and does not consider the changes occurring in the beryllium components due to radiation exposure. Specifically, beryllium poisoning, the accumulation of high neutron capture cross-section isotopes within the reflector material (*e.g.,* ^{3}H, ^{3}He, ^{6}Li), could have a small but significant impact on the reactor's reactivity and, thus, impact neutron flux seen at the irradiation sites [P11], [P12].

Similarly, impurities in the reactor components exposed to the reactor's operational conditions, which have not been evaluated over time, could impact reactivity. Puig & Dennis highlight that the burnup of impurities in the beryllium reflector could increase reactivity over time, even when considering the negative reactivity contribution from the creation of poisoning isotopes [P12].

Mode Restrictions

Due to computational and complexity restrictions, the MNCP mode used for the present simulation is "`n`" (neutron only). Therefore, other potential sources of neutrons and material interactions are not considered. Namely, photofission and photodisintegration are not included in the MCNP model. Both reactions were assumed to be negligible regarding their impact on neutron flux.

Photodisintegration

Considering the amount of beryllium around the reactor and the low incident gamma energy threshold necessary for the reaction to occur (1.67 MeV), the photodisintegration reaction of beryllium ((γ, n), Eq. (P–2)) could have an impact on the neutron field [P13].

$$^{9}Be + \gamma \rightarrow 2\ ^{4}He + \ ^{1}n \qquad (\text{P–2})$$

Few studies could be found discussing photoneutrons in the SLOWPOKE-2 context, and conclusions as to the impact of photoneutrons to the neutron flux appear to be at odds with each other. Lamarre estimated the photoneutron flux at the inner site at 8.55×10^{5} $n \cdot cm^{-2} \cdot s^{-1}$ and therefore, compared to the total flux of ~ 1×10^{12} $n \cdot cm^{-2} \cdot s^{-1}$ assessed it was negligible [P14]. Haddad & Alsomel, however, who evaluated the photoneutron flux after the shutdown of the Syrian Miniature Neutron Source Reactor (MNSR), a reactor design cloned from the SLOWPOKE-2, report photoneutron flux of ~ 1×10^{9} $n \cdot cm^{-2} \cdot s^{-1}$ at the inner site which, depending on their energy distribution, could have an impact on thermal and epithermal fluxes [P15]. Considering the measures taken from the inner site, it could be posited that the effect of the photoneutrons would be higher at the inner sites since they are located within the beryllium annulus.

Haddad & Alsomel highlight that fission products and activations products (*e.g.,* ^{138}Xe and ^{117}Cd) are the driving photoneutron inducers [P15]. With the current model, as stated above, the reactor's material is not assessed for operational time's impact, which prevents the assessment of fission products and activation products' contributions to the neutron field.

Rook's model revealed that the photon flux energy distribution in RMC's SLOWPOKE-2 was typically between 0.025 and 10 MeV [P16]. There is a significant flux peak at 2.14 and 2.55 from the capture of neutrons by hydrogen in the reactor light water (reaction H(n,γ)D). A significant portion of the photon field is above the photoneutron creation threshold of 1.665 MeV and could therefore support the creation of photoneutrons.

Photofission

The impact of photofission on the neutron flux of the SLOWPOKE-2 could not be ascertained from historical studies. However, considering the photon distribution from Rook and the reaction threshold for photofission for the two most prevalent nuclides in the SLOWPOKE-2 fuel, ^{235}U and ^{238}U (both 5.8 ± 0.2 MeV), it could be posited that the contribution of photofission to the overall fission amount would be minimal [P17]. However, this could not be ascertained with the current code.

Burnup and Decay

CINDER Module

While MCNP 6.2 tallies provide standard deviations which can be used to compute an error range for results, the CINDER module of MCNP 6.2 does not give computed errors for any of its results. Considering the 5% errors assessed for the inner site and the 25% assessed for the outer site, and considering all reactions within the core are encompassed within the estimated 5% error, a conservative error of 20% has been applied to the isotopic activity results obtained from the depletion code.

Omitted Isotopes

Multiple isotopes have been omitted from the initial fuel loadout and further depletion by the CINDER module due to MCNP computational limitations. Also, isotopes that were expected, most notably ^{137m}Ba, a short-lived daughter of decaying ^{137}Cs, were not seen in the results, while the resulting stable ^{137}Ba was detected.

Therefore, the activity and heat decay results represent an unknown fraction of the actual values. It was not possible to expand on the missing isotopes and determine their contribution to total activities and decay heat values. However, it is posited that the omitted isotopes' contribution would be encompassed by the 20% error applied to the CINDER activities results.

Simulation Runs Discontinuities

Due to the time required to run decay simulations (a few weeks) with the computational resources available, the simulation runs were susceptible to unforeseen external events. For both the half power and full power decay simulations, issues of power failures at the RMC and computer crashes/resets during the runs required for their completion to 10 million years necessitated that they be conducted with discontinuities. In each occurrence of a simulation failure due to external factors, it was assured that steps between subsequent runs overlapped. No difference between the overlapping steps could be seen, and it is assessed that the impact on the results, if any, is negligible. Only complete runs with discontinuities could be conducted for the decay simulations.

CANDU Data Errors

The data generated by ORIGEN-S, taken from Heckman & Edward for activity and decay heat for the CANDU reference spent fuel, do not contain any attached error [P18]. However, a regression study conducted on previous data from Ontario Power Generation Nuclear Waste Management Division (2000) (Report 06819-REP-01200-10029-R00) shows a maximum difference of 5.1% between the NWMO and OPG data for both thermal power and total activity, with most of the other discrepancies being around 1.5% from 0 to 10 million years after reactor discharge. Therefore, a conservative error of 5% has been retained for all CANDU values.

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Annex Q

Updated Model Details

Rook – Detailed Model

Of the three models used by Rook, the “detailed model” was retained as the best representation of the physical SLOWPOKE-2 installed at the RMC [Q1]. The only remaining complete code for the detailed model resides in an MCNP output file. An input file had to be recreated from that information.

Few complete notes remain in the code, but enough to trace its provenance and updates. The code was created by CNL and heavily modified by Dr. C. Jewett in February 2017. It was then changed to fit Rook’s purposes in April 2018. The original code for the present study was reconstructed from an output file from an MCNP run conducted on 23 April 2018.

Figure Q-1 and Figure Q-2 present the visual rendition of the original MCNP code geometry as used by Rook in 2018.

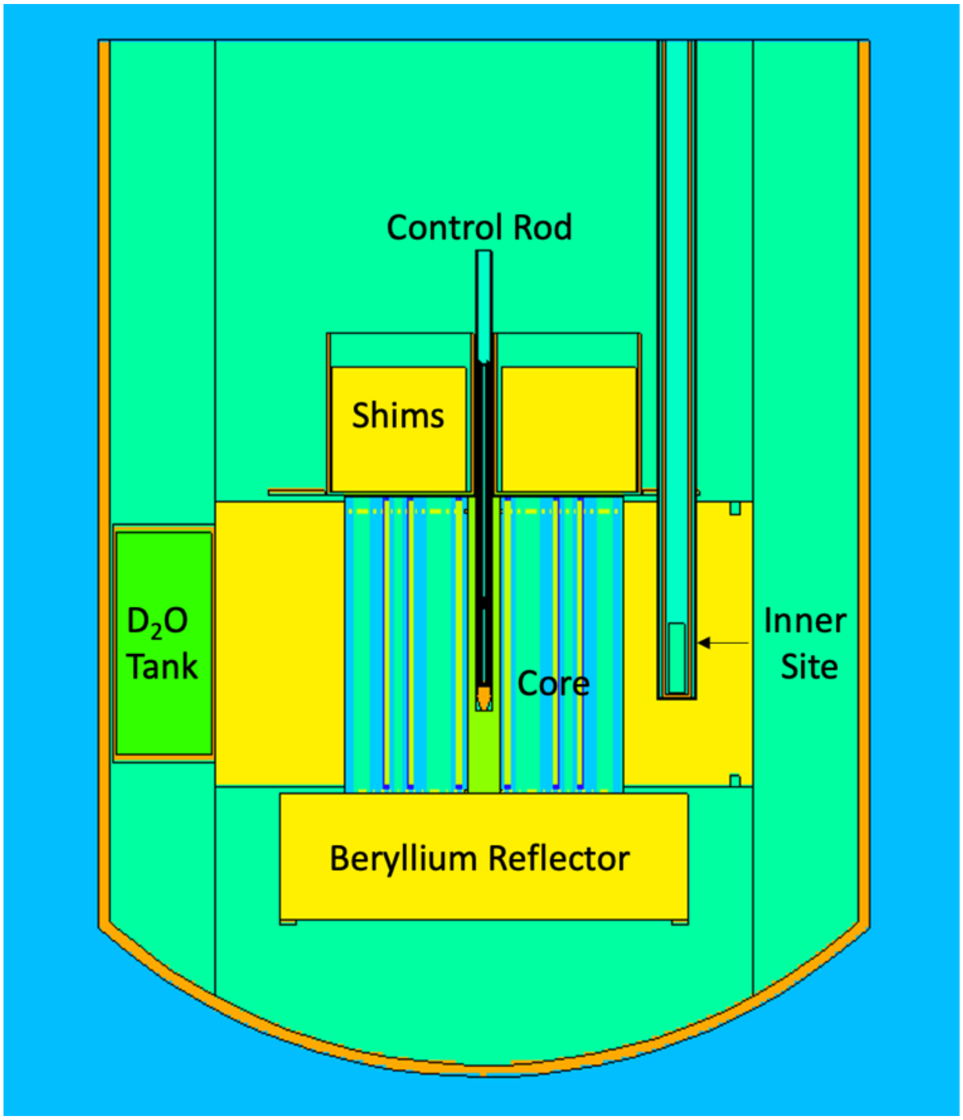

Figure Q-1. Rook MCNP Model Axial View

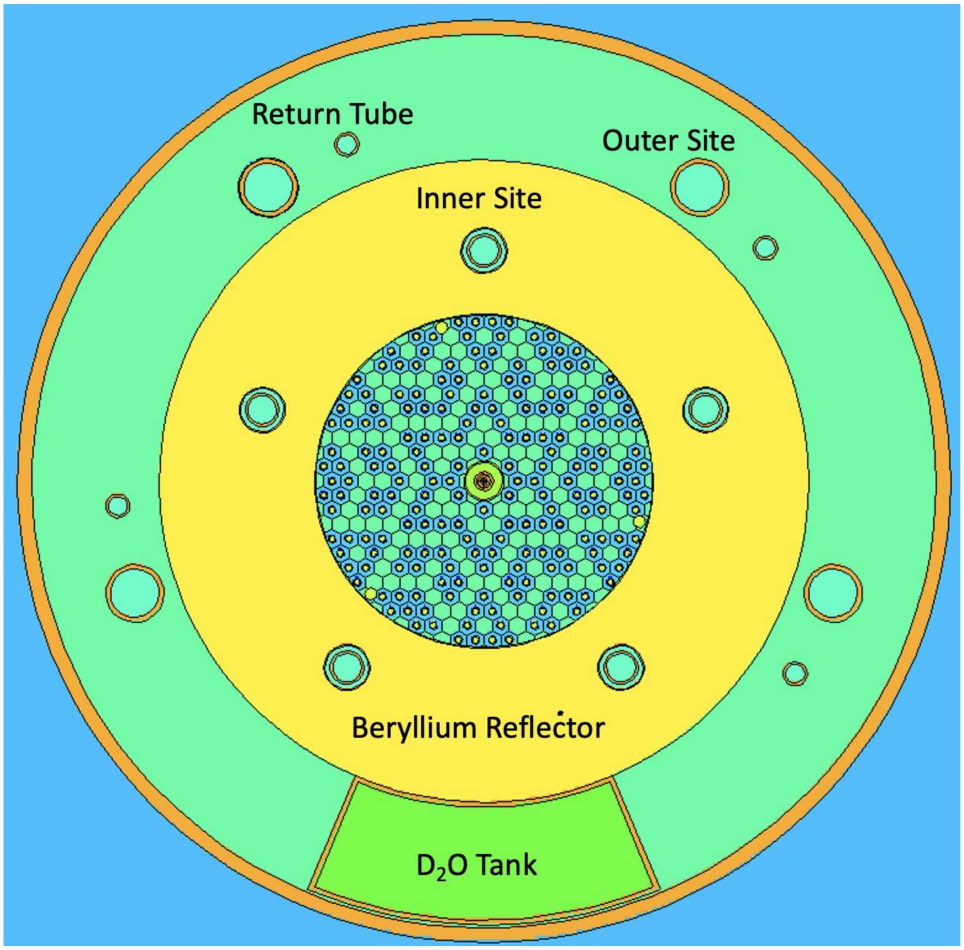

Figure Q-2. Rook Model Radial View

Model Controls

The detailed model is controlled by two main parameters: shim thickness and control rod height.

The beryllium shim thickness controls the amount of beryllium reflector shims located above the reactor. They compensate for the significant reactivity changes required to keep the reactor operation at its stated flux.

The control rod height is used for the operational control of the reactor with fine reactivity adjustment to start/stop the reactor and maintain the flux within the stated parameters selected by the operator.

The following code excerpt is the original code from Rook, identifying the shim cell (340) and the control rod cell (350) [Q1]. The shim height is set at 0.079375 cm (commissioning height in 1985), and the control rod height at 5.8674 cm

```
340  0  -333 +335 +332 -334 fill=340(0 0 0.079375) u=151 imp:n=1  $ shim <yes>
c
c NB: The control rod is fully inserted if z = -0.750158865031 cm
350  0            -350 trcl=(0 0 5.8674) fill=350  u=151 imp:n=1 $ control rod
```

The height of the shims and control rod are adjusted as required by modifying the input code to the required values. Figure Q-1 displays the control rod at the 5.8674 cm position and the shims at a 10 cm thickness.

All other changes to the code are made by physically changing the geometry of the reactor, which was done to update the model for the present work. A detailed description of the changes made is presented at below.

Updated Model

The updated model was built on the framework already established by CNL and Rook. It was assumed that the geometry and dimensions were accurate. None of the structural components of the reactor were modified, nor were the materials already included in the code. The original code needed more organization, titles, and labels to easily identify components. Those were added where relevant to facilitate faultfinding and code operation. Likewise, notes were added where needed. Since the original code was obtained from a MCNP output file, most legacy notes were cut past the 80 characters limit of MCNP 6.2. It was not possible to get the original input file of the code to complete the notes. Nevertheless, the notes were kept as is in the chance that the original input file be found in the future, and correlations between the legacy code and the updated code might be done to complete the notes.

The following sections detail the modifications implemented on the original Rook model to represent the physical reactor arrangement at the RMC more accurately.

Fuel Composition

Since the reactor has been refuelled, the coded fuel must be updated. Originally, ideal fuel containing no impurities was modelled. For the new core, two fuel material analysis reports were obtained.

The first one, conducted by thermal ionization mass spectrometry, analyzed the isotopic uranium in the LEU metal (batch 58/Y-12 ES-3100-61049, parent lot 3C19P30707) obtained from the United States Department of Energy (DOE) in 2016 [Q2]. Results are presented inTable Q-1.

Table Q-1. Average Isotopic Uranium in LEU from DOE

Uranium Isotope	Weight %
234	0.2089 ± 0.0014
235	19.632 ± 0.021
236	0.07555 ± 0.00021
238	80.08 ± 0.09

The second report contains the chemical analysis conducted by the Analytical Chemistry Branch at CNL on the UO_2 powder prior the sinterization process of the fuel pellets and identifies the impurity contents of the fuel [Q3]. The uranium powder was analyzed in four batches, presented at Table Q-2:

Table Q-2. UO_2 Powder Impurity Composition

Element	Batch 1 $g \cdot cm^{-3}$	Batch 2 (ppm U)	Batch 3 (ppm U)	Batch 4 (ppm U)	MCNP Model (ppm U)
Aluminium	< 10	< 10	7.8 ± 0.8	< 10	9.45
Boron	< 0.2	< 0.1	< 0.3	< 0.3	0.225
Carbon	36	76	135	135	95.5
Calcium	< 20	< 10	< 30	< 20	20
Cadmium	< 0.06	< 0.06	< 0.05	< 0.02	0.0475
Chromium	4.9 ± 0.3	2.8 ± 0.3	1.8 ± 0.1	3.8 ± 0.3	3.575
Copper	2.2 ± 0.2	< 3	2.65 ± 0.1	2.3 ± 0.2	2.64
Dysprosium	< 0.02	< 0.03	< 0.02	< 0.02	0.0225
Fluorine	4.9	2.4	1.1	1.1	2.375
Iron	43 ± 3	47 ± 2	48 ± 6	47 ± 5	50.25
Gadolinium	< 0.06	< 0.05	< 0.02	< 0.01	0.035
Magnesium	< 6	< 1	< 2	< 7	4
Manganese	5 ± 1	5 ± 1	6.7 ± 0.3	5.3 ± 0.9	6.3
Molybdenum	11.8 ± 0.8	10.9 ± 0.7	11.9 ± 0.6	11.1 ± 1.0	12.2
Nickel	1.8 ± 0.1	< 3	< 2	2.3 ± 0.3	2.375
Silicon	< 10	< 30	< 60	< 30	32.5
Thorium	< 0.1	< 1	0.09 ± 0.02	0.69 ± 0.03	0.4825

MCNP's inputs, including uncertainties, are not possible. It is also impossible to accurately determine an approximation of the "less than" values. Therefore, the maximum possible values, including the uncertainties, were taken and averaged to capture the variations between the batches to obtain the model's impurities concentrations. Since only the elements are listed in the material analysis reports, it was assumed that they were in their natural state, with standard isotopic abundances. All natural isotopes of the impurities were thus included in the input card for the fuel material.

The final fuel composition, including all impurities, uranium isotopes and oxygen content can be seen at Annex R, under the "UO2 – Fuel" section.

Fuel Density

Fuel pellets were produced by CNL in four batches. For each batch, 50 pellets were selected to test the density of the fuel. Table Q-3 presents the density of the pellets in each batch as tested [Q3]:

Table Q-3. Measured Density of New Fuel

Batch	Density ($g \cdot cm^{-3}$)
Batch 1	10.66 ± 0.55
Batch 2	10.72 ± 0.04
Batch 3	10.72 ± 0.02
Batch 4	10.70 ± 0.03
MCNP Model	10.70

The average of the four batches was taken as the modelling value for MCNP. Some pellets had higher densities, up to 10.8 $g \cdot cm^{-3}$ and were used to manufacture the elements. However, they were used so that no single elements weighted more than 33.84 g, corresponding to the maximum allowable density specification of 10.75 $g \cdot cm^{-3}$. As there is no way to ascertain the specific density of each pellet as fitted in the core, all pellets were given the average density for the fuel material.

Core layout and Alignment

The original SLOWPOKE-2 core model used the 198 elements core commissioned in 1985 (Figure Q-3).

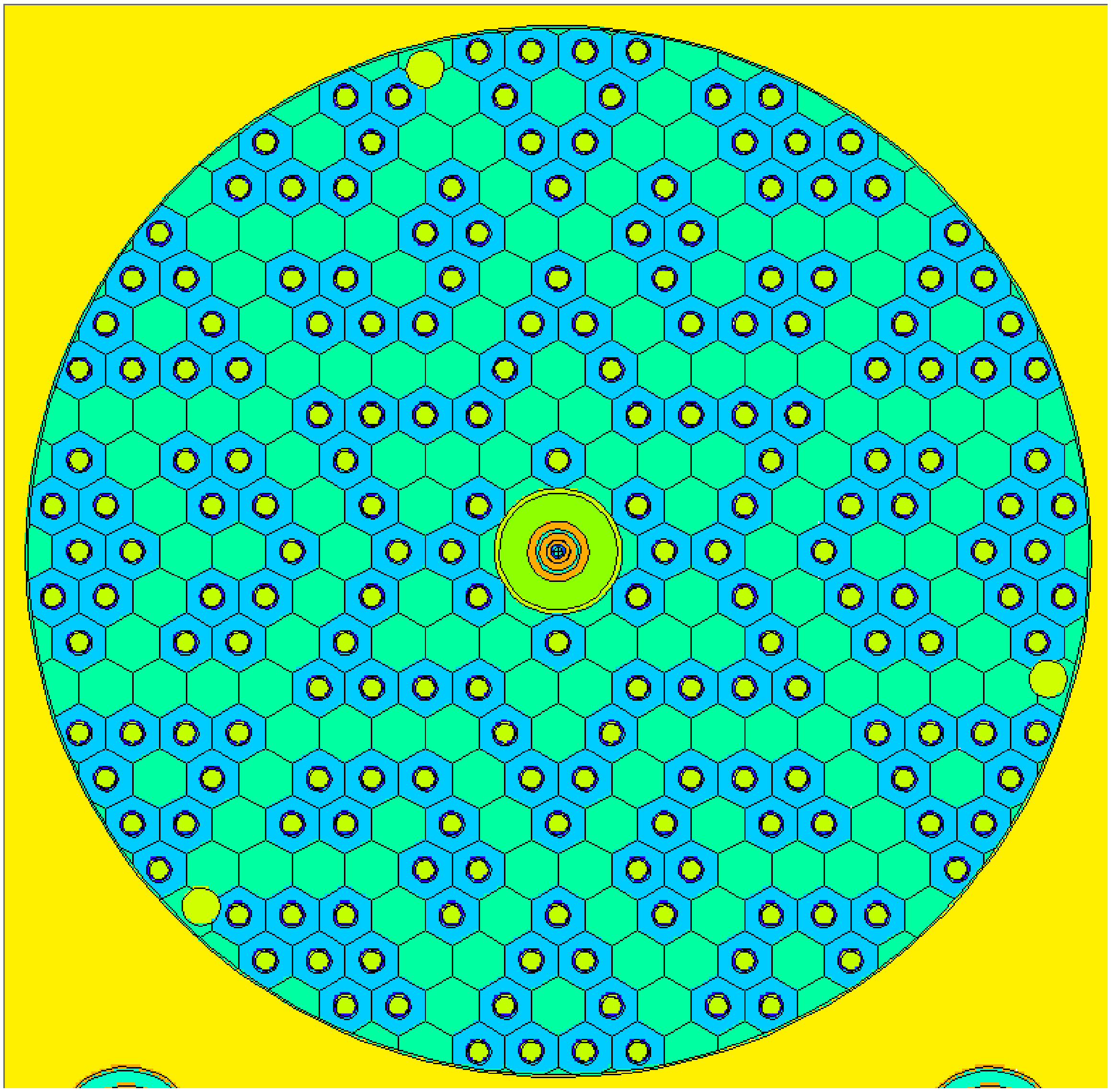

Figure Q-3. Core from Original MCNP Model (Rook)

Due to the higher density of the fuel material used in refuelling the core in 2021, the new core has 195 elements. The MCNP model was therefore updated to reflect the core layout and its orientation in the reactor. Figure Q-4 presents the new core in its current position within the SLOWPOKE-2. Using inner irradiation site no. 5 and the D_2O tank in Figure Q-4 as reference points, estimating the rotation necessary to the original model of approximately 10 degrees clockwise was possible. The elements absent from the new core, compared to the 1985 core, were used to ensure the proper orientation of the updated MCNP model core. Figure Q-5 presents the updated model core. Highlighted in red are the *three* (3) absent pins from the new core which relate to the physical core (Figure Q-4).

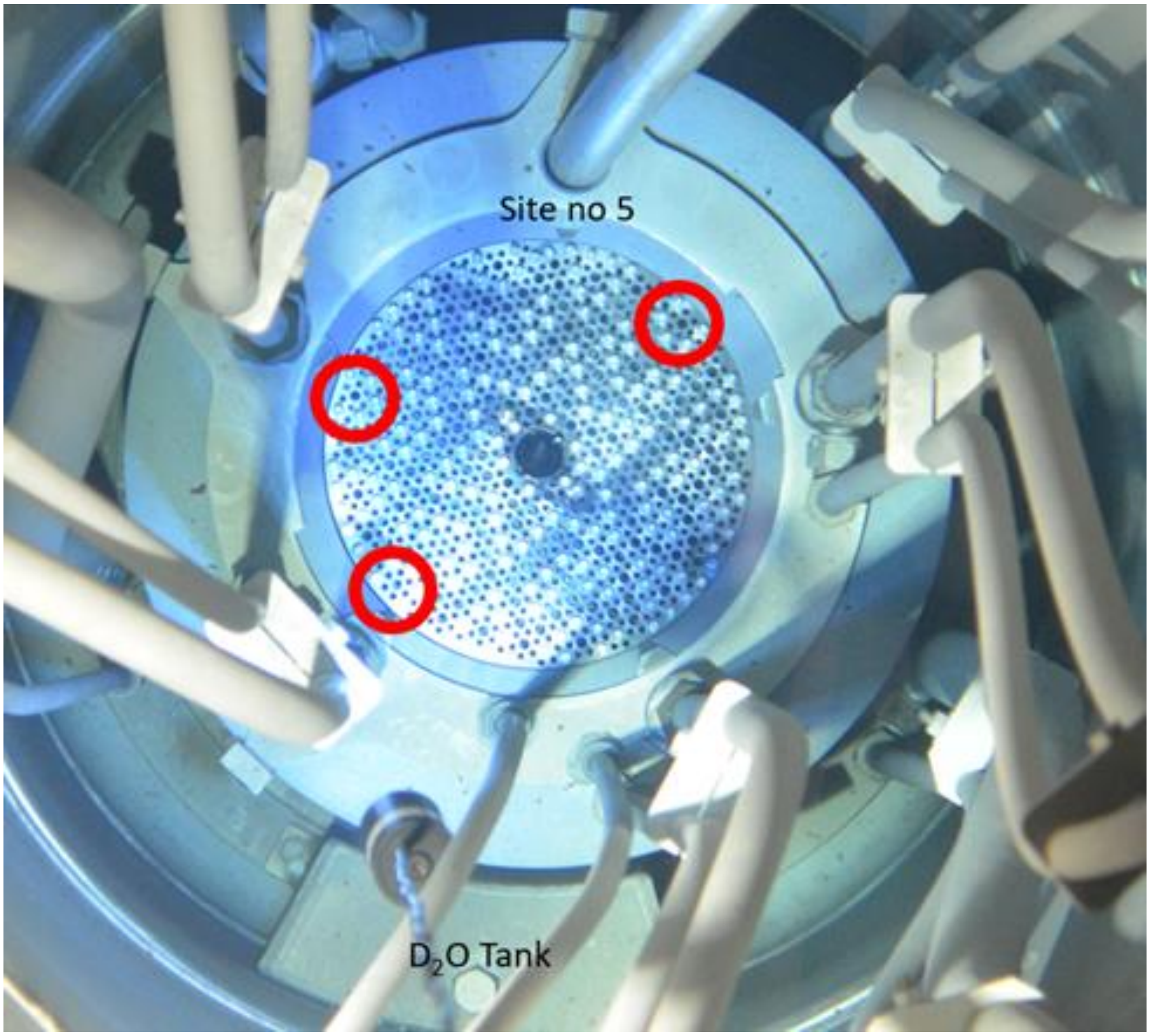

Figure Q-4. Refuelled Core Position

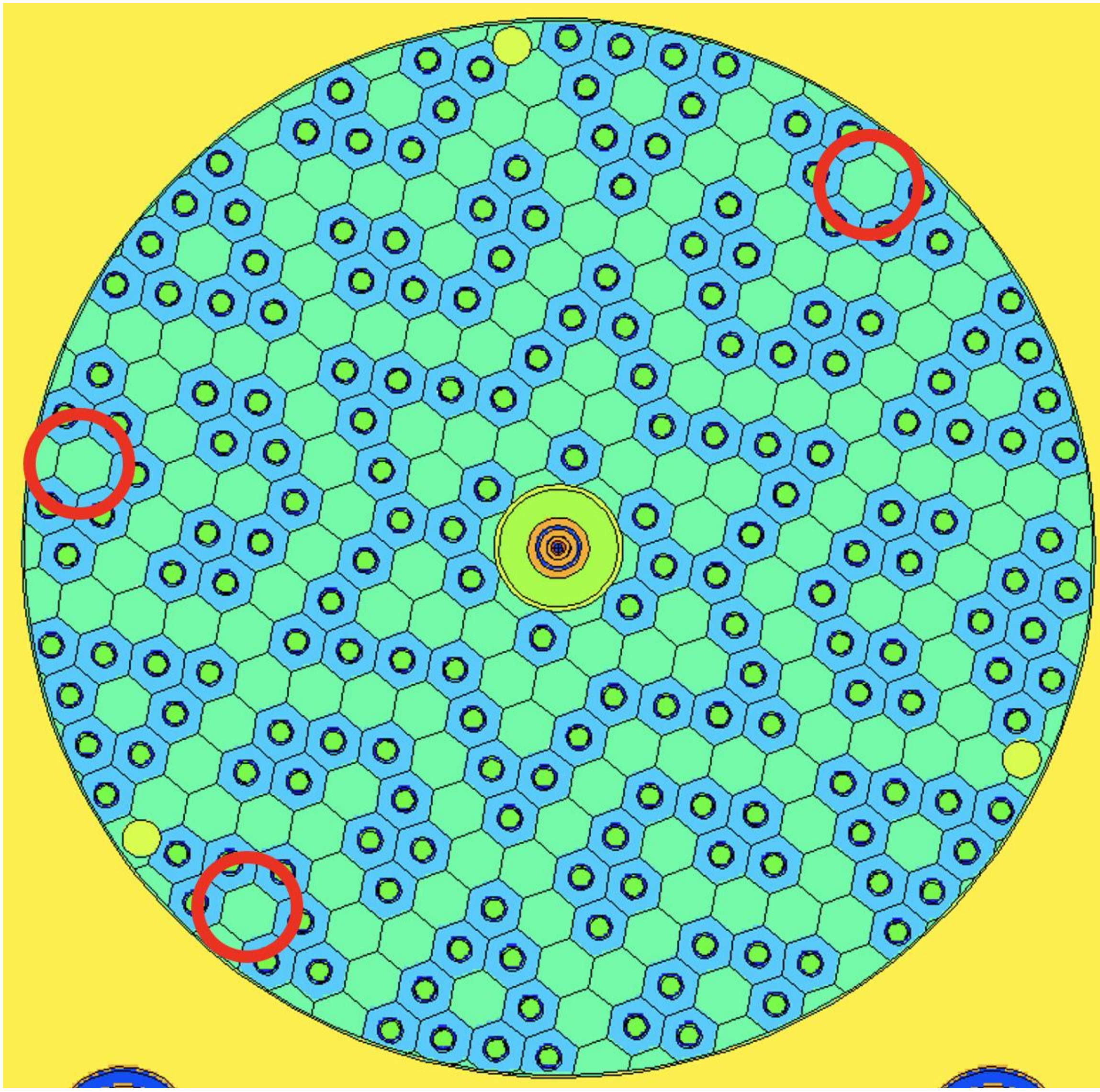

Figure Q-5. Update Core Model, Aligned with 195 Elements

Flooded Site 8

The outer irradiation site no. 8 was converted to a flooded site in 1989. The site was modified to allow the reactor container water to flow freely within the site. The site was modified to accommodate samples generating significant heat, which the standard air-filled sites could not accommodate. The model was updated by changing the material of the site's internal cell to that of the container's light water.

Figure Q-6 displays site no. 8's cross-section showing light water (green) both within the site and in the reactor container section.

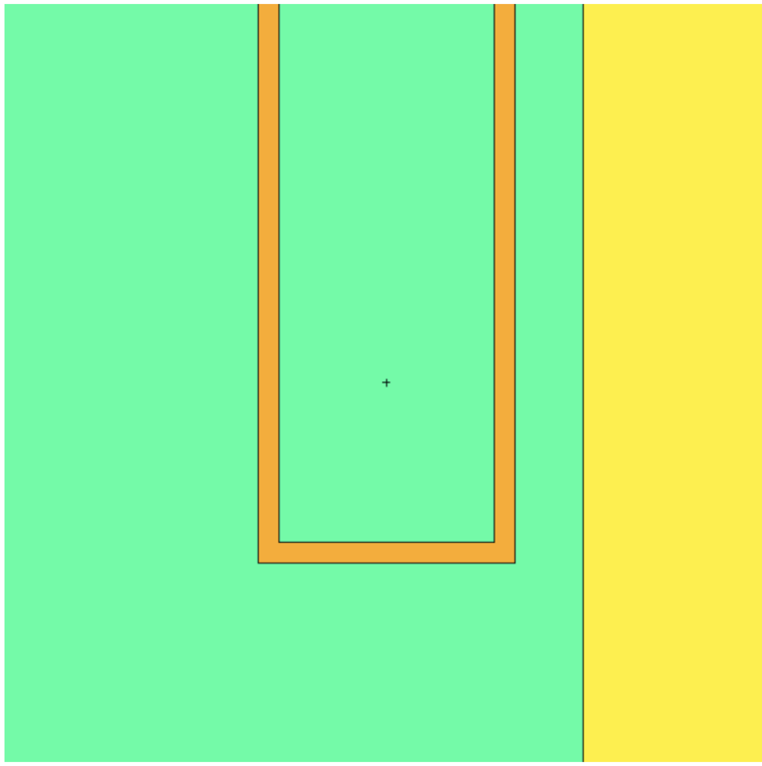

Figure Q-6. Flooded Site 8 Cross-secti0n (Updated Model)

Reactor Pool and Container Size

The legacy model had only a small portion of the reactor container in a 200 cm x 200 cm x 200 cm cube representing the pool. The reactor container was elongated, and the pool changed from a cube to a cylinder to the diameter of the physical pool at the RMC (Annex C). Figure Q-7 presents the redesigned pool in context.

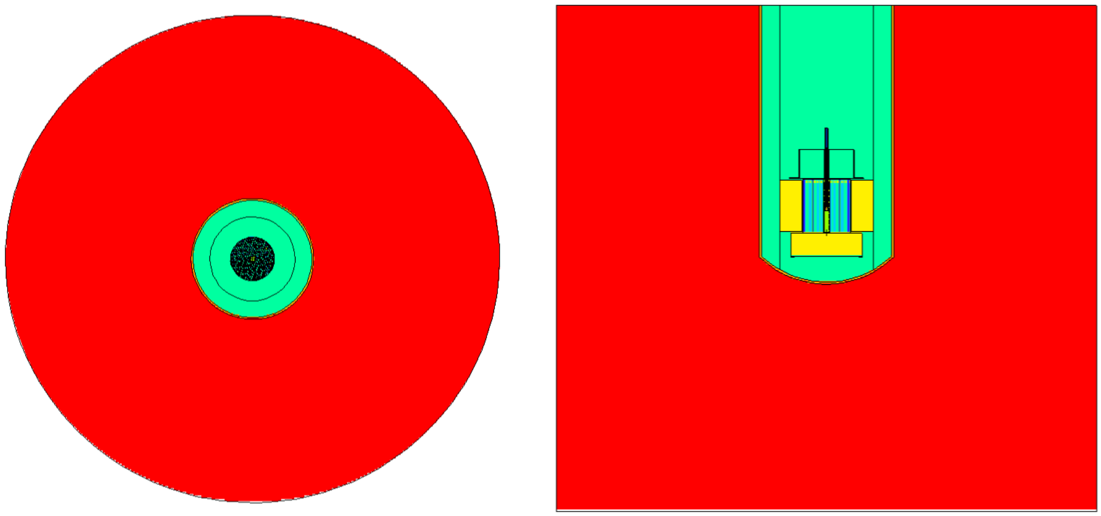

Figure Q-7. Axial and Side Views of the Reactor Container and Reactor Pool

REFERENCES

[Q1] J. C. Rook, "Degradation of PER- and Polyfluoroalkyl Substances: Irradiation and MCNP Modeling with the SLOWPOKE-2 Nuclear Reactor," Master of Applied Science, Royal Military College of Canada, Kingston, ON, 2018.

[Q2] J. Spencer, "Contract Number COMM-PSPC-008254-001 Royal Military College of Campus (RMCC) SLOWPOKE-2 Refuel (Client Contract Number W6369-18A021/001/KIN): Partial Fulfillment of Milestone No. 7," Chalk River, ON, Jul. 2019.

[Q3] Canadian Nuclear Laboratories, "Fabrication Report: SLOWPOKE-2 Core for RMC - SLWPK4-124246-407-001 Rev. 0," Chalk River, ON, 2021.

Annex R

MCNP Input File

Shielded Sample, Inner Site

```
MCNP Model of RMC's SLOWPOKE-2 LEU
C Unshielded Sample in Inner Site no 2
C Control Rod at 14.24 cm (8.8 kW)
C Shims at 0 cm
C
C
C October 2022, Alterations made by LCdr Simon P.J. Parent
C - General code maintenance (layout, titles, etc.)
C - Updated fuel density (10.70 g/cm3 vice 10.60g/cm3) to correspond to
C   information received from AECL during refuelling
C - Updated the core layout to reflect the new core's element positioning
C    (195 elements vice 198)
C - Aligned the core 10 degrees clockwise to align with RMC Core's actual
C   position
C - Removal of legacy code with no purpose (surfaces and cells)
C - Removed 7cc cells created by Rook and inserted samples (cells, surfaces,
C   materials) used in NAA experimentation conducted in August 2022
C - Defined Site 8 as the flooded site, filled with reactor container light
C   water
C - Updated the whole model to ENDF\B-VIII
C - Modified self-powered neutron detector to be more representative of the
C    actual installed detector
C - Altered the reactor pool to conform to the dimensions of the pool (2.46m diameter)
at RMC
C - Raised reactor container and radiation tube to the upper limit of the pool
C
C
C April 2018 alterations made by JADEN ROOK
C - Beryllium MAT Impurities added
C - Defined 7cc cells in the inner and outer irradiation sites
C - Cadmium lining on outer site #9
C - All Fuel pins use same mcard (fresh fuel)
C
C
C    The following modifications were made by Dr. C. Jewett in February 2017:
C 1. Changes to the control rod geometry to make it conform to drawings A15292 a
C 2. Addition of the conical control rod sheath tip to the control rod geometry
C The following modifications were made by Dr. C. Jewett in March 2017:
C 1. Shifted the control rod so that it touches the bottom of the water cell hol
C 2. The following temperature changes were made:
C    a. Irradiation Tubes were tmp = 2.87087E-08, everything else was tmp = 2.58
C    b. Irradiation tubes are now tmp = 2.52607355E-08, everything else is now t
C 3. The following temperature change was made on 24 March 2017
c    a. Irradiation Tubes were tmp = 2.87087E-08
c    b. Irradiation tubes are now tmp = 2.52607355E-08
C
C
C ___________________________________________________________________________
C ******************************** CELL CARDS*******************************
C ___________________________________________________________________________
C
1    0   600 imp:n=0 $Void outside of the pool
C
C Lower Container Section
2    0          (-701 -703 -710):(710 -701)     imp:n=1  fill=151 $ inside cont
3    800 -2.70 ((-700 -702 -711):(711 -700)) #2 imp:n=1 $ container wall
4    410 -0.9966  -600 (700:(702 -711))         imp:n=1 $ Pool water
     tmp=2.52607355E-08
C
C -----------------------
C universe 121 - fuel surrounding (common for all fuel sites)
C -----------------------
2110 100 -6.5 (+411:+402)      -403      -410  u=121 imp:n=1  $ reduced tip on l
```

```
     tmp=2.52607355E-08
2115 100 -6.5 (+413:-414:-404) -405 +403 -412  u=121 imp:n=1  $ lower stud
     tmp=2.52607355E-08
2120 100 -6.5        -415 +416 -407 +405       u=121 imp:n=1  $ fuel sheath
     tmp=2.52607355E-08
2125 100 -6.5 (+413:-414:+408)      +407 -412  u=121 imp:n=1  $ upper stud
     tmp=2.52607355E-08
2130 300 -0.00018 -416 -408 +404 #2115 #2125   u=121 imp:n=1 $ He cover
     tmp=2.52607355E-08
2135 600 -6.5  +420 +501 -403 571 572 573 574 575 576 u=121 imp:n=1 $ lower flan
     tmp=2.52607355E-08
2140 600 -6.5  +425 +502 -503 581 582 583 584 585 586 u=121 imp:n=1 $ upper flan
     tmp=2.52607355E-08
2145 301 -.9966 #2110 #2115 #2120 #2125 #2130 #2135 #2140 u=121 imp:n=1  $ coola
     tmp=2.52607355E-08
C ------------------------
C universe 01-pins A1(6)=6
C ------------------------
40190   0       -601 -405:+406:+417  fill=121 u=01 imp:n=1 $ non-fuel
40100   0            +405 -406 -417  fill=401 u=01 imp:n=1 $ fuel stack
40101 40000 -10.70   -1010                     u=401 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
40102 40000 -10.70   -1030 1010                u=401 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40104 40000 -10.70   -1050 1030                u=401 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40106 40000 -10.70   -1070 1050                u=401 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40108 40000 -10.70   -1090 1070                u=401 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40110 40000 -10.70   -1110 1090                u=401 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40112 40000 -10.70   -1130 1110                u=401 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40114 40000 -10.70   -1150 1130                u=401 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40116 40000 -10.70   -1170 1150                u=401 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40118 40000 -10.70   -1190 1170                u=401 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40120 40000 -10.70   -1210 1190                u=401 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40121 40000 -10.70   -1220 1210                u=401 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
40122 40000 -10.70         1220                u=401 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C ------------------------
C universe 02- A0(6)=12
C ------------------------
40290   0       -601 -405:+406:+417  fill=121 u=02 imp:n=1 $ non-fuel
40200   0            +405 -406 -417  fill=402 u=02 imp:n=1 $ fuel stack
40201 40000 -10.70   -1010                     u=402 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
40202 40000 -10.70   -1030 1010                u=402 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40204 40000 -10.70   -1050 1030                u=402 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40206 40000 -10.70   -1070 1050                u=402 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40208 40000 -10.70   -1090 1070                u=402 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40210 40000 -10.70   -1110 1090                u=402 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
```

```
40212 40000 -10.70   -1130 1110               u=402 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40214 40000 -10.70   -1150 1130               u=402 imp:n=1 vol=0.267776897$
      tmp=2.52607355E-08
40216 40000 -10.70   -1170 1150               u=402 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40218 40000 -10.70   -1190 1170               u=402 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40220 40000 -10.70   -1210 1190               u=402 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
40221 40000 -10.70   -1220 1210               u=402 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
40222 40000 -10.70         1220               u=402 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C -----------------------
C universe 10- B0(6)=18
C -----------------------
41090   0       -601 -405:+406:+417  fill=121 u=10 imp:n=1 $ non-fuel
41000   0            +405 -406 -417  fill=410 u=10 imp:n=1 $ fuel stack
41001 40000 -10.70   -1010                    u=410 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
41002 40000 -10.70   -1030 1010               u=410 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
41004 40000 -10.70   -1050 1030               u=410 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
41006 40000 -10.70   -1070 1050               u=410 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
41008 40000 -10.70   -1090 1070               u=410 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
41010 40000 -10.70   -1110 1090               u=410 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
41012 40000 -10.70   -1130 1110               u=410 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
41014 40000 -10.70   -1150 1130               u=410 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
41016 40000 -10.70   -1170 1150               u=410 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
41018 40000 -10.70   -1190 1170               u=410 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
41020 40000 -10.70   -1210 1190               u=410 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
41021 40000 -10.70   -1220 1210               u=410 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
41022 40000 -10.70         1220               u=410 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C -----------------------
C universe 21- C1(12)=30
C -----------------------
42190   0       -601 -405:+406:+417  fill=121 u=21 imp:n=1 $ non-fuel
42100   0            +405 -406 -417  fill=421 u=21 imp:n=1 $ fuel stack
42101 40000 -10.70   -1010                    u=421 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
42102 40000 -10.70   -1030 1010               u=421 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
42104 40000 -10.70   -1050 1030               u=421 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
42106 40000 -10.70   -1070 1050               u=421 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
42108 40000 -10.70   -1090 1070               u=421 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
42110 40000 -10.70   -1110 1090               u=421 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
42112 40000 -10.70   -1130 1110               u=421 imp:n=1 vol=0.267776897$
```

```
     tmp=2.52607355E-08
42114 40000 -10.70   -1150 1130               u=421 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
42116 40000 -10.70   -1170 1150               u=421 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
42118 40000 -10.70   -1190 1170               u=421 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
42120 40000 -10.70   -1210 1190               u=421 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
42121 40000 -10.70   -1220 1210               u=421 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
42122 40000 -10.70         1220               u=421 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C ----------------------
C universe 30- D0(6)=36
C -----------------------
43090   0       -601 -405:+406:+417  fill=121 u=30 imp:n=1 $ non-fuel
43000   0            +405 -406 -417  fill=430 u=30 imp:n=1 $ fuel stack
43001 40000 -10.70   -1010                    u=430 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
43002 40000 -10.70   -1030 1010               u=430 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43004 40000 -10.70   -1050 1030               u=430 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43006 40000 -10.70   -1070 1050               u=430 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43008 40000 -10.70   -1090 1070               u=430 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43010 40000 -10.70   -1110 1090               u=430 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43012 40000 -10.70   -1130 1110               u=430 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43014 40000 -10.70   -1150 1130               u=430 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43016 40000 -10.70   -1170 1150               u=430 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43018 40000 -10.70   -1190 1170               u=430 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43020 40000 -10.70   -1210 1190               u=430 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43021 40000 -10.70   -1220 1210               u=430 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
43022 40000 -10.70         1220               u=430 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C -----------------------
C universe 32- D2(12)=48
C -----------------------
43290   0       -601 -405:+406:+417  fill=121 u=32 imp:n=1 $ non-fuel
43200   0            +405 -406 -417  fill=432 u=32 imp:n=1 $ fuel stack
43201 40000 -10.70   -1010                    u=432 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
43202 40000 -10.70   -1030 1010               u=432 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43204 40000 -10.70   -1050 1030               u=432 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43206 40000 -10.70   -1070 1050               u=432 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43208 40000 -10.70   -1090 1070               u=432 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43210 40000 -10.70   -1110 1090               u=432 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43212 40000 -10.70   -1130 1110               u=432 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
```

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43214 40000 -10.70   -1150 1130               u=432 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43216 40000 -10.70   -1170 1150               u=432 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43218 40000 -10.70   -1190 1170               u=432 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43220 40000 -10.70   -1210 1190               u=432 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
43221 40000 -10.70   -1220 1210               u=432 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
43222 40000 -10.70         1220               u=432 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C -----------------------
C universe 41- E1(12)=60
C -----------------------
44190   0       -601 -405:+406:+417  fill=121 u=41 imp:n=1 $ non-fuel
44100   0            +405 -406 -417  fill=441 u=41 imp:n=1 $ fuel stack
44101 40000 -10.70   -1010                    u=441 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
44102 40000 -10.70   -1030 1010               u=441 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44104 40000 -10.70   -1050 1030               u=441 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44106 40000 -10.70   -1070 1050               u=441 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44108 40000 -10.70   -1090 1070               u=441 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44110 40000 -10.70   -1110 1090               u=441 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44112 40000 -10.70   -1130 1110               u=441 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44114 40000 -10.70   -1150 1130               u=441 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44116 40000 -10.70   -1170 1150               u=441 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44118 40000 -10.70   -1190 1170               u=441 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44120 40000 -10.70   -1210 1190               u=441 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44121 40000 -10.70   -1220 1210               u=441 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
44122 40000 -10.70         1220               u=441 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C -----------------------
C universe 43- E2(6)=66
C -----------------------
44390   0       -601 -405:+406:+417  fill=121 u=43 imp:n=1 $ non-fuel
44300   0            +405 -406 -417  fill=443 u=43 imp:n=1 $ fuel stack
44301 40000 -10.70   -1010                    u=443 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
44302 40000 -10.70   -1030 1010               u=443 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44304 40000 -10.70   -1050 1030               u=443 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44306 40000 -10.70   -1070 1050               u=443 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44308 40000 -10.70   -1090 1070               u=443 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44310 40000 -10.70   -1110 1090               u=443 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44312 40000 -10.70   -1130 1110               u=443 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44314 40000 -10.70   -1150 1130               u=443 imp:n=1 vol=0.267776897$
```

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     tmp=2.52607355E-08
44316 40000 -10.70   -1170 1150               u=443 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44318 40000 -10.70   -1190 1170               u=443 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44320 40000 -10.70   -1210 1190               u=443 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
44321 40000 -10.70   -1220 1210               u=443 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
44322 40000 -10.70         1220               u=443 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C -----------------------
C universe 51- F1(12)=78
C -----------------------
45190   0       -601 -405:+406:+417  fill=121 u=51 imp:n=1 $ non-fuel
45100   0            +405 -406 -417  fill=451 u=51 imp:n=1 $ fuel stack
45101 40000 -10.70   -1010                    u=451 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
45102 40000 -10.70   -1030 1010               u=451 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45104 40000 -10.70   -1050 1030               u=451 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45106 40000 -10.70   -1070 1050               u=451 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45108 40000 -10.70   -1090 1070               u=451 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45110 40000 -10.70   -1110 1090               u=451 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45112 40000 -10.70   -1130 1110               u=451 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45114 40000 -10.70   -1150 1130               u=451 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45116 40000 -10.70   -1170 1150               u=451 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45118 40000 -10.70   -1190 1170               u=451 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45120 40000 -10.70   -1210 1190               u=451 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45121 40000 -10.70   -1220 1210               u=451 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
45122 40000 -10.70         1220               u=451 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C -----------------------
C universe 52- F3(12)=90
C -----------------------
45290   0       -601 -405:+406:+417  fill=121 u=52 imp:n=1 $ non-fuel
45200   0            +405 -406 -417  fill=452 u=52 imp:n=1 $ fuel stack
45201 40000 -10.70   -1010                    u=452 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
45202 40000 -10.70   -1030 1010               u=452 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45204 40000 -10.70   -1050 1030               u=452 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45206 40000 -10.70   -1070 1050               u=452 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45208 40000 -10.70   -1090 1070               u=452 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45210 40000 -10.70   -1110 1090               u=452 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45212 40000 -10.70   -1130 1110               u=452 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45214 40000 -10.70   -1150 1130               u=452 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
```

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45216 40000 -10.70   -1170 1150               u=452 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45218 40000 -10.70   -1190 1170               u=452 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45220 40000 -10.70   -1210 1190               u=452 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
45221 40000 -10.70   -1220 1210               u=452 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
45222 40000 -10.70         1220               u=452 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C ------------------------
C universe 60- G0(6)=96
C ------------------------
46090   0       -601 -405:+406:+417  fill=121 u=60 imp:n=1 $ non-fuel
46000   0            +405 -406 -417  fill=460 u=60 imp:n=1 $ fuel stack
46001 40000 -10.70   -1010                    u=460 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
46002 40000 -10.70   -1030 1010               u=460 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46004 40000 -10.70   -1050 1030               u=460 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46006 40000 -10.70   -1070 1050               u=460 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46008 40000 -10.70   -1090 1070               u=460 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46010 40000 -10.70   -1110 1090               u=460 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46012 40000 -10.70   -1130 1110               u=460 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46014 40000 -10.70   -1150 1130               u=460 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46016 40000 -10.70   -1170 1150               u=460 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46018 40000 -10.70   -1190 1170               u=460 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46020 40000 -10.70   -1210 1190               u=460 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46021 40000 -10.70   -1220 1210               u=460 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
46022 40000 -10.70         1220               u=460 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C ------------------------
C universe 62- G2(12)=108
C ------------------------
46290   0       -601 -405:+406:+417  fill=121 u=62 imp:n=1 $ non-fuel
46200   0            +405 -406 -417  fill=462 u=62 imp:n=1 $ fuel stack
46201 40000 -10.70   -1010                    u=462 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
46202 40000 -10.70   -1030 1010               u=462 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46204 40000 -10.70   -1050 1030               u=462 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46206 40000 -10.70   -1070 1050               u=462 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46208 40000 -10.70   -1090 1070               u=462 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46210 40000 -10.70   -1110 1090               u=462 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46212 40000 -10.70   -1130 1110               u=462 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46214 40000 -10.70   -1150 1130               u=462 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46216 40000 -10.70   -1170 1150               u=462 imp:n=1 vol=0.267776897$
```

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     tmp=2.52607355E-08
46218 40000 -10.70   -1190 1170                u=462 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46220 40000 -10.70   -1210 1190                u=462 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46221 40000 -10.70   -1220 1210                u=462 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
46222 40000 -10.70         1220                u=462 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C ------------------------
C universe 64- G4(6)=114
C ------------------------
46490   0       -601 -405:+406:+417  fill=121 u=64 imp:n=1 $ non-fuel
46400   0            +405 -406 -417  fill=464 u=64 imp:n=1 $ fuel stack
46401 40000 -10.70   -1010                     u=464 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
46402 40000 -10.70   -1030 1010                u=464 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46404 40000 -10.70   -1050 1030                u=464 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46406 40000 -10.70   -1070 1050                u=464 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46408 40000 -10.70   -1090 1070                u=464 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46410 40000 -10.70   -1110 1090                u=464 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46412 40000 -10.70   -1130 1110                u=464 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46414 40000 -10.70   -1150 1130                u=464 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46416 40000 -10.70   -1170 1150                u=464 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46418 40000 -10.70   -1190 1170                u=464 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46420 40000 -10.70   -1210 1190                u=464 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
46421 40000 -10.70   -1220 1210                u=464 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
46422 40000 -10.70         1220                u=464 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C ------------------------
C universe 71- H1(9)=123
C ------------------------
47190   0       -601 -405:+406:+417  fill=121 u=71 imp:n=1 $ non-fuel
47100   0            +405 -406 -417  fill=471 u=71 imp:n=1 $ fuel stack
47101 40000 -10.70   -1010                     u=471 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
47102 40000 -10.70   -1030 1010                u=471 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47104 40000 -10.70   -1050 1030                u=471 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47106 40000 -10.70   -1070 1050                u=471 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47108 40000 -10.70   -1090 1070                u=471 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47110 40000 -10.70   -1110 1090                u=471 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47112 40000 -10.70   -1130 1110                u=471 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47114 40000 -10.70   -1150 1130                u=471 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47116 40000 -10.70   -1170 1150                u=471 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
```

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47118 40000 -10.70   -1190 1170               u=471 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47120 40000 -10.70   -1210 1190               u=471 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47121 40000 -10.70   -1220 1210               u=471 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
47122 40000 -10.70         1220               u=471 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C -------------------------
C universe 74- H4(12)=135
C -------------------------
47490   0       -601 -405:+406:+417  fill=121 u=74 imp:n=1 $ non-fuel
47400   0            +405 -406 -417  fill=474 u=74 imp:n=1 $ fuel stack
47401 40000 -10.70   -1010                    u=474 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
47402 40000 -10.70   -1030 1010               u=474 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47404 40000 -10.70   -1050 1030               u=474 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47406 40000 -10.70   -1070 1050               u=474 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47408 40000 -10.70   -1090 1070               u=474 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47410 40000 -10.70   -1110 1090               u=474 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47412 40000 -10.70   -1130 1110               u=474 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47414 40000 -10.70   -1150 1130               u=474 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47416 40000 -10.70   -1170 1150               u=474 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47418 40000 -10.70   -1190 1170               u=474 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47420 40000 -10.70   -1210 1190               u=474 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
47421 40000 -10.70   -1220 1210               u=474 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
47422 40000 -10.70         1220               u=474 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C ------------------------
C universe 81- I1(12)=147
C -------------------------
48190   0       -601 -405:+406:+417  fill=121 u=81 imp:n=1 $ non-fuel
48100   0            +405 -406 -417  fill=481 u=81 imp:n=1 $ fuel stack
48101 40000 -10.70   -1010                    u=481 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
48102 40000 -10.70   -1030 1010               u=481 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48104 40000 -10.70   -1050 1030               u=481 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48106 40000 -10.70   -1070 1050               u=481 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48108 40000 -10.70   -1090 1070               u=481 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48110 40000 -10.70   -1110 1090               u=481 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48112 40000 -10.70   -1130 1110               u=481 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48114 40000 -10.70   -1150 1130               u=481 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48116 40000 -10.70   -1170 1150               u=481 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48118 40000 -10.70   -1190 1170               u=481 imp:n=1 vol=0.267776897$
```

```
     tmp=2.52607355E-08
48120 40000 -10.70   -1210 1190               u=481 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48121 40000 -10.70   -1220 1210               u=481 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
48122 40000 -10.70         1220               u=481 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C -----------------------
C universe 82- I2(12)=159
C ------------------------
48290   0       -601 -405:+406:+417  fill=121 u=82 imp:n=1 $ non-fuel
48200   0            +405 -406 -417  fill=482 u=82 imp:n=1 $ fuel stack
48201 40000 -10.70   -1010                    u=482 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
48202 40000 -10.70   -1030 1010               u=482 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48204 40000 -10.70   -1050 1030               u=482 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48206 40000 -10.70   -1070 1050               u=482 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48208 40000 -10.70   -1090 1070               u=482 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48210 40000 -10.70   -1110 1090               u=482 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48212 40000 -10.70   -1130 1110               u=482 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48214 40000 -10.70   -1150 1130               u=482 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48216 40000 -10.70   -1170 1150               u=482 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48218 40000 -10.70   -1190 1170               u=482 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48220 40000 -10.70   -1210 1190               u=482 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48221 40000 -10.70   -1220 1210               u=482 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
48222 40000 -10.70         1220               u=482 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C ------------------------
C universe 84- I4(12)=171
C -----------------------
48490   0       -601 -405:+406:+417  fill=121 u=84 imp:n=1 $ non-fuel
48400   0            +405 -406 -417  fill=484 u=84 imp:n=1 $ fuel stack
48401 40000 -10.70   -1010                    u=484 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
48402 40000 -10.70   -1030 1010               u=484 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48404 40000 -10.70   -1050 1030               u=484 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48406 40000 -10.70   -1070 1050               u=484 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48408 40000 -10.70   -1090 1070               u=484 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48410 40000 -10.70   -1110 1090               u=484 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48412 40000 -10.70   -1130 1110               u=484 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48414 40000 -10.70   -1150 1130               u=484 imp:n=1 vol=0.267776897$
      tmp=2.52607355E-08
48416 40000 -10.70   -1170 1150               u=484 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48418 40000 -10.70   -1190 1170               u=484 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
```

```
48420 40000 -10.70   -1210 1190               u=484 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
48421 40000 -10.70   -1220 1210               u=484 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
48422 40000 -10.70         1220               u=484 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C -----------------------
C universe 94- J4(12)=183
C ------------------------
49490   0       -601 -405:+406:+417  fill=121 u=94 imp:n=1 $ non-fuel
49400   0            +405 -406 -417  fill=494 u=94 imp:n=1 $ fuel stack
49401 40000 -10.70   -1010                    u=494 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
49402 40000 -10.70   -1030 1010               u=494 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49404 40000 -10.70   -1050 1030               u=494 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49406 40000 -10.70   -1070 1050               u=494 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49408 40000 -10.70   -1090 1070               u=494 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49410 40000 -10.70   -1110 1090               u=494 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49412 40000 -10.70   -1130 1110               u=494 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49414 40000 -10.70   -1150 1130               u=494 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49416 40000 -10.70   -1170 1150               u=494 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49418 40000 -10.70   -1190 1170               u=494 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49420 40000 -10.70   -1210 1190               u=494 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49421 40000 -10.70   -1220 1210               u=494 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
49422 40000 -10.70         1220               u=494 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C -----------------------
C universe 95- J5(12)=195
C ------------------------
49590   0       -601 -405:+406:+417  fill=121 u=95 imp:n=1 $ non-fuel
49500   0            +405 -406 -417  fill=495 u=95 imp:n=1 $ fuel stack
49501 40000 -10.70   -1010                    u=495 imp:n=4 vol=0.099880782$ low
     tmp=2.52607355E-08
49502 40000 -10.70   -1030 1010               u=495 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49504 40000 -10.70   -1050 1030               u=495 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49506 40000 -10.70   -1070 1050               u=495 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49508 40000 -10.70   -1090 1070               u=495 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49510 40000 -10.70   -1110 1090               u=495 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49512 40000 -10.70   -1130 1110               u=495 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49514 40000 -10.70   -1150 1130               u=495 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49516 40000 -10.70   -1170 1150               u=495 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49518 40000 -10.70   -1190 1170               u=495 imp:n=1 vol=0.267776897$
     tmp=2.52607355E-08
49520 40000 -10.70   -1210 1190               u=495 imp:n=1 vol=0.267776897$
```

```
     tmp=2.52607355E-08
49521 40000 -10.70   -1220 1210               u=495 imp:n=2 vol=0.133888448$ nea
     tmp=2.52607355E-08
49522 40000 -10.70         1220               u=495 imp:n=4 vol=0.127461803$ upp
     tmp=2.52607355E-08
C
C ------------------------
C universe 99 - blocked site
C ------------------------
510  400 -.9966      #511 #512                  u=99 imp:n=1 $ moderator
     tmp=2.52607355E-08
511  600 -6.5 +501 -403 571 572 573 574 575 576 u=99 imp:n=1 $ lower flange
     tmp=2.52607355E-08
512  600 -6.5 +502 -503 581 582 583 584 585 586 u=99 imp:n=1 $ upper flange
     tmp=2.52607355E-08
C
C ------------------------
C Core
C ------------------------
100  0 -980 981 984 -982 985 -983  lat=2 *TRCL=(0 0 0 -10 100 90 -80
         10 90 90 90 0 1) u=150 imp:n=1 fill=-12:12 -12:12 0:0 $
C -------1---------2---------3---------4---------5---------6---------7---------8
C total 195 LEU elements
C 20 burnup (groups) universes:  U=XY
C    X=0..9 = hexagon-ring A to J
C    Y=0, 1, 2, ... = position counted from the nearest vertex (0) of the hexago
C    exceptions: U=02 instead of U=00 for an A-vertex (0 - default of void)
C                U=99 coolant site anywhere
C
C i=>  -11-10 -9 -8 -7 -6 -5 -4 -3 -2 -1  0 +1 +2 +3 +4 +5 +6 +7 +8 +9 10 11 12
C
     00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 99 99 99 99 99 00 00 00 00
     00 00 00 00 00 00 00 00 00 00 00 00 00 99 99 99 94 95 95 94 99 99 99 00 00
     00 00 00 00 00 00 00 00 00 00 00 99 99 81 82 99 84 99 84 99 82 81 99 99 00
     00 00 00 00 00 00 00 00 00 99 99 81 99 71 99 99 74 74 99 99 71 99 81 99 00
     00 00 00 00 00 00 00 00 99 99 82 71 60 99 62 99 64 99 62 99 60 71 82 99 99
     00 00 00 00 00 00 00 99 94 99 99 99 99 51 52 99 99 52 51 99 99 99 99 94 99
     00 00 00 00 00 99 99 95 84 99 62 51 99 41 99 43 99 41 99 51 62 99 84 95 99
     00 00 00 00 00 99 95 99 74 99 52 41 30 99 32 32 99 30 41 52 99 74 99 95 99
     00 00 00 00 99 94 84 74 64 99 99 99 99 21 99 21 99 99 99 99 64 74 84 94 99
     00 00 00 00 99 99 99 99 99 43 32 21 10 99 99 10 21 32 43 99 99 99 99 99 00
     00 00 00 99 82 99 62 52 99 32 99 99 99 01 99 99 99 32 99 52 62 99 82 99 00
     00 00 99 81 71 99 51 41 99 21 99 01 99 99 01 99 21 99 41 51 99 71 81 99 00
     00 00 99 99 60 99 99 30 99 10 02 99 00 99 02 10 99 30 99 99 60 71 99 00 00
     00 99 81 71 99 51 41 99 21 99 01 99 99 01 99 21 99 41 51 99 71 81 99 00 00
     00 99 82 99 62 52 99 32 99 99 99 01 99 99 99 32 99 52 62 99 82 99 00 00 00
     00 99 99 99 99 99 43 32 21 10 99 99 10 21 32 43 99 99 99 99 99 00 00 00 00
     99 94 84 74 64 99 99 99 99 21 99 21 99 99 99 99 64 74 84 94 99 00 00 00 00
     99 95 99 74 99 52 41 30 99 32 32 99 30 41 52 99 74 99 95 99 00 00 00 00 00
     99 95 84 99 62 51 99 41 99 43 99 41 99 51 62 99 84 95 99 99 00 00 00 00 00
     99 94 99 99 99 99 51 52 99 99 52 51 99 99 99 99 94 99 00 00 00 00 00 00 00
     99 99 82 71 60 99 62 99 64 99 62 99 60 71 82 99 99 00 00 00 00 00 00 00 00
     00 99 81 99 71 99 99 74 74 99 99 71 99 81 99 00 00 00 00 00 00 00 00 00 00
     00 99 99 81 82 99 84 99 84 99 82 81 99 99 00 00 00 00 00 00 00 00 00 00 00
     00 00 99 99 99 94 95 95 94 99 99 99 00 00 00 00 00 00 00 00 00 00 00 00 00
     00 00 00 00 99 99 99 99 99 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
C
C i=>  -11-10 -9 -8 -7 -6 -5 -4 -3 -2 -1  0 +1 +2 +3 +4 +5 +6 +7 +8 +9 10 11 12
C -------1---------2---------3---------4---------5---------6---------7---------8
C
C ------------------------
C Core Cage
C ------------------------
```

```
C
110  0  +401 -409 -510 +512 #112 #113 #114 fill=150 u=151 imp:n=1 $ core
C
111  600 -6.5 +501 -503 -512 +514
              520 521 522 523 524 525 526 527 528
              529 530 531 532 533 534 535 536 537
              538 539 540 541                      u=151 imp:n=1 $ Cage Spindle
        tmp=2.52607355E-08
C
112  600 -6.5 +403 -502 (-504:-505:-506) *TRCL=(0 0 0 -10 100 90 -80
         10 90 90 90 0 1)                        u=151 imp:n=1 $ Cage Posts
     tmp=2.52607355E-08
113  600 -6.5 ((501 -403):(502 -503)) -590 +512    u=151 imp:n=1 $ fill central
     tmp=2.52607355E-08
114  600 -6.5 ((501 -403):(502 -503)) (-591:-592:-593) -510 u=151 imp:n=1 $ Fill
     tmp=2.52607355E-08
115  500 -.9966 +401 -409 -512 #111 #350           u=151 imp:n=1  $ coolant in s
     tmp=2.52607355E-08
116  500 -.9966 +409 -331 -510 #350                u=151 imp:n=1  $ coolant abov
     tmp=2.52607355E-08
C
121  400 -.9966 (-401:+331:+510) -320
               #300                     $ Be lower refflector
               #310                     $ Be annular reflector
               #325 #321 #322 #323 #324 $ irradiation tubes above annular refle
               #328 #326 #327           $ small & detector holes in annular ref
               #330 #340                $ stray with shim
               #3300                    $ shim tray spacer
               #350                     $ control rod above core
               #380                     $ coolant reflector
               u=151 imp:n=1
               tmp=2.52607355E-08
122  400 -.9966 +320
               #720 #726 #729 #728      $ outer irradiation tubes
               #3100                    $ D2O tank
               #731 #732 #733 #734 $ return-tubes
                                                 u=151 imp:n=1  $ coolant refl
     tmp=2.52607355E-08
C
C ------------------------
C Beryllium Reflectors
C ------------------------
300  700 -1.854 -401 +300 -310 u=151 imp:n=1 $ Lower Beryllium Reflector
     tmp=2.52607355E-08
C
310  700 -1.854 -320 +321 +319 -329
             #325 #321 #322 #323 #324 #328 #326 #327 u=151 imp:n=1 $ Be Annular
     tmp=2.52607355E-08
C
C
C ------------------------
C D2O Tank
C ------------------------
3100 0   -3204 -3203 +3205 -3208 +3209 -3211 u=151 imp:n=1 $D2O tank added by Dr
     fill=3100
3101 401 -1.107 -3201 -3202 +3206 -3207 +3210 -3212 u=3100 imp:n=1 $D2O added by
      tmp=2.52607355E-08
3102 800 -2.7 #3101 u=3100 imp:n=1 $D2O tank added by Dr. C. Jewett on 06 Januar
      tmp=2.52607355E-08
C
C ------------------------
C In-core Neutron Detector
C ------------------------
```

```
C Altered by LCdr Simon P.J. Parent, October 2022
C
328  400 -.9966 -324 +325 -329      u=151 imp:n=1 trcl=(0 19.8425 0) $ Small&Sho
     tmp=2.52607355E-08
326  400 -.9966 -324 -326 +319      u=151 imp:n=1 trcl=(0 19.8425 0) $ Small&Sho
     tmp=2.52607355E-08
C
327  400 -.9966 -327 +328 -331      u=151 imp:n=1 trcl=(4.9841 -15.3396 0) $ Flu
     tmp=2.52607355E-08 fill=327
C
3270 900 -8.65 -3270                u=327 imp:n=1 $Cd flux detector emitter
3271 3271 -3.95 3270 -3271 #(32711 -3273)
                                    u=327 imp:n=1  $Al2O3 flux detector in
3272 3272 -8.47 (-32721 32711 -3273):(3271 -3272 3273)
                                     u=327 imp:n=1  $Inconel 600 flux detec
3273 400 -.9966 #3272 #3271 3270     u=327 imp:n=1  $Light water outside of the
C
C
C ------------------------
C Shims and Shim Tray
C ------------------------
330  800 -2.70  (-330 +336 +331 -332)            $ base
               :(((-330 +333)                    $ outer wall
                 :(-335 +336)) +332 -334)        $ inner wall
                                    u=151 imp:n=1 $ shim stray
     tmp=2.52607355E-08
C
3300 800 -2.70 -3300 +3310 -3320 +3330
               #325 #321 #322 #323 #324 $ irradiation tubes above annular refle
               u=151 imp:n=1 $ shim tray spacer
C
C Shim height controlled by changing third (Z) into fill=340(0 0 0)
C Model Shim height= No shim
340  0  -333 +335 +332 -334 fill=340(0 0 0) u=151 imp:n=1  $ shims
C
C -------1---------2---------3---------4---------5---------6---------7---------8
C
C ****************************** CONTROL ROD **********************************
C _____________________________________________________________________________
C NB: The control rod is fully inserted if z = -0.750158865031 cm
C Rod height controlled by changing third term (Z) into trcl=(X Y Z) of cell 350
C Model Rod height= 14.24 cm
350  0             -350 trcl=(0 0 14.24) fill=350  u=151 imp:n=1 $ control rod
c
3410 700 -1.854  -340 +341 -342 (-343:+344)  u=340 imp:n=1 $ be
     tmp=2.52607355E-08
3420 400 -.9966  #3410                       u=340 imp:n=1 $ h2o
     tmp=2.52607355E-08
C
3510 800 -2.7    +3501 +3503 +3507             u=350 imp:n=1 $ outer Al-tube (Co
3511 800 -2.7    -3502 -3503 3504 :(-3502 -3505 -3504 ):-3506 u=350 imp:n=1 $ ou
3520 800 -2.7    -351 +3511 #3531 #3532        u=350 imp:n=1 $ Al-enclosure and
3525 800 -2.7    -3512 +352 u=350 imp:n=1 $ Inner Al-enclosere (Control Rod Inse
3530 900 -8.65   110 -111          u=350 imp:n=1 $ cd-tube
3531 800 -2.7    +1101 -35111 u=350 imp:n=1 $ lower weld
3532 800 -2.7    +1102 -35112 u=350 imp:n=1 $ uppwer weld
3540 330 -0.0014 +3503 #3510 #3511 #3530 #3531 #3532 #3525 #3520 u=350 imp:n=1 $
3545 400 -0.9966 -3503 #3511  u=350 imp:n=1 $ water below the control rod sheath
C
380  800 -2.70  -380 +381 +382 -300 u=151 imp:n=1 $ Thrust Ring
C
C
C -------1---------2---------3---------4---------5---------6---------7---------8
```

```
C
C ****************************** INNER SITES ***********************************
C _____________________________________________________________________________
C Altered by LCdr Simon P.J. Parent, September 2022
C
C ------------------------
C IRRADIATION TUBE NO 1
C ------------------------
321  0 -322 trcl=(14.4941   4.7094 0)  fill=321   u=151 imp:n=1
         tmp=2.52607355E-08
3210 800 -2.7          3220         u=321 imp:n=1 $ wall
3211 800 -2.70   -3221 3222         u=321 imp:n=1 $ sample tube
3212 330 -0.0014 -3220 #3211        u=321 imp:n=1 $ air
C
C
C ------------------------
C IRRADIATION TUBE NO 2
C ------------------------
322  0 -322 trcl=(8.9578 -12.3294 0)  fill=322   u=151 imp:n=1
              tmp=2.52607355E-08
3220 800 -2.7          3220         u=322 imp:n=1 $ wall
3221 800 -2.70   -3221 3222         u=322 imp:n=1 $ sample tube
3222 330 -0.0014 -3220 #3221 #702 #703
                  #704 #705 #706 #707    u=322 imp:n=1 $ air
702  813 -0.92   -900 901           u=322 imp:n=1 $ 7cc vial
703  812 -0.905  -902 903 904       u=322 imp:n=1 $ 2cc vial
704  815 -0.92   -905 906           u=322 imp:n=1 $ Inner tube
705  811 -2.719  -907               u=322 imp:n=1 $ Sample wire
706  900 -8.65   -909 908           u=322 imp:n=1 $ Cadmium Shielding (0.5mm)
707  814 -0.69   -904 910           u=322 imp:n=1 $ Filter paper holder
C
C
C ------------------------
C IRRADIATION TUBE NO 3
C ------------------------
323  0 -322 trcl=(-8.9578 -12.3294 0)  fill=323   u=151 imp:n=1
            tmp=2.52607355E-08
3230 800 -2.7          3220         u=323 imp:n=1 $ wall
3231 800 -2.70   -3221 3222         u=323 imp:n=1 $ sample tube
3232 330 -0.0014 -3220 #3231        u=323 imp:n=1 $ air
C
C
C ------------------------
C IRRADIATION TUBE NO 4
C ------------------------
324  0 -322 trcl=(-14.4941   4.7094 0)  fill=324   u=151 imp:n=1
            tmp=2.52607355E-08
3240 800 -2.7          3220         u=324 imp:n=1 $ wall
3241 800 -2.70   -3221 3222         u=324 imp:n=1 $ sample tube
3242 330 -0.0014 -3220 #3241        u=324 imp:n=1 $ air
C
C
C ------------------------
C IRRADIATION TUBE NO 5
C ------------------------
325  0 -322 trcl=(0 15.24 0)  fill=325   u=151 imp:n=1
        tmp=2.52607355E-08
3250 800 -2.7          3220         u=325 imp:n=1 $ wall
3251 800 -2.70   -3221 3222         u=325 imp:n=1 $ sample tube
3252 330 -0.0014 -3220 #3251        u=325 imp:n=1 $ air
C
C
C -------1---------2---------3---------4---------5---------6---------7---------8
```

```
C
C ***************************** OUTER SITES *********************************
C ___________________________________________________________________________
C Altered by LCdr Simon P.J. Parent, September 2022
C
C -----------------------
C IRRADIATION TUBE NO 6
C -----------------------
726  0 -722 trcl=(22.82536 -7.41641 0) fill=726 u=151 imp:n=1 tmp=2.52607355E-08
7261 800 -2.7 723                      u=726 imp:n=1 $ wall
7262 330 -0.0014 -723                  u=726 imp:n=1 $ air
C
C
C -----------------------
C IRRADIATION TUBE NO 8 Flooded Site
C -----------------------
728 0 -722 trcl=(-22.82536 -7.41641 0) fill=728 u=151 imp:n=1 tmp=2.52607355E-08
7281 800 -2.7          723             u=728 imp:n=1 $ wall
7282 400 -0.0014 -723                  u=728 imp:n=1 $ Container light water
C
C
C -----------------------
C IRRADIATION TUBE NO 9 Cadmium lined
C -----------------------
729 0 -724 trcl=(-14.10685 19.41641 0) fill=729 u=151 imp:n=1 tmp=2.52607355E-08
7291 800 -2.7     723 -722              u=729 imp:n=1 $wall
7292 330 -0.0014 -723                   u=729 imp:n=1 $air
7293 900 -8.65    722                   u=729 imp:n=1 $cadmium lining
C
C
C -----------------------
C IRRADIATION TUBE NO 10
C -----------------------
720  0 -722 trcl=(14.10685 19.41641 0) fill=720 u=151 imp:n=1 tmp=2.52607355E-08
7201 800 -2.7          723             u=720 imp:n=1 $ wall
7202 330 -0.0014 -723                  u=720 imp:n=1 $ air
C
C
C -----------------------
C Return Tubes
C -----------------------
731 0 -732 but trcl=(20.34031802 -12.73858167 0) fill=730 u=151 imp:n=1 $ Irradi
      tmp=2.52607355E-08
7301 800 -2.7          733          u=730 imp:n=1 $ wall
7302 330 -0.0014 -733               u=730 imp:n=1 $ air
C
732  like 731 but trcl=(18.4006157    15.40835299 0) $ Irradiation tube 3
733  like 731 but trcl=(-8.968115151  22.26146695 0) $ Irradiation tube 4
734  like 731 but trcl=(-23.94321326 -1.650011728 0) $ Irradiation tube 5
C
C
C
C
C -------1---------2---------3---------4---------5---------6---------7---------8
C ____________________________________________________________________________
C ****************************** SURFACE CARDS*****************************
C ___________________________________________________________________________
C
C -----------------------
C LEU Fuel Element Assembly as per Drawing A17997
C -----------------------
401  pz -0.279    $ Bottom surface of reduced tip on lower stud.
```

```
402  pz -0.152    $ -0.279 + 0.127 , hole in reduced tip on lower stud.
403  pz  0.000    $ Bottom surface of lower stud and top surface of lower cage p
404  pz  0.135    $ 0.216 - 0.081 , lower stud top surface (without standoff).
405  pz  0.254    $ Top of bottom stud fuel standoff.
406  pz 22.952    $ Top of fuel, mm measurement.  Changed by Dr. C. Jewett on 10
407  pz 23.114    $ 23.368 - 0.254 , bottom of top stud fuel standoff.
408  pz 23.233    $ 23.368 - 0.216 + 0.081 , upper stud bottom surface (without
409  pz 23.368    $ Top of upper stud.
C
410  cz  0.1395   $ 0.279/2 , radius  of reduced tip on lower stud.
411  cz  0.10287  $ Radius of hole in reduced tip on lower stud.
412  cz  0.273    $ Radius of studs.  Changed by Dr. C. Jewett on 12 November 20
413  cz  0.197    $ Inner radius of indents on studs.
414  cz  0.0635   $ Radius of standoff on studs.
415  cz  0.2625    $ Outer radius of fuel sheath (SLWPK-A-17997).  Changed by Dr
416  cz  0.212    $ Inner radius of fuel sheath (Reference).
417  cz  0.2064481371902070 $ Radius of fuel stack.  Changed by Dr. C. Jewett on
C
420  cz  0.1985   $ centre hole in lower flange (0.397 OD)
425  cz  0.3175   $ centre hole in upper flange (0.635 OD)
C
441  pz  7.8195   $ top of lower section (0.254 + 22.6965/3)
442  pz 15.3850   $ top of mid section (22.9505 - 22.6965/3)
C
C -----------------------
C LEU Fuel Cage Assembly as per Drawing A18245
C -----------------------
C
501  pz -0.25908  $ Bottom surface of lower cage plate (SLWPK3-96000-FSAR-001 sa
502  pz 22.1234   $ Bottom surface of upper cage plate.
503  pz 22.38248  $ Top surface of upper cage plate.
504  c/z    10.16584     -2.68326    0.39688 $ Cage Post
505  c/z    -7.40664     -7.46227    0.39688 $ Cage Post
506  c/z    -2.75920     10.14552    0.39688 $ Cage Post
C
571  1 cz 0.2778125 $ coolant holes in lower flange
572  2 cz 0.2778125 $
573  3 cz 0.2778125 $
574  4 cz 0.2778125 $
575  5 cz 0.2778125 $
576  6 cz 0.2778125 $
581  1 cz 0.189865  $ coolant holes in upper flange
582  2 cz 0.189865  $
583  3 cz 0.189865  $
584  4 cz 0.189865  $
585  5 cz 0.189865  $
586  6 cz 0.189865  $
C
590  hex  0          0           -1 0 0 25  1.38 0 0
591  hex 10.484485  -2.867314849 -1 0 0 25  0.83 0 0
592  hex -7.72541   -7.646172931 -1 0 0 25  0.83 0 0
593  hex -2.759075  10.51348778  -1 0 0 25  0.83 0 0
C
510  cz 10.9982   $ Radius of cage flages (SLWPK3-96000-FSAR-001 says this shoul
512  cz  1.33069  $ Outer radius of cage spindle.
514  cz  1.22936  $ Inner radius of cage spindle.
520     c/x     0.0         0.9525                     0.3175 $ spindle holes' r
521     RCC -2 -3.464101615 2.619375   4 6.92820323 0  0.3175 $ spindle holes' r
522     RCC  2 -3.464101615 1.7859375 -4 6.92820323 0  0.3175 $ spindle holes' r
523  10 c/x     0.0         0.9525                     0.3175 $ spindle holes' r
524  10 RCC -2 -3.464101615 2.619375   4 6.92820323 0  0.3175 $ spindle holes' r
525  10 RCC  2 -3.464101615 1.7859375 -4 6.92820323 0  0.3175 $ spindle holes' r
526  20 c/x     0.0         0.9525                     0.3175 $ spindle holes' r
```

```
527  20 RCC -2 -3.464101615 2.619375   4 6.92820323 0  0.3175 $ spindle holes' r
528  20 RCC  2 -3.464101615 1.7859375 -4 6.92820323 0  0.3175 $ spindle holes' r
529  30 c/x     0.0         0.9525                     0.3175 $ spindle holes' r
530  30 RCC -2 -3.464101615 2.619375   4 6.92820323 0  0.3175 $ spindle holes' r
531  30 RCC  2 -3.464101615 1.7859375 -4 6.92820323 0  0.3175 $ spindle holes' r
532  40 c/x     0.0         0.9525                     0.3175 $ spindle holes' r
533  40 RCC -2 -3.464101615 2.619375   4 6.92820323 0  0.3175 $ spindle holes' r
534  40 RCC  2 -3.464101615 1.7859375 -4 6.92820323 0  0.3175 $ spindle holes' r
535  50 c/x     0.0         0.9525                     0.3175 $ spindle holes' r
536  50 RCC -2 -3.464101615 2.619375   4 6.92820323 0  0.3175 $ spindle holes' r
537  50 RCC  2 -3.464101615 1.7859375 -4 6.92820323 0  0.3175 $ spindle holes' r
538  60 c/x     0.0         0.9525                     0.3175 $ spindle holes' r
539  60 RCC -2 -3.464101615 2.619375   4 6.92820323 0  0.3175 $ spindle holes' r
540  60 RCC  2 -3.464101615 1.7859375 -4 6.92820323 0  0.3175 $ spindle holes' r
541  70 c/x     0.0         0.9525                     0.3175 $ spindle holes' r
C
980  px   0.551815                     $
981  px  -0.551815                     $
982  p   -1  1.7320508076 0  1.10363    $    LATTICE SURFACES
983  p    1  1.7320508076 0  1.10363    $
984  p   -1  1.7320508076 0 -1.10363    $
985  p    1  1.7320508076 0 -1.10363    $
C
C ------------------------
C Outside Pool
C ------------------------
600  RCC 0 0 -123 0 0 223 123 $ Outside Pool
601  cz   1
C
C ------------------------
C Reactor Container
C ------------------------
700  rcc  0 0 -23 0 0 123 30.5   $ container OR (61 OD, 83 depth)
701  rcc  0 0 -23 0 0 123 29.55  $ container IR (0.95 wall)
702  sz   21.76 44.76  $ tori-spherical end OR (calculated)
703  sz   21.76 43.81  $ tori-spherical end IR (0.95 wall)
C
710  pz    20 $ for excluding upper part of shpere
711  pz   -11 $ cylinder-sphere separation (?)
C
722  rcc   0 0 7.2775 0 0 107  1.905     $ outer irradiation hole (3.81 OD)
723  rcc   0 0 7.5823 0 0 107  1.6002    $ wall (0.3048)
724  rcc   0 0 7.5823 0 0 107  1.9558    $ Cadmium Lining
732  rcc   0 0 7.2775 0 0 107  0.79375   $ return tube OR (1.59 OD)
733  rcc   0 0 7.5823 0 0 107  0.62865   $ return tube IR (0.089 wall)
C
C ------------------------
C Be Lower Reflector, as described in FSAR
C ------------------------
300  pz -10.479 $ Be Lower Reflector Bottom Surface - Surface 401 minus 10.2 cm
310  cz  16.1   $ Be Lower Reflector Radius.
C
C ------------------------
C Inner Irradiation Hole
C ------------------------
320  cz   21.2344      $ OR
321  cz   11.049       $ IR
322  rcc   0 0 7.22924 0 0 107  1.50749     $ inner irradiation hole
3220 rcc   0 0 7.39434 0 0 107  1.42494     $ wall (0.08255)
3221 rcc   0 0 7.39434 0 0 107  1.11125     $ sample tube OR (2.2225 OD)
3222 rcc   0 0 7.55944 0 0 107  0.94615     $ sample tube IR (0.1651 wall)
C
C ------------------------
```

```
C D2O Tank
C ------------------------
C Added by Dr. C. Jewett on 05 January 2016
C
3201 p  9.184402377 -22.17310878 0  9.184402377 -22.17310878 10 0 0 0 $D2O tank
3202 p -9.184402377 -22.17310878 0 -9.184402377 -22.17310878 10 0 0 0 $D2O tank
3203 p 9.477734128 -22.05160679 0 9.477734128 -22.05160679 10
       0.293331752 0.12150199 0 $D2O tank wall3
3204 p -9.477734128 -22.05160679 0 -9.477734128 -22.05160679 10
      -0.293331752 0.12150199 0 $D2O tank wall4
3205 cz 21.2344 $D2O tank IR 1
3206 cz 21.5519 $D2O tank IR 2
3207 cz 29.0195 $D2O tank OR 1
3208 cz 29.337  $D2O tank OR 2
3209 pz 2.12765 $D2O tank bottom 1
3210 pz 2.76265 $D2O tank bottom 2
3211 pz 21.17765 $D2O tank top 1
3212 pz 20.54265 $D2O tank top 2
C
C ------------------------
C Irradiation Sites holes and SPND hole
C ------------------------
323  pz    7.2292      $ Irradiation holes Depth (Bottom Surface)
324  cz    0.33734375  $ small and short holes or.
325  pz    22.0247     $ small and short holes Depth (Bottom Surface)
326  pz    1.1815      $ small and short holes Depth (Bottom Surface)
327  cz    0.15875     $ Flux detector hole OR
328  pz    2.6572      $ Flux detector hole Depth (Bottom Surface)
329  pz   22.97724     $ Height (Top Surface)
319  pz    0.229       $ Bottom Surface
C ------------------------
C Self-Powered Neutron Detector
C ------------------------
3270 rcc 0 0 3.2272 0 0 20.32 0.04572       $Cd emitter radius
3271 cz 0.08001                             $Inconel 600 collector inner radius
32711 sph 0 0 2.76261 0.08001               $Inner Radius lower cap
3272 cz 0.10541                             $Inconel 600 collector outer radius
32721 sph 0 0 2.76261 0.10541               $Outer radius lower cap
3273 pz 2.76261                             $Cap cut for juction with side
C
C ------------------------
C Shim Tray
C ------------------------
330  cz   12.461875    $ Shim Tray OR
331  pz     23.61224   $ Base Bottom Surface
332  pz     23.850365  $ Base Top Surface
333  cz   12.22375     $ Wall IR
334  pz     36.550365  $ Wall&Inner Tube Height
335  cz   1.0668       $ Inner Tube OR
336  cz   0.710565     $ Inner Tube IR
C
C ------------------------
C Shim Tray Spacer
C ------------------------
3300 cz  16.986        $ Shim Tray Spacer OR
3310 pz  23.61224      $ Shim Tray Spacer Bottom Surface
3320 pz  23.94824      $ Shim Tray Spacer Top Surface
3330 cz  12.54125      $ Shim Tray Spacer IR
C
C ------------------------
C Shims
C ------------------------
340  cz   12.065       $ Shim OR
```

```
341  cz    1.3890625   $ Shim IR
342  pz   23.850       $ no shim (shim height to be added by TRCL above this in
343  py     -0.1190625 $ Shim Saw Cut -x
344  py      0.1190625 $ Shim Saw Cut +x
C
C ------------------------
C Thrust Ring
C ------------------------
C Ring used to elevate core/lower beryllium reflector
380  cz   16.113125   $ Shim OR
381  cz   14.843125   $ Shim IR
382  pz    -10.7965   $ Ring Lower Surface
C
C ------------------------
C  Control Rod
C ------------------------
C From FSAR, page 5.11 section 5.8 and Drawings A15292 and A10759
C
110  rcc  0 0 2.693658865031 0 0 25.320625 0.09652 $ Cd tube inner radius (0.193
1101 rcc  0 0 2.376158865031 0 0 0.15875 0.23749 $ Lower Control Rod Insert Weld
1102 rcc  0 0 28.252408865031 0 0 0.15875 0.23749 $ Upper Control Rod Insert Wel
111  rcc  0 0 2.693658865031 0 0 25.320625 0.1475 $ Cd tube outer radius (0.295
C
C
350  rcc  0 0 0.471158865031  0 0 36.83  0.63373 $ outer Al-tube OR (1.27 OD [SL
3501 rcc  0 0 1.741158865031  0 0 36.83 0.46863 $ outer Al-tube ID (Drawing A107
3502 kz 0 0.13247433143179 1 $ outer Al-tube ID (Drawing A10759) (Control Rod Sh
3503 pz 1.741158865031 $ outer Al-tube ID (Drawing A10759) (Control Rod Sheath b
3504 pz 0.788658865031 $ outer Al-tube ID (Drawing A10759) (Control Rod Sheath b
3505 sz 0.788658865031 0.3175 $ outer Al-tube ID (Drawing A10759) (Control Rod S
3506 rcc 0 0 1.741158865031 0 0 0.635 0.46863 $ outer Al-tube ID (Drawing A10759
3507 c/x 0 3.011158865031 0.3175 $ Hole in Control Rod Sheath (Drawing A10759)
351  rcc  0 0 2.376158865031 0 0 26.035 0.396875 $ outer Al-tube OR (Control Rod
35111 rcc 0 0 2.376158865031 0 0 0.3175 0.316865 $ Lower Control Rod Insert Weld
35112 rcc 0 0 28.093658865031 0 0 0.3175 0.316865 $ Upper Control Rod Insert Wel
3511 rcc  0 0 2.376158865031 0 0 26.035  0.249555 $ outer Al-tube IR (Control Ro
3512 rcc  0 0 2.693658865031 0 0 25.320625 0.238125 $ inner Al-tube OR (Drawing
352  cz   0.149225                $ inner Al-tube IR (Drawing A15292)
C
C ------------------------
C Dividing planes and surfaces
C ------------------------
1000  pz  0
1005  pz  0.5
1010  pz  1
1015  pz  1.5
1020  pz  2
1025  pz  2.5
1030  pz  3
1035  pz  3.5
1040  pz  4
1045  pz  4.5
1050  pz  5
1055  pz  5.5
1060  pz  6
1065  pz  6.5
1070  pz  7
1075  pz  7.5
1080  pz  8
1085  pz  8.5
1090  pz  9
1095  pz  9.5
1100  pz  10
```

```
1105  pz  10.5
1110  pz  11
1115  pz  11.5
1120  pz  12
1125  pz  12.5
1130  pz  13
1135  pz  13.5
1140  pz  14
1145  pz  14.5
1150  pz  15
1155  pz  15.5
1160  pz  16
1165  pz  16.5
1170  pz  17
1175  pz  17.5
1180  pz  18
1185  pz  18.5
1190  pz  19
1195  pz  19.5
1200  pz  20
1205  pz  20.5
1210  pz  21
1215  pz  21.5
1220  pz  22
1225  pz  22.5
1230  pz  23
1235  pz  23.5
1240  pz  24
C
3000  c/x 0 9 2.5
C
2001  cz  0.1
2002  cz  0.2
2003  cz  0.3
2004  cz  0.4
2005  cz  0.5
2006  cz  0.6
2007  cz  0.7
2008  cz  0.8
2009  cz  0.9
2010  cz  1.0
2011  cz  1.1
2012  cz  1.2
2013  cz  1.3
2014  cz  1.4
 2015  cz  1.5
C
2110  px  11
2112  px  11.2
2114  px  11.4
2116  px  11.6
2118  px  11.8
2120  px  12
2125  px  12.5
2130  px  13
2135  px  13.5
2140  px  14
2145  px  14.5
2150  px  15
2155  px  15.5
2160  px  16
c
2170  px  17
```

```
2180  px  18
2190  px  19
2200  px  20
2210  px  21
2220  px  22
2230  px  23
2240  px  24
2250  px  25
2260  px  26
2270  px  27
2280  px  28
2290  px  29
2300  px  30
C
C -------1---------2---------3---------4---------5---------6---------7---------8
C
C *************************** SAMPLES SURFACES *******************************
C ____________________________________________________________________________
C - Modified by LCdr Simon P.J. Parent, Sept 2022
C
C ------------------------
C Gold-Aluminium Samples
C ------------------------
C Set for Outer Sites(Outer site modelled 0.02286 cm higher than the inner site)
C
C ------------------------
C Filter Paper
C ------------------------
C Fisherbrand P4 Cat no. 09-803-6G, Porosity Medium-Fine, Flow rate:Slow
910 rcc 0 0 8.52281 0 0 3.815 0.15875 $ Inner surface of the filter paper
C
C ------------------------
C 7cc Vial
C ------------------------
C Polyvial EP-290 NAA neutron activation analysis Lab Vial, LDPE
900       rcc 0 0 7.58231 0 0 5.6896 0.8636  $ 7cc Outer surface
901       rcc 0 0 7.77281 0 0 5.3086 0.7239  $ 7cc Inner Surface
C
C ------------------------
C 2cc Vial
C ------------------------
C Perfector Scientific Cryo-Stor 2.0 mL vial, Polypropelene Copolymer
C Catalog 2190
902       rcc 0 0 7.82281 0 0 4.65 0.62      $ 2cc Outer surface
903       rcc 0 0 7.82281 0 0 0.565 0.485    $ 2cc Bottom for removal
904       rcc 0 0 8.52281 0 0 3.815 0.485    $ 2cc Inner Surface
C
C
C ------------------------
C Inner Tube
C ------------------------
C  Cole-Parmer Instrument Company, Polyethylene Tubing, ID 5/64"
C OD 1/8", Wall Diameter 1/32", Lot 06100-13
905       rcc 0 0 8.68031 0 0 3.5 0.15875     $ Inner Tube Outer surface
906       rcc 0 0 8.68031 0 0 3.5 0.0992185   $ Inner tube Inner Surface
C
C
C ------------------------
C WIRES Samples
C ------------------------
C  Shieldwerx Gold-Aluminium Wire, 0.020" diameter lot:ALAU49019111
C Gold 0.12%, Aluminium 99.88%, Assuming no impurities
907       rcc 0 0 9.38031 0 0 2.1 0.0254     $ Sample Wire
```

```
C
C
C -----------------------
C Cadmium Shield
C -----------------------
908       rcc 0 0 7.82281 0 0 4.7 0.62     $ Cadmium shield Inner surface
909       rcc 0 0 7.77281 0 0 4.8 0.67     $ Cadmium shield outer surface
C
C
C
C -------1---------2---------3---------4---------5---------6---------7---------8
C ____________________________________________________________________________
C ******************************** DATA CARDS******************************
C ____________________________________________________________________________
TR1  0.551815  0.318590539 0.0
TR2  0.551815 -0.318590539 0.0
TR3 -0.551815  0.318590539 0.0
TR4 -0.551815 -0.318590539 0.0
TR5  0.0       0.637181078 0.0
TR6  0.0      -0.637181078 0.0
C
TR10 0.0  0.0  2.54
TR20 0.0  0.0  5.08
TR30 0.0  0.0  7.62
TR40 0.0  0.0 10.16
TR50 0.0  0.0 12.70
TR60 0.0  0.0 15.24
TR70 0.0  0.0 17.78
C ____________________________________________________________________________
C
C ******************************** MATERIAL CARDS*****************************
C      ____________________________________________________________________________
C
C -----------------------
C fuel sheath
C -----------------------
m100  5010.00c   -0.00005962
      24050.00c  -0.0041737
      24052.00c  -0.0837008
      24053.00c  -0.0096726
      24054.00c  -0.0024534
      26054.00c  -0.0119675
      26056.00c  -0.1929267
      26057.00c  -0.0044963
      26058.00c  -0.0006100
      28058.00c  -0.0047175
      28060.00c  -0.0018657
      28061.00c  -0.0000821
      28062.00c  -0.0002651
      28064.00c  -0.0000693
      40090.00c  -49.784792
      40091.00c  -10.977651
      40092.00c  -16.963765
      40094.00c  -17.565616
      40096.00c  -2.890163
C
C -----------------------
C Helium Gas
C -----------------------
m300   2004.00c 1.0000
C
C -----------------------
```

```
C Fuel Surroundings
C ------------------------
m301  1001.00c  6.66906E-01
      8016.00c  3.33319E-01
      8017.00c  1.33381E-05
mt301  h-h2o.40t
C
C ------------------------
C Light water 25.80C (density 0.988 g/cm3)
C ------------------------
m400  1001.00c  6.66906E-01
      8016.00c  3.33319E-01
      8017.00c  1.33381E-05
mt400  h-h2o.40t
C
C ------------------------
C Heavy water (density 1.107 g/cm3)
C ------------------------
m401  1001.00c  6.66906E-01
      8016.00c  3.33319E-01
      8017.00c  1.33381E-05
mt401 d-d2o.40t o-d2o.40t
C
C ------------------------
C Empty Fuel Site
C ------------------------
m500  1001.00c  6.66906E-01
      8016.00c  3.33319E-01
      8017.00c  1.33381E-05
mt500  h-h2o.40t
C
C ------------------------
C Fuel Cage Material
C ------------------------
m600  5010.00c   -0.00005962
      24050.00c  -0.0041737
      24052.00c  -0.0837008
      24053.00c  -0.0096726
      24054.00c  -0.0024534
      26054.00c  -0.0119675
      26056.00c  -0.1929267
      26057.00c  -0.0044963
      26058.00c  -0.0006100
      28058.00c  -0.0047175
      28060.00c  -0.0018657
      28061.00c  -0.0000821
      28062.00c  -0.0002651
      28064.00c  -0.0000693
      40090.00c  -49.784792
      40091.00c  -10.977651
      40092.00c  -16.963765
      40094.00c  -17.565616
      40096.00c  -2.890163
C
C ------------------------
C Beryllium Reflectors as per Pierre, 1996
C ------------------------
m700 4009.00c   -0.9860
     6012.00c   -0.0011
     8016.00c   -0.01024
     12024.00c  -0.0003
     13027.00c  -0.0003
     14028.00c  -0.0003
```

```
     26056.00c  -0.0007
     5010.00c   -0.00000017910
     5011.00c   -0.00000072909
     25055.00c  -0.00005
     3006.00c   -0.000000050094
     3007.00c   -0.00000060991
     62149.00c  -0.00000033
     64155.00c  -0.000000019536
     64157.00c  -0.00000002702
     63151.00c  -0.0000001577
     63153.00c  -0.00000017223
     49115.00c  -0.00000066
     77191.00c  -0.00000024618
     77193.00c  -0.00000041382
mt700 be-met.40t
C
C ------------------------
C Aluminum 6061
C ------------------------
m800  12024.00c  8.82365E-03
      12025.00c  1.11706E-03
      12026.00c  1.22988E-03
      13027.00c  9.76531E-01
      14028.00c  5.34950E-03
      14029.00c  2.70868E-04
      14030.00c  1.79805E-04
      22046.00c  6.80454E-05
      22047.00c  6.20915E-05
      22048.00c  6.27719E-04
      22049.00c  4.67812E-05
      22050.00c  4.59307E-05
      24050.00c  4.42412E-05
      24052.00c  8.53157E-04
      24053.00c  9.67298E-05
      24054.00c  2.40806E-05
      25055.00c  4.94195E-04
      26054.00c  1.33854E-04
      26056.00c  2.08086E-03
      26057.00c  4.76429E-05
      26058.00c  6.35239E-06
      29063.00c  8.12707E-04
      29065.00c  3.62235E-04
      30000      3.36315E-04
      30000      1.93069E-04
      30000      2.83722E-05
      30000      1.30097E-04
      30000      4.15203E-06
C
C
C ------------------------
C Cadmium
C ------------------------
m900  48106.00c  1.25000E-02
      48108.00c  8.90000E-03
      48110.00c  1.24900E-01
      48111.00c  1.28000E-01
      48112.00c  2.41300E-01
      48113.00c  1.22200E-01
      48114.00c  2.87300E-01
      48116.00c  7.49000E-02
C
C ------------------------
C pool water (density 0.998 g/cm3)
```

```
C ------------------------
m410  1001.00c  6.669057E-01
      8016.00c  3.333194E-01
      8017.00c  1.333811E-05
mt410  h-h2o.40t
C
C ------------------------
C Air  0.0014 g/cm3
C ------------------------
m330  7014.00c   -75.47
      8016.00c   -23.20
      18040.00c  -1.28
C
C ------------------------
C Al2O3 flux detector insulation
C ------------------------
m3271 13027.00c 2.0 $ Al-2
      8016.00c  3.0 $ O-3
C
C ------------------------
C Inconel 600
C ------------------------
m3272 28058.00c  -48.38242244
      28060.00c  -19.27862096
      28061.00c  -0.852018583
      28062.00c  -2.761148117
      28064.00c  -0.725789894 $Ni -72.0%
      24050.00c  -0.701301943
      24052.00c  -14.06395109
      24053.00c  -1.625446703
      24054.00c  -0.459300267 $ Cr -16.85%
      26054.00c  -0.508100245
      26056.00c  -8.271137584
      26057.00c  -0.194433177
      26058.00c  -0.026328994 $ Fe -9.0%
       6012.00c  -0.15        $ C -0.15%
      25055.00c  -1.0         $ Mn -1.0%
      14028.00c  -0.459332434
      14029.00c  -0.024168144
      14030.00c  -0.016499421 $ Si
      29063.00c  -0.342395975
      29065.00c  -0.157604025 $ Cu -0.50%
C
C ------------------------
C UO2 - Fuel
C ------------------------
C - Modified by LCdr Simon P.J. Parent, Nov 2022
C
C Fuel Composition as per CNL manufacturing reports
C Fuel Enrichment at 19.632 %
m40000 8016.00c   -0.118192461471   $ O-16
       8017.00c   -0.000045437221   $ O-17
       8018.00c   -0.000242292354   $ O-1
      92234.00c   -0.001841114732   $ U-234
      92235.00c   -0.173024243273   $ U-235
      92236.00c   -0.000665850732   $ U-236
      92238.00c   -0.705775336252   $ U-238
      13027.00c   -0.000008328643   $ Al-27
       5010.00c   -0.000000038966   $ B-10
       5011.00c   -0.000000159335   $ B-11
       6012.00c   -0.000083275585   $ C-12
       6013.00c   -0.000000892178   $ C-13
      20040.00c   -0.000017087554   $ Ca-40
```

```
      20042.00c   -0.000000114045   $ Ca-42
      20043.00c   -0.000000023796   $ Ca-43
      20044.00c   -0.000000367694   $ Ca-44
      20046.00c   -0.000000000705   $ Ca-46
      20048.00c   -0.000000032962   $ Ca-48
      48106.00c   -0.000000000525   $ Cd-106
      48108.00c   -0.000000000372   $ Cd-108
      48110.00c   -0.000000005220   $ Cd-110
      48111.00c   -0.000000005356   $ Cd-111
      48112.00c   -0.000000010093   $ Cd-112
      48113.00c   -0.000000005119   $ Cd-113
      48114.00c   -0.000000012037   $ Cd-114
      48116.00c   -0.000000003145   $ Cd-116
      24050.00c   -0.000000136902   $ Cr-50
      24052.00c   -0.000002640009   $ Cr-52
      24053.00c   -0.000000299356   $ Cr-53
      24054.00c   -0.000000074516   $ Cr-54
      29063.00c   -0.000001608935   $ Cu-63
      29065.00c   -0.000000717797   $ Cu-65
      66156.00c   -0.000000000011   $ Dy-156
      66158.00c   -0.000000000019   $ Dy-158
      66160.00c   -0.000000000462   $ Dy-160
      66162.00c   -0.000000003746   $ Dy-161
      66162.00c   -0.000000005052   $ Dy-162
      66163.00c   -0.000000004937   $ Dy-163
      66164.00c   -0.000000005604   $ Dy-164
       9019.00c   -0.000002093177   $ F-19
      26054.00c   -0.000002588588   $ Fe-54
      26056.00c   -0.000040635301   $ Fe-56
      26057.00c   -0.000000938446   $ Fe-57
      26058.00c   -0.000000124890   $ Fe-58
      64152.00c   -0.000000000062   $ Gd-152
      64154.00c   -0.000000000672   $ Gd-154
      64155.00c   -0.000000004565   $ Gd-155
      64156.00c   -0.000000006314   $ Gd-156
      64157.00c   -0.000000004828   $ Gd-157
      64158.00c   -0.000000007662   $ Gd-158
      64160.00c   -0.000000006743   $ Gd-160
      12024.00c   -0.000002783794   $ Mg-24
      12025.00c   -0.000000352923   $ Mg-25
      12026.00c   -0.000000388670   $ Mg-26
      25055.00c   -0.000005552428   $ Mn-55
      42092.00c   -0.000001575108   $ Mo-92
      42094.00c   -0.000000987816   $ Mo-94
      42095.00c   -0.000001706716   $ Mo-95
      42096.00c   -0.000001792735   $ Mo-96
      42097.00c   -0.000001030287   $ Mo-97
      42098.00c   -0.000002611954   $ Mo-98
      42100.00c   -0.000001047706   $ Mo-100
      28058.00c   -0.000001424970   $ Ni-58
      28060.00c   -0.000000548896   $ Ni-60
      28061.00c   -0.000000023860   $ Ni-61
      28062.00c   -0.000000076077   $ Ni-62
      28064.00c   -0.000000019374   $ Ni-64
      14028.00c   -0.000026424899   $ Si-28
      14029.00c   -0.000001338223   $ Si-29
      14030.00c   -0.000000880357   $ Si-30
      90230.00c   -0.000000000085   $ Th-230
      90232.00c   -0.000000425160   $ Th-232
C
C -------1---------2---------3---------4---------5---------6---------7---------8
C
C ****************************** SAMPLE'S MATERIAL ****************************
```

```
C ____________________________________________________________________________
C ------------------------
C WIRES Samples (density 2.719 g/cm3)
C ------------------------
C Shieldwerx Gold-Aluminium Wire, 0.020" diameter lot:ALAU49019111
C Gold 0.12%, Aluminium 99.88%, Assuming no impurities
m811    79197.00c -0.0012 $ Gold Au-197 at 0.12%wt
        13027.00c -0.9988 $ Aluminium Al-27 at 99.88%wt
C
C ------------------------
C 2cc Vial (0.905 g/cm3)
C ------------------------
C  Perfector Scientific Cryo-Stor 2.0 mL vial, Polypropelene Copolymer
C Catalog 2190
C C3H6
m812    1001.00c 6.0 $ H-6
        6012.00c 3.0 $ C-3
C
C
C ------------------------
C 7cc Vial (0.92 g/cm3)
C ------------------------
C Polyvial EP-290 NAA neutron activation analysis Lab Vial, LDPE
C C2H4
m813    1001.00c 4.0 $ H-4
        6012.00c 2.0 $ C-2
mt813 h-poly.40t
C
C ------------------------
C Filter Paper (0.69g/cm3)
C ------------------------
C      Fisherbrand P4 Cat no. 09-803-6G, Porosity Medium-Fine, Flow rate:Slow
C C6H10O5
C
m814     6012.00c  6.0 $C-6
         1001.00c  10.0 $H-10
         8016.00c  5.0 $O-5
C
C ------------------------
C Inner Tube (0.92 g/cm3)
C ------------------------
C Cole-Parmer Instrument Company, Polyethylene Tubing, ID 5/64"
C      OD 1/8", Wall Diameter 1/32", Lot 06100-13
C C2H4
m815    1001.00c 4.0 $ H-4
        6012.00c 2.0 $ C-2
mt815 h-poly.40t
C
C ____________________________________________________________________________
C
C ********************************* TALLIES **********************************
C ____________________________________________________________________________
C
FC104 Flux at the Sample
F104:N 705
E104 1e-12 150ilog 1e-6 100ilog 1e-1 70ilog 20
FM104 7.432870526e14
C
FC114 Flux at the Sample (Standard energy Bins, Lamarre, Rook, Andrews)
F114:N 705
E114 0.625e-6 4e-6 10
FM114 7.432870526e14
C
```

```
FC204 Flux at Sample (Standard Energy Bins - Duchesne Correction)
F204:N 705
E204 0.625e-6 4e-6 10
FM204 8.062774808e14
C
C -------1---------2---------3---------4---------5---------6---------7---------8
C _____________________________________________________________________________
C
C ********************************* RUN PARAMETERS*****************************
C _____________________________________________________________________________
C
mode n
totnu
kcode 500000 1.0 30 1000
C
rand gen=1 seed=100009
ksrc  1.1 -1.9 12 $ [0 -2 0]
     -1.1  1.9 12 $ [0  2 0]
C
ACT FISSION=N
print
C
C _____________________________________________________________________________
C ********************************* END ***************************************
C _____________________________________________________________________________
C -------1---------2---------3---------4---------5---------6---------7---------8
```

Annex S

MCNP Simulation Methodology

Shannon Entropy

MCNP starts its initial computational cycle with a best guess of its initial k_{eff} inputted by the operator. Each subsequent cycle's results refine the following starting parameters. In that manner, the results are expected to converge to the "true result" after enough iteration. However, the first few cycles must be dismissed to not skew the results.

The selection of the number of cycles to be dismissed, inactive cycles before each run's data is considered, is done by an assessment of the convergence of the fission source distribution, conducted by plotting the Shannon entropy (H_{src}) over the cycles, and identifying where the curve has stabilized. It is outside of the scope of this thesis to provide a full demonstration of the Shannon entropy method and calculations used by MCNP. Its demonstration has been conducted extensively, notably by work spearheaded by Brown at LANL [S1]-[S4].

MCNP automatically provides an assessment of the Shannon entropy of the simulation and suggests a number of cycles to dismiss. The following is an excerpt of an output file showing the recommendation to dismiss at least *seven* (7) cycles :

```
comment. Average fission-source entropy for the last half of cycles:
comment.      H=  1.22E+01  with population std.dev.=  1.18E-03
comment.
comment.
comment. Cycle    7 is the first cycle having fission-source
comment.   entropy within 1 std.dev. of the average
comment.   entropy for the last half of cycles.
comment.   At least this many cycles should be discarded.
comment.
comment. Source entropy convergence check passed.
```

Regardless of MCNP's recommendation, it is a best practice to use the MCNP plot function to assess the Shannon entropy during preliminary runs to identify the number of inactive cycles required and after production runs to confirm the correct number of cycles have been discarded [S5].

For all simulations, 30 cycles were selected as inactive and dismissed before the tallies were computed. Table S-1 presents the recommended inactive cycles from the simulation's output files. The recommended number of inactive cycles by MCNP is based on the first instance of the fission-source entropy being within 1 standard deviation of the average entropy for the last half of the cycles. All the recommendations are well below the modelled 30 cycles' threshold, and all MCNP source entropy convergence checks are passed.

Table S-1. Recommended Inactive Cycles

	MCNP Recommended Minimum Inactive Cycles (Output File)	**Modelled MNCP Inactive Cycles**
Inner Unshielded	4	30
Inner Shielded	6	30
Outer Unshielded	5	30
Outer Shielded	7	30

As per LANL's recommended best practices, all simulations were assessed using the internal MCNP plot functionality to graph the Shannon entropy *vs.* the cycle number [S5]. Figure S-1 presents the obtained plot for the inner unshielded sample simulation, with Figure S-2 showing a magnification of cycle 0 to 10. The plotted Shannon entropy stabilizes around the fourth cycle, which also corresponds to MCNP's recommendation (Table S-1). All other simulations display a similar trend, with the convergence occurring well below the 30 inactive cycles' threshold. It is therefore assessed that the convergence of the distribution will not impact the tallies' results negatively.

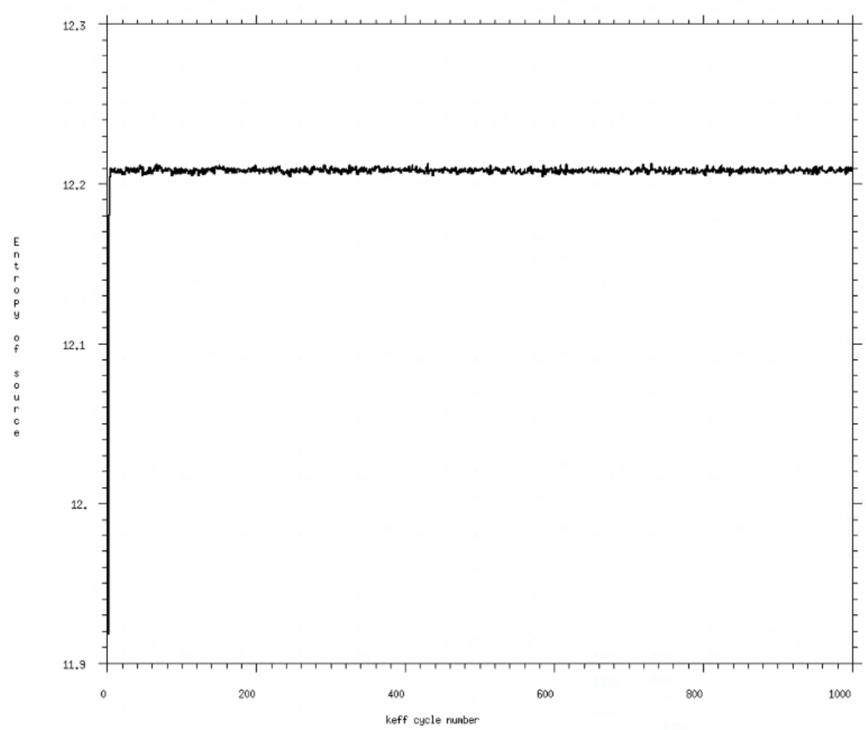

Figure S-1. Shannon Entropy *vs.* Cycle of the Inner Unshielded Sample Simulation

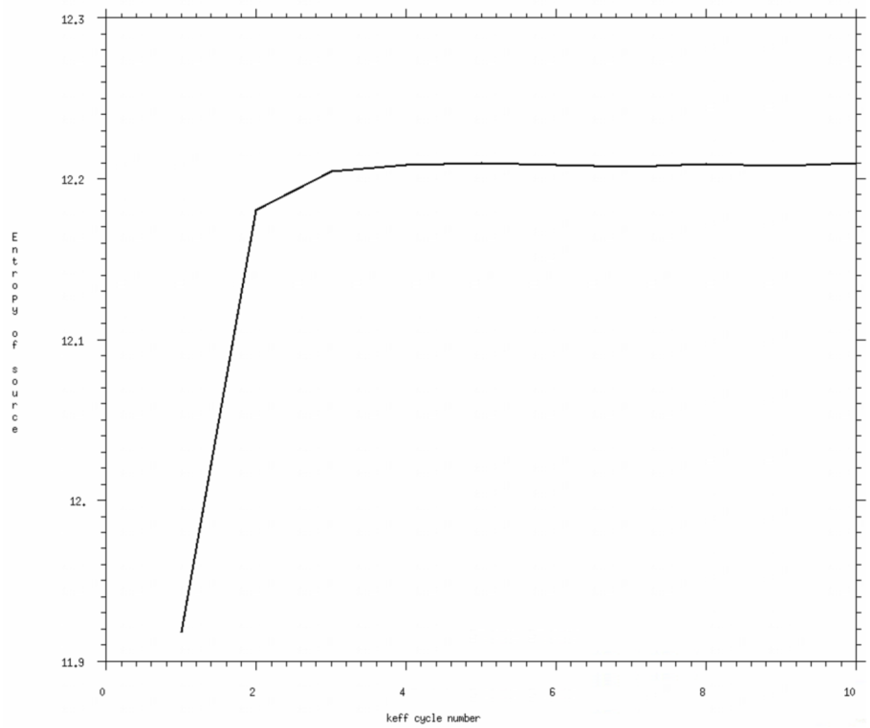

Figure S-2. Shannon Entropy *vs.* Cycle of Inner Unshielded Sample Simulation (cycle 0 to 10)

Neutron Energy Groups

Neutron energy groups were selected based on historical neutron flux studies on the RMC SLOWPOKE-2 going back to Andrews in 1989 [S6]. To allow for a direct comparison between the present work and that of Andrews, Lamarre and Rook, the same neutron energy grouping scheme will be used, presented in Table S-2 [S7], [S8], [S9]:

Table S-2. Neutron Energy Groups

Neutron Group	Energy Range
Thermal	0 - 0.625 eV
Epithermal	0.625 - 4.0 eV
Fast	4 eV – 10 MeV

All reported neutron fluxes for MCNP results will be based on those energy ranges unless stipulated otherwise.

Simulation Parameters

The simulation parameters control how MCNP will use the geometry and materials to answer the questions it is given. Parameters were selected based on computational requirements, results requirements, and reactor model geometry.

The following lines of code are identical for all MCNP simulations unless otherwise stated:

```
C ____________________________________________________________________________
C
C ******************************** RUN PARAMETERS ***************************
C ____________________________________________________________________________
C
mode n
totnu
kcode 500000 1.0 30 1000
C
rand gen=1 seed=100009
ksrc  1.1 -1.9 12 $ [0 -2 0]
     -1.1  1.9 12 $ [0  2 0]
C
ACT FISSION=N
print
```

Mode

```
mode n
```

The mode was restricted to neutron (mode `n`) on account of computational limitations and results needs. Rook demonstrated that a significant increase in computational time was required to solve simulations involving neutrons, photons and electrons (`mode n p e`) [S8]. Preliminary simulations that were not retained here, showed a similar trend.

Preliminary simulations using all modes were also investigated for photofission. Still, no data returned by MCNP showed any photofission occurring in the reactor fuel, which could affect the neutron flux values obtained from the simulations. Its impact has therefore been assessed as negligible.

Therefore, considering the need to keep computation times to a workable level due to the high number of simulations required by the present work, and no explicit requirements to track neither photons nor electrons, the simulation mode was restricted to neutrons.

Delayed Neutrons

```
totnu
ACT FISSION=N
```

Considering the model benchmark is based on neutron flux, it was essential to ensure that prompt and delayed neutrons were considered in the simulation. Both lines of code, therefore, ensure that delayed neutrons are created, tracked and considered for the calculated neutron fluxes [S5].

Criticality Source

```
kcode 500000 1.0 30 1000
ksrc  1.1 -1.9 12 $ [0 -2 0]
     -1.1  1.9 12 $ [0  2 0]
```

All the simulations conducted in the present work use a KCODE card specifying the number of histories per cycle (500 000), number of cycles (1000) and the number of cycles to be skipped prior to the simulations commencing the tallying of results (30). Those numbers have been used throughout.

The simulations' initial neutrons starting point, in cartesian coordinates, are identified using the KSRC card. From there, MCNP calculate the initial neutron distributions for all subsequent cycles. The KSRC card has not been modified from the original model.

Tallies and Scaling Factor

Tallies are used to tabulate the operator's required results from the simulation. It identifies what is investigated. All tallies used for the model benchmark involve neutron volume flux tallies (F4 tallies). In the current case, the volume of interest is occupied by the Au-Al sample (cell 705), with energy bins based on the energy groups defined in Table S-2. Therefore, the tally is inputted as follows:

```
FC114 Flux at the Sample (Standard energy Bins, Lamarre, Rook, Andrews)
F114:N 705
E114 0.625e-6 4e-6 10
FM114 7.432870526e14
```

Where

`FC114` = Tally Title
`F114:N` = Neutron flux tally for cell 705 (Au-Al Sample)
`E114` = Energy bins (MeV)
`FM114` = Scaling factor (neutron·s^{-1})

MCNP F4 tallies return flux averaged over a cell volume with units of neutron·cm^{-2}. A scaling factor must be used to convert the tally values to standard flux units (n·cm^{-2}·s^{-1}) a scaling factor has to be used. The scaling factor is calculated using Eq. (R–1) [S10]:

$$\mathrm{SF} = \frac{\mathrm{P} \cdot \mathrm{v}}{k_{eff} \cdot w_f} \qquad \text{(R–1)}$$

Where

SF = Scaling factor
P = reactor power (W)
v = neutrons generated per fission (neutron·fission^{-1})
k_{eff}= effective multiplication factor (1 for steady state reactors)

w_f = effective energy realeased per fission of ^{235}U (MeV·Fission^{-1})

Assessing Eq. (R–1) for units yields Eq. (R–2):

$$\text{SF}\left(\frac{\text{neutron}}{s}\right) = \frac{\text{P}\left(\frac{\text{J}}{s}\right)\cdot \text{v}\left(\frac{\text{neutron}}{Fission}\right)}{1.6022x10^{-13}\left(\frac{J}{MeV}\right)\cdot k_{eff}\cdot w_f\left(\frac{MeV}{Fission}\right)} \qquad (\text{R–2})$$

Consequently, once the scaling factor is applied to the MCNP tally values, Eq. (R–3)returns the neutron flux experienced by the sample

$$\Phi_{Actual}\left(\frac{\text{neutron}}{cm^2\cdot s}\right) = \Phi_{F4\,Tally}\left(\frac{\text{neutron}}{cm^2}\right)\cdot \text{SF}\left(\frac{\text{neutron}}{s}\right) \qquad (\text{R–3})$$

Where

Φ_{Actual} = Neutron flux at the sample (n·cm^{-2}·s^{-1})
$\Phi_{F4\,Tally}$ = Neutron Track length (Raw Tally) (neutron·cm^{-22})

During the thesis, questions were raised about how power is calculated for the RMC SLOWPOKE-2. Accurate power determination is essential, considering how power relates to the calculated neutron flux through the scaling factor. Two methods were looked at. The first one assumes that the current method of calculating the reactor power, using the conversion factor (1.77 ± 0.05) x 10^{-11} kW·cm^2·s·n^{-1} is accurate. The second scaling factor assumes that the current method is imprecise and subs the original conversion factor for Duchesne's (1.92 ± 0.04) x10^{-11} kW·cm^2·s·n^{-1} [S11]. A detailed evaluation is conducted at Annex U and a sample calculation for the current method can be seen at Annex K.

The values for the average neutron produced per fission (2.434 neutrons/fission) and the energy produced per fission (180.88 MeV/fission) for the scaling factor determination were obtained from the MCNP output files. Those values were selected as they are the specific ones used by the MCNP simulations, vice estimates from the literature. In the end, only the Duchesne method was retained and is used to present MCNP returned data below.

NAA Experiment Simulation

The NAA experiment was simulated using the modelled Au-Al wire samples, both with and without cadmium shielding, in the inner site 2 and outer site 10, for a total of four simulations for a complete benchmarking run. The focus of the simulations is the neutron flux at the Al-Au sample. The neutron fluxes are separated into three energy bins, thermal, epithermal, and fast neutrons, as defined in Table S-2. Using the results obtained in the bins, the cadmium and thermal-to-epithermal ratios were calculated to provide neutron field information related to the literature data.

The fluxes and ratios of the simulated NAA experiment were compared to the actual NAA experimental values and with the literature values. An agreement between all sources should confirm the model's validity to represent the SLOWPOKE-2 reactor adequately.

Computer Specifications

The computer running all simulations for the present work has the specifications listed at Table S-3.

Table S-3. Computer Specifications

Processors	2
Processor Type	Intel Xeon Silver 4114 CPU @ 2.20Ghz
RAM	32 GB
Operating System	Windows 10 Enterprise version 22H2, 64-bits
Cores	20
Logical Processors	40

To maximize the use of the computing resources, MCNP was consistently ran on 30 of the 40 available logical processors, consistently allowing a CPU utilization of approximatively 85%.

REFERENCES

[S1] F. B. Brown, "'K-effective of the World' and Other Concerns for Monte Carlo Eigenvalue Calculations," *Progress in Nuclear Science and Technology*, vol. 2, no. 0, pp. 738–742, Oct. 2011, doi: 10.15669/pnst.2.738.

[S2] F. B. Brown, B. Nease and J. Cheatham, "Convergence Testing for MCNP5 Monte Carlo Eigenvalue Calculations," in *M&C+SNA-2007, ANS Mathematics & Computation Topical Meeting*, Monterey, CA: Los Alamos National Laboratories, Apr. 2007.

[S3] F. B. Brown, "On the Use of Shannon Entropy of the Fission Distribution for Assessing Convergence of Monte Carlo Criticality Calculations," in *PHYSOR-2006, ANS Reactor Physics Division*, Vancouver, BC: Los Alamos National Laboratories, Sep. 2006.

[S4] T. Ueki and F. B. Brown, "Stationarity Diagnostics Using Shannon Entropy in Monte Carlo Criticality Calculation I: F test, LA-UR-02-3783," in *American Nuclear Society 2002 Winter Meeting*, Washington, DC: Los Alamos National Laboratories, Nov. 2002.

[S5] C. J. Werner, J. C. Armstrong, F. B. Brown, J. S. Bull, L. Casswell, L. J. Cox, D. A. Dixon, R. A. Forster III, J. T. Goorley, H. G. Hughes III, J. A. Favorite, R. L. Martz, S. G. Mashnik, M. E. Rising, C. J. Solomon Jr., A. Sood, J. E. Sweezy, A. J. Zukaitis, C. A. Anderson *et al.*, *MCNP User's Manual - Code Version 6.2, LA-UR-17-29981*, Manual Rev. 0. Los Alamos: Los Alamos National Security, 2017.

[S6] W. S. Andrews, "Thermal Neutron Flux Mapping Around the Reactor Core of the SLOWPOKE-2 at RMC," Royal Military College of Canada, Kingston, 1989.
[S7] G. B. Lamarre, "Experimental and Computational Determination of Radiation Dose Rates in SLOWPOKE-2 Research Reactor at RMC," Master of Engineering, Royal Military College of Canada, Kingston, ON, 1999.
[S8] J. C. Rook, "Degradation of PER- and Polyfluoroalkyl Substances: Irradiation and MCNP Modeling with the SLOWPOKE-2 Nuclear Reactor," Master of Applied Science, Royal Military College of Canada, Kingston, ON, 2018.
[S9] W. S. Andrews, "Thermal Neutron Flux Mapping Around the Reactor Core of the SLOWPOKE-2 at RMC," Royal Military College of Canada, Kingston, 1989.
[S10] G. Žerovnik, M. Podvratnik and L. Snoj, "On normalization of fluxes and reaction rates in MCNP criticality calculations," *Ann Nucl Energy*, vol. 63, pp. 126–128, 2014, doi: 10.1016/J.ANUCENE.2013.07.045.
[S11] J. C. D. Duchesne, "RMC SLOWPOKE-2 Reactor Thermal Power Determination by Core Water Temperature Measurements," Master of Engineering, Royal Military College of Canada, 1994.

Annex T

Burnup Code Details

Burnup Code

The following code was used to call up the depletion module in the code for the 10 kW_t run [T1]:

```
BURN Time  = 1696
PFRAC = 1.0
POWER = 0.01 $10 kW Power in MW
MAT   = 40000 $Fuel
OMIT  = -1,129,6012,6013,6014,7016,8018,8019,9018,10020,
      10021,29066,30066,30067,30068,30069,30070,31070,
      32071,32075,33072,33073,34075,34081,35080,36079,
      36081,38085,39086,39087,39088,39092,39093,40088,
      40089,40097,41091,41092,41096,41097,41098,41099,
      41100,42091,42093,42101,43097,43098,44097,45104,
      45106,45107,45108,45109,45110,45111,46103,46109,
      46111,46112,46113,46114,47106,47108,47110,48107,
      48109,48115,49114,49116,49117,49118,49119,49120,
      49121,49122,49123,49124,49125,50121,51122,52121,
      52127,52129,53128,53132,53133,53134,54125,54127,
      56131,58137,60149,61145,61146,62145,62146,64150,
      64151,64158,64159,66157,66159,67163,67164,67166,
      68163,68165,68169,69166,69167,69168,69169,69170,
      69171,69172,69173,70168,70169,70170,70171,70172,
      70173,70174,88227,89228,90231,91230,92231,95240,
      97245
      BOPT  = 1.0 -22 1
      MATVOL= 592.605000585
```

The isotopes identified in the OMIT section are similar to those omitted by Rook and are a consequence of MCNP's limitations and the computer used for the simulations [T2]. The listed isotopes required MCNP physics models that could not be run with multiple logic cores engaged.

Reactor Fuel

In a similar manner, several of the impurities modelled in the fuel produced similar difficulties and the fuel material card had to be simplified significantly to remove impurities, returning to a simplified UO_2 model:

```
m40000 8016.00c   -0.118192461471   $ O-16
       8017.00c   -0.000045437221   $ O-17
       8018.00c   -0.000242292354   $ O-18
      92234.00c   -0.001841114732   $ U-234
      92235.00c   -0.173024243273   $ U-235
      92236.00c   -0.000665850732   $ U-236
      92238.00c   -0.705775336252   $ U-238
```

Reactor Control

Table T-1 presents the model controls that were used for the operational burnup runs.

Table T-1. Model Control Parameters

	MCNP Code POWER (MW$_t$)	**Control Rod Height** (cm)	**Shim Height** (cm)
½ Power	0.01	8.88	5.07
¾ Power	0.015	14.50	5.07
Full Power	0.02	25.00 (removed)	5.07

10 000 000 Years Decay

To simulate the decay in MCNP, the CINDER90 module was used, using a power fraction (PFRAC) of *zero* (0), simulating a decaying core [T1]. The following code lines were used to create the time steps and decay in the MCNP simulation, replacing the equivalent line from the burnup code above:

```
BURN Time  = 1825 1825 1825 1825 3650 3650 3650 7300 10950 36500 36500 73000
             182500 3285000 32850000 328500000 3285000000
PFRAC = 0
```

REFERENCES

[T1] C. J. Werner, J. C. Armstrong, F. B. Brown, J. S. Bull, L. Casswell, L. J. Cox, D. A. Dixon, R. A. Forster III, J. T. Goorley, H. G. Hughes III, J. A. Favorite, R. L. Martz, S. G. Mashnik, M. E. Rising, C. J. Solomon Jr., A. Sood, J. E. Sweezy, A. J. Zukaitis, C. A. Anderson *et al.*, *MCNP User's Manual - Code Version 6.2, LA-UR-17-29981*, Manual Rev. 0. Los Alamos: Los Alamos National Security, 2017.

[T2] J. C. Rook, "Degradation of PER- and Polyfluoroalkyl Substances: Irradiation and MCNP Modeling with the SLOWPOKE-2 Nuclear Reactor," Master of Applied Science, Royal Military College of Canada, Kingston, ON, 2018.

Annex U

Reactor Power Determination

Power Calculations

The LabView software controlling the reactor provides real-time information as to the state of the reactor. It allows for post-experiment analysis of reactor states (*e.g.,* control rod height, neutron flux at the SPND). The reactor's power is calculated based on the neutron flux data obtained from SPND using the data retrieved from the control system. Eq. (U–1) determines the power of the reactor in operation.

$$P = K\phi \qquad \text{(U–1)}$$

Where

P = Reactor power (kW_t)

K = Conversion factor ($kW_t\cdot cm^2\cdot s\cdot n^{-1}$)

ϕ = Flux detected by the self-powered neutron detector ($n\cdot cm^{-2}\cdot s^{-1}$)

The conversion factor currently used by the RMC SLOWPOKE-2 LabView comes from the original commissioning calibration and is equal to (1.77 ± 0.05) x 10^{-11} $kW_t\cdot cm^2\cdot s\cdot n^{-1}$ [U1].

The basis for the present study's comparisons with existing literature is half-power (10 kW) for a neutron flux at the self-powered neutron detector of 5 x 10^{11} $n\cdot cm^{-2}\cdot s^{-1}$. The NAA experiment, for the same flux, obtained a calculated power of 8.8 ± 0.2 kW_t with the current calculation method. There is, therefore, a 1.2 kW_t difference between the results obtained from the literature and the present experimental results. During the present study, the SLOWPOKE-2 Director highlighted that it was suspected that the conversion factor was erroneous and another conversion factor would better represent the reactor's power [U2].

Duchesne, in 1994, proposed the use of (1.92 ± 0.04) x 10^{-11} $kW_t\cdot cm^2\cdot s\cdot n^{-1}$ vice (1.77 ± 0.05) x 10^{-11} $kW_t\cdot cm^2\cdot s\cdot n^{-1}$ [†††] based on core water temperature measurements [U1]. Such an approach would bring the reactor power, when the flux is set at the nominal flux of 5 x 10^{11} $n\cdot cm^{-2}\cdot s^{-1}$, to 9.6 ± 0.2 kW_t, much more comparable to the 10 kW_t basis for Andrews, Lamarre and Rook's experimental fluxes [U3], [U4], [U5].

Self-Powered Neutron Detector

The SLOWPOKE-2 was designed to hold a steady neutron flux within 1% of its set value [U6]. As such, it requires high confidence in the control system's inputs from the self-powered neutron detector. The last test and calibration of the self-powered neutron

[†††] No uncertainties could be found for the historical power conversion factor. An uncertainty of ± 0.05 is estimated based on the uncertainties determined by Duchesne [203].

detector on record were in 2011 at the ZED-2 reactor at the Chalk River Laboratories [U7]. At that time, the sensitivity of the detector was determined. Still, no recommendations can be seen in the report, nor information exists as to whether any changes have been made to how the LabView control system calculates power. However, it is known that the power conversion factor has remained the same since the reactor's first operation at the RMC in 1985. It is also possible that the neutron detector has lost its sensitivity and calibration over its time in the reactor, affecting the reported power.

MCNP Investigation

Both Lamarre and Rook use half power to mean 10 kW_t, half of the SLOWPOKE-2 nominal design thermal power of 20 kW_t. Specifically, both link the SLOWPOKE-2 half power of 10 kW_t to the 5 x 10^{11} $n \cdot cm^{-2} \cdot s^{-1}$ neutron flux at the self-powered detector position. In the case of Lamarre, the control rod was not fully simulated, but in the case of Rook, the control rod was entered into the core at half height to simulate half power and kept there for the duration of the simulations.

During the experimental phase of the present work, data gathered by the SLOWPOKE-2 control system were used in the rendition of the simulated NAA experiments. The control system gathers information on the rod position every second. For all NAA experimental runs, the rod positions were averaged according to the type of run and location. Table U-1 presents the experimental control rod position average that has been modelled in each kind of MCNP simulation run.

Table U-1. Control Rod Position for MCNP Simulations

	Unshielded Sample (cm)	**Shielded Sample** (cm)
Inner Site	8.88	14.24
Outer site	8.90	9.48

Comparatively, Rook sets the control rod at 10.16 cm, noticeably higher than the 8.88 cm and 8.90 cm used here. To investigate that potential source of discrepancy, simulations using the control rod at 10.16 cm were conducted for both the inner site and the outer site. Table U-2 presents the neutron flux obtained from the investigation. Only the control rod height was modified.

Table U-2. Neutron Flux with Control Rod at 10.16 cm

		Control Rod Position	
		10.16 cm	8.88 cm (Inner) 8.90 (Outer)
Thermal Flux ($n \cdot cm^{-2} \cdot s^{-1}$) x$10^{11}$	Inner Site	4.46 ± 0.03	4.50 ± 0.03
	Outer site	2.18 ± 0.02	2.19 ± 0.02
Epithermal Flux ($n \cdot cm^{-2} \cdot s^{-1}$) x$10^{11}$	Inner Site	0.40 ± 0.01	0.42 ± 0.01
	Outer site	0.069 ± 0.001	0.066 ± 0.004
Fast Flux ($n \cdot cm^{-2} \cdot s^{-1}$) x$10^{11}$	Inner Site	4.80 ± 0.03	4.74 ± 0.03
	Outer site	0.49 ± 0.02	0.49 ± 0.01

The difference between the fluxes obtained from a simulation with the control rod at 10.16 cm does not differ significantly from those conducted with the NAA experiment settings. The reason for the discrepancy between the present study and the literature, therefore, lies elsewhere.

The assumptions made to calculate the scaling factor have a direct impact on the computed neutron flux. A comparison of the values used to compute the scaling factor using Eq. (U–1) for the present study and for Rook is presented Table U-3 [U4].

Table U-3. Scaling Factor Terms Comparison

Scaling Factor Terms	**Present Study**	**Rook** [U4]
Power (kW_t)	8.85	10
ν ($neutron \cdot fission^{-1}$)	2.434	2.45
k_{eff}	1	1
w_f ($MeV \cdot fission^{-1}$)	180.88	180.88
Scaling Factor ($neutron \cdot s^{-1}$)	7.432870526x10^{14}	8.4513214 x10^{14}

The only significant difference between the two methods is for the operating power of the reactor. It is possible to remove the impact of the scaling factor from the results, in both cases, by dividing the MCNP values by their respective scaling factor: rearranging Eq. (R–3) and obtaining Eq. (U–2):

$$\Phi_{F4\,Tally}\left(\frac{\text{neutron}}{cm^2}\right) = \frac{\Phi_{Actual}\left(\frac{\text{neutron}}{cm^2 \cdot s}\right)}{\text{SF}\left(\frac{\text{neutron}}{s}\right)} \quad \text{(U–2)}$$

Removing the scaling factor as a potential error in the assessment of the tallies yields the original raw tally results from MCNP. Table U-4 presents the raw data obtained from the F4 tallies based on Eq. (U–2).

Table U-4. Raw F4 Tally Results

		Present Study	**Rook** [U4] RMC		
		RMC	Fresh Fuel	Depleted Fuel	Detailed Fuel
Thermal Flux ($n\cdot cm^{-2}\cdot s^{-1}$) x10^{-4}	Inner Site	**6.05 ± 0.04**	6.1±0.2	6.3±0.2	6.0±0.2
	Outer site	**2.95 ± 0.03**	3.1±0.1	3.1±0.2	3.0±0.2
Epithermal Flux ($n\cdot cm^{-2}\cdot s^{-1}$) x10^{-4}	Inner Site	**0.56 ± 0.01**	0.59±0.03	0.54±0.03	0.56±0.03
	Outer site	**0.089 ± 0.005**	0.095±0.005	0.093±0.005	0.092±0.005
Fast Flux ($n\cdot cm^{-2}\cdot s^{-1}$) x10^{-4}	Inner Site	**6.38 ± 0.04**	6.4±0.2	6.6±0.2	6.4±0.2
	Outer site	**0.66±0.01**	0.65±0.03	0.69±0.03	0.66±0.3

For Rook's models of interest, "fresh" and "detailed," both for the inner and outer sites, the results obtained for the F4 tallies with MCNP 6.1 encompasses in the error margin, the results obtained from MCNP 6.2 with the updated SLOWPOKE-2 model using the new fuel. The results are essentially identical. Therefore, the scaling factor, and by extension, the power at which it is believed the SLOWPOKE-2 operates, is the main factor impacting the neutron flux results obtained from the F4 tallies.

Ideal Power Factor

The inner site's thermal neutron flux obtained from the NAA experiment corresponds exactly to the 5x10^{11} $n\cdot cm^{-2}\cdot s^{-1}$ setting selected at the reactor controls and recorded at the SPND during irradiation of the samples. However, the MCNP results using the current scaling factor method for the sample show a flux of 4.50 ± 0.03 $n\cdot cm^{-2}\cdot s^{-1}$. Table U-5 displays the ideal scaling factor, corresponding operating power and correction factors that would be applied to the raw F4 tally to obtain the experimental result.

Table U-5. Ideal Factors for the Inner Site Thermal Flux Computation

NAA Result (x10^{11} $n\cdot cm^{-2}\cdot s^{-1}$)	**Raw F4 Tally** (x10^{-4} $n\cdot cm^{-2}$)	**Ideal Scaling Factor** (x10^{14} $n\cdot s^{-1}$)	**Ideal Power** (kW_t)	**Ideal Power Correction Factor** (x10^{11} $kW\cdot cm^2\cdot s\cdot n^{-1}$)
5.0 ± 0.2	6.05 ± 0.04	8.3 ± 0.3	~ 9.8	~ 1.97

The ideal power is significantly closer to the 10 kW used by Rook and Lamarre than it is from the 8.85 kWt that has been used here to compute the scaling factor to be applied to the MCNP tallies [U3], [U4]. Likewise, the ideal power correction factor is approximately 10% higher than the 1.77x10^{-11} $kW\cdot cm^2\cdot s\cdot n^{-1}$ used since the reactor's commissioning. It is therefore posited here that the power correction factor of 1.77 x10^{-11} $kW\cdot cm^2\cdot s\cdot n^{-1}$ is imprecise and should be amended. However, no current data directly supports using the ideal case presented in Table U-5.

While it is not a perfect fit with the NAA experiment, Duchesne's proposed power correction factor of (1.92± 0.04) x 10^{-11} kW·cm²·s·n^{-1}, an increase of approximately 8% on the current factor supported by experimental data [U1]. Considering Duchesne's findings and MCNP's simulation results here, the preponderance of evidence points to the need to increase the power correction factor. In support of the power correction factor increase, Townes & Hilborne's 1985 assessment of the LEU core (180 elements) using a WISM-CITATION code put the thermal flux at the inner site at 10^{12} n·cm^{-2}·s^{-1} for a power of 19.6 kW_t. This simulation provides a power correction factor of 1.96 x 10^{-11} kW·cm²·s·n^{-1}, further supporting an amendment to the currently used power correction factor [U8].

Conclusion

Experimental and simulated data point to the need to change the power correction factor. If used as the basis to calculate a MCNP scaling factor, it is posited that the original factor would not provide fluxes representative of the experimental values. Faced with uncertainty about the proper factor to be used, the Duchesne factor was selected here as a better estimate of the actual factor for an operating power of 9.6 kW_t during the NAA experiment, vice the originally calculated 8.9 kW_t.

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Annex V

Operational Burnup Results – 1696 Days
CINDER Module Output File Excerpt
Half and Full Power

Half Power CINDER Module Output

nuclides with atom fractions below 1.000E-10 for a material are zeroed and deleted from print tables after t=0

neutronics and burnup data

step	duration (days)	time (days)	power (MW)	keff	flux	ave. nu	ave. q	burnup (GWd/MTU)	source (nts/sec)
0	0.000E+00	0.000E+00	1.000E-02	1.01124	1.653E+12	2.434	200.961	0.000E+00	7.560E+14
1	1.696E+03	1.696E+03	1.000E-02	0.99786	1.677E+12	2.435	200.979	3.035E+00	7.562E+14

nuclide data are sorted by decreasing activity for material 40000 volume 5.9261E+02 (cm**3)

actinide inventory for material 40000 at end of step 1, time 1.696E+03 (days), power 1.000E-02 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92239	1.625E-05	5.445E+02	3.351E+07	6.907E-11	9.629E-10	2.562E-09
2	93239	2.348E-03	5.445E+02	2.319E+05	9.979E-09	1.391E-07	3.702E-07
3	92237	1.210E-04	9.871E+00	8.160E+04	5.185E-10	7.229E-09	1.908E-08
4	92234	1.161E+01	7.220E-02	6.217E-03	5.042E-05	7.030E-04	1.831E-03
5	94239	1.144E+00	7.098E-02	6.203E-02	4.864E-06	6.782E-05	1.805E-04
6	94241	1.320E-04	1.364E-02	1.033E+02	5.564E-10	7.758E-09	2.082E-08
7	92235	1.076E+03	2.326E-03	2.161E-06	4.654E-03	6.488E-02	1.698E-01
8	94240	8.210E-03	1.863E-03	2.269E-01	3.475E-08	4.845E-07	1.295E-06
9	92238	4.475E+03	1.504E-03	3.361E-07	1.910E-02	2.663E-01	7.057E-01
10	94238	6.534E-05	1.119E-03	1.712E+01	2.789E-10	3.889E-09	1.030E-08
11	92236	7.693E+00	4.975E-04	6.467E-05	3.312E-05	4.617E-04	1.213E-03
12	93237	1.771E-02	1.248E-05	7.047E-04	7.590E-08	1.058E-06	2.792E-06
13	90230	1.495E-04	3.081E-06	2.062E-02	6.602E-10	9.205E-09	2.357E-08
14	91231	5.329E-06	2.517E-07	4.723E-02	2.344E-11	3.268E-10	8.404E-10
15	92233	3.753E-06	3.617E-08	9.636E-03	1.637E-11	2.282E-10	5.920E-10
	totals	5.572E+03	1.099E+03	1.973E-01	2.384E-02	3.324E-01	8.787E-01

nonactinide inventory for material 40000 at end of step 1, time 1.696E+03 (days), power 1.000E-02 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	54133	2.973E-03	5.571E+02	1.874E+05	2.273E-08	3.169E-07	4.689E-07
2	40095	2.513E-02	5.400E+02	2.149E+04	2.690E-07	3.751E-06	3.963E-06
3	41095	1.372E-02	5.400E+02	3.934E+04	1.470E-07	2.049E-06	2.165E-06
4	54135	2.083E-04	5.294E+02	2.541E+06	1.569E-09	2.188E-08	3.285E-08
5	53135	1.478E-04	5.227E+02	3.536E+06	1.114E-09	1.553E-08	2.331E-08
6	57140	9.286E-04	5.164E+02	5.561E+05	6.745E-09	9.403E-08	1.465E-07
7	56140	7.049E-03	5.158E+02	7.318E+04	5.120E-08	7.138E-07	1.112E-06
8	42099	1.056E-03	5.074E+02	4.805E+05	1.085E-08	1.513E-07	1.665E-07
9	59143	7.335E-03	4.939E+02	6.733E+04	5.216E-08	7.272E-07	1.157E-06
10	58143	7.431E-04	4.938E+02	6.645E+05	5.284E-09	7.367E-08	1.172E-07
11	58141	1.703E-02	4.857E+02	2.851E+04	1.228E-07	1.713E-06	2.686E-06
12	39091	1.968E-02	4.832E+02	2.455E+04	2.200E-07	3.067E-06	3.104E-06
13	58144	1.415E-01	4.506E+02	3.185E+03	9.990E-07	1.393E-05	2.231E-05
14	38089	1.349E-02	3.920E+02	2.905E+04	1.542E-07	2.150E-06	2.128E-06
15	52132	1.177E-03	3.576E+02	3.038E+05	9.068E-09	1.264E-07	1.856E-07
16	44103	7.859E-03	2.540E+02	3.232E+04	7.761E-08	1.082E-06	1.239E-06
17	53131	1.941E-03	2.408E+02	1.241E+05	1.507E-08	2.100E-07	3.061E-07
18	60147	2.308E-03	1.868E+02	8.094E+04	1.596E-08	2.225E-07	3.639E-07
19	61147	1.419E-01	1.316E+02	9.276E+02	9.814E-07	1.368E-05	2.238E-05
20	61149	2.276E-04	9.022E+01	3.964E+05	1.553E-09	2.165E-08	3.589E-08
21	44105	1.225E-05	8.244E+01	6.728E+06	1.187E-10	1.655E-09	1.933E-09
22	45105	9.744E-05	8.231E+01	8.448E+05	9.439E-10	1.316E-08	1.537E-08
23	55137	6.062E-01	5.277E+01	8.704E+01	4.500E-06	6.273E-05	9.561E-05
24	38090	3.694E-01	5.218E+01	1.413E+02	4.175E-06	5.821E-05	5.826E-05
25	39090	9.579E-05	5.209E+01	5.438E+05	1.083E-09	1.509E-08	1.511E-08
26	61151	4.797E-05	3.508E+01	7.311E+05	3.230E-10	4.504E-09	7.566E-09
27	44106	1.011E-02	3.353E+01	3.318E+03	9.698E-08	1.352E-06	1.594E-06
28	62153	3.140E-05	1.391E+01	4.429E+05	2.086E-10	2.909E-09	4.951E-09
29	36085	1.510E-02	5.932E+00	3.927E+02	1.807E-07	2.520E-06	2.382E-06
30	51125	1.890E-03	1.981E+00	1.048E+03	1.537E-08	2.143E-07	2.980E-07
31	63156	2.990E-05	1.648E+00	5.513E+04	1.949E-10	2.717E-09	4.715E-09
32	47111	9.199E-06	1.454E+00	1.580E+05	8.429E-11	1.175E-09	1.451E-09
33	63155	2.560E-03	1.262E+00	4.931E+02	1.679E-08	2.341E-07	4.038E-07
34	62151	4.040E-02	1.063E+00	2.632E+01	2.720E-07	3.793E-06	6.372E-06
35	61148	5.329E-06	8.760E-01	1.644E+05	3.661E-11	5.104E-10	8.405E-10
36	50125	7.364E-06	7.986E-01	1.084E+05	5.991E-11	8.353E-10	1.161E-09
37	55134	6.027E-04	7.803E-01	1.295E+03	4.574E-09	6.376E-08	9.505E-08
38	55136	9.478E-06	6.920E-01	7.301E+04	7.087E-11	9.881E-10	1.495E-09

39	50123	1.221E-05	1.004E-01	8.223E+03	1.010E-10	1.408E-09	1.926E-09
40	51126	8.895E-07	7.439E-02	8.363E+04	7.179E-12	1.001E-10	1.403E-10
41	63154	1.329E-04	3.594E-02	2.703E+02	8.777E-10	1.224E-08	2.097E-08
42	43099	4.546E-01	7.783E-03	1.712E-02	4.670E-06	6.511E-05	7.169E-05
43	63152	3.407E-05	6.014E-03	1.765E+02	2.279E-10	3.177E-09	5.372E-09
44	40093	4.441E-01	1.117E-03	2.515E-03	4.858E-06	6.773E-05	7.004E-05
45	55135	6.484E-01	7.470E-04	1.152E-03	4.884E-06	6.809E-05	1.023E-04
46	34079	2.657E-03	3.647E-04	1.373E-01	3.421E-08	4.770E-07	4.190E-07
47	50126	5.351E-03	1.519E-04	2.839E-02	4.319E-08	6.022E-07	8.440E-07
48	53129	5.306E-02	9.372E-06	1.766E-04	4.183E-07	5.831E-06	8.367E-06
49	46107	1.270E-02	6.533E-06	5.145E-04	1.207E-07	1.683E-06	2.003E-06
50	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.753E-05	2.664E-05
51	62147	1.037E-01	2.381E-09	2.296E-08	7.175E-07	1.000E-05	1.636E-05
52	60144	4.579E-01	5.439E-13	1.188E-12	3.233E-06	4.508E-05	7.222E-05
53	57138	3.328E-06	8.217E-14	2.469E-08	2.452E-11	3.419E-10	5.249E-10
54	62149	4.963E-02	5.958E-14	1.200E-12	3.387E-07	4.722E-06	7.828E-06
55	58142	6.256E-01	3.154E-14	5.042E-14	4.480E-06	6.246E-05	9.867E-05
56	60145	4.296E-01	1.766E-14	4.112E-14	3.012E-06	4.200E-05	6.775E-05
57	49115	1.033E-03	7.289E-15	7.055E-12	9.137E-09	1.274E-07	1.629E-07
58	62148	1.423E-03	4.340E-16	3.051E-13	9.773E-09	1.363E-07	2.244E-07
59	64152	1.694E-05	3.692E-16	2.179E-11	1.133E-10	1.580E-09	2.672E-09
60	48113	7.809E-04	2.659E-16	3.405E-13	7.029E-09	9.799E-08	1.232E-07
61	34082	2.001E-02	6.264E-19	3.130E-17	2.483E-07	3.462E-06	3.156E-06
62	8016	7.496E+02	0.000E+00	0.000E+00	4.762E-02	6.640E-01	1.182E-01
63	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.545E-05
64	7015	1.249E-06	0.000E+00	0.000E+00	8.460E-11	1.180E-09	1.969E-10
65	8018	1.537E+00	0.000E+00	0.000E+00	8.676E-05	1.210E-03	2.423E-04
66	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.903E-10	2.324E-10
67	32073	5.646E-06	0.000E+00	0.000E+00	7.868E-11	1.097E-09	8.905E-10
68	32074	1.908E-05	0.000E+00	0.000E+00	2.622E-10	3.656E-09	3.008E-09
69	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.299E-08	2.788E-08
70	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.136E-08	9.476E-09
71	34077	4.591E-04	0.000E+00	0.000E+00	6.066E-09	8.457E-08	7.241E-08
72	34078	1.229E-03	0.000E+00	0.000E+00	1.603E-08	2.236E-07	1.939E-07
73	34080	7.731E-03	0.000E+00	0.000E+00	9.831E-08	1.371E-06	1.219E-06
74	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.168E-06	1.952E-06
75	36082	5.658E-06	0.000E+00	0.000E+00	7.019E-11	9.786E-10	8.923E-10
76	36083	3.358E-02	0.000E+00	0.000E+00	4.115E-07	5.738E-06	5.296E-06
77	36084	6.197E-02	0.000E+00	0.000E+00	7.505E-07	1.046E-05	9.773E-06
78	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.242E-05	2.144E-05
79	37085	6.173E-02	0.000E+00	0.000E+00	7.387E-07	1.030E-05	9.735E-06
80	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.111E-10	3.931E-10
81	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.785E-05	3.704E-05
82	39089	3.030E-01	0.000E+00	0.000E+00	3.464E-06	4.829E-05	4.779E-05
83	40090	2.150E-02	0.000E+00	0.000E+00	2.430E-07	3.389E-06	3.391E-06
84	40091	3.791E-01	0.000E+00	0.000E+00	4.237E-06	5.908E-05	5.978E-05
85	40092	4.167E-01	0.000E+00	0.000E+00	4.608E-06	6.424E-05	6.572E-05
86	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.906E-05	7.219E-05
87	40096	4.586E-01	0.000E+00	0.000E+00	4.860E-06	6.775E-05	7.233E-05
88	42095	4.263E-01	0.000E+00	0.000E+00	4.564E-06	6.363E-05	6.723E-05
89	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.358E-08	3.585E-08
90	42097	4.409E-01	0.000E+00	0.000E+00	4.624E-06	6.447E-05	6.954E-05
91	42098	4.250E-01	0.000E+00	0.000E+00	4.411E-06	6.150E-05	6.702E-05
92	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.736E-05	7.492E-05
93	44099	1.828E-05	0.000E+00	0.000E+00	1.878E-10	2.618E-09	2.882E-09
94	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.549E-05	6.233E-05
95	44102	3.309E-01	0.000E+00	0.000E+00	3.300E-06	4.601E-05	5.219E-05
96	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.039E-05	2.359E-05
97	45103	2.286E-01	0.000E+00	0.000E+00	2.257E-06	3.147E-05	3.605E-05
98	46105	7.824E-02	0.000E+00	0.000E+00	7.579E-07	1.057E-05	1.234E-05
99	46106	2.349E-02	0.000E+00	0.000E+00	2.254E-07	3.142E-06	3.704E-06
100	46108	4.781E-03	0.000E+00	0.000E+00	4.503E-08	6.278E-07	7.540E-07
101	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.848E-07	3.485E-07
102	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.515E-07	4.261E-07
103	48111	1.466E-03	0.000E+00	0.000E+00	1.343E-08	1.873E-07	2.312E-07
104	48112	1.128E-03	0.000E+00	0.000E+00	1.025E-08	1.428E-07	1.779E-07
105	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.842E-07	2.336E-07
106	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.442E-07	1.861E-07
107	49113	1.613E-06	0.000E+00	0.000E+00	1.451E-11	2.024E-10	2.543E-10
108	50115	5.312E-05	0.000E+00	0.000E+00	4.698E-10	6.550E-09	8.378E-09
109	50116	4.684E-06	0.000E+00	0.000E+00	4.107E-11	5.726E-10	7.387E-10
110	50117	1.142E-03	0.000E+00	0.000E+00	9.929E-09	1.384E-07	1.801E-07
111	50118	1.033E-03	0.000E+00	0.000E+00	8.904E-09	1.241E-07	1.629E-07
112	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.399E-07	1.852E-07
113	50120	1.161E-03	0.000E+00	0.000E+00	9.841E-09	1.372E-07	1.831E-07
114	50122	1.445E-03	0.000E+00	0.000E+00	1.205E-08	1.679E-07	2.279E-07
115	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.885E-07	3.979E-07
116	51121	1.142E-03	0.000E+00	0.000E+00	9.603E-09	1.339E-07	1.802E-07
117	51123	1.465E-03	0.000E+00	0.000E+00	1.211E-08	1.689E-07	2.310E-07
118	52124	1.387E-06	0.000E+00	0.000E+00	1.137E-11	1.586E-10	2.187E-10
119	52125	1.304E-03	0.000E+00	0.000E+00	1.061E-08	1.480E-07	2.057E-07
120	52126	2.234E-04	0.000E+00	0.000E+00	1.803E-09	2.514E-08	3.524E-08

121	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.728E-06	5.309E-06
122	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.938E-05	2.803E-05
123	53127	1.475E-02	0.000E+00	0.000E+00	1.181E-07	1.646E-06	2.326E-06
124	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.736E-10	3.896E-10
125	54130	4.435E-05	0.000E+00	0.000E+00	3.469E-10	4.837E-09	6.994E-09
126	54131	2.832E-01	0.000E+00	0.000E+00	2.198E-06	3.065E-05	4.466E-05
127	54132	4.302E-01	0.000E+00	0.000E+00	3.314E-06	4.620E-05	6.784E-05
128	54134	7.960E-01	0.000E+00	0.000E+00	6.041E-06	8.422E-05	1.255E-04
129	54136	6.664E-01	0.000E+00	0.000E+00	4.982E-06	6.947E-05	1.051E-04
130	55133	6.681E-01	0.000E+00	0.000E+00	5.108E-06	7.122E-05	1.054E-04
131	56134	3.487E-04	0.000E+00	0.000E+00	2.646E-09	3.690E-08	5.500E-08
132	56136	6.853E-04	0.000E+00	0.000E+00	5.124E-09	7.144E-08	1.081E-07
133	56137	3.323E-02	0.000E+00	0.000E+00	2.466E-07	3.438E-06	5.240E-06
134	56138	7.040E-01	0.000E+00	0.000E+00	5.188E-06	7.233E-05	1.110E-04
135	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.855E-05	1.060E-04
136	58140	6.485E-01	0.000E+00	0.000E+00	4.710E-06	6.567E-05	1.023E-04
137	59141	6.044E-01	0.000E+00	0.000E+00	4.359E-06	6.077E-05	9.531E-05
138	60142	9.082E-05	0.000E+00	0.000E+00	6.503E-10	9.067E-09	1.432E-08
139	60143	6.305E-01	0.000E+00	0.000E+00	4.483E-06	6.250E-05	9.943E-05
140	60146	3.312E-01	0.000E+00	0.000E+00	2.306E-06	3.215E-05	5.223E-05
141	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.793E-05	2.952E-05
142	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.042E-06	1.175E-05
143	62150	7.263E-02	0.000E+00	0.000E+00	4.923E-07	6.864E-06	1.145E-05
144	62152	3.751E-02	0.000E+00	0.000E+00	2.509E-07	3.498E-06	5.915E-06
145	62154	8.784E-03	0.000E+00	0.000E+00	5.799E-08	8.085E-07	1.385E-06
146	63151	7.055E-04	0.000E+00	0.000E+00	4.750E-09	6.623E-08	1.113E-07
147	63153	1.871E-02	0.000E+00	0.000E+00	1.244E-07	1.734E-06	2.951E-06
148	64154	1.702E-05	0.000E+00	0.000E+00	1.124E-10	1.566E-09	2.684E-09
149	64155	6.948E-04	0.000E+00	0.000E+00	4.557E-09	6.354E-08	1.096E-07
150	64156	2.398E-03	0.000E+00	0.000E+00	1.563E-08	2.179E-07	3.782E-07
151	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.396E-08	2.439E-08
152	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.704E-09	6.595E-09
153	65159	1.293E-04	0.000E+00	0.000E+00	8.269E-10	1.153E-08	2.039E-08
154	66161	1.145E-05	0.000E+00	0.000E+00	7.229E-11	1.008E-09	1.805E-09
155	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.196E-10	3.959E-10
	totals	7.690E+02	8.710E+03	1.133E+01	4.788E-02	6.676E-01	1.213E-01

Full Power CINDER Module Output

nuclides with atom fractions below 1.000E-10 for a material are zeroed and deleted from print tables after t=0

neutronics and burnup data

step	duration (days)	time (days)	power (MW)	keff	flux	ave. nu	ave. q	burnup (GWd/MTU)	source (nts/sec)
0	0.000E+00	0.000E+00	2.000E-02	1.01544	3.293E+12	2.434	200.961	0.000E+00	1.512E+15
1	1.696E+03	1.696E+03	2.000E-02	0.99517	3.369E+12	2.436	200.997	6.070E+00	1.513E+15

nuclide data are sorted by decreasing activity for material 40000 volume 5.9261E+02 (cm**3)

actinide inventory for material 40000 at end of step 1, time 1.696E+03 (days), power 2.000E-02 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92239	3.258E-05	1.092E+03	3.351E+07	1.385E-10	1.929E-09	5.138E-09
2	93239	4.707E-03	1.092E+03	2.319E+05	2.001E-08	2.787E-07	7.424E-07
3	92237	3.116E-04	2.543E+01	8.160E+04	1.336E-09	1.860E-08	4.915E-08
4	94239	2.245E+00	1.392E-01	6.203E-02	9.543E-06	1.329E-04	3.541E-04
5	94241	1.030E-03	1.064E-01	1.033E+02	4.340E-09	6.045E-08	1.624E-07
6	92234	1.155E+01	7.180E-02	6.217E-03	5.014E-05	6.983E-04	1.821E-03
7	94240	3.209E-02	7.281E-03	2.269E-01	1.358E-07	1.892E-06	5.060E-06
8	94238	3.344E-04	5.726E-03	1.712E+01	1.428E-09	1.988E-08	5.274E-08
9	92235	1.055E+03	2.281E-03	2.161E-06	4.563E-03	6.355E-02	1.665E-01
10	92238	4.474E+03	1.504E-03	3.361E-07	1.910E-02	2.660E-01	7.055E-01
11	92236	1.114E+01	7.206E-04	6.467E-05	4.797E-05	6.681E-04	1.757E-03
12	93237	4.122E-02	2.905E-05	7.047E-04	1.767E-07	2.461E-06	6.501E-06
13	90230	1.486E-04	3.063E-06	2.062E-02	6.563E-10	9.141E-09	2.343E-08
14	91231	5.722E-06	2.703E-07	4.723E-02	2.517E-11	3.505E-10	9.024E-10
15	92233	7.423E-06	7.153E-08	9.636E-03	3.237E-11	4.508E-10	1.171E-09
16	94242	6.429E-06	2.542E-08	3.954E-03	2.699E-11	3.759E-10	1.014E-09
	totals	5.554E+03	2.209E+03	3.978E-01	2.377E-02	3.310E-01	8.759E-01

nonactinide inventory for material 40000 at end of step 1, time 1.696E+03 (days), power 2.000E-02 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	54133	5.889E-03	1.104E+03	1.874E+05	4.503E-08	6.271E-07	9.288E-07
2	41095	2.720E-02	1.070E+03	3.934E+04	2.913E-07	4.057E-06	4.290E-06
3	40095	4.978E-02	1.070E+03	2.149E+04	5.330E-07	7.423E-06	7.850E-06

4	53135	2.928E-04	1.035E+03	3.536E+06	2.205E-09	3.071E-08	4.617E-08
5	57140	1.838E-03	1.022E+03	5.561E+05	1.335E-08	1.860E-07	2.900E-07
6	54135	4.018E-04	1.021E+03	2.541E+06	3.027E-09	4.215E-08	6.337E-08
7	56140	1.395E-02	1.021E+03	7.318E+04	1.013E-07	1.411E-06	2.200E-06
8	42099	2.090E-03	1.004E+03	4.805E+05	2.147E-08	2.991E-07	3.296E-07
9	59143	1.451E-02	9.773E+02	6.733E+04	1.032E-07	1.437E-06	2.289E-06
10	58143	1.470E-03	9.769E+02	6.645E+05	1.045E-08	1.456E-07	2.319E-07
11	58141	3.373E-02	9.616E+02	2.851E+04	2.432E-07	3.388E-06	5.319E-06
12	39091	3.897E-02	9.567E+02	2.455E+04	4.356E-07	6.067E-06	6.146E-06
13	58144	2.811E-01	8.952E+02	3.185E+03	1.985E-06	2.764E-05	4.433E-05
14	38089	2.671E-02	7.759E+02	2.905E+04	3.053E-07	4.251E-06	4.212E-06
15	52132	2.335E-03	7.092E+02	3.038E+05	1.798E-08	2.505E-07	3.682E-07
16	44103	1.556E-02	5.028E+02	3.232E+04	1.536E-07	2.140E-06	2.454E-06
17	53131	3.847E-03	4.773E+02	1.241E+05	2.986E-08	4.159E-07	6.067E-07
18	60147	4.565E-03	3.695E+02	8.094E+04	3.158E-08	4.398E-07	7.200E-07
19	61147	2.812E-01	2.608E+02	9.276E+02	1.945E-06	2.709E-05	4.435E-05
20	61149	4.505E-04	1.786E+02	3.964E+05	3.074E-09	4.281E-08	7.105E-08
21	44105	2.432E-05	1.636E+02	6.728E+06	2.356E-10	3.281E-09	3.836E-09
22	45105	1.931E-04	1.631E+02	8.448E+05	1.871E-09	2.605E-08	3.046E-08
23	55137	1.212E+00	1.055E+02	8.704E+01	8.998E-06	1.253E-04	1.912E-04
24	38090	7.377E-01	1.042E+02	1.413E+02	8.338E-06	1.161E-04	1.163E-04
25	39090	1.913E-04	1.040E+02	5.438E+05	2.163E-09	3.012E-08	3.018E-08
26	61151	9.504E-05	6.949E+01	7.311E+05	6.399E-10	8.912E-09	1.499E-08
27	44106	2.012E-02	6.677E+01	3.318E+03	1.931E-07	2.689E-06	3.174E-06
28	62153	6.553E-05	2.902E+01	4.429E+05	4.355E-10	6.065E-09	1.034E-08
29	36085	3.015E-02	1.184E+01	3.927E+02	3.609E-07	5.026E-06	4.756E-06
30	51125	3.777E-03	3.960E+00	1.048E+03	3.073E-08	4.279E-07	5.957E-07
31	63156	7.078E-05	3.902E+00	5.513E+04	4.613E-10	6.425E-09	1.116E-08
32	61148	2.097E-05	3.448E+00	1.644E+05	1.441E-10	2.007E-09	3.308E-09
33	55134	2.411E-03	3.122E+00	1.295E+03	1.830E-08	2.549E-07	3.803E-07
34	47111	1.820E-05	2.877E+00	1.580E+05	1.668E-10	2.323E-09	2.871E-09
35	63155	4.709E-03	2.322E+00	4.931E+02	3.089E-08	4.302E-07	7.427E-07
36	62151	6.966E-02	1.833E+00	2.632E+01	4.690E-07	6.532E-06	1.099E-05
37	55136	2.497E-05	1.823E+00	7.301E+04	1.867E-10	2.600E-09	3.938E-09
38	50125	1.473E-05	1.597E+00	1.084E+05	1.198E-10	1.669E-09	2.323E-09
39	50123	2.456E-05	2.020E-01	8.223E+03	2.031E-10	2.828E-09	3.874E-09
40	51126	1.782E-06	1.490E-01	8.363E+04	1.438E-11	2.003E-10	2.811E-10
41	63154	5.292E-04	1.430E-01	2.703E+02	3.493E-09	4.865E-08	8.345E-08
42	63152	1.120E-04	1.978E-02	1.765E+02	7.494E-10	1.044E-08	1.767E-08
43	43099	9.073E-01	1.554E-02	1.712E-02	9.322E-06	1.298E-04	1.431E-04
44	40093	8.873E-01	2.231E-03	2.515E-03	9.705E-06	1.352E-04	1.399E-04
45	55135	1.262E+00	1.454E-03	1.152E-03	9.504E-06	1.324E-04	1.990E-04
46	34079	5.303E-03	7.280E-04	1.373E-01	6.829E-08	9.510E-07	8.364E-07
47	50126	1.072E-02	3.044E-04	2.839E-02	8.653E-08	1.205E-06	1.691E-06
48	53129	1.060E-01	1.873E-05	1.766E-04	8.360E-07	1.164E-05	1.672E-05
49	46107	2.525E-02	1.299E-05	5.145E-04	2.400E-07	3.343E-06	3.982E-06
50	37087	3.374E-01	2.891E-08	8.570E-08	3.945E-06	5.494E-05	5.321E-05
51	62147	2.065E-01	4.741E-09	2.296E-08	1.428E-06	1.989E-05	3.257E-05
52	60144	9.220E-01	1.095E-12	1.188E-12	6.511E-06	9.068E-05	1.454E-04
53	57138	6.741E-06	1.664E-13	2.469E-08	4.967E-11	6.918E-10	1.063E-09
54	62149	5.443E-02	6.533E-14	1.200E-12	3.714E-07	5.173E-06	8.584E-06
55	58142	1.250E+00	6.304E-14	5.042E-14	8.954E-06	1.247E-04	1.972E-04
56	60145	8.573E-01	3.525E-14	4.112E-14	6.012E-06	8.373E-05	1.352E-04
57	49115	2.030E-03	1.432E-14	7.055E-12	1.795E-08	2.500E-07	3.201E-07
58	62148	5.577E-03	1.701E-15	3.051E-13	3.832E-08	5.336E-07	8.796E-07
59	64152	5.927E-05	1.291E-15	2.179E-11	3.964E-10	5.521E-09	9.347E-09
60	48113	1.071E-03	3.648E-16	3.405E-13	9.643E-09	1.343E-07	1.690E-07
61	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.909E-06	6.307E-06
62	8016	7.496E+02	0.000E+00	0.000E+00	4.762E-02	6.633E-01	1.182E-01
63	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.399E-04	4.545E-05
64	7015	2.497E-06	0.000E+00	0.000E+00	1.692E-10	2.356E-09	3.938E-10
65	8018	1.537E+00	0.000E+00	0.000E+00	8.676E-05	1.208E-03	2.424E-04
66	31071	9.399E-07	0.000E+00	0.000E+00	1.347E-11	1.875E-10	1.482E-10
67	32072	2.950E-06	0.000E+00	0.000E+00	4.168E-11	5.804E-10	4.652E-10
68	32073	1.127E-05	0.000E+00	0.000E+00	1.571E-10	2.188E-09	1.778E-09
69	32074	3.812E-05	0.000E+00	0.000E+00	5.240E-10	7.298E-09	6.012E-09
70	32076	3.532E-04	0.000E+00	0.000E+00	4.727E-09	6.583E-08	5.570E-08
71	33075	1.200E-04	0.000E+00	0.000E+00	1.628E-09	2.267E-08	1.892E-08
72	34077	9.168E-04	0.000E+00	0.000E+00	1.211E-08	1.687E-07	1.446E-07
73	34078	2.458E-03	0.000E+00	0.000E+00	3.206E-08	4.464E-07	3.876E-07
74	34080	1.545E-02	0.000E+00	0.000E+00	1.964E-07	2.736E-06	2.436E-06
75	35081	2.473E-02	0.000E+00	0.000E+00	3.105E-07	4.325E-06	3.900E-06
76	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.749E-09	2.509E-09
77	36083	6.688E-02	0.000E+00	0.000E+00	8.196E-07	1.142E-05	1.055E-05
78	36084	1.241E-01	0.000E+00	0.000E+00	1.503E-06	2.093E-05	1.957E-05
79	36086	2.716E-01	0.000E+00	0.000E+00	3.213E-06	4.474E-05	4.284E-05
80	37085	1.233E-01	0.000E+00	0.000E+00	1.476E-06	2.055E-05	1.945E-05
81	38086	8.978E-06	0.000E+00	0.000E+00	1.062E-10	1.479E-09	1.416E-09
82	38088	4.692E-01	0.000E+00	0.000E+00	5.425E-06	7.555E-05	7.401E-05
83	39089	6.055E-01	0.000E+00	0.000E+00	6.921E-06	9.640E-05	9.550E-05
84	40090	4.310E-02	0.000E+00	0.000E+00	4.872E-07	6.785E-06	6.797E-06
85	40091	7.576E-01	0.000E+00	0.000E+00	8.469E-06	1.179E-04	1.195E-04

86	40092	8.325E-01	0.000E+00	0.000E+00	9.205E-06	1.282E-04	1.313E-04
87	40094	9.145E-01	0.000E+00	0.000E+00	9.896E-06	1.378E-04	1.442E-04
88	40096	9.162E-01	0.000E+00	0.000E+00	9.708E-06	1.352E-04	1.445E-04
89	42095	8.520E-01	0.000E+00	0.000E+00	9.122E-06	1.270E-04	1.344E-04
90	42096	8.353E-04	0.000E+00	0.000E+00	8.851E-09	1.233E-07	1.317E-07
91	42097	8.807E-01	0.000E+00	0.000E+00	9.236E-06	1.286E-04	1.389E-04
92	42098	8.489E-01	0.000E+00	0.000E+00	8.811E-06	1.227E-04	1.339E-04
93	42100	9.489E-01	0.000E+00	0.000E+00	9.651E-06	1.344E-04	1.497E-04
94	44099	3.652E-05	0.000E+00	0.000E+00	3.752E-10	5.225E-09	5.759E-09
95	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.790E-10	1.992E-10
96	44101	7.892E-01	0.000E+00	0.000E+00	7.948E-06	1.107E-04	1.245E-04
97	44102	6.613E-01	0.000E+00	0.000E+00	6.594E-06	9.184E-05	1.043E-04
98	44104	2.989E-01	0.000E+00	0.000E+00	2.923E-06	4.071E-05	4.713E-05
99	45103	4.547E-01	0.000E+00	0.000E+00	4.490E-06	6.253E-05	7.171E-05
100	46105	1.563E-01	0.000E+00	0.000E+00	1.514E-06	2.108E-05	2.465E-05
101	46106	4.719E-02	0.000E+00	0.000E+00	4.528E-07	6.307E-06	7.443E-06
102	46108	9.557E-03	0.000E+00	0.000E+00	9.000E-08	1.253E-06	1.507E-06
103	46110	4.414E-03	0.000E+00	0.000E+00	4.081E-08	5.684E-07	6.961E-07
104	47109	5.371E-03	0.000E+00	0.000E+00	5.012E-08	6.980E-07	8.472E-07
105	48110	2.040E-06	0.000E+00	0.000E+00	1.886E-11	2.627E-10	3.217E-10
106	48111	2.928E-03	0.000E+00	0.000E+00	2.683E-08	3.736E-07	4.618E-07
107	48112	2.255E-03	0.000E+00	0.000E+00	2.047E-08	2.852E-07	3.556E-07
108	48114	3.459E-03	0.000E+00	0.000E+00	3.086E-08	4.298E-07	5.456E-07
109	48116	2.357E-03	0.000E+00	0.000E+00	2.067E-08	2.878E-07	3.717E-07
110	49113	2.529E-06	0.000E+00	0.000E+00	2.277E-11	3.171E-10	3.989E-10
111	50115	1.060E-04	0.000E+00	0.000E+00	9.379E-10	1.306E-08	1.673E-08
112	50116	1.861E-05	0.000E+00	0.000E+00	1.632E-10	2.273E-09	2.936E-09
113	50117	2.282E-03	0.000E+00	0.000E+00	1.984E-08	2.763E-07	3.599E-07
114	50118	2.064E-03	0.000E+00	0.000E+00	1.779E-08	2.477E-07	3.255E-07
115	50119	2.348E-03	0.000E+00	0.000E+00	2.007E-08	2.795E-07	3.703E-07
116	50120	2.319E-03	0.000E+00	0.000E+00	1.966E-08	2.738E-07	3.658E-07
117	50122	2.888E-03	0.000E+00	0.000E+00	2.407E-08	3.352E-07	4.554E-07
118	50124	5.048E-03	0.000E+00	0.000E+00	4.140E-08	5.766E-07	7.961E-07
119	51121	2.282E-03	0.000E+00	0.000E+00	1.918E-08	2.671E-07	3.599E-07
120	51123	2.928E-03	0.000E+00	0.000E+00	2.421E-08	3.372E-07	4.618E-07
121	52122	2.643E-06	0.000E+00	0.000E+00	2.203E-11	3.068E-10	4.168E-10
122	52124	3.697E-06	0.000E+00	0.000E+00	3.032E-11	4.223E-10	5.831E-10
123	52125	2.616E-03	0.000E+00	0.000E+00	2.129E-08	2.964E-07	4.126E-07
124	52126	4.481E-04	0.000E+00	0.000E+00	3.617E-09	5.037E-08	7.067E-08
125	52128	6.726E-02	0.000E+00	0.000E+00	5.344E-07	7.442E-06	1.061E-05
126	52130	3.554E-01	0.000E+00	0.000E+00	2.780E-06	3.872E-05	5.605E-05
127	53127	2.955E-02	0.000E+00	0.000E+00	2.366E-07	3.295E-06	4.660E-06
128	54128	2.377E-05	0.000E+00	0.000E+00	1.889E-10	2.631E-09	3.749E-09
129	54130	1.351E-04	0.000E+00	0.000E+00	1.057E-09	1.472E-08	2.130E-08
130	54131	5.643E-01	0.000E+00	0.000E+00	4.381E-06	6.101E-05	8.900E-05
131	54132	8.624E-01	0.000E+00	0.000E+00	6.644E-06	9.253E-05	1.360E-04
132	54134	1.591E+00	0.000E+00	0.000E+00	1.207E-05	1.681E-04	2.509E-04
133	54136	1.366E+00	0.000E+00	0.000E+00	1.022E-05	1.423E-04	2.155E-04
134	55133	1.334E+00	0.000E+00	0.000E+00	1.020E-05	1.420E-04	2.103E-04
135	56134	1.398E-03	0.000E+00	0.000E+00	1.061E-08	1.478E-07	2.205E-07
136	56135	1.039E-06	0.000E+00	0.000E+00	7.825E-12	1.090E-10	1.638E-10
137	56136	1.613E-03	0.000E+00	0.000E+00	1.206E-08	1.679E-07	2.543E-07
138	56137	6.658E-02	0.000E+00	0.000E+00	4.942E-07	6.883E-06	1.050E-05
139	56138	1.407E+00	0.000E+00	0.000E+00	1.037E-05	1.444E-04	2.220E-04
140	57139	1.343E+00	0.000E+00	0.000E+00	9.824E-06	1.368E-04	2.118E-04
141	58140	1.296E+00	0.000E+00	0.000E+00	9.413E-06	1.311E-04	2.044E-04
142	59141	1.208E+00	0.000E+00	0.000E+00	8.709E-06	1.213E-04	1.905E-04
143	60142	3.190E-04	0.000E+00	0.000E+00	2.284E-09	3.181E-08	5.031E-08
144	60143	1.254E+00	0.000E+00	0.000E+00	8.916E-06	1.242E-04	1.978E-04
145	60146	6.627E-01	0.000E+00	0.000E+00	4.615E-06	6.428E-05	1.045E-04
146	60148	3.740E-01	0.000E+00	0.000E+00	2.569E-06	3.578E-05	5.898E-05
147	60150	1.489E-01	0.000E+00	0.000E+00	1.009E-06	1.406E-05	2.348E-05
148	62150	1.898E-01	0.000E+00	0.000E+00	1.287E-06	1.792E-05	2.994E-05
149	62152	8.574E-02	0.000E+00	0.000E+00	5.735E-07	7.987E-06	1.352E-05
150	62154	1.755E-02	0.000E+00	0.000E+00	1.159E-07	1.613E-06	2.768E-06
151	63151	1.176E-03	0.000E+00	0.000E+00	7.921E-09	1.103E-07	1.855E-07
152	63153	3.801E-02	0.000E+00	0.000E+00	2.526E-07	3.518E-06	5.995E-06
153	64154	6.732E-05	0.000E+00	0.000E+00	4.444E-10	6.190E-09	1.062E-08
154	64155	9.508E-04	0.000E+00	0.000E+00	6.237E-09	8.686E-08	1.500E-07
155	64156	5.661E-03	0.000E+00	0.000E+00	3.689E-08	5.138E-07	8.928E-07
156	64157	1.550E-04	0.000E+00	0.000E+00	1.004E-09	1.398E-08	2.445E-08
157	64160	8.376E-05	0.000E+00	0.000E+00	5.322E-10	7.412E-09	1.321E-08
158	65159	2.600E-04	0.000E+00	0.000E+00	1.663E-09	2.316E-08	4.101E-08
159	66161	2.237E-05	0.000E+00	0.000E+00	1.412E-10	1.967E-09	3.528E-09
160	66162	5.873E-06	0.000E+00	0.000E+00	3.686E-11	5.133E-10	9.263E-10
161	66163	2.023E-06	0.000E+00	0.000E+00	1.261E-11	1.757E-10	3.190E-10
	totals	7.866E+02	1.723E+04	2.191E+01	4.803E-02	6.690E-01	1.241E-01

Annex W

Decay Results

CINDER Module Output File Excerpt

Half Power (10 kW_t)

Step 1 - 5 years

actinide inventory for material 40000 at end of step 1, time 1.825E+03 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92234	1.161E+01	7.220E-02	6.217E-03	5.043E-05	7.030E-04	1.832E-03
2	94239	1.147E+00	7.112E-02	6.203E-02	4.874E-06	6.795E-05	1.808E-04
3	94241	1.037E-04	1.072E-02	1.033E+02	4.372E-10	6.094E-09	1.635E-08
4	92235	1.076E+03	2.327E-03	2.161E-06	4.654E-03	6.488E-02	1.698E-01
5	94240	8.206E-03	1.862E-03	2.269E-01	3.474E-08	4.842E-07	1.294E-06
6	92238	4.475E+03	1.504E-03	3.361E-07	1.910E-02	2.663E-01	7.057E-01
7	94238	6.282E-05	1.076E-03	1.712E+01	2.682E-10	3.738E-09	9.907E-09
8	92236	7.693E+00	4.975E-04	6.467E-05	3.312E-05	4.617E-04	1.213E-03
9	95241	2.819E-05	9.662E-05	3.427E+00	1.188E-10	1.657E-09	4.446E-09
10	93237	1.782E-02	1.256E-05	7.047E-04	7.641E-08	1.065E-06	2.811E-06
11	90230	3.104E-04	6.399E-06	2.062E-02	1.371E-09	1.911E-08	4.895E-08
12	91231	1.053E-05	4.975E-07	4.723E-02	4.632E-11	6.458E-10	1.661E-09
13	92233	3.782E-06	3.644E-08	9.636E-03	1.649E-11	2.299E-10	5.964E-10
	totals	5.572E+03	1.614E-01	2.897E-05	2.384E-02	3.324E-01	8.787E-01

nonactinide inventory for material 40000 at end of step 1, time 1.825E+03 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	5.401E-01	4.701E+01	8.704E+01	4.009E-06	5.589E-05	8.518E-05
2	39090	8.488E-05	4.615E+01	5.438E+05	9.593E-10	1.337E-08	1.339E-08
3	38090	3.267E-01	4.614E+01	1.413E+02	3.692E-06	5.147E-05	5.152E-05
4	61147	3.851E-02	3.572E+01	9.276E+02	2.664E-07	3.714E-06	6.074E-06
5	58144	1.669E-03	5.315E+00	3.185E+03	1.178E-08	1.643E-07	2.632E-07
6	36085	1.093E-02	4.294E+00	3.927E+02	1.309E-07	1.824E-06	1.724E-06
7	44106	3.359E-04	1.114E+00	3.318E+03	3.223E-09	4.493E-08	5.297E-08
8	62151	3.893E-02	1.025E+00	2.632E+01	2.621E-07	3.654E-06	6.139E-06
9	63155	1.221E-03	6.022E-01	4.931E+02	8.012E-09	1.117E-07	1.926E-07
10	51125	5.334E-04	5.592E-01	1.048E+03	4.340E-09	6.050E-08	8.412E-08
11	55134	1.124E-04	1.455E-01	1.295E+03	8.527E-10	1.189E-08	1.772E-08
12	63154	8.887E-05	2.402E-02	2.703E+02	5.867E-10	8.179E-09	1.402E-08
13	43099	4.556E-01	7.801E-03	1.712E-02	4.681E-06	6.526E-05	7.185E-05
14	63152	2.627E-05	4.638E-03	1.765E+02	1.757E-10	2.450E-09	4.144E-09
15	40093	4.442E-01	1.117E-03	2.515E-03	4.858E-06	6.773E-05	7.005E-05
16	55135	6.488E-01	7.475E-04	1.152E-03	4.887E-06	6.813E-05	1.023E-04
17	34079	2.657E-03	3.647E-04	1.373E-01	3.421E-08	4.769E-07	4.190E-07
18	50126	5.352E-03	1.520E-04	2.839E-02	4.320E-08	6.022E-07	8.440E-07
19	53129	5.306E-02	9.372E-06	1.766E-04	4.183E-07	5.831E-06	8.368E-06
20	46107	1.270E-02	6.534E-06	5.145E-04	1.207E-07	1.683E-06	2.003E-06
21	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.753E-05	2.664E-05
22	62147	2.094E-01	4.806E-09	2.296E-08	1.448E-06	2.019E-05	3.302E-05
23	60144	5.978E-01	7.100E-13	1.188E-12	4.221E-06	5.885E-05	9.427E-05
24	57138	3.328E-06	8.217E-14	2.469E-08	2.453E-11	3.419E-10	5.249E-10
25	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.744E-06	7.864E-06
26	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.246E-05	9.867E-05
27	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.200E-05	6.775E-05
28	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.274E-07	1.630E-07
29	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.368E-07	2.253E-07
30	64152	1.912E-05	4.166E-16	2.179E-11	1.279E-10	1.783E-09	3.015E-09
31	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.799E-08	1.232E-07
32	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.462E-06	3.157E-06
33	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.903E-10	2.324E-10
34	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.097E-09	8.905E-10
35	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.656E-09	3.009E-09
36	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.299E-08	2.788E-08
37	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.136E-08	9.475E-09
38	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.457E-08	7.242E-08
39	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.236E-07	1.940E-07
40	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.371E-06	1.220E-06
41	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.168E-06	1.953E-06
42	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.786E-10	8.924E-10
43	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.738E-06	5.296E-06
44	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.046E-05	9.771E-06
45	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.242E-05	2.144E-05
46	37085	6.591E-02	0.000E+00	0.000E+00	7.887E-07	1.100E-05	1.039E-05
47	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.111E-10	3.932E-10
48	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.785E-05	3.704E-05
49	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.044E-05	4.992E-05
50	40090	6.419E-02	0.000E+00	0.000E+00	7.255E-07	1.011E-05	1.012E-05
51	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.215E-05	6.289E-05
52	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.424E-05	6.572E-05
53	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.906E-05	7.219E-05
54	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.775E-05	7.234E-05
55	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.943E-05	7.335E-05
56	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.358E-08	3.585E-08

57	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.447E-05	6.955E-05
58	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.150E-05	6.703E-05
59	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.736E-05	7.492E-05
60	44099	2.579E-05	0.000E+00	0.000E+00	2.650E-10	3.694E-09	4.067E-09
61	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.549E-05	6.233E-05
62	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.601E-05	5.220E-05
63	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.039E-05	2.359E-05
64	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.255E-05	3.729E-05
65	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.058E-05	1.236E-05
66	46106	3.326E-02	0.000E+00	0.000E+00	3.191E-07	4.449E-06	5.245E-06
67	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.278E-07	7.541E-07
68	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.848E-07	3.485E-07
69	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.515E-07	4.261E-07
70	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.885E-07	2.327E-07
71	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.428E-07	1.779E-07
72	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.842E-07	2.336E-07
73	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.442E-07	1.861E-07
74	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.024E-10	2.544E-10
75	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.550E-09	8.378E-09
76	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.726E-10	7.388E-10
77	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.384E-07	1.801E-07
78	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.241E-07	1.629E-07
79	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.399E-07	1.852E-07
80	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.372E-07	1.831E-07
81	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.679E-07	2.279E-07
82	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.885E-07	3.979E-07
83	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.339E-07	1.802E-07
84	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.703E-07	2.330E-07
85	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.586E-10	2.188E-10
86	52125	2.661E-03	0.000E+00	0.000E+00	2.165E-08	3.018E-07	4.196E-07
87	52126	2.236E-04	0.000E+00	0.000E+00	1.805E-09	2.516E-08	3.527E-08
88	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.728E-06	5.308E-06
89	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.938E-05	2.803E-05
90	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.646E-06	2.325E-06
91	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.736E-10	3.896E-10
92	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.837E-09	6.995E-09
93	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.086E-05	4.497E-05
94	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.633E-05	6.803E-05
95	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.422E-05	1.255E-04
96	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.947E-05	1.051E-04
97	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.154E-05	1.058E-04
98	56134	8.391E-04	0.000E+00	0.000E+00	6.368E-09	8.877E-08	1.323E-07
99	56135	9.769E-07	0.000E+00	0.000E+00	7.359E-12	1.026E-10	1.541E-10
100	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.243E-08	1.096E-07
101	56137	9.932E-02	0.000E+00	0.000E+00	7.372E-07	1.028E-05	1.566E-05
102	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.233E-05	1.110E-04
103	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.855E-05	1.060E-04
104	58140	6.556E-01	0.000E+00	0.000E+00	4.762E-06	6.638E-05	1.034E-04
105	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.248E-05	9.801E-05
106	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.067E-09	1.432E-08
107	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.330E-05	1.007E-04
108	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.215E-05	5.222E-05
109	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.793E-05	2.952E-05
110	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.042E-06	1.175E-05
111	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.864E-06	1.146E-05
112	62152	3.752E-02	0.000E+00	0.000E+00	2.510E-07	3.499E-06	5.917E-06
113	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.085E-07	1.385E-06
114	63151	2.233E-03	0.000E+00	0.000E+00	1.503E-08	2.096E-07	3.521E-07
115	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.737E-06	2.957E-06
116	64154	6.112E-05	0.000E+00	0.000E+00	4.036E-10	5.626E-09	9.640E-09
117	64155	2.034E-03	0.000E+00	0.000E+00	1.334E-08	1.860E-07	3.207E-07
118	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.206E-07	3.829E-07
119	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.396E-08	2.439E-08
120	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.704E-09	6.594E-09
121	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.153E-08	2.040E-08
122	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.008E-09	1.806E-09
123	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.196E-10	3.959E-10
124	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.640E-01	1.182E-01
125	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.546E-05
126	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.180E-09	1.970E-10
127	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.210E-03	2.424E-04
	totals	7.691E+02	1.881E+02	2.446E-01	4.789E-02	6.676E-01	1.213E-01

Step 2 - 10 years

actinide inventory for material 40000 at end of step 2, time 3.650E+03 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92234	1.161E+01	7.220E-02	6.217E-03	5.043E-05	7.030E-04	1.832E-03
2	94239	1.146E+00	7.111E-02	6.203E-02	4.874E-06	6.794E-05	1.808E-04

3	94241	8.146E-05	8.419E-03	1.033E+02	3.434E-10	4.788E-09	1.285E-08
4	92235	1.076E+03	2.327E-03	2.161E-06	4.654E-03	6.488E-02	1.698E-01
5	94240	8.201E-03	1.861E-03	2.269E-01	3.472E-08	4.840E-07	1.293E-06
6	92238	4.475E+03	1.504E-03	3.361E-07	1.910E-02	2.663E-01	7.057E-01
7	94238	6.039E-05	1.034E-03	1.712E+01	2.578E-10	3.594E-09	9.523E-09
8	92236	7.693E+00	4.975E-04	6.467E-05	3.312E-05	4.617E-04	1.213E-03
9	95241	5.011E-05	1.717E-04	3.427E+00	2.112E-10	2.945E-09	7.903E-09
10	93237	1.782E-02	1.256E-05	7.047E-04	7.641E-08	1.065E-06	2.811E-06
11	90230	4.713E-04	9.716E-06	2.062E-02	2.082E-09	2.902E-08	7.432E-08
12	91231	1.574E-05	7.434E-07	4.723E-02	6.922E-11	9.650E-10	2.482E-09
13	92233	3.810E-06	3.671E-08	9.636E-03	1.661E-11	2.316E-10	6.008E-10
14	90232	2.237E-06	2.453E-13	1.097E-07	9.795E-12	1.366E-10	3.527E-10
totals		5.572E+03	1.591E-01	2.856E-05	2.384E-02	3.324E-01	8.787E-01

nonactinide inventory for material 40000 at end of step 2, time 3.650E+03 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	4.812E-01	4.189E+01	8.704E+01	3.572E-06	4.980E-05	7.589E-05
2	39090	7.505E-05	4.081E+01	5.438E+05	8.483E-10	1.183E-08	1.184E-08
3	38090	2.888E-01	4.080E+01	1.413E+02	3.265E-06	4.551E-05	4.555E-05
4	61147	1.029E-02	9.541E+00	9.276E+02	7.115E-08	9.919E-07	1.622E-06
5	36085	7.916E-03	3.109E+00	3.927E+02	9.473E-08	1.321E-06	1.248E-06
6	62151	3.746E-02	9.859E-01	2.632E+01	2.522E-07	3.516E-06	5.907E-06
7	63155	5.827E-04	2.873E-01	4.931E+02	3.822E-09	5.329E-08	9.190E-08
8	51125	1.500E-04	1.573E-01	1.048E+03	1.220E-09	1.701E-08	2.366E-08
9	58144	1.968E-05	6.268E-02	3.185E+03	1.390E-10	1.938E-09	3.104E-09
10	44106	1.116E-05	3.703E-02	3.318E+03	1.071E-10	1.493E-09	1.760E-09
11	55134	2.095E-05	2.712E-02	1.295E+03	1.590E-10	2.216E-09	3.304E-09
12	63154	5.939E-05	1.605E-02	2.703E+02	3.921E-10	5.466E-09	9.366E-09
13	43099	4.556E-01	7.801E-03	1.712E-02	4.681E-06	6.526E-05	7.185E-05
14	63152	2.026E-05	3.577E-03	1.765E+02	1.355E-10	1.889E-09	3.196E-09
15	40093	4.442E-01	1.117E-03	2.515E-03	4.858E-06	6.773E-05	7.005E-05
16	55135	6.488E-01	7.475E-04	1.152E-03	4.887E-06	6.813E-05	1.023E-04
17	34079	2.657E-03	3.647E-04	1.373E-01	3.421E-08	4.769E-07	4.190E-07
18	50126	5.352E-03	1.520E-04	2.839E-02	4.319E-08	6.022E-07	8.440E-07
19	53129	5.306E-02	9.372E-06	1.766E-04	4.183E-07	5.831E-06	8.368E-06
20	46107	1.270E-02	6.534E-06	5.145E-04	1.207E-07	1.683E-06	2.003E-06
21	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.753E-05	2.664E-05
22	62147	2.376E-01	5.454E-09	2.296E-08	1.643E-06	2.291E-05	3.747E-05
23	60144	5.994E-01	7.120E-13	1.188E-12	4.233E-06	5.901E-05	9.453E-05
24	57138	3.328E-06	8.217E-14	2.469E-08	2.453E-11	3.419E-10	5.249E-10
25	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.744E-06	7.864E-06
26	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.246E-05	9.867E-05
27	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.200E-05	6.775E-05
28	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.274E-07	1.630E-07
29	64152	2.080E-05	4.532E-16	2.179E-11	1.391E-10	1.939E-09	3.280E-09
30	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.368E-07	2.253E-07
31	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.799E-08	1.232E-07
32	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.462E-06	3.157E-06
33	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.903E-10	2.324E-10
34	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.097E-09	8.905E-10
35	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.656E-09	3.009E-09
36	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.299E-08	2.788E-08
37	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.136E-08	9.475E-09
38	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.457E-08	7.242E-08
39	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.236E-07	1.940E-07
40	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.371E-06	1.220E-06
41	35079	5.577E-07	0.000E+00	0.000E+00	7.181E-12	1.001E-10	8.795E-11
42	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.168E-06	1.953E-06
43	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.786E-10	8.924E-10
44	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.738E-06	5.296E-06
45	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.046E-05	9.771E-06
46	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.242E-05	2.144E-05
47	37085	6.892E-02	0.000E+00	0.000E+00	8.249E-07	1.150E-05	1.087E-05
48	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.111E-10	3.932E-10
49	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.785E-05	3.704E-05
50	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.044E-05	4.992E-05
51	40090	1.019E-01	0.000E+00	0.000E+00	1.152E-06	1.606E-05	1.607E-05
52	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.215E-05	6.289E-05
53	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.424E-05	6.572E-05
54	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.906E-05	7.219E-05
55	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.775E-05	7.234E-05
56	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.943E-05	7.335E-05
57	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.358E-08	3.585E-08
58	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.447E-05	6.955E-05
59	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.150E-05	6.703E-05
60	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.736E-05	7.492E-05
61	44099	3.326E-05	0.000E+00	0.000E+00	3.418E-10	4.764E-09	5.246E-09
62	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.549E-05	6.233E-05
63	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.601E-05	5.220E-05
64	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.039E-05	2.359E-05

65	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.255E-05	3.729E-05
66	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.058E-05	1.236E-05
67	46106	3.358E-02	0.000E+00	0.000E+00	3.223E-07	4.492E-06	5.296E-06
68	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.278E-07	7.541E-07
69	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.848E-07	3.485E-07
70	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.515E-07	4.261E-07
71	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.885E-07	2.327E-07
72	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.428E-07	1.779E-07
73	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.842E-07	2.336E-07
74	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.442E-07	1.861E-07
75	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.024E-10	2.544E-10
76	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.550E-09	8.378E-09
77	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.726E-10	7.388E-10
78	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.384E-07	1.801E-07
79	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.241E-07	1.629E-07
80	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.399E-07	1.852E-07
81	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.372E-07	1.831E-07
82	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.679E-07	2.279E-07
83	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.885E-07	3.979E-07
84	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.339E-07	1.802E-07
85	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.703E-07	2.330E-07
86	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.586E-10	2.188E-10
87	52125	3.050E-03	0.000E+00	0.000E+00	2.481E-08	3.459E-07	4.809E-07
88	52126	2.238E-04	0.000E+00	0.000E+00	1.806E-09	2.518E-08	3.529E-08
89	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.728E-06	5.308E-06
90	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.938E-05	2.803E-05
91	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.646E-06	2.325E-06
92	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.736E-10	3.896E-10
93	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.837E-09	6.995E-09
94	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.086E-05	4.497E-05
95	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.633E-05	6.803E-05
96	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.422E-05	1.255E-04
97	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.947E-05	1.051E-04
98	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.154E-05	1.058E-04
99	56134	9.305E-04	0.000E+00	0.000E+00	7.062E-09	9.844E-08	1.467E-07
100	56135	1.954E-06	0.000E+00	0.000E+00	1.472E-11	2.052E-10	3.081E-10
101	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.243E-08	1.096E-07
102	56137	1.582E-01	0.000E+00	0.000E+00	1.174E-06	1.637E-05	2.495E-05
103	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.233E-05	1.110E-04
104	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.855E-05	1.060E-04
105	58140	6.556E-01	0.000E+00	0.000E+00	4.762E-06	6.638E-05	1.034E-04
106	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.248E-05	9.801E-05
107	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.067E-09	1.432E-08
108	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.330E-05	1.007E-04
109	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.215E-05	5.222E-05
110	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.793E-05	2.952E-05
111	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.042E-06	1.175E-05
112	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.864E-06	1.146E-05
113	62152	3.752E-02	0.000E+00	0.000E+00	2.510E-07	3.499E-06	5.917E-06
114	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.085E-07	1.385E-06
115	63151	3.702E-03	0.000E+00	0.000E+00	2.493E-08	3.475E-07	5.839E-07
116	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.737E-06	2.957E-06
117	64154	9.060E-05	0.000E+00	0.000E+00	5.982E-10	8.339E-09	1.429E-08
118	64155	2.672E-03	0.000E+00	0.000E+00	1.753E-08	2.444E-07	4.214E-07
119	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.206E-07	3.829E-07
120	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.396E-08	2.439E-08
121	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.704E-09	6.594E-09
122	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.153E-08	2.040E-08
123	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.008E-09	1.806E-09
124	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.196E-10	3.959E-10
125	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.640E-01	1.182E-01
126	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.546E-05
127	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.180E-09	1.970E-10
128	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.210E-03	2.424E-04
	totals	7.691E+02	1.377E+02	1.791E-01	4.789E-02	6.676E-01	1.213E-01

Step 3 - 15 years

actinide inventory for material 40000 at end of step 3, time 5.475E+03 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92234	1.161E+01	7.220E-02	6.217E-03	5.043E-05	7.030E-04	1.832E-03
2	94239	1.146E+00	7.110E-02	6.203E-02	4.873E-06	6.793E-05	1.808E-04
3	94241	6.399E-05	6.614E-03	1.033E+02	2.698E-10	3.761E-09	1.009E-08
4	92235	1.076E+03	2.327E-03	2.161E-06	4.654E-03	6.488E-02	1.698E-01
5	94240	8.197E-03	1.860E-03	2.269E-01	3.470E-08	4.837E-07	1.293E-06
6	92238	4.475E+03	1.504E-03	3.361E-07	1.910E-02	2.663E-01	7.057E-01
7	94238	5.805E-05	9.940E-04	1.712E+01	2.478E-10	3.454E-09	9.155E-09
8	92236	7.693E+00	4.975E-04	6.467E-05	3.312E-05	4.617E-04	1.213E-03
9	95241	6.711E-05	2.300E-04	3.427E+00	2.829E-10	3.944E-09	1.058E-08

10	90230	6.321E-04	1.303E-05	2.062E-02	2.793E-09	3.893E-08	9.969E-08
11	93237	1.783E-02	1.256E-05	7.047E-04	7.641E-08	1.065E-06	2.811E-06
12	91231	2.094E-05	9.893E-07	4.723E-02	9.212E-11	1.284E-09	3.303E-09
13	92233	3.838E-06	3.698E-08	9.636E-03	1.674E-11	2.333E-10	6.053E-10
14	90232	3.355E-06	3.679E-13	1.097E-07	1.469E-11	2.048E-10	5.291E-10
	totals	5.572E+03	1.574E-01	2.824E-05	2.384E-02	3.324E-01	8.787E-01

nonactinide inventory for material 40000 at end of step 3, time 5.475E+03 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	4.288E-01	3.732E+01	8.704E+01	3.183E-06	4.437E-05	6.762E-05
2	39090	6.636E-05	3.609E+01	5.438E+05	7.501E-10	1.046E-08	1.047E-08
3	38090	2.554E-01	3.608E+01	1.413E+02	2.887E-06	4.024E-05	4.028E-05
4	61147	2.747E-03	2.548E+00	9.276E+02	1.900E-08	2.649E-07	4.332E-07
5	36085	5.730E-03	2.250E+00	3.927E+02	6.858E-08	9.560E-07	9.037E-07
6	62151	3.604E-02	9.487E-01	2.632E+01	2.427E-07	3.383E-06	5.684E-06
7	63155	2.780E-04	1.371E-01	4.931E+02	1.824E-09	2.542E-08	4.385E-08
8	51125	4.218E-05	4.422E-02	1.048E+03	3.432E-10	4.784E-09	6.652E-09
9	63154	3.969E-05	1.073E-02	2.703E+02	2.620E-10	3.653E-09	6.259E-09
10	43099	4.556E-01	7.801E-03	1.712E-02	4.681E-06	6.526E-05	7.185E-05
11	55134	3.906E-06	5.057E-03	1.295E+03	2.964E-11	4.132E-10	6.159E-10
12	63152	1.563E-05	2.759E-03	1.765E+02	1.045E-10	1.457E-09	2.464E-09
13	40093	4.442E-01	1.117E-03	2.515E-03	4.858E-06	6.773E-05	7.005E-05
14	55135	6.488E-01	7.475E-04	1.152E-03	4.887E-06	6.813E-05	1.023E-04
15	34079	2.656E-03	3.646E-04	1.373E-01	3.421E-08	4.768E-07	4.189E-07
16	50126	5.352E-03	1.520E-04	2.839E-02	4.319E-08	6.021E-07	8.440E-07
17	53129	5.306E-02	9.372E-06	1.766E-04	4.183E-07	5.831E-06	8.368E-06
18	46107	1.270E-02	6.534E-06	5.145E-04	1.207E-07	1.683E-06	2.003E-06
19	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.753E-05	2.664E-05
20	62147	2.451E-01	5.627E-09	2.296E-08	1.696E-06	2.364E-05	3.866E-05
21	60144	5.994E-01	7.120E-13	1.188E-12	4.233E-06	5.901E-05	9.454E-05
22	57138	3.328E-06	8.217E-14	2.469E-08	2.453E-11	3.419E-10	5.249E-10
23	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.744E-06	7.864E-06
24	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.246E-05	9.867E-05
25	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.200E-05	6.775E-05
26	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.274E-07	1.630E-07
27	64152	2.209E-05	4.814E-16	2.179E-11	1.478E-10	2.060E-09	3.484E-09
28	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.368E-07	2.253E-07
29	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.799E-08	1.232E-07
30	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.462E-06	3.157E-06
31	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.903E-10	2.324E-10
32	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.097E-09	8.906E-10
33	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.656E-09	3.009E-09
34	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.299E-08	2.788E-08
35	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.136E-08	9.475E-09
36	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.457E-08	7.242E-08
37	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.236E-07	1.940E-07
38	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.371E-06	1.220E-06
39	35079	8.365E-07	0.000E+00	0.000E+00	1.077E-11	1.502E-10	1.319E-10
40	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.168E-06	1.953E-06
41	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.786E-10	8.924E-10
42	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.738E-06	5.296E-06
43	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.046E-05	9.771E-06
44	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.242E-05	2.144E-05
45	37085	7.111E-02	0.000E+00	0.000E+00	8.510E-07	1.186E-05	1.121E-05
46	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.111E-10	3.932E-10
47	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.785E-05	3.704E-05
48	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.044E-05	4.992E-05
49	40090	1.353E-01	0.000E+00	0.000E+00	1.529E-06	2.132E-05	2.134E-05
50	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.215E-05	6.289E-05
51	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.424E-05	6.572E-05
52	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.906E-05	7.219E-05
53	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.775E-05	7.234E-05
54	41093	7.926E-07	0.000E+00	0.000E+00	8.670E-12	1.209E-10	1.250E-10
55	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.943E-05	7.335E-05
56	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.358E-08	3.585E-08
57	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.447E-05	6.955E-05
58	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.150E-05	6.703E-05
59	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.736E-05	7.492E-05
60	44099	4.074E-05	0.000E+00	0.000E+00	4.186E-10	5.835E-09	6.425E-09
61	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.549E-05	6.233E-05
62	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.601E-05	5.220E-05
63	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.039E-05	2.359E-05
64	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.255E-05	3.729E-05
65	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.058E-05	1.236E-05
66	46106	3.359E-02	0.000E+00	0.000E+00	3.224E-07	4.494E-06	5.298E-06
67	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.278E-07	7.541E-07
68	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.848E-07	3.485E-07
69	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.515E-07	4.261E-07
70	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.885E-07	2.327E-07
71	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.428E-07	1.779E-07

72	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.842E-07	2.336E-07
73	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.442E-07	1.861E-07
74	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.024E-10	2.544E-10
75	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.550E-09	8.378E-09
76	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.726E-10	7.388E-10
77	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.384E-07	1.801E-07
78	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.241E-07	1.629E-07
79	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.399E-07	1.852E-07
80	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.372E-07	1.831E-07
81	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.679E-07	2.279E-07
82	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.885E-07	3.979E-07
83	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.339E-07	1.802E-07
84	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.703E-07	2.330E-07
85	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.586E-10	2.188E-10
86	52125	3.159E-03	0.000E+00	0.000E+00	2.570E-08	3.583E-07	4.982E-07
87	52126	2.240E-04	0.000E+00	0.000E+00	1.808E-09	2.520E-08	3.532E-08
88	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.728E-06	5.308E-06
89	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.938E-05	2.803E-05
90	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.646E-06	2.325E-06
91	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.736E-10	3.896E-10
92	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.837E-09	6.995E-09
93	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.086E-05	4.497E-05
94	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.633E-05	6.803E-05
95	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.422E-05	1.255E-04
96	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.947E-05	1.051E-04
97	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.154E-05	1.058E-04
98	56134	9.475E-04	0.000E+00	0.000E+00	7.191E-09	1.002E-07	1.494E-07
99	56135	2.931E-06	0.000E+00	0.000E+00	2.208E-11	3.078E-10	4.622E-10
100	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.243E-08	1.096E-07
101	56137	2.107E-01	0.000E+00	0.000E+00	1.564E-06	2.180E-05	3.323E-05
102	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.233E-05	1.110E-04
103	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.855E-05	1.060E-04
104	58140	6.556E-01	0.000E+00	0.000E+00	4.762E-06	6.638E-05	1.034E-04
105	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.248E-05	9.801E-05
106	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.067E-09	1.432E-08
107	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.330E-05	1.007E-04
108	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.215E-05	5.222E-05
109	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.793E-05	2.952E-05
110	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.042E-06	1.175E-05
111	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.864E-06	1.146E-05
112	62152	3.753E-02	0.000E+00	0.000E+00	2.510E-07	3.499E-06	5.918E-06
113	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.085E-07	1.385E-06
114	63151	5.117E-03	0.000E+00	0.000E+00	3.445E-08	4.803E-07	8.069E-07
115	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.737E-06	2.957E-06
116	64154	1.103E-04	0.000E+00	0.000E+00	7.282E-10	1.015E-08	1.739E-08
117	64155	2.977E-03	0.000E+00	0.000E+00	1.953E-08	2.722E-07	4.695E-07
118	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.206E-07	3.829E-07
119	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.396E-08	2.439E-08
120	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.704E-09	6.594E-09
121	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.153E-08	2.040E-08
122	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.008E-09	1.806E-09
123	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.196E-10	3.959E-10
124	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.640E-01	1.182E-01
125	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.546E-05
126	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.180E-09	1.970E-10
127	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.210E-03	2.424E-04
	totals	7.691E+02	1.154E+02	1.501E-01	4.789E-02	6.676E-01	1.213E-01

Step 4 - 20 years

actinide inventory for material 40000 at end of step 4, time 7.300E+03 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92234	1.161E+01	7.220E-02	6.217E-03	5.042E-05	7.030E-04	1.832E-03
2	94239	1.146E+00	7.109E-02	6.203E-02	4.872E-06	6.792E-05	1.808E-04
3	94241	5.027E-05	5.196E-03	1.033E+02	2.119E-10	2.954E-09	7.928E-09
4	92235	1.076E+03	2.327E-03	2.161E-06	4.654E-03	6.488E-02	1.698E-01
5	94240	8.193E-03	1.859E-03	2.269E-01	3.468E-08	4.835E-07	1.292E-06
6	92238	4.475E+03	1.504E-03	3.361E-07	1.910E-02	2.663E-01	7.057E-01
7	94238	5.580E-05	9.555E-04	1.712E+01	2.382E-10	3.321E-09	8.800E-09
8	92236	7.693E+00	4.975E-04	6.467E-05	3.312E-05	4.617E-04	1.213E-03
9	95241	8.024E-05	2.750E-04	3.427E+00	3.382E-10	4.715E-09	1.265E-08
10	90230	7.930E-04	1.635E-05	2.062E-02	3.503E-09	4.884E-08	1.251E-07
11	93237	1.783E-02	1.256E-05	7.047E-04	7.642E-08	1.065E-06	2.811E-06
12	91231	2.615E-05	1.235E-06	4.723E-02	1.150E-10	1.603E-09	4.124E-09
13	92233	3.866E-06	3.726E-08	9.636E-03	1.686E-11	2.350E-10	6.098E-10
14	90232	4.473E-06	4.905E-13	1.097E-07	1.959E-11	2.731E-10	7.055E-10
	totals	5.572E+03	1.559E-01	2.799E-05	2.384E-02	3.324E-01	8.787E-01

nonactinide inventory for material 40000 at end of step 4, time 7.300E+03 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	3.820E-01	3.325E+01	8.704E+01	2.836E-06	3.953E-05	6.025E-05
2	39090	5.868E-05	3.191E+01	5.438E+05	6.632E-10	9.246E-09	9.254E-09
3	38090	2.258E-01	3.190E+01	1.413E+02	2.553E-06	3.558E-05	3.562E-05
4	36085	4.148E-03	1.629E+00	3.927E+02	4.964E-08	6.921E-07	6.542E-07
5	62151	3.468E-02	9.129E-01	2.632E+01	2.335E-07	3.256E-06	5.470E-06
6	61147	7.337E-04	6.806E-01	9.276E+02	5.075E-09	7.075E-08	1.157E-07
7	63155	1.326E-04	6.540E-02	4.931E+02	8.701E-10	1.213E-08	2.092E-08
8	51125	1.186E-05	1.244E-02	1.048E+03	9.650E-11	1.345E-09	1.871E-09
9	43099	4.556E-01	7.801E-03	1.712E-02	4.681E-06	6.526E-05	7.185E-05
10	63154	2.652E-05	7.169E-03	2.703E+02	1.751E-10	2.441E-09	4.182E-09
11	63152	1.205E-05	2.127E-03	1.765E+02	8.061E-11	1.124E-09	1.900E-09
12	40093	4.442E-01	1.117E-03	2.515E-03	4.858E-06	6.773E-05	7.005E-05
13	55135	6.488E-01	7.475E-04	1.152E-03	4.887E-06	6.813E-05	1.023E-04
14	34079	2.656E-03	3.646E-04	1.373E-01	3.420E-08	4.768E-07	4.189E-07
15	50126	5.351E-03	1.519E-04	2.839E-02	4.319E-08	6.021E-07	8.440E-07
16	53129	5.306E-02	9.372E-06	1.766E-04	4.183E-07	5.831E-06	8.368E-06
17	46107	1.270E-02	6.534E-06	5.145E-04	1.207E-07	1.683E-06	2.003E-06
18	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.753E-05	2.664E-05
19	62147	2.471E-01	5.674E-09	2.296E-08	1.709E-06	2.383E-05	3.898E-05
20	60144	5.994E-01	7.120E-13	1.188E-12	4.233E-06	5.901E-05	9.454E-05
21	57138	3.328E-06	8.217E-14	2.469E-08	2.453E-11	3.419E-10	5.249E-10
22	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.744E-06	7.864E-06
23	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.246E-05	9.867E-05
24	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.200E-05	6.775E-05
25	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.274E-07	1.630E-07
26	64152	2.309E-05	5.032E-16	2.179E-11	1.545E-10	2.153E-09	3.642E-09
27	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.368E-07	2.253E-07
28	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.799E-08	1.232E-07
29	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.462E-06	3.157E-06
30	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.903E-10	2.324E-10
31	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.097E-09	8.906E-10
32	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.656E-09	3.009E-09
33	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.299E-08	2.788E-08
34	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.136E-08	9.475E-09
35	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.457E-08	7.242E-08
36	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.236E-07	1.940E-07
37	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.371E-06	1.220E-06
38	35079	1.115E-06	0.000E+00	0.000E+00	1.436E-11	2.002E-10	1.759E-10
39	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.168E-06	1.953E-06
40	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.786E-10	8.924E-10
41	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.738E-06	5.296E-06
42	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.046E-05	9.771E-06
43	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.242E-05	2.144E-05
44	37085	7.269E-02	0.000E+00	0.000E+00	8.700E-07	1.213E-05	1.146E-05
45	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.111E-10	3.932E-10
46	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.785E-05	3.704E-05
47	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.044E-05	4.992E-05
48	40090	1.648E-01	0.000E+00	0.000E+00	1.863E-06	2.597E-05	2.599E-05
49	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.215E-05	6.289E-05
50	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.424E-05	6.572E-05
51	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.906E-05	7.219E-05
52	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.775E-05	7.234E-05
53	41093	1.323E-06	0.000E+00	0.000E+00	1.447E-11	2.017E-10	2.086E-10
54	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.943E-05	7.335E-05
55	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.358E-08	3.585E-08
56	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.447E-05	6.955E-05
57	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.150E-05	6.703E-05
58	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.736E-05	7.492E-05
59	44099	4.821E-05	0.000E+00	0.000E+00	4.954E-10	6.906E-09	7.603E-09
60	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.549E-05	6.233E-05
61	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.601E-05	5.220E-05
62	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.039E-05	2.359E-05
63	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.255E-05	3.729E-05
64	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.058E-05	1.236E-05
65	46106	3.360E-02	0.000E+00	0.000E+00	3.224E-07	4.494E-06	5.298E-06
66	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.278E-07	7.541E-07
67	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.848E-07	3.485E-07
68	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.515E-07	4.261E-07
69	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.885E-07	2.327E-07
70	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.428E-07	1.779E-07
71	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.842E-07	2.336E-07
72	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.442E-07	1.861E-07
73	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.024E-10	2.544E-10
74	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.550E-09	8.378E-09
75	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.726E-10	7.388E-10
76	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.384E-07	1.801E-07
77	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.241E-07	1.629E-07
78	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.399E-07	1.852E-07
79	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.372E-07	1.831E-07

80	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.679E-07	2.279E-07
81	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.885E-07	3.979E-07
82	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.339E-07	1.802E-07
83	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.703E-07	2.330E-07
84	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.586E-10	2.188E-10
85	52125	3.190E-03	0.000E+00	0.000E+00	2.595E-08	3.618E-07	5.030E-07
86	52126	2.242E-04	0.000E+00	0.000E+00	1.809E-09	2.522E-08	3.535E-08
87	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.728E-06	5.308E-06
88	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.938E-05	2.803E-05
89	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.646E-06	2.325E-06
90	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.736E-10	3.896E-10
91	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.837E-09	6.995E-09
92	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.086E-05	4.497E-05
93	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.633E-05	6.803E-05
94	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.422E-05	1.255E-04
95	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.947E-05	1.051E-04
96	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.154E-05	1.058E-04
97	56134	9.507E-04	0.000E+00	0.000E+00	7.215E-09	1.006E-07	1.499E-07
98	56135	3.908E-06	0.000E+00	0.000E+00	2.944E-11	4.104E-10	6.163E-10
99	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.243E-08	1.096E-07
100	56137	2.574E-01	0.000E+00	0.000E+00	1.911E-06	2.664E-05	4.060E-05
101	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.233E-05	1.110E-04
102	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.855E-05	1.060E-04
103	58140	6.556E-01	0.000E+00	0.000E+00	4.762E-06	6.638E-05	1.034E-04
104	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.248E-05	9.801E-05
105	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.067E-09	1.432E-08
106	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.330E-05	1.007E-04
107	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.215E-05	5.222E-05
108	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.793E-05	2.952E-05
109	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.042E-06	1.175E-05
110	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.864E-06	1.146E-05
111	62152	3.753E-02	0.000E+00	0.000E+00	2.510E-07	3.499E-06	5.918E-06
112	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.085E-07	1.385E-06
113	63151	6.477E-03	0.000E+00	0.000E+00	4.361E-08	6.080E-07	1.022E-06
114	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.737E-06	2.957E-06
115	64154	1.235E-04	0.000E+00	0.000E+00	8.151E-10	1.136E-08	1.947E-08
116	64155	3.122E-03	0.000E+00	0.000E+00	2.048E-08	2.855E-07	4.924E-07
117	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.206E-07	3.829E-07
118	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.396E-08	2.439E-08
119	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.704E-09	6.594E-09
120	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.153E-08	2.040E-08
121	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.008E-09	1.806E-09
122	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.196E-10	3.959E-10
123	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.640E-01	1.182E-01
124	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.546E-05
125	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.180E-09	1.970E-10
126	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.210E-03	2.424E-04
	totals	7.691E+02	1.004E+02	1.305E-01	4.789E-02	6.676E-01	1.213E-01

Step 5 - 30 years

actinide inventory for material 40000 at end of step 5, time 1.095E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92234	1.161E+01	7.220E-02	6.217E-03	5.042E-05	7.029E-04	1.831E-03
2	94239	1.146E+00	7.107E-02	6.203E-02	4.871E-06	6.790E-05	1.807E-04
3	94241	3.102E-05	3.206E-03	1.033E+02	1.308E-10	1.823E-09	4.893E-09
4	92235	1.076E+03	2.327E-03	2.161E-06	4.654E-03	6.488E-02	1.698E-01
5	94240	8.184E-03	1.857E-03	2.269E-01	3.464E-08	4.830E-07	1.291E-06
6	92238	4.475E+03	1.504E-03	3.361E-07	1.910E-02	2.663E-01	7.057E-01
7	94238	5.156E-05	8.830E-04	1.712E+01	2.201E-10	3.069E-09	8.132E-09
8	92236	7.693E+00	4.975E-04	6.467E-05	3.312E-05	4.617E-04	1.213E-03
9	95241	9.805E-05	3.360E-04	3.427E+00	4.133E-10	5.762E-09	1.546E-08
10	90230	1.115E-03	2.298E-05	2.062E-02	4.924E-09	6.865E-08	1.758E-07
11	93237	1.783E-02	1.256E-05	7.047E-04	7.642E-08	1.065E-06	2.811E-06
12	91231	3.656E-05	1.727E-06	4.723E-02	1.608E-10	2.242E-09	5.765E-09
13	92233	3.923E-06	3.780E-08	9.636E-03	1.711E-11	2.385E-10	6.187E-10
14	90232	6.710E-06	7.358E-13	1.097E-07	2.939E-11	4.097E-10	1.058E-09
	totals	5.572E+03	1.539E-01	2.762E-05	2.384E-02	3.324E-01	8.787E-01

nonactinide inventory for material 40000 at end of step 5, time 1.095E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	3.033E-01	2.640E+01	8.704E+01	2.251E-06	3.138E-05	4.783E-05
2	39090	4.588E-05	2.495E+01	5.438E+05	5.186E-10	7.229E-09	7.236E-09
3	38090	1.766E-01	2.494E+01	1.413E+02	1.996E-06	2.782E-05	2.785E-05
4	36085	2.174E-03	8.538E-01	3.927E+02	2.602E-08	3.627E-07	3.428E-07
5	62151	3.211E-02	8.453E-01	2.632E+01	2.162E-07	3.015E-06	5.065E-06
6	61147	5.234E-05	4.854E-02	9.276E+02	3.620E-10	5.047E-09	8.254E-09

7	63155	3.019E-05	1.489E-02	4.931E+02	1.980E-10	2.761E-09	4.762E-09
8	43099	4.556E-01	7.801E-03	1.712E-02	4.681E-06	6.525E-05	7.185E-05
9	63154	1.184E-05	3.201E-03	2.703E+02	7.818E-11	1.090E-09	1.868E-09
10	63152	7.167E-06	1.265E-03	1.765E+02	4.794E-11	6.683E-10	1.130E-09
11	40093	4.442E-01	1.117E-03	2.515E-03	4.858E-06	6.773E-05	7.005E-05
12	51125	9.380E-07	9.834E-04	1.048E+03	7.631E-12	1.064E-10	1.479E-10
13	55135	6.488E-01	7.475E-04	1.152E-03	4.887E-06	6.813E-05	1.023E-04
14	34079	2.656E-03	3.645E-04	1.373E-01	3.419E-08	4.767E-07	4.188E-07
15	50126	5.351E-03	1.519E-04	2.839E-02	4.319E-08	6.021E-07	8.439E-07
16	53129	5.306E-02	9.372E-06	1.766E-04	4.183E-07	5.831E-06	8.368E-06
17	46107	1.270E-02	6.534E-06	5.145E-04	1.207E-07	1.683E-06	2.003E-06
18	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.753E-05	2.664E-05
19	62147	2.478E-01	5.689E-09	2.296E-08	1.714E-06	2.390E-05	3.908E-05
20	60144	5.994E-01	7.120E-13	1.188E-12	4.233E-06	5.901E-05	9.454E-05
21	57138	3.328E-06	8.217E-14	2.469E-08	2.453E-11	3.419E-10	5.249E-10
22	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.744E-06	7.864E-06
23	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.246E-05	9.867E-05
24	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.200E-05	6.775E-05
25	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.274E-07	1.630E-07
26	64152	2.445E-05	5.329E-16	2.179E-11	1.636E-10	2.280E-09	3.857E-09
27	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.368E-07	2.253E-07
28	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.799E-08	1.232E-07
29	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.462E-06	3.157E-06
30	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.903E-10	2.324E-10
31	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.097E-09	8.906E-10
32	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.656E-09	3.009E-09
33	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.299E-08	2.788E-08
34	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.136E-08	9.475E-09
35	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.457E-08	7.242E-08
36	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.236E-07	1.940E-07
37	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.371E-06	1.220E-06
38	35079	1.673E-06	0.000E+00	0.000E+00	2.154E-11	3.003E-10	2.638E-10
39	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.168E-06	1.953E-06
40	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.786E-10	8.924E-10
41	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.738E-06	5.296E-06
42	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.046E-05	9.771E-06
43	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.242E-05	2.144E-05
44	37085	7.467E-02	0.000E+00	0.000E+00	8.936E-07	1.246E-05	1.178E-05
45	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.111E-10	3.932E-10
46	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.785E-05	3.704E-05
47	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.044E-05	4.992E-05
48	40090	2.140E-01	0.000E+00	0.000E+00	2.419E-06	3.372E-05	3.375E-05
49	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.215E-05	6.289E-05
50	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.424E-05	6.572E-05
51	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.906E-05	7.219E-05
52	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.775E-05	7.234E-05
53	41093	2.641E-06	0.000E+00	0.000E+00	2.889E-11	4.028E-10	4.166E-10
54	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.943E-05	7.335E-05
55	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.358E-08	3.585E-08
56	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.447E-05	6.955E-05
57	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.150E-05	6.703E-05
58	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.736E-05	7.492E-05
59	44099	6.316E-05	0.000E+00	0.000E+00	6.489E-10	9.047E-09	9.961E-09
60	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.549E-05	6.233E-05
61	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.601E-05	5.220E-05
62	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.039E-05	2.359E-05
63	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.255E-05	3.729E-05
64	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.058E-05	1.236E-05
65	46106	3.360E-02	0.000E+00	0.000E+00	3.224E-07	4.494E-06	5.298E-06
66	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.278E-07	7.541E-07
67	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.848E-07	3.485E-07
68	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.515E-07	4.261E-07
69	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.885E-07	2.327E-07
70	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.428E-07	1.779E-07
71	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.842E-07	2.336E-07
72	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.442E-07	1.861E-07
73	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.024E-10	2.544E-10
74	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.550E-09	8.378E-09
75	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.726E-10	7.388E-10
76	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.384E-07	1.801E-07
77	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.241E-07	1.629E-07
78	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.399E-07	1.852E-07
79	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.372E-07	1.831E-07
80	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.679E-07	2.279E-07
81	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.885E-07	3.979E-07
82	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.339E-07	1.802E-07
83	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.703E-07	2.330E-07
84	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.586E-10	2.188E-10
85	52125	3.201E-03	0.000E+00	0.000E+00	2.604E-08	3.630E-07	5.048E-07
86	52126	2.245E-04	0.000E+00	0.000E+00	1.812E-09	2.526E-08	3.541E-08
87	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.728E-06	5.308E-06
88	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.938E-05	2.803E-05

89	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.646E-06	2.325E-06
90	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.736E-10	3.896E-10
91	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.837E-09	6.995E-09
92	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.086E-05	4.497E-05
93	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.633E-05	6.803E-05
94	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.422E-05	1.255E-04
95	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.947E-05	1.051E-04
96	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.154E-05	1.058E-04
97	56134	9.514E-04	0.000E+00	0.000E+00	7.220E-09	1.007E-07	1.500E-07
98	56135	5.862E-06	0.000E+00	0.000E+00	4.415E-11	6.155E-10	9.244E-10
99	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.243E-08	1.096E-07
100	56137	3.362E-01	0.000E+00	0.000E+00	2.495E-06	3.479E-05	5.302E-05
101	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.233E-05	1.110E-04
102	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.855E-05	1.060E-04
103	58140	6.556E-01	0.000E+00	0.000E+00	4.762E-06	6.638E-05	1.034E-04
104	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.248E-05	9.801E-05
105	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.067E-09	1.432E-08
106	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.330E-05	1.007E-04
107	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.215E-05	5.222E-05
108	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.793E-05	2.952E-05
109	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.042E-06	1.175E-05
110	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.864E-06	1.146E-05
111	62152	3.753E-02	0.000E+00	0.000E+00	2.510E-07	3.500E-06	5.919E-06
112	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.085E-07	1.385E-06
113	63151	9.047E-03	0.000E+00	0.000E+00	6.091E-08	8.492E-07	1.427E-06
114	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.737E-06	2.957E-06
115	64154	1.381E-04	0.000E+00	0.000E+00	9.120E-10	1.271E-08	2.179E-08
116	64155	3.225E-03	0.000E+00	0.000E+00	2.115E-08	2.949E-07	5.086E-07
117	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.206E-07	3.829E-07
118	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.396E-08	2.439E-08
119	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.704E-09	6.594E-09
120	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.153E-08	2.040E-08
121	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.008E-09	1.806E-09
122	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.196E-10	3.959E-10
123	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.640E-01	1.182E-01
124	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.546E-05
125	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.180E-09	1.970E-10
126	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.210E-03	2.424E-04
	totals	7.691E+02	7.806E+01	1.015E-01	4.789E-02	6.676E-01	1.213E-01

Step 6 - 40 years

actinide inventory for material 40000 at end of step 6, time 1.460E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92234	1.161E+01	7.220E-02	6.217E-03	5.042E-05	7.029E-04	1.831E-03
2	94239	1.145E+00	7.105E-02	6.203E-02	4.869E-06	6.788E-05	1.806E-04
3	92235	1.076E+03	2.327E-03	2.161E-06	4.654E-03	6.488E-02	1.698E-01
4	94241	1.914E-05	1.979E-03	1.033E+02	8.071E-11	1.125E-09	3.019E-09
5	94240	8.175E-03	1.855E-03	2.269E-01	3.461E-08	4.825E-07	1.289E-06
6	92238	4.475E+03	1.504E-03	3.361E-07	1.910E-02	2.663E-01	7.057E-01
7	94238	4.765E-05	8.159E-04	1.712E+01	2.034E-10	2.835E-09	7.514E-09
8	92236	7.693E+00	4.975E-04	6.467E-05	3.312E-05	4.617E-04	1.213E-03
9	95241	1.083E-04	3.711E-04	3.427E+00	4.564E-10	6.363E-09	1.707E-08
10	90230	1.436E-03	2.961E-05	2.062E-02	6.345E-09	8.846E-08	2.265E-07
11	93237	1.783E-02	1.256E-05	7.047E-04	7.643E-08	1.065E-06	2.812E-06
12	91231	4.696E-05	2.218E-06	4.723E-02	2.066E-10	2.880E-09	7.407E-09
13	92233	3.979E-06	3.835E-08	9.636E-03	1.735E-11	2.419E-10	6.276E-10
14	90232	8.947E-06	9.811E-13	1.097E-07	3.918E-11	5.462E-10	1.411E-09
	totals	5.572E+03	1.526E-01	2.740E-05	2.384E-02	3.324E-01	8.787E-01

nonactinide inventory for material 40000 at end of step 6, time 1.460E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	2.407E-01	2.095E+01	8.704E+01	1.787E-06	2.491E-05	3.796E-05
2	39090	3.587E-05	1.951E+01	5.438E+05	4.055E-10	5.652E-09	5.657E-09
3	38090	1.381E-01	1.950E+01	1.413E+02	1.560E-06	2.175E-05	2.177E-05
4	62151	2.974E-02	7.826E-01	2.632E+01	2.002E-07	2.791E-06	4.689E-06
5	36085	1.139E-03	4.474E-01	3.927E+02	1.363E-08	1.901E-07	1.797E-07
6	43099	4.556E-01	7.800E-03	1.712E-02	4.681E-06	6.525E-05	7.185E-05
7	61147	3.733E-06	3.463E-03	9.276E+02	2.582E-11	3.600E-10	5.887E-10
8	63155	6.872E-06	3.389E-03	4.931E+02	4.508E-11	6.284E-10	1.084E-09
9	63154	5.288E-06	1.430E-03	2.703E+02	3.491E-11	4.867E-10	8.340E-10
10	40093	4.442E-01	1.117E-03	2.515E-03	4.858E-06	6.773E-05	7.005E-05
11	63152	4.262E-06	7.524E-04	1.765E+02	2.851E-11	3.975E-10	6.722E-10
12	55135	6.488E-01	7.475E-04	1.152E-03	4.887E-06	6.813E-05	1.023E-04
13	34079	2.655E-03	3.644E-04	1.373E-01	3.419E-08	4.766E-07	4.187E-07
14	50126	5.351E-03	1.519E-04	2.839E-02	4.318E-08	6.020E-07	8.438E-07
15	53129	5.306E-02	9.372E-06	1.766E-04	4.183E-07	5.831E-06	8.368E-06

16	46107	1.270E-02	6.534E-06	5.145E-04	1.207E-07	1.683E-06	2.003E-06
17	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.753E-05	2.664E-05
18	62147	2.479E-01	5.690E-09	2.296E-08	1.715E-06	2.390E-05	3.909E-05
19	60144	5.994E-01	7.120E-13	1.188E-12	4.233E-06	5.901E-05	9.454E-05
20	57138	3.328E-06	8.217E-14	2.469E-08	2.453E-11	3.419E-10	5.249E-10
21	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.744E-06	7.864E-06
22	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.246E-05	9.867E-05
23	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.200E-05	6.775E-05
24	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.274E-07	1.630E-07
25	64152	2.527E-05	5.505E-16	2.179E-11	1.690E-10	2.356E-09	3.985E-09
26	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.368E-07	2.253E-07
27	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.799E-08	1.232E-07
28	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.462E-06	3.157E-06
29	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.903E-10	2.324E-10
30	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.097E-09	8.906E-10
31	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.656E-09	3.009E-09
32	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.299E-08	2.788E-08
33	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.136E-08	9.475E-09
34	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.457E-08	7.242E-08
35	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.236E-07	1.940E-07
36	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.371E-06	1.220E-06
37	35079	2.230E-06	0.000E+00	0.000E+00	2.872E-11	4.003E-10	3.517E-10
38	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.168E-06	1.953E-06
39	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.786E-10	8.924E-10
40	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.738E-06	5.296E-06
41	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.046E-05	9.771E-06
42	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.242E-05	2.144E-05
43	37085	7.570E-02	0.000E+00	0.000E+00	9.060E-07	1.263E-05	1.194E-05
44	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.111E-10	3.932E-10
45	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.785E-05	3.704E-05
46	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.044E-05	4.992E-05
47	40090	2.525E-01	0.000E+00	0.000E+00	2.854E-06	3.979E-05	3.982E-05
48	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.215E-05	6.289E-05
49	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.424E-05	6.572E-05
50	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.906E-05	7.219E-05
51	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.775E-05	7.234E-05
52	41093	4.202E-06	0.000E+00	0.000E+00	4.596E-11	6.407E-10	6.626E-10
53	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.943E-05	7.335E-05
54	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.358E-08	3.585E-08
55	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.447E-05	6.955E-05
56	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.150E-05	6.703E-05
57	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.736E-05	7.492E-05
58	44099	7.811E-05	0.000E+00	0.000E+00	8.025E-10	1.119E-08	1.232E-08
59	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.549E-05	6.233E-05
60	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.601E-05	5.220E-05
61	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.039E-05	2.359E-05
62	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.255E-05	3.729E-05
63	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.058E-05	1.236E-05
64	46106	3.360E-02	0.000E+00	0.000E+00	3.224E-07	4.494E-06	5.298E-06
65	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.278E-07	7.541E-07
66	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.848E-07	3.485E-07
67	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.515E-07	4.261E-07
68	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.885E-07	2.327E-07
69	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.428E-07	1.779E-07
70	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.842E-07	2.336E-07
71	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.442E-07	1.861E-07
72	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.024E-10	2.544E-10
73	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.550E-09	8.378E-09
74	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.726E-10	7.388E-10
75	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.384E-07	1.801E-07
76	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.241E-07	1.629E-07
77	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.399E-07	1.852E-07
78	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.372E-07	1.831E-07
79	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.679E-07	2.279E-07
80	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.885E-07	3.979E-07
81	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.339E-07	1.802E-07
82	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.703E-07	2.330E-07
83	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.586E-10	2.188E-10
84	52125	3.201E-03	0.000E+00	0.000E+00	2.605E-08	3.631E-07	5.049E-07
85	52126	2.249E-04	0.000E+00	0.000E+00	1.815E-09	2.531E-08	3.547E-08
86	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.728E-06	5.308E-06
87	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.938E-05	2.803E-05
88	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.646E-06	2.325E-06
89	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.736E-10	3.896E-10
90	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.837E-09	6.995E-09
91	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.086E-05	4.497E-05
92	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.633E-05	6.803E-05
93	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.422E-05	1.255E-04
94	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.947E-05	1.051E-04
95	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.154E-05	1.058E-04
96	56134	9.514E-04	0.000E+00	0.000E+00	7.221E-09	1.007E-07	1.501E-07
97	56135	7.815E-06	0.000E+00	0.000E+00	5.887E-11	8.207E-10	1.233E-09

98	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.243E-08	1.096E-07
99	56137	3.987E-01	0.000E+00	0.000E+00	2.960E-06	4.126E-05	6.288E-05
100	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.233E-05	1.110E-04
101	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.855E-05	1.060E-04
102	58140	6.556E-01	0.000E+00	0.000E+00	4.762E-06	6.638E-05	1.034E-04
103	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.248E-05	9.801E-05
104	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.067E-09	1.432E-08
105	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.330E-05	1.007E-04
106	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.215E-05	5.222E-05
107	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.793E-05	2.952E-05
108	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.042E-06	1.175E-05
109	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.864E-06	1.146E-05
110	62152	3.753E-02	0.000E+00	0.000E+00	2.511E-07	3.500E-06	5.919E-06
111	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.085E-07	1.385E-06
112	63151	1.143E-02	0.000E+00	0.000E+00	7.693E-08	1.073E-06	1.802E-06
113	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.737E-06	2.957E-06
114	64154	1.447E-04	0.000E+00	0.000E+00	9.552E-10	1.332E-08	2.282E-08
115	64155	3.248E-03	0.000E+00	0.000E+00	2.131E-08	2.970E-07	5.122E-07
116	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.206E-07	3.829E-07
117	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.396E-08	2.439E-08
118	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.704E-09	6.594E-09
119	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.153E-08	2.040E-08
120	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.008E-09	1.806E-09
121	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.196E-10	3.959E-10
122	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.640E-01	1.182E-01
123	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.546E-05
124	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.180E-09	1.970E-10
125	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.210E-03	2.424E-04
	totals	7.691E+02	6.121E+01	7.958E-02	4.789E-02	6.676E-01	1.213E-01

Step 7 - 50 years

actinide inventory for material 40000 at end of step 7, time 1.825E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92234	1.161E+01	7.219E-02	6.217E-03	5.042E-05	7.029E-04	1.831E-03
2	94239	1.145E+00	7.103E-02	6.203E-02	4.868E-06	6.786E-05	1.806E-04
3	92235	1.076E+03	2.327E-03	2.161E-06	4.654E-03	6.488E-02	1.698E-01
4	94240	8.167E-03	1.853E-03	2.269E-01	3.457E-08	4.819E-07	1.288E-06
5	92238	4.475E+03	1.504E-03	3.361E-07	1.910E-02	2.663E-01	7.057E-01
6	94241	1.181E-05	1.221E-03	1.033E+02	4.980E-11	6.943E-10	1.863E-09
7	94238	4.403E-05	7.539E-04	1.712E+01	1.879E-10	2.620E-09	6.943E-09
8	92236	7.693E+00	4.975E-04	6.467E-05	3.312E-05	4.617E-04	1.213E-03
9	95241	1.138E-04	3.901E-04	3.427E+00	4.798E-10	6.689E-09	1.795E-08
10	90230	1.758E-03	3.624E-05	2.062E-02	7.766E-09	1.083E-07	2.773E-07
11	93237	1.783E-02	1.257E-05	7.047E-04	7.644E-08	1.066E-06	2.812E-06
12	91231	5.737E-05	2.710E-06	4.723E-02	2.523E-10	3.518E-09	9.047E-09
13	92233	4.036E-06	3.889E-08	9.636E-03	1.760E-11	2.454E-10	6.365E-10
14	90232	1.118E-05	1.226E-12	1.097E-07	4.898E-11	6.828E-10	1.764E-09
	totals	5.572E+03	1.518E-01	2.725E-05	2.384E-02	3.324E-01	8.787E-01

nonactinide inventory for material 40000 at end of step 7, time 1.825E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	1.911E-01	1.663E+01	8.704E+01	1.418E-06	1.977E-05	3.014E-05
2	39090	2.805E-05	1.525E+01	5.438E+05	3.170E-10	4.419E-09	4.423E-09
3	38090	1.079E-01	1.525E+01	1.413E+02	1.220E-06	1.701E-05	1.702E-05
4	62151	2.753E-02	7.247E-01	2.632E+01	1.854E-07	2.584E-06	4.342E-06
5	36085	5.970E-04	2.345E-01	3.927E+02	7.145E-09	9.960E-08	9.415E-08
6	43099	4.556E-01	7.800E-03	1.712E-02	4.681E-06	6.525E-05	7.184E-05
7	40093	4.442E-01	1.117E-03	2.515E-03	4.858E-06	6.773E-05	7.005E-05
8	63155	1.564E-06	7.713E-04	4.931E+02	1.026E-11	1.430E-10	2.467E-10
9	55135	6.488E-01	7.475E-04	1.152E-03	4.887E-06	6.813E-05	1.023E-04
10	63154	2.362E-06	6.384E-04	2.703E+02	1.559E-11	2.173E-10	3.724E-10
11	63152	2.535E-06	4.475E-04	1.765E+02	1.696E-11	2.364E-10	3.998E-10
12	34079	2.654E-03	3.644E-04	1.373E-01	3.418E-08	4.765E-07	4.186E-07
13	50126	5.350E-03	1.519E-04	2.839E-02	4.318E-08	6.020E-07	8.438E-07
14	53129	5.306E-02	9.372E-06	1.766E-04	4.183E-07	5.831E-06	8.368E-06
15	46107	1.270E-02	6.534E-06	5.145E-04	1.207E-07	1.683E-06	2.003E-06
16	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.753E-05	2.664E-05
17	62147	2.479E-01	5.690E-09	2.296E-08	1.715E-06	2.390E-05	3.909E-05
18	60144	5.994E-01	7.120E-13	1.188E-12	4.233E-06	5.901E-05	9.454E-05
19	57138	3.328E-06	8.217E-14	2.469E-08	2.453E-11	3.419E-10	5.249E-10
20	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.744E-06	7.864E-06
21	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.246E-05	9.867E-05
22	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.200E-05	6.775E-05
23	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.274E-07	1.630E-07
24	64152	2.575E-05	5.610E-16	2.179E-11	1.722E-10	2.401E-09	4.061E-09
25	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.368E-07	2.253E-07

26	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.799E-08	1.232E-07
27	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.462E-06	3.157E-06
28	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.903E-10	2.324E-10
29	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.097E-09	8.906E-10
30	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.656E-09	3.009E-09
31	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.299E-08	2.788E-08
32	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.136E-08	9.475E-09
33	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.457E-08	7.242E-08
34	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.236E-07	1.940E-07
35	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.371E-06	1.220E-06
36	35079	2.787E-06	0.000E+00	0.000E+00	3.589E-11	5.003E-10	4.396E-10
37	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.168E-06	1.953E-06
38	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.786E-10	8.924E-10
39	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.738E-06	5.296E-06
40	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.046E-05	9.771E-06
41	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.242E-05	2.144E-05
42	37085	7.624E-02	0.000E+00	0.000E+00	9.125E-07	1.272E-05	1.202E-05
43	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.111E-10	3.932E-10
44	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.785E-05	3.704E-05
45	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.044E-05	4.992E-05
46	40090	2.826E-01	0.000E+00	0.000E+00	3.194E-06	4.453E-05	4.457E-05
47	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.215E-05	6.289E-05
48	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.424E-05	6.572E-05
49	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.906E-05	7.219E-05
50	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.775E-05	7.234E-05
51	41093	5.919E-06	0.000E+00	0.000E+00	6.474E-11	9.026E-10	9.335E-10
52	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.943E-05	7.335E-05
53	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.358E-08	3.585E-08
54	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.447E-05	6.955E-05
55	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.150E-05	6.703E-05
56	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.736E-05	7.492E-05
57	44099	9.306E-05	0.000E+00	0.000E+00	9.561E-10	1.333E-08	1.468E-08
58	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.549E-05	6.233E-05
59	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.601E-05	5.220E-05
60	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.039E-05	2.359E-05
61	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.255E-05	3.729E-05
62	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.058E-05	1.236E-05
63	46106	3.360E-02	0.000E+00	0.000E+00	3.224E-07	4.494E-06	5.298E-06
64	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.278E-07	7.541E-07
65	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.848E-07	3.485E-07
66	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.515E-07	4.261E-07
67	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.885E-07	2.327E-07
68	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.428E-07	1.779E-07
69	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.842E-07	2.336E-07
70	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.442E-07	1.861E-07
71	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.024E-10	2.544E-10
72	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.550E-09	8.378E-09
73	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.726E-10	7.388E-10
74	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.384E-07	1.801E-07
75	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.241E-07	1.629E-07
76	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.399E-07	1.852E-07
77	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.372E-07	1.831E-07
78	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.679E-07	2.279E-07
79	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.885E-07	3.979E-07
80	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.339E-07	1.802E-07
81	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.703E-07	2.330E-07
82	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.586E-10	2.188E-10
83	52125	3.202E-03	0.000E+00	0.000E+00	2.605E-08	3.631E-07	5.049E-07
84	52126	2.253E-04	0.000E+00	0.000E+00	1.818E-09	2.535E-08	3.553E-08
85	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.728E-06	5.308E-06
86	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.938E-05	2.803E-05
87	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.646E-06	2.325E-06
88	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.736E-10	3.896E-10
89	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.837E-09	6.995E-09
90	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.086E-05	4.497E-05
91	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.633E-05	6.803E-05
92	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.422E-05	1.255E-04
93	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.947E-05	1.051E-04
94	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.154E-05	1.058E-04
95	56134	9.514E-04	0.000E+00	0.000E+00	7.221E-09	1.007E-07	1.501E-07
96	56135	9.769E-06	0.000E+00	0.000E+00	7.359E-11	1.026E-09	1.541E-09
97	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.243E-08	1.096E-07
98	56137	4.484E-01	0.000E+00	0.000E+00	3.328E-06	4.639E-05	7.071E-05
99	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.233E-05	1.110E-04
100	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.855E-05	1.060E-04
101	58140	6.556E-01	0.000E+00	0.000E+00	4.762E-06	6.638E-05	1.034E-04
102	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.248E-05	9.801E-05
103	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.067E-09	1.432E-08
104	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.330E-05	1.007E-04
105	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.215E-05	5.222E-05
106	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.793E-05	2.952E-05
107	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.042E-06	1.175E-05

108	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.864E-06	1.146E-05
109	62152	3.753E-02	0.000E+00	0.000E+00	2.511E-07	3.500E-06	5.919E-06
110	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.085E-07	1.385E-06
111	63151	1.363E-02	0.000E+00	0.000E+00	9.177E-08	1.279E-06	2.149E-06
112	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.737E-06	2.957E-06
113	64154	1.476E-04	0.000E+00	0.000E+00	9.746E-10	1.359E-08	2.328E-08
114	64155	3.253E-03	0.000E+00	0.000E+00	2.134E-08	2.975E-07	5.131E-07
115	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.206E-07	3.829E-07
116	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.396E-08	2.439E-08
117	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.704E-09	6.594E-09
118	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.153E-08	2.040E-08
119	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.008E-09	1.806E-09
120	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.196E-10	3.959E-10
121	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.640E-01	1.182E-01
122	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.546E-05
123	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.180E-09	1.970E-10
124	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.210E-03	2.424E-04
	totals	7.691E+02	4.810E+01	6.254E-02	4.789E-02	6.676E-01	1.213E-01

Step 8 - 70 years

actinide inventory for material 40000 at end of step 8, time 2.555E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92234	1.161E+01	7.219E-02	6.217E-03	5.042E-05	7.029E-04	1.831E-03
2	94239	1.144E+00	7.099E-02	6.203E-02	4.865E-06	6.782E-05	1.805E-04
3	92235	1.076E+03	2.327E-03	2.161E-06	4.654E-03	6.488E-02	1.698E-01
4	94240	8.149E-03	1.849E-03	2.269E-01	3.450E-08	4.809E-07	1.285E-06
5	92238	4.475E+03	1.504E-03	3.361E-07	1.910E-02	2.663E-01	7.057E-01
6	94238	3.759E-05	6.438E-04	1.712E+01	1.605E-10	2.237E-09	5.929E-09
7	92236	7.693E+00	4.975E-04	6.467E-05	3.312E-05	4.617E-04	1.213E-03
8	94241	4.499E-06	4.650E-04	1.033E+02	1.897E-11	2.644E-10	7.095E-10
9	95241	1.174E-04	4.024E-04	3.427E+00	4.949E-10	6.900E-09	1.852E-08
10	90230	2.401E-03	4.950E-05	2.062E-02	1.061E-08	1.479E-07	3.787E-07
11	93237	1.783E-02	1.257E-05	7.047E-04	7.645E-08	1.066E-06	2.813E-06
12	91231	7.817E-05	3.692E-06	4.723E-02	3.438E-10	4.793E-09	1.233E-08
13	92233	4.149E-06	3.998E-08	9.636E-03	1.809E-11	2.522E-10	6.544E-10
14	90232	1.566E-05	1.717E-12	1.097E-07	6.857E-11	9.559E-10	2.469E-09
	totals	5.572E+03	1.509E-01	2.709E-05	2.384E-02	3.324E-01	8.787E-01

nonactinide inventory for material 40000 at end of step 8, time 2.555E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	1.204E-01	1.048E+01	8.704E+01	8.938E-07	1.246E-05	1.899E-05
2	39090	1.715E-05	9.323E+00	5.438E+05	1.938E-10	2.702E-09	2.704E-09
3	38090	6.599E-02	9.321E+00	1.413E+02	7.458E-07	1.040E-05	1.041E-05
4	62151	2.360E-02	6.213E-01	2.632E+01	1.589E-07	2.216E-06	3.723E-06
5	36085	1.640E-04	6.439E-02	3.927E+02	1.962E-09	2.735E-08	2.586E-08
6	43099	4.555E-01	7.800E-03	1.712E-02	4.680E-06	6.525E-05	7.184E-05
7	40093	4.442E-01	1.117E-03	2.515E-03	4.858E-06	6.773E-05	7.005E-05
8	55135	6.487E-01	7.475E-04	1.152E-03	4.887E-06	6.813E-05	1.023E-04
9	34079	2.653E-03	3.642E-04	1.373E-01	3.417E-08	4.763E-07	4.184E-07
10	50126	5.350E-03	1.519E-04	2.839E-02	4.318E-08	6.019E-07	8.437E-07
11	53129	5.306E-02	9.372E-06	1.766E-04	4.183E-07	5.831E-06	8.368E-06
12	46107	1.270E-02	6.534E-06	5.145E-04	1.207E-07	1.683E-06	2.003E-06
13	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.753E-05	2.664E-05
14	62147	2.479E-01	5.690E-09	2.296E-08	1.715E-06	2.390E-05	3.909E-05
15	60144	5.994E-01	7.120E-13	1.188E-12	4.233E-06	5.901E-05	9.454E-05
16	57138	3.328E-06	8.217E-14	2.469E-08	2.453E-11	3.419E-10	5.249E-10
17	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.744E-06	7.864E-06
18	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.246E-05	9.867E-05
19	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.200E-05	6.775E-05
20	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.274E-07	1.630E-07
21	64152	2.621E-05	5.710E-16	2.179E-11	1.753E-10	2.444E-09	4.133E-09
22	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.368E-07	2.253E-07
23	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.799E-08	1.232E-07
24	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.462E-06	3.157E-06
25	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.903E-10	2.324E-10
26	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.097E-09	8.906E-10
27	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.656E-09	3.009E-09
28	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.299E-08	2.788E-08
29	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.136E-08	9.475E-09
30	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.457E-08	7.242E-08
31	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.236E-07	1.940E-07
32	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.371E-06	1.220E-06
33	35079	3.901E-06	0.000E+00	0.000E+00	5.024E-11	7.003E-10	6.153E-10
34	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.168E-06	1.953E-06
35	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.786E-10	8.924E-10
36	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.738E-06	5.296E-06

37	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.046E-05	9.771E-06
38	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.242E-05	2.144E-05
39	37085	7.668E-02	0.000E+00	0.000E+00	9.176E-07	1.279E-05	1.209E-05
40	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.111E-10	3.932E-10
41	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.785E-05	3.704E-05
42	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.044E-05	4.992E-05
43	40090	3.245E-01	0.000E+00	0.000E+00	3.668E-06	5.114E-05	5.118E-05
44	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.215E-05	6.289E-05
45	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.424E-05	6.572E-05
46	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.906E-05	7.219E-05
47	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.775E-05	7.234E-05
48	41093	9.626E-06	0.000E+00	0.000E+00	1.053E-10	1.468E-09	1.518E-09
49	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.943E-05	7.335E-05
50	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.358E-08	3.585E-08
51	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.447E-05	6.955E-05
52	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.150E-05	6.703E-05
53	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.736E-05	7.492E-05
54	44099	1.230E-04	0.000E+00	0.000E+00	1.263E-09	1.761E-08	1.939E-08
55	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.549E-05	6.233E-05
56	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.601E-05	5.220E-05
57	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.039E-05	2.359E-05
58	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.255E-05	3.729E-05
59	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.058E-05	1.236E-05
60	46106	3.360E-02	0.000E+00	0.000E+00	3.224E-07	4.494E-06	5.298E-06
61	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.278E-07	7.541E-07
62	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.848E-07	3.485E-07
63	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.515E-07	4.261E-07
64	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.885E-07	2.327E-07
65	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.428E-07	1.779E-07
66	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.842E-07	2.336E-07
67	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.442E-07	1.861E-07
68	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.024E-10	2.544E-10
69	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.550E-09	8.378E-09
70	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.726E-10	7.388E-10
71	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.384E-07	1.801E-07
72	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.241E-07	1.629E-07
73	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.399E-07	1.852E-07
74	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.372E-07	1.831E-07
75	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.679E-07	2.279E-07
76	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.885E-07	3.979E-07
77	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.339E-07	1.802E-07
78	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.703E-07	2.330E-07
79	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.586E-10	2.188E-10
80	52125	3.202E-03	0.000E+00	0.000E+00	2.605E-08	3.631E-07	5.049E-07
81	52126	2.260E-04	0.000E+00	0.000E+00	1.824E-09	2.543E-08	3.564E-08
82	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.728E-06	5.308E-06
83	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.938E-05	2.803E-05
84	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.646E-06	2.325E-06
85	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.736E-10	3.896E-10
86	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.837E-09	6.995E-09
87	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.086E-05	4.497E-05
88	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.633E-05	6.803E-05
89	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.422E-05	1.255E-04
90	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.947E-05	1.051E-04
91	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.154E-05	1.058E-04
92	56134	9.514E-04	0.000E+00	0.000E+00	7.221E-09	1.007E-07	1.501E-07
93	56135	1.368E-05	0.000E+00	0.000E+00	1.030E-10	1.436E-09	2.157E-09
94	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.243E-08	1.096E-07
95	56137	5.190E-01	0.000E+00	0.000E+00	3.853E-06	5.371E-05	8.185E-05
96	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.233E-05	1.110E-04
97	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.855E-05	1.060E-04
98	58140	6.556E-01	0.000E+00	0.000E+00	4.762E-06	6.638E-05	1.034E-04
99	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.248E-05	9.801E-05
100	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.067E-09	1.432E-08
101	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.330E-05	1.007E-04
102	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.215E-05	5.222E-05
103	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.793E-05	2.952E-05
104	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.042E-06	1.175E-05
105	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.864E-06	1.146E-05
106	62152	3.754E-02	0.000E+00	0.000E+00	2.511E-07	3.500E-06	5.920E-06
107	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.085E-07	1.385E-06
108	63151	1.756E-02	0.000E+00	0.000E+00	1.182E-07	1.648E-06	2.769E-06
109	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.737E-06	2.957E-06
110	64154	1.495E-04	0.000E+00	0.000E+00	9.870E-10	1.376E-08	2.358E-08
111	64155	3.255E-03	0.000E+00	0.000E+00	2.135E-08	2.976E-07	5.133E-07
112	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.206E-07	3.829E-07
113	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.396E-08	2.439E-08
114	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.704E-09	6.594E-09
115	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.153E-08	2.040E-08
116	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.008E-09	1.806E-09
117	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.196E-10	3.959E-10
118	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.640E-01	1.182E-01

119	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.546E-05
120	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.180E-09	1.970E-10
121	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.210E-03	2.424E-04
	totals	7.691E+02	2.982E+01	3.877E-02	4.789E-02	6.676E-01	1.213E-01

Step 9 - 100 years

actinide inventory for material 40000 at end of step 9, time 3.650E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92234	1.161E+01	7.218E-02	6.217E-03	5.041E-05	7.028E-04	1.831E-03
2	94239	1.143E+00	7.093E-02	6.203E-02	4.861E-06	6.776E-05	1.803E-04
3	92235	1.076E+03	2.327E-03	2.161E-06	4.654E-03	6.488E-02	1.698E-01
4	94240	8.124E-03	1.843E-03	2.269E-01	3.439E-08	4.794E-07	1.281E-06
5	92238	4.475E+03	1.504E-03	3.361E-07	1.910E-02	2.663E-01	7.057E-01
6	94238	2.966E-05	5.080E-04	1.712E+01	1.266E-10	1.765E-09	4.678E-09
7	92236	7.693E+00	4.975E-04	6.467E-05	3.312E-05	4.617E-04	1.213E-03
8	95241	1.152E-04	3.950E-04	3.427E+00	4.858E-10	6.773E-09	1.817E-08
9	90230	3.366E-03	6.939E-05	2.062E-02	1.487E-08	2.073E-07	5.308E-07
10	93237	1.784E-02	1.257E-05	7.047E-04	7.647E-08	1.066E-06	2.813E-06
11	91231	1.094E-04	5.165E-06	4.723E-02	4.810E-10	6.705E-09	1.725E-08
12	92233	4.319E-06	4.162E-08	9.636E-03	1.883E-11	2.625E-10	6.811E-10
13	90232	2.237E-05	2.453E-12	1.097E-07	9.795E-11	1.366E-09	3.527E-09
	totals	5.572E+03	1.503E-01	2.697E-05	2.384E-02	3.324E-01	8.787E-01

nonactinide inventory for material 40000 at end of step 9, time 3.650E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	6.024E-02	5.243E+00	8.704E+01	4.471E-07	6.233E-06	9.500E-06
2	39090	8.195E-06	4.456E+00	5.438E+05	9.263E-11	1.291E-09	1.292E-09
3	38090	3.154E-02	4.455E+00	1.413E+02	3.565E-07	4.970E-06	4.974E-06
4	62151	1.874E-02	4.932E-01	2.632E+01	1.262E-07	1.759E-06	2.955E-06
5	36085	2.360E-05	9.267E-03	3.927E+02	2.824E-10	3.937E-09	3.721E-09
6	43099	4.555E-01	7.799E-03	1.712E-02	4.680E-06	6.524E-05	7.183E-05
7	40093	4.442E-01	1.117E-03	2.515E-03	4.858E-06	6.773E-05	7.005E-05
8	55135	6.487E-01	7.475E-04	1.152E-03	4.887E-06	6.813E-05	1.023E-04
9	34079	2.652E-03	3.640E-04	1.373E-01	3.414E-08	4.760E-07	4.182E-07
10	50126	5.348E-03	1.519E-04	2.839E-02	4.317E-08	6.018E-07	8.435E-07
11	53129	5.306E-02	9.372E-06	1.766E-04	4.183E-07	5.831E-06	8.367E-06
12	46107	1.270E-02	6.534E-06	5.145E-04	1.207E-07	1.683E-06	2.003E-06
13	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.753E-05	2.664E-05
14	62147	2.479E-01	5.690E-09	2.296E-08	1.715E-06	2.390E-05	3.909E-05
15	60144	5.994E-01	7.120E-13	1.188E-12	4.233E-06	5.901E-05	9.454E-05
16	57138	3.328E-06	8.217E-14	2.469E-08	2.453E-11	3.419E-10	5.249E-10
17	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.744E-06	7.864E-06
18	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.246E-05	9.867E-05
19	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.200E-05	6.775E-05
20	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.274E-07	1.630E-07
21	64152	2.640E-05	5.753E-16	2.179E-11	1.766E-10	2.462E-09	4.164E-09
22	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.368E-07	2.253E-07
23	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.799E-08	1.232E-07
24	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.462E-06	3.157E-06
25	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.903E-10	2.324E-10
26	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.097E-09	8.906E-10
27	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.656E-09	3.009E-09
28	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.299E-08	2.788E-08
29	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.136E-08	9.475E-09
30	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.457E-08	7.242E-08
31	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.236E-07	1.940E-07
32	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.371E-06	1.220E-06
33	35079	5.572E-06	0.000E+00	0.000E+00	7.174E-11	1.000E-09	8.787E-10
34	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.168E-06	1.953E-06
35	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.786E-10	8.924E-10
36	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.738E-06	5.296E-06
37	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.046E-05	9.771E-06
38	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.242E-05	2.144E-05
39	37085	7.682E-02	0.000E+00	0.000E+00	9.193E-07	1.282E-05	1.211E-05
40	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.111E-10	3.932E-10
41	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.785E-05	3.704E-05
42	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.044E-05	4.992E-05
43	40090	3.590E-01	0.000E+00	0.000E+00	4.057E-06	5.656E-05	5.661E-05
44	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.215E-05	6.289E-05
45	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.424E-05	6.572E-05
46	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.906E-05	7.219E-05
47	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.775E-05	7.234E-05
48	41093	1.549E-05	0.000E+00	0.000E+00	1.694E-10	2.362E-09	2.443E-09
49	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.943E-05	7.335E-05
50	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.358E-08	3.585E-08
51	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.447E-05	6.955E-05

52	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.150E-05	6.703E-05
53	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.736E-05	7.492E-05
54	44099	1.678E-04	0.000E+00	0.000E+00	1.724E-09	2.403E-08	2.646E-08
55	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.549E-05	6.233E-05
56	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.601E-05	5.220E-05
57	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.039E-05	2.359E-05
58	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.255E-05	3.729E-05
59	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.058E-05	1.236E-05
60	46106	3.360E-02	0.000E+00	0.000E+00	3.224E-07	4.494E-06	5.298E-06
61	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.278E-07	7.541E-07
62	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.848E-07	3.485E-07
63	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.515E-07	4.261E-07
64	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.885E-07	2.327E-07
65	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.428E-07	1.779E-07
66	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.842E-07	2.336E-07
67	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.442E-07	1.861E-07
68	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.024E-10	2.544E-10
69	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.550E-09	8.378E-09
70	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.726E-10	7.388E-10
71	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.384E-07	1.801E-07
72	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.241E-07	1.629E-07
73	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.399E-07	1.852E-07
74	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.372E-07	1.831E-07
75	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.679E-07	2.279E-07
76	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.885E-07	3.979E-07
77	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.339E-07	1.802E-07
78	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.703E-07	2.330E-07
79	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.586E-10	2.188E-10
80	52125	3.202E-03	0.000E+00	0.000E+00	2.605E-08	3.631E-07	5.049E-07
81	52126	2.271E-04	0.000E+00	0.000E+00	1.833E-09	2.556E-08	3.582E-08
82	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.728E-06	5.308E-06
83	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.938E-05	2.803E-05
84	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.646E-06	2.325E-06
85	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.736E-10	3.896E-10
86	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.837E-09	6.995E-09
87	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.086E-05	4.497E-05
88	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.633E-05	6.803E-05
89	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.422E-05	1.255E-04
90	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.947E-05	1.051E-04
91	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.154E-05	1.058E-04
92	56134	9.514E-04	0.000E+00	0.000E+00	7.221E-09	1.007E-07	1.501E-07
93	56135	1.954E-05	0.000E+00	0.000E+00	1.472E-10	2.052E-09	3.081E-09
94	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.243E-08	1.096E-07
95	56137	5.792E-01	0.000E+00	0.000E+00	4.299E-06	5.993E-05	9.135E-05
96	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.233E-05	1.110E-04
97	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.855E-05	1.060E-04
98	58140	6.556E-01	0.000E+00	0.000E+00	4.762E-06	6.638E-05	1.034E-04
99	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.248E-05	9.801E-05
100	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.067E-09	1.432E-08
101	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.330E-05	1.007E-04
102	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.215E-05	5.222E-05
103	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.793E-05	2.952E-05
104	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.042E-06	1.175E-05
105	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.864E-06	1.146E-05
106	62152	3.754E-02	0.000E+00	0.000E+00	2.511E-07	3.500E-06	5.920E-06
107	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.085E-07	1.385E-06
108	63151	2.242E-02	0.000E+00	0.000E+00	1.510E-07	2.105E-06	3.536E-06
109	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.737E-06	2.957E-06
110	64154	1.499E-04	0.000E+00	0.000E+00	9.899E-10	1.380E-08	2.365E-08
111	64155	3.255E-03	0.000E+00	0.000E+00	2.135E-08	2.976E-07	5.133E-07
112	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.206E-07	3.829E-07
113	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.396E-08	2.439E-08
114	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.704E-09	6.594E-09
115	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.153E-08	2.040E-08
116	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.008E-09	1.806E-09
117	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.196E-10	3.959E-10
118	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.640E-01	1.182E-01
119	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.546E-05
120	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.180E-09	1.970E-10
121	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.210E-03	2.424E-04
	totals	7.691E+02	1.467E+01	1.907E-02	4.789E-02	6.676E-01	1.213E-01

Step 10 - 200 years

actinide inventory for material 40000 at end of step 10, time 7.300E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92234	1.161E+01	7.216E-02	6.217E-03	5.040E-05	7.026E-04	1.831E-03
2	94239	1.140E+00	7.072E-02	6.203E-02	4.847E-06	6.757E-05	1.798E-04

3	92235	1.076E+03	2.327E-03	2.161E-06	4.654E-03	6.488E-02	1.698E-01
4	94240	8.038E-03	1.824E-03	2.269E-01	3.403E-08	4.744E-07	1.268E-06
5	92238	4.475E+03	1.504E-03	3.361E-07	1.910E-02	2.663E-01	7.057E-01
6	92236	7.693E+00	4.975E-04	6.467E-05	3.312E-05	4.617E-04	1.213E-03
7	95241	9.912E-05	3.397E-04	3.427E+00	4.178E-10	5.825E-09	1.563E-08
8	94238	1.346E-05	2.306E-04	1.712E+01	5.748E-11	8.013E-10	2.123E-09
9	90230	6.578E-03	1.356E-04	2.062E-02	2.906E-08	4.051E-07	1.037E-06
10	93237	1.786E-02	1.258E-05	7.047E-04	7.654E-08	1.067E-06	2.816E-06
11	91231	2.132E-04	1.007E-05	4.723E-02	9.376E-10	1.307E-08	3.362E-08
12	92233	4.885E-06	4.707E-08	9.636E-03	2.130E-11	2.970E-10	7.704E-10
13	90232	4.473E-05	4.905E-12	1.097E-07	1.959E-10	2.731E-09	7.055E-09
	totals	5.572E+03	1.498E-01	2.688E-05	2.384E-02	3.324E-01	8.787E-01

nonactinide inventory for material 40000 at end of step 10, time 7.300E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	5.986E-03	5.210E-01	8.704E+01	4.443E-08	6.194E-07	9.440E-07
2	39090	6.997E-07	3.805E-01	5.438E+05	7.908E-12	1.102E-10	1.103E-10
3	38090	2.693E-03	3.804E-01	1.413E+02	3.044E-08	4.243E-07	4.247E-07
4	62151	8.679E-03	2.284E-01	2.632E+01	5.844E-08	8.147E-07	1.369E-06
5	43099	4.553E-01	7.796E-03	1.712E-02	4.678E-06	6.522E-05	7.181E-05
6	40093	4.441E-01	1.117E-03	2.515E-03	4.858E-06	6.772E-05	7.004E-05
7	55135	6.487E-01	7.474E-04	1.152E-03	4.887E-06	6.812E-05	1.023E-04
8	34079	2.646E-03	3.632E-04	1.373E-01	3.407E-08	4.750E-07	4.173E-07
9	50126	5.345E-03	1.518E-04	2.839E-02	4.314E-08	6.014E-07	8.429E-07
10	53129	5.306E-02	9.372E-06	1.766E-04	4.183E-07	5.831E-06	8.367E-06
11	46107	1.270E-02	6.534E-06	5.145E-04	1.207E-07	1.683E-06	2.003E-06
12	88226	5.901E-06	5.833E-06	9.885E-01	2.653E-11	3.699E-10	9.306E-10
13	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.753E-05	2.664E-05
14	62147	2.479E-01	5.690E-09	2.296E-08	1.715E-06	2.390E-05	3.909E-05
15	60144	5.994E-01	7.120E-13	1.188E-12	4.233E-06	5.901E-05	9.454E-05
16	57138	3.328E-06	8.217E-14	2.469E-08	2.453E-11	3.419E-10	5.249E-10
17	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.744E-06	7.864E-06
18	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.246E-05	9.867E-05
19	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.200E-05	6.775E-05
20	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.274E-07	1.630E-07
21	64152	2.646E-05	5.765E-16	2.179E-11	1.770E-10	2.467E-09	4.172E-09
22	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.368E-07	2.253E-07
23	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.799E-08	1.232E-07
24	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.462E-06	3.157E-06
25	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.903E-10	2.324E-10
26	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.097E-09	8.906E-10
27	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.656E-09	3.009E-09
28	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.299E-08	2.788E-08
29	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.136E-08	9.475E-09
30	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.457E-08	7.242E-08
31	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.236E-07	1.940E-07
32	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.371E-06	1.220E-06
33	35079	1.113E-05	0.000E+00	0.000E+00	1.433E-10	1.998E-09	1.756E-09
34	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.168E-06	1.953E-06
35	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.786E-10	8.924E-10
36	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.738E-06	5.296E-06
37	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.046E-05	9.771E-06
38	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.242E-05	2.144E-05
39	37085	7.684E-02	0.000E+00	0.000E+00	9.196E-07	1.282E-05	1.212E-05
40	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.111E-10	3.932E-10
41	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.785E-05	3.704E-05
42	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.044E-05	4.992E-05
43	40090	3.878E-01	0.000E+00	0.000E+00	4.383E-06	6.111E-05	6.116E-05
44	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.215E-05	6.289E-05
45	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.424E-05	6.572E-05
46	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.906E-05	7.219E-05
47	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.775E-05	7.234E-05
48	41093	3.554E-05	0.000E+00	0.000E+00	3.887E-10	5.419E-09	5.604E-09
49	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.943E-05	7.335E-05
50	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.358E-08	3.585E-08
51	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.447E-05	6.955E-05
52	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.150E-05	6.703E-05
53	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.736E-05	7.492E-05
54	44099	3.172E-04	0.000E+00	0.000E+00	3.259E-09	4.544E-08	5.003E-08
55	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.549E-05	6.233E-05
56	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.601E-05	5.220E-05
57	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.039E-05	2.359E-05
58	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.255E-05	3.729E-05
59	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.058E-05	1.236E-05
60	46106	3.360E-02	0.000E+00	0.000E+00	3.224E-07	4.494E-06	5.298E-06
61	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.278E-07	7.541E-07
62	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.848E-07	3.485E-07
63	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.515E-07	4.261E-07
64	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.885E-07	2.327E-07
65	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.428E-07	1.779E-07

66	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.842E-07	2.336E-07
67	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.442E-07	1.861E-07
68	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.024E-10	2.544E-10
69	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.550E-09	8.378E-09
70	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.726E-10	7.388E-10
71	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.384E-07	1.801E-07
72	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.241E-07	1.629E-07
73	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.399E-07	1.852E-07
74	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.372E-07	1.831E-07
75	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.679E-07	2.279E-07
76	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.885E-07	3.979E-07
77	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.339E-07	1.802E-07
78	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.703E-07	2.330E-07
79	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.586E-10	2.188E-10
80	52125	3.202E-03	0.000E+00	0.000E+00	2.605E-08	3.631E-07	5.049E-07
81	52126	2.308E-04	0.000E+00	0.000E+00	1.863E-09	2.597E-08	3.640E-08
82	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.728E-06	5.308E-06
83	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.938E-05	2.803E-05
84	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.646E-06	2.325E-06
85	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.736E-10	3.896E-10
86	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.837E-09	6.995E-09
87	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.086E-05	4.497E-05
88	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.633E-05	6.803E-05
89	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.422E-05	1.255E-04
90	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.947E-05	1.051E-04
91	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.154E-05	1.058E-04
92	56134	9.514E-04	0.000E+00	0.000E+00	7.221E-09	1.007E-07	1.501E-07
93	56135	3.908E-05	0.000E+00	0.000E+00	2.943E-10	4.103E-09	6.163E-09
94	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.243E-08	1.096E-07
95	56137	6.335E-01	0.000E+00	0.000E+00	4.702E-06	6.555E-05	9.990E-05
96	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.233E-05	1.110E-04
97	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.855E-05	1.060E-04
98	58140	6.556E-01	0.000E+00	0.000E+00	4.762E-06	6.638E-05	1.034E-04
99	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.248E-05	9.801E-05
100	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.067E-09	1.432E-08
101	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.330E-05	1.007E-04
102	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.215E-05	5.222E-05
103	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.793E-05	2.952E-05
104	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.042E-06	1.175E-05
105	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.864E-06	1.146E-05
106	62152	3.754E-02	0.000E+00	0.000E+00	2.511E-07	3.500E-06	5.920E-06
107	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.085E-07	1.385E-06
108	63151	3.248E-02	0.000E+00	0.000E+00	2.187E-07	3.049E-06	5.123E-06
109	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.737E-06	2.957E-06
110	64154	1.500E-04	0.000E+00	0.000E+00	9.902E-10	1.380E-08	2.365E-08
111	64155	3.255E-03	0.000E+00	0.000E+00	2.135E-08	2.976E-07	5.133E-07
112	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.206E-07	3.829E-07
113	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.396E-08	2.439E-08
114	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.704E-09	6.594E-09
115	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.153E-08	2.040E-08
116	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.008E-09	1.806E-09
117	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.196E-10	3.959E-10
118	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.640E-01	1.182E-01
119	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.546E-05
120	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.180E-09	1.970E-10
121	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.210E-03	2.424E-04
	totals	7.691E+02	1.520E+00	1.977E-03	4.789E-02	6.676E-01	1.213E-01

Step 11 - 300 years

actinide inventory for material 40000 at end of step 11, time 1.095E+05 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92234	1.160E+01	7.214E-02	6.217E-03	5.039E-05	7.024E-04	1.830E-03
2	94239	1.137E+00	7.052E-02	6.203E-02	4.833E-06	6.738E-05	1.793E-04
3	92235	1.076E+03	2.327E-03	2.161E-06	4.654E-03	6.488E-02	1.698E-01
4	94240	7.954E-03	1.805E-03	2.269E-01	3.367E-08	4.694E-07	1.254E-06
5	92238	4.475E+03	1.504E-03	3.361E-07	1.910E-02	2.663E-01	7.057E-01
6	92236	7.693E+00	4.975E-04	6.467E-05	3.312E-05	4.617E-04	1.213E-03
7	95241	8.446E-05	2.895E-04	3.427E+00	3.561E-10	4.964E-09	1.332E-08
8	90230	9.786E-03	2.018E-04	2.062E-02	4.323E-08	6.027E-07	1.543E-06
9	94238	6.112E-06	1.047E-04	1.712E+01	2.609E-11	3.637E-10	9.638E-10
10	91231	3.168E-04	1.496E-05	4.723E-02	1.393E-09	1.942E-08	4.996E-08
11	93237	1.787E-02	1.259E-05	7.047E-04	7.660E-08	1.068E-06	2.818E-06
12	92233	5.451E-06	5.253E-08	9.636E-03	2.377E-11	3.314E-10	8.597E-10
13	90232	6.710E-05	7.358E-12	1.097E-07	2.939E-10	4.097E-09	1.058E-08
	totals	5.572E+03	1.494E-01	2.682E-05	2.384E-02	3.324E-01	8.787E-01

nonactinide inventory for material 40000 at end of step 11, time 1.095E+05 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	62151	4.020E-03	1.058E-01	2.632E+01	2.707E-08	3.773E-07	6.339E-07
2	55137	5.948E-04	5.177E-02	8.704E+01	4.415E-09	6.154E-08	9.380E-08
3	38090	2.299E-04	3.247E-02	1.413E+02	2.598E-09	3.622E-08	3.626E-08
4	43099	4.552E-01	7.794E-03	1.712E-02	4.677E-06	6.520E-05	7.179E-05
5	40093	4.441E-01	1.117E-03	2.515E-03	4.858E-06	6.772E-05	7.004E-05
6	55135	6.487E-01	7.474E-04	1.152E-03	4.886E-06	6.812E-05	1.023E-04
7	34079	2.641E-03	3.625E-04	1.373E-01	3.400E-08	4.740E-07	4.164E-07
8	50126	5.341E-03	1.517E-04	2.839E-02	4.311E-08	6.009E-07	8.423E-07
9	88226	1.289E-05	1.274E-05	9.885E-01	5.796E-11	8.080E-10	2.033E-09
10	53129	5.306E-02	9.372E-06	1.766E-04	4.183E-07	5.831E-06	8.367E-06
11	46107	1.270E-02	6.534E-06	5.145E-04	1.207E-07	1.683E-06	2.003E-06
12	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.753E-05	2.664E-05
13	62147	2.479E-01	5.690E-09	2.296E-08	1.715E-06	2.390E-05	3.909E-05
14	60144	5.994E-01	7.120E-13	1.188E-12	4.233E-06	5.901E-05	9.454E-05
15	57138	3.328E-06	8.217E-14	2.469E-08	2.453E-11	3.419E-10	5.249E-10
16	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.744E-06	7.864E-06
17	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.246E-05	9.867E-05
18	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.200E-05	6.775E-05
19	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.274E-07	1.630E-07
20	64152	2.646E-05	5.765E-16	2.179E-11	1.770E-10	2.467E-09	4.172E-09
21	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.368E-07	2.253E-07
22	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.799E-08	1.232E-07
23	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.462E-06	3.157E-06
24	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.903E-10	2.324E-10
25	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.097E-09	8.906E-10
26	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.656E-09	3.009E-09
27	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.299E-08	2.788E-08
28	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.136E-08	9.475E-09
29	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.457E-08	7.242E-08
30	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.236E-07	1.940E-07
31	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.371E-06	1.220E-06
32	35079	1.668E-05	0.000E+00	0.000E+00	2.148E-10	2.994E-09	2.631E-09
33	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.168E-06	1.953E-06
34	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.786E-10	8.924E-10
35	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.738E-06	5.296E-06
36	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.046E-05	9.771E-06
37	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.242E-05	2.144E-05
38	37085	7.684E-02	0.000E+00	0.000E+00	9.196E-07	1.282E-05	1.212E-05
39	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.111E-10	3.932E-10
40	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.785E-05	3.704E-05
41	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.044E-05	4.992E-05
42	40090	3.903E-01	0.000E+00	0.000E+00	4.411E-06	6.150E-05	6.155E-05
43	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.215E-05	6.289E-05
44	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.424E-05	6.572E-05
45	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.906E-05	7.219E-05
46	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.775E-05	7.234E-05
47	41093	5.564E-05	0.000E+00	0.000E+00	6.086E-10	8.485E-09	8.775E-09
48	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.943E-05	7.335E-05
49	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.358E-08	3.585E-08
50	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.447E-05	6.955E-05
51	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.150E-05	6.703E-05
52	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.736E-05	7.492E-05
53	44099	4.666E-04	0.000E+00	0.000E+00	4.794E-09	6.683E-08	7.359E-08
54	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.549E-05	6.233E-05
55	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.601E-05	5.220E-05
56	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.039E-05	2.359E-05
57	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.255E-05	3.729E-05
58	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.058E-05	1.236E-05
59	46106	3.360E-02	0.000E+00	0.000E+00	3.224E-07	4.494E-06	5.298E-06
60	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.278E-07	7.541E-07
61	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.848E-07	3.485E-07
62	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.515E-07	4.261E-07
63	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.885E-07	2.327E-07
64	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.428E-07	1.779E-07
65	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.842E-07	2.336E-07
66	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.442E-07	1.861E-07
67	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.024E-10	2.544E-10
68	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.550E-09	8.378E-09
69	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.726E-10	7.388E-10
70	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.384E-07	1.801E-07
71	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.241E-07	1.629E-07
72	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.399E-07	1.852E-07
73	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.372E-07	1.831E-07
74	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.679E-07	2.279E-07
75	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.885E-07	3.979E-07
76	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.339E-07	1.802E-07
77	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.703E-07	2.330E-07
78	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.586E-10	2.188E-10
79	52125	3.202E-03	0.000E+00	0.000E+00	2.605E-08	3.631E-07	5.049E-07

80	52126	2.345E-04	0.000E+00	0.000E+00	1.893E-09	2.639E-08	3.699E-08
81	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.728E-06	5.308E-06
82	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.938E-05	2.803E-05
83	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.646E-06	2.325E-06
84	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.736E-10	3.896E-10
85	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.837E-09	6.995E-09
86	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.086E-05	4.497E-05
87	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.633E-05	6.803E-05
88	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.422E-05	1.255E-04
89	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.947E-05	1.051E-04
90	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.154E-05	1.058E-04
91	56134	9.514E-04	0.000E+00	0.000E+00	7.221E-09	1.007E-07	1.501E-07
92	56135	5.861E-05	0.000E+00	0.000E+00	4.415E-10	6.155E-09	9.244E-09
93	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.243E-08	1.096E-07
94	56137	6.389E-01	0.000E+00	0.000E+00	4.742E-06	6.611E-05	1.008E-04
95	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.233E-05	1.110E-04
96	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.855E-05	1.060E-04
97	58140	6.556E-01	0.000E+00	0.000E+00	4.762E-06	6.638E-05	1.034E-04
98	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.248E-05	9.801E-05
99	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.067E-09	1.432E-08
100	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.330E-05	1.007E-04
101	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.215E-05	5.222E-05
102	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.793E-05	2.952E-05
103	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.042E-06	1.175E-05
104	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.864E-06	1.146E-05
105	62152	3.754E-02	0.000E+00	0.000E+00	2.511E-07	3.500E-06	5.920E-06
106	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.085E-07	1.385E-06
107	63151	3.714E-02	0.000E+00	0.000E+00	2.501E-07	3.486E-06	5.857E-06
108	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.737E-06	2.957E-06
109	64154	1.500E-04	0.000E+00	0.000E+00	9.902E-10	1.380E-08	2.365E-08
110	64155	3.255E-03	0.000E+00	0.000E+00	2.135E-08	2.976E-07	5.133E-07
111	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.206E-07	3.829E-07
112	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.396E-08	2.439E-08
113	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.704E-09	6.594E-09
114	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.153E-08	2.040E-08
115	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.008E-09	1.806E-09
116	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.196E-10	3.959E-10
117	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.640E-01	1.182E-01
118	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.546E-05
119	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.180E-09	1.970E-10
120	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.210E-03	2.424E-04
	totals	7.691E+02	2.002E-01	2.603E-04	4.789E-02	6.676E-01	1.213E-01

Step 12 - 500 years

actinide inventory for material 40000 at end of step 12, time 1.825E+05 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92234	1.160E+01	7.210E-02	6.217E-03	5.036E-05	7.020E-04	1.829E-03
2	94239	1.130E+00	7.012E-02	6.203E-02	4.805E-06	6.699E-05	1.783E-04
3	92235	1.076E+03	2.327E-03	2.161E-06	4.654E-03	6.488E-02	1.698E-01
4	94240	7.788E-03	1.767E-03	2.269E-01	3.297E-08	4.596E-07	1.228E-06
5	92238	4.475E+03	1.504E-03	3.361E-07	1.910E-02	2.663E-01	7.057E-01
6	92236	7.693E+00	4.975E-04	6.467E-05	3.312E-05	4.617E-04	1.213E-03
7	90230	1.619E-02	3.338E-04	2.062E-02	7.153E-08	9.972E-07	2.554E-06
8	95241	6.132E-05	2.102E-04	3.427E+00	2.585E-10	3.604E-09	9.671E-09
9	91231	5.233E-04	2.472E-05	4.723E-02	2.302E-09	3.209E-08	8.253E-08
10	93237	1.789E-02	1.261E-05	7.047E-04	7.670E-08	1.069E-06	2.822E-06
11	92233	6.584E-06	6.344E-08	9.636E-03	2.871E-11	4.002E-10	1.038E-09
12	90232	1.118E-04	1.226E-11	1.097E-07	4.898E-10	6.828E-09	1.764E-08
	totals	5.572E+03	1.489E-01	2.672E-05	2.384E-02	3.324E-01	8.787E-01

nonactinide inventory for material 40000 at end of step 12, time 1.825E+05 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	62151	8.624E-04	2.270E-02	2.632E+01	5.807E-09	8.095E-08	1.360E-07
2	43099	4.549E-01	7.789E-03	1.712E-02	4.674E-06	6.515E-05	7.174E-05
3	40093	4.441E-01	1.117E-03	2.515E-03	4.857E-06	6.771E-05	7.003E-05
4	55135	6.487E-01	7.474E-04	1.152E-03	4.886E-06	6.812E-05	1.023E-04
5	55137	5.872E-06	5.111E-04	8.704E+01	4.359E-11	6.076E-10	9.261E-10
6	34079	2.629E-03	3.609E-04	1.373E-01	3.386E-08	4.720E-07	4.147E-07
7	38090	1.676E-06	2.367E-04	1.413E+02	1.894E-11	2.640E-10	2.643E-10
8	50126	5.334E-03	1.514E-04	2.839E-02	4.305E-08	6.001E-07	8.411E-07
9	88226	3.437E-05	3.398E-05	9.885E-01	1.545E-10	2.154E-09	5.421E-09
10	53129	5.306E-02	9.372E-06	1.766E-04	4.183E-07	5.831E-06	8.367E-06
11	46107	1.270E-02	6.534E-06	5.145E-04	1.207E-07	1.683E-06	2.003E-06
12	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.753E-05	2.664E-05
13	62147	2.479E-01	5.690E-09	2.296E-08	1.715E-06	2.390E-05	3.909E-05
14	60144	5.994E-01	7.120E-13	1.188E-12	4.233E-06	5.901E-05	9.454E-05

15	57138	3.328E-06	8.217E-14	2.469E-08	2.453E-11	3.419E-10	5.249E-10
16	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.744E-06	7.864E-06
17	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.246E-05	9.867E-05
18	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.200E-05	6.775E-05
19	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.274E-07	1.630E-07
20	64152	2.646E-05	5.765E-16	2.179E-11	1.770E-10	2.467E-09	4.172E-09
21	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.368E-07	2.253E-07
22	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.799E-08	1.232E-07
23	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.462E-06	3.157E-06
24	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.903E-10	2.324E-10
25	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.097E-09	8.906E-10
26	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.656E-09	3.009E-09
27	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.299E-08	2.788E-08
28	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.136E-08	9.475E-09
29	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.457E-08	7.242E-08
30	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.236E-07	1.940E-07
31	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.371E-06	1.220E-06
32	35079	2.774E-05	0.000E+00	0.000E+00	3.572E-10	4.980E-09	4.375E-09
33	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.168E-06	1.953E-06
34	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.786E-10	8.924E-10
35	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.738E-06	5.296E-06
36	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.046E-05	9.771E-06
37	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.242E-05	2.144E-05
38	37085	7.684E-02	0.000E+00	0.000E+00	9.196E-07	1.282E-05	1.212E-05
39	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.111E-10	3.932E-10
40	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.785E-05	3.704E-05
41	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.044E-05	4.992E-05
42	40090	3.905E-01	0.000E+00	0.000E+00	4.414E-06	6.153E-05	6.158E-05
43	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.215E-05	6.289E-05
44	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.424E-05	6.572E-05
45	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.906E-05	7.219E-05
46	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.775E-05	7.234E-05
47	41093	9.586E-05	0.000E+00	0.000E+00	1.048E-09	1.462E-08	1.512E-08
48	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.943E-05	7.335E-05
49	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.358E-08	3.585E-08
50	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.447E-05	6.955E-05
51	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.150E-05	6.703E-05
52	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.736E-05	7.492E-05
53	44099	7.652E-04	0.000E+00	0.000E+00	7.862E-09	1.096E-07	1.207E-07
54	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.549E-05	6.233E-05
55	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.601E-05	5.220E-05
56	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.039E-05	2.359E-05
57	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.255E-05	3.729E-05
58	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.058E-05	1.236E-05
59	46106	3.360E-02	0.000E+00	0.000E+00	3.224E-07	4.494E-06	5.298E-06
60	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.278E-07	7.541E-07
61	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.848E-07	3.485E-07
62	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.515E-07	4.261E-07
63	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.885E-07	2.327E-07
64	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.428E-07	1.779E-07
65	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.842E-07	2.336E-07
66	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.442E-07	1.861E-07
67	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.024E-10	2.544E-10
68	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.550E-09	8.378E-09
69	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.726E-10	7.388E-10
70	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.384E-07	1.801E-07
71	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.241E-07	1.629E-07
72	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.399E-07	1.852E-07
73	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.372E-07	1.831E-07
74	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.679E-07	2.279E-07
75	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.885E-07	3.979E-07
76	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.339E-07	1.802E-07
77	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.703E-07	2.330E-07
78	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.586E-10	2.188E-10
79	52125	3.202E-03	0.000E+00	0.000E+00	2.605E-08	3.631E-07	5.049E-07
80	52126	2.419E-04	0.000E+00	0.000E+00	1.953E-09	2.722E-08	3.815E-08
81	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.728E-06	5.308E-06
82	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.938E-05	2.803E-05
83	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.646E-06	2.325E-06
84	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.736E-10	3.896E-10
85	54129	1.170E-06	0.000E+00	0.000E+00	9.227E-12	1.286E-10	1.846E-10
86	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.837E-09	6.995E-09
87	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.086E-05	4.497E-05
88	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.633E-05	6.803E-05
89	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.422E-05	1.255E-04
90	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.947E-05	1.051E-04
91	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.154E-05	1.058E-04
92	56134	9.514E-04	0.000E+00	0.000E+00	7.221E-09	1.007E-07	1.501E-07
93	56135	9.769E-05	0.000E+00	0.000E+00	7.358E-10	1.026E-08	1.541E-08
94	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.243E-08	1.096E-07
95	56137	6.394E-01	0.000E+00	0.000E+00	4.746E-06	6.617E-05	1.008E-04
96	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.233E-05	1.110E-04

97	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.855E-05	1.060E-04
98	58140	6.556E-01	0.000E+00	0.000E+00	4.762E-06	6.638E-05	1.034E-04
99	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.248E-05	9.801E-05
100	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.067E-09	1.432E-08
101	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.330E-05	1.007E-04
102	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.215E-05	5.222E-05
103	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.793E-05	2.952E-05
104	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.042E-06	1.175E-05
105	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.864E-06	1.146E-05
106	62152	3.754E-02	0.000E+00	0.000E+00	2.511E-07	3.500E-06	5.920E-06
107	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.085E-07	1.385E-06
108	63151	4.030E-02	0.000E+00	0.000E+00	2.713E-07	3.783E-06	6.355E-06
109	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.737E-06	2.957E-06
110	64154	1.500E-04	0.000E+00	0.000E+00	9.902E-10	1.380E-08	2.365E-08
111	64155	3.255E-03	0.000E+00	0.000E+00	2.135E-08	2.976E-07	5.133E-07
112	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.206E-07	3.829E-07
113	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.396E-08	2.439E-08
114	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.704E-09	6.594E-09
115	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.153E-08	2.040E-08
116	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.008E-09	1.806E-09
117	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.196E-10	3.959E-10
118	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.640E-01	1.182E-01
119	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.546E-05
120	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.180E-09	1.970E-10
121	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.210E-03	2.424E-04
	totals	7.691E+02	3.366E-02	4.376E-05	4.789E-02	6.676E-01	1.213E-01

Step 13 - 1 000 years

actinide inventory for material 40000 at end of step 13, time 3.650E+05 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92234	1.158E+01	7.200E-02	6.217E-03	5.029E-05	7.011E-04	1.827E-03
2	94239	1.114E+00	6.912E-02	6.203E-02	4.737E-06	6.604E-05	1.757E-04
3	92235	1.076E+03	2.327E-03	2.161E-06	4.654E-03	6.488E-02	1.698E-01
4	94240	7.388E-03	1.676E-03	2.269E-01	3.127E-08	4.360E-07	1.165E-06
5	92238	4.475E+03	1.504E-03	3.361E-07	1.910E-02	2.663E-01	7.057E-01
6	90230	3.214E-02	6.626E-04	2.062E-02	1.420E-07	1.979E-06	5.068E-06
7	92236	7.693E+00	4.975E-04	6.467E-05	3.312E-05	4.617E-04	1.213E-03
8	95241	2.754E-05	9.440E-05	3.427E+00	1.161E-10	1.619E-09	4.344E-09
9	91231	1.036E-03	4.893E-05	4.723E-02	4.556E-09	6.351E-08	1.634E-07
10	93237	1.792E-02	1.263E-05	7.047E-04	7.683E-08	1.071E-06	2.826E-06
11	92233	9.416E-06	9.073E-08	9.636E-03	4.106E-11	5.724E-10	1.485E-09
12	90232	2.237E-04	2.453E-11	1.097E-07	9.796E-10	1.366E-08	3.528E-08
	totals	5.572E+03	1.479E-01	2.655E-05	2.384E-02	3.324E-01	8.787E-01

nonactinide inventory for material 40000 at end of step 13, time 3.650E+05 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	43099	4.541E-01	7.776E-03	1.712E-02	4.666E-06	6.505E-05	7.162E-05
2	40093	4.440E-01	1.117E-03	2.515E-03	4.856E-06	6.770E-05	7.002E-05
3	55135	6.486E-01	7.473E-04	1.152E-03	4.885E-06	6.811E-05	1.023E-04
4	62151	1.838E-05	4.838E-04	2.632E+01	1.238E-10	1.725E-09	2.899E-09
5	34079	2.602E-03	3.572E-04	1.373E-01	3.351E-08	4.671E-07	4.104E-07
6	50126	5.315E-03	1.509E-04	2.839E-02	4.290E-08	5.980E-07	8.382E-07
7	88226	1.270E-04	1.255E-04	9.885E-01	5.709E-10	7.959E-09	2.003E-08
8	53129	5.306E-02	9.372E-06	1.766E-04	4.182E-07	5.831E-06	8.367E-06
9	46107	1.270E-02	6.533E-06	5.145E-04	1.207E-07	1.683E-06	2.003E-06
10	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.753E-05	2.664E-05
11	62147	2.479E-01	5.690E-09	2.296E-08	1.715E-06	2.390E-05	3.909E-05
12	60144	5.994E-01	7.120E-13	1.188E-12	4.233E-06	5.901E-05	9.454E-05
13	57138	3.328E-06	8.217E-14	2.469E-08	2.453E-11	3.419E-10	5.249E-10
14	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.744E-06	7.864E-06
15	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.246E-05	9.867E-05
16	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.200E-05	6.775E-05
17	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.274E-07	1.630E-07
18	64152	2.646E-05	5.765E-16	2.179E-11	1.770E-10	2.467E-09	4.172E-09
19	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.368E-07	2.253E-07
20	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.799E-08	1.232E-07
21	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.462E-06	3.157E-06
22	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.903E-10	2.324E-10
23	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.097E-09	8.906E-10
24	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.656E-09	3.009E-09
25	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.299E-08	2.788E-08
26	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.136E-08	9.475E-09
27	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.457E-08	7.242E-08
28	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.236E-07	1.940E-07
29	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.371E-06	1.220E-06
30	35079	5.519E-05	0.000E+00	0.000E+00	7.107E-10	9.908E-09	8.705E-09

31	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.168E-06	1.953E-06
32	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.786E-10	8.924E-10
33	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.738E-06	5.296E-06
34	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.046E-05	9.771E-06
35	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.242E-05	2.144E-05
36	37085	7.684E-02	0.000E+00	0.000E+00	9.196E-07	1.282E-05	1.212E-05
37	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.111E-10	3.932E-10
38	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.785E-05	3.704E-05
39	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.044E-05	4.992E-05
40	40090	3.905E-01	0.000E+00	0.000E+00	4.414E-06	6.153E-05	6.158E-05
41	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.215E-05	6.289E-05
42	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.424E-05	6.572E-05
43	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.906E-05	7.219E-05
44	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.775E-05	7.234E-05
45	41093	1.964E-04	0.000E+00	0.000E+00	2.148E-09	2.994E-08	3.097E-08
46	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.943E-05	7.335E-05
47	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.358E-08	3.585E-08
48	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.447E-05	6.955E-05
49	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.150E-05	6.703E-05
50	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.736E-05	7.492E-05
51	44099	1.511E-03	0.000E+00	0.000E+00	1.552E-08	2.164E-07	2.383E-07
52	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.549E-05	6.233E-05
53	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.601E-05	5.220E-05
54	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.039E-05	2.359E-05
55	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.255E-05	3.729E-05
56	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.058E-05	1.236E-05
57	46106	3.360E-02	0.000E+00	0.000E+00	3.224E-07	4.494E-06	5.298E-06
58	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.278E-07	7.541E-07
59	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.848E-07	3.485E-07
60	47107	1.353E-06	0.000E+00	0.000E+00	1.286E-11	1.793E-10	2.134E-10
61	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.515E-07	4.261E-07
62	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.885E-07	2.327E-07
63	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.428E-07	1.779E-07
64	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.842E-07	2.336E-07
65	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.442E-07	1.861E-07
66	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.024E-10	2.544E-10
67	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.550E-09	8.378E-09
68	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.726E-10	7.388E-10
69	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.384E-07	1.801E-07
70	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.241E-07	1.629E-07
71	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.399E-07	1.852E-07
72	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.372E-07	1.831E-07
73	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.679E-07	2.279E-07
74	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.885E-07	3.979E-07
75	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.339E-07	1.802E-07
76	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.703E-07	2.330E-07
77	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.586E-10	2.188E-10
78	52125	3.202E-03	0.000E+00	0.000E+00	2.605E-08	3.631E-07	5.049E-07
79	52126	2.604E-04	0.000E+00	0.000E+00	2.101E-09	2.930E-08	4.106E-08
80	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.728E-06	5.308E-06
81	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.938E-05	2.803E-05
82	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.646E-06	2.325E-06
83	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.736E-10	3.896E-10
84	54129	2.341E-06	0.000E+00	0.000E+00	1.845E-11	2.573E-10	3.692E-10
85	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.837E-09	6.995E-09
86	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.086E-05	4.497E-05
87	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.633E-05	6.803E-05
88	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.422E-05	1.255E-04
89	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.947E-05	1.051E-04
90	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.154E-05	1.058E-04
91	56134	9.514E-04	0.000E+00	0.000E+00	7.221E-09	1.007E-07	1.501E-07
92	56135	1.954E-04	0.000E+00	0.000E+00	1.472E-09	2.051E-08	3.081E-08
93	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.243E-08	1.096E-07
94	56137	6.394E-01	0.000E+00	0.000E+00	4.746E-06	6.617E-05	1.008E-04
95	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.233E-05	1.110E-04
96	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.855E-05	1.060E-04
97	58140	6.556E-01	0.000E+00	0.000E+00	4.762E-06	6.638E-05	1.034E-04
98	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.248E-05	9.801E-05
99	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.067E-09	1.432E-08
100	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.330E-05	1.007E-04
101	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.215E-05	5.222E-05
102	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.793E-05	2.952E-05
103	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.042E-06	1.175E-05
104	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.864E-06	1.146E-05
105	62152	3.754E-02	0.000E+00	0.000E+00	2.511E-07	3.500E-06	5.920E-06
106	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.085E-07	1.385E-06
107	63151	4.114E-02	0.000E+00	0.000E+00	2.770E-07	3.862E-06	6.488E-06
108	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.737E-06	2.957E-06
109	64154	1.500E-04	0.000E+00	0.000E+00	9.902E-10	1.380E-08	2.365E-08
110	64155	3.255E-03	0.000E+00	0.000E+00	2.135E-08	2.976E-07	5.133E-07
111	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.206E-07	3.829E-07
112	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.396E-08	2.439E-08

113	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.704E-09	6.594E-09
114	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.153E-08	2.040E-08
115	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.008E-09	1.806E-09
116	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.196E-10	3.959E-10
117	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.640E-01	1.182E-01
118	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.546E-05
119	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.180E-09	1.970E-10
120	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.210E-03	2.424E-04
	totals	7.691E+02	1.077E-02	1.401E-05	4.789E-02	6.676E-01	1.213E-01

Step 14 - 10 000 years

actinide inventory for material 40000 at end of step 14, time 3.650E+06 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92234	1.130E+01	7.024E-02	6.217E-03	4.906E-05	6.839E-04	1.782E-03
2	94239	8.604E-01	5.337E-02	6.203E-02	3.658E-06	5.099E-05	1.357E-04
3	90230	3.033E-01	6.254E-03	2.062E-02	1.340E-06	1.868E-05	4.784E-05
4	92235	1.077E+03	2.327E-03	2.161E-06	4.655E-03	6.490E-02	1.698E-01
5	92238	4.475E+03	1.504E-03	3.361E-07	1.910E-02	2.663E-01	7.057E-01
6	94240	2.857E-03	6.484E-04	2.269E-01	1.210E-08	1.686E-07	4.506E-07
7	92236	7.696E+00	4.977E-04	6.467E-05	3.313E-05	4.619E-04	1.214E-03
8	91231	9.393E-03	4.437E-04	4.723E-02	4.132E-08	5.760E-07	1.481E-06
9	93237	1.790E-02	1.261E-05	7.047E-04	7.672E-08	1.070E-06	2.822E-06
10	92233	5.938E-05	5.722E-07	9.636E-03	2.590E-10	3.610E-09	9.365E-09
11	90232	2.237E-03	2.453E-10	1.097E-07	9.798E-09	1.366E-07	3.528E-07
	totals	5.572E+03	1.353E-01	2.428E-05	2.384E-02	3.324E-01	8.787E-01

nonactinide inventory for material 40000 at end of step 14, time 3.650E+06 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	43099	4.409E-01	7.550E-03	1.712E-02	4.530E-06	6.315E-05	6.954E-05
2	88226	4.934E-03	4.877E-03	9.885E-01	2.218E-08	3.092E-07	7.781E-07
3	40093	4.422E-01	1.112E-03	2.515E-03	4.836E-06	6.742E-05	6.973E-05
4	55135	6.468E-01	7.452E-04	1.152E-03	4.872E-06	6.792E-05	1.020E-04
5	89227	6.117E-06	4.424E-04	7.233E+01	2.738E-11	3.817E-10	9.646E-10
6	34079	2.154E-03	2.957E-04	1.373E-01	2.774E-08	3.867E-07	3.397E-07
7	50126	4.994E-03	1.418E-04	2.839E-02	4.031E-08	5.619E-07	7.876E-07
8	53129	5.303E-02	9.368E-06	1.766E-04	4.181E-07	5.828E-06	8.364E-06
9	46107	1.269E-02	6.527E-06	5.145E-04	1.206E-07	1.681E-06	2.001E-06
10	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.753E-05	2.664E-05
11	62147	2.479E-01	5.690E-09	2.296E-08	1.715E-06	2.390E-05	3.909E-05
12	60144	5.994E-01	7.120E-13	1.188E-12	4.233E-06	5.901E-05	9.454E-05
13	57138	3.328E-06	8.217E-14	2.469E-08	2.453E-11	3.419E-10	5.249E-10
14	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.744E-06	7.864E-06
15	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.246E-05	9.867E-05
16	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.200E-05	6.775E-05
17	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.274E-07	1.630E-07
18	64152	2.646E-05	5.765E-16	2.179E-11	1.770E-10	2.467E-09	4.172E-09
19	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.368E-07	2.253E-07
20	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.799E-08	1.232E-07
21	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.462E-06	3.157E-06
22	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.903E-10	2.324E-10
23	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.097E-09	8.906E-10
24	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.656E-09	3.009E-09
25	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.299E-08	2.788E-08
26	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.136E-08	9.475E-09
27	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.457E-08	7.242E-08
28	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.236E-07	1.940E-07
29	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.371E-06	1.220E-06
30	35079	5.031E-04	0.000E+00	0.000E+00	6.478E-09	9.031E-08	7.934E-08
31	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.168E-06	1.953E-06
32	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.786E-10	8.924E-10
33	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.738E-06	5.296E-06
34	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.046E-05	9.771E-06
35	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.242E-05	2.144E-05
36	37085	7.684E-02	0.000E+00	0.000E+00	9.196E-07	1.282E-05	1.212E-05
37	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.111E-10	3.932E-10
38	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.785E-05	3.704E-05
39	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.044E-05	4.992E-05
40	40090	3.909E-01	0.000E+00	0.000E+00	4.419E-06	6.160E-05	6.165E-05
41	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.215E-05	6.289E-05
42	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.424E-05	6.573E-05
43	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.906E-05	7.220E-05
44	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.775E-05	7.234E-05
45	41093	2.002E-03	0.000E+00	0.000E+00	2.190E-08	3.052E-07	3.157E-07
46	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.943E-05	7.335E-05
47	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.358E-08	3.585E-08
48	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.447E-05	6.955E-05

49	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.150E-05	6.703E-05
50	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.736E-05	7.492E-05
51	44099	1.473E-02	0.000E+00	0.000E+00	1.513E-07	2.109E-06	2.322E-06
52	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.549E-05	6.233E-05
53	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.601E-05	5.220E-05
54	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.039E-05	2.359E-05
55	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.255E-05	3.729E-05
56	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.058E-05	1.236E-05
57	46106	3.360E-02	0.000E+00	0.000E+00	3.224E-07	4.494E-06	5.298E-06
58	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.278E-07	7.541E-07
59	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.848E-07	3.485E-07
60	47107	1.353E-05	0.000E+00	0.000E+00	1.286E-10	1.793E-09	2.133E-09
61	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.515E-07	4.261E-07
62	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.885E-07	2.327E-07
63	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.428E-07	1.779E-07
64	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.842E-07	2.336E-07
65	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.442E-07	1.861E-07
66	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.024E-10	2.544E-10
67	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.550E-09	8.378E-09
68	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.726E-10	7.388E-10
69	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.384E-07	1.801E-07
70	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.241E-07	1.629E-07
71	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.399E-07	1.852E-07
72	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.372E-07	1.831E-07
73	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.679E-07	2.279E-07
74	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.885E-07	3.979E-07
75	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.339E-07	1.802E-07
76	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.703E-07	2.330E-07
77	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.586E-10	2.188E-10
78	52125	3.202E-03	0.000E+00	0.000E+00	2.605E-08	3.631E-07	5.049E-07
79	52126	5.816E-04	0.000E+00	0.000E+00	4.694E-09	6.544E-08	9.172E-08
80	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.728E-06	5.308E-06
81	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.938E-05	2.803E-05
82	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.646E-06	2.325E-06
83	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.736E-10	3.896E-10
84	54129	2.340E-05	0.000E+00	0.000E+00	1.845E-10	2.572E-09	3.691E-09
85	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.837E-09	6.995E-09
86	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.086E-05	4.497E-05
87	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.633E-05	6.803E-05
88	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.422E-05	1.255E-04
89	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.947E-05	1.051E-04
90	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.154E-05	1.058E-04
91	56134	9.514E-04	0.000E+00	0.000E+00	7.221E-09	1.007E-07	1.501E-07
92	56135	1.951E-03	0.000E+00	0.000E+00	1.470E-08	2.049E-07	3.077E-07
93	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.243E-08	1.096E-07
94	56137	6.394E-01	0.000E+00	0.000E+00	4.746E-06	6.617E-05	1.008E-04
95	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.233E-05	1.110E-04
96	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.855E-05	1.060E-04
97	58140	6.565E-01	0.000E+00	0.000E+00	4.769E-06	6.648E-05	1.035E-04
98	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.248E-05	9.801E-05
99	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.067E-09	1.432E-08
100	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.330E-05	1.007E-04
101	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.215E-05	5.222E-05
102	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.793E-05	2.952E-05
103	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.042E-06	1.175E-05
104	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.864E-06	1.146E-05
105	62152	3.754E-02	0.000E+00	0.000E+00	2.511E-07	3.500E-06	5.920E-06
106	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.085E-07	1.385E-06
107	63151	4.116E-02	0.000E+00	0.000E+00	2.772E-07	3.864E-06	6.491E-06
108	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.737E-06	2.957E-06
109	64154	1.500E-04	0.000E+00	0.000E+00	9.902E-10	1.380E-08	2.365E-08
110	64155	3.255E-03	0.000E+00	0.000E+00	2.135E-08	2.976E-07	5.133E-07
111	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.206E-07	3.829E-07
112	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.396E-08	2.439E-08
113	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.704E-09	6.594E-09
114	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.153E-08	2.040E-08
115	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.008E-09	1.806E-09
116	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.196E-10	3.959E-10
117	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.640E-01	1.182E-01
118	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.546E-05
119	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.180E-09	1.970E-10
120	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.210E-03	2.425E-04
	totals	7.691E+02	1.518E-02	1.974E-05	4.789E-02	6.676E-01	1.213E-01

Step 15 - 100 000 years

actinide inventory for material 40000 at end of step 15, time 3.650E+07 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92234	8.820E+00	5.484E-02	6.217E-03	3.830E-05	5.339E-04	1.391E-03
2	90230	1.802E+00	3.715E-02	2.062E-02	7.960E-06	1.110E-04	2.842E-04
3	94239	6.483E-02	4.021E-03	6.203E-02	2.756E-07	3.842E-06	1.023E-05
4	92235	1.077E+03	2.329E-03	2.161E-06	4.658E-03	6.494E-02	1.699E-01
5	91231	4.335E-02	2.047E-03	4.723E-02	1.907E-07	2.658E-06	6.837E-06
6	92238	4.475E+03	1.504E-03	3.361E-07	1.910E-02	2.663E-01	7.058E-01
7	92236	7.678E+00	4.965E-04	6.467E-05	3.306E-05	4.608E-04	1.211E-03
8	93237	1.738E-02	1.225E-05	7.047E-04	7.452E-08	1.039E-06	2.742E-06
9	92233	4.577E-04	4.411E-06	9.636E-03	1.996E-09	2.783E-08	7.220E-08
10	90229	2.019E-05	4.000E-06	1.981E-01	8.960E-11	1.249E-09	3.185E-09
11	90232	2.235E-02	2.451E-09	1.097E-07	9.790E-08	1.365E-06	3.526E-06
	totals	5.571E+03	1.024E-01	1.838E-05	2.384E-02	3.324E-01	8.787E-01

nonactinide inventory for material 40000 at end of step 15, time 3.650E+07 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	88226	3.719E-02	3.676E-02	9.885E-01	1.672E-07	2.331E-06	5.865E-06
2	43099	3.282E-01	5.619E-03	1.712E-02	3.372E-06	4.701E-05	5.176E-05
3	89227	2.830E-05	2.047E-03	7.233E+01	1.267E-10	1.766E-09	4.464E-09
4	40093	4.245E-01	1.068E-03	2.515E-03	4.643E-06	6.474E-05	6.696E-05
5	55135	6.295E-01	7.253E-04	1.152E-03	4.742E-06	6.611E-05	9.930E-05
6	50126	2.677E-03	7.602E-05	2.839E-02	2.161E-08	3.013E-07	4.223E-07
7	34079	3.257E-04	4.471E-05	1.373E-01	4.194E-09	5.847E-08	5.138E-08
8	53129	5.282E-02	9.331E-06	1.766E-04	4.164E-07	5.806E-06	8.332E-06
9	46107	1.257E-02	6.465E-06	5.145E-04	1.194E-07	1.665E-06	1.982E-06
10	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.753E-05	2.664E-05
11	62147	2.479E-01	5.690E-09	2.296E-08	1.715E-06	2.390E-05	3.910E-05
12	60144	5.994E-01	7.120E-13	1.188E-12	4.233E-06	5.901E-05	9.455E-05
13	57138	3.328E-06	8.217E-14	2.469E-08	2.453E-11	3.419E-10	5.250E-10
14	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.744E-06	7.865E-06
15	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.246E-05	9.869E-05
16	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.200E-05	6.777E-05
17	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.274E-07	1.630E-07
18	64152	2.646E-05	5.765E-16	2.179E-11	1.770E-10	2.467E-09	4.173E-09
19	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.368E-07	2.253E-07
20	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.800E-08	1.232E-07
21	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.462E-06	3.158E-06
22	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.903E-10	2.325E-10
23	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.097E-09	8.907E-10
24	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.656E-09	3.009E-09
25	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.299E-08	2.789E-08
26	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.136E-08	9.476E-09
27	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.458E-08	7.243E-08
28	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.236E-07	1.940E-07
29	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.371E-06	1.220E-06
30	35079	2.332E-03	0.000E+00	0.000E+00	3.002E-08	4.186E-07	3.678E-07
31	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.168E-06	1.953E-06
32	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.787E-10	8.925E-10
33	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.738E-06	5.297E-06
34	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.046E-05	9.773E-06
35	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.242E-05	2.145E-05
36	37085	7.684E-02	0.000E+00	0.000E+00	9.196E-07	1.282E-05	1.212E-05
37	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.111E-10	3.932E-10
38	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.785E-05	3.705E-05
39	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.044E-05	4.993E-05
40	40090	3.909E-01	0.000E+00	0.000E+00	4.419E-06	6.160E-05	6.166E-05
41	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.215E-05	6.290E-05
42	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.424E-05	6.574E-05
43	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.906E-05	7.221E-05
44	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.775E-05	7.235E-05
45	41093	1.965E-02	0.000E+00	0.000E+00	2.150E-07	2.997E-06	3.100E-06
46	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.943E-05	7.337E-05
47	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.358E-08	3.586E-08
48	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.447E-05	6.956E-05
49	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.150E-05	6.704E-05
50	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.736E-05	7.493E-05
51	44099	1.275E-01	0.000E+00	0.000E+00	1.310E-06	1.826E-05	2.011E-05
52	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.549E-05	6.234E-05
53	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.601E-05	5.220E-05
54	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.039E-05	2.359E-05
55	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.255E-05	3.730E-05
56	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.059E-05	1.236E-05
57	46106	3.360E-02	0.000E+00	0.000E+00	3.224E-07	4.494E-06	5.299E-06
58	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.278E-07	7.543E-07
59	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.848E-07	3.485E-07
60	47107	1.346E-04	0.000E+00	0.000E+00	1.280E-09	1.784E-08	2.124E-08

61	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.515E-07	4.262E-07
62	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.885E-07	2.327E-07
63	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.428E-07	1.779E-07
64	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.842E-07	2.336E-07
65	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.442E-07	1.861E-07
66	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.024E-10	2.544E-10
67	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.550E-09	8.380E-09
68	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.726E-10	7.389E-10
69	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.384E-07	1.801E-07
70	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.241E-07	1.629E-07
71	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.399E-07	1.852E-07
72	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.372E-07	1.832E-07
73	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.679E-07	2.279E-07
74	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.885E-07	3.980E-07
75	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.339E-07	1.803E-07
76	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.703E-07	2.331E-07
77	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.586E-10	2.188E-10
78	52125	3.202E-03	0.000E+00	0.000E+00	2.605E-08	3.632E-07	5.050E-07
79	52126	2.898E-03	0.000E+00	0.000E+00	2.339E-08	3.261E-07	4.571E-07
80	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.728E-06	5.309E-06
81	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.938E-05	2.803E-05
82	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.646E-06	2.326E-06
83	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.736E-10	3.896E-10
84	54129	2.336E-04	0.000E+00	0.000E+00	1.841E-09	2.567E-08	3.684E-08
85	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.837E-09	6.996E-09
86	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.086E-05	4.498E-05
87	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.633E-05	6.804E-05
88	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.423E-05	1.256E-04
89	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.947E-05	1.051E-04
90	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.154E-05	1.059E-04
91	56134	9.514E-04	0.000E+00	0.000E+00	7.221E-09	1.007E-07	1.501E-07
92	56135	1.925E-02	0.000E+00	0.000E+00	1.450E-07	2.021E-06	3.036E-06
93	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.243E-08	1.096E-07
94	56137	6.394E-01	0.000E+00	0.000E+00	4.746E-06	6.617E-05	1.009E-04
95	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.233E-05	1.111E-04
96	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.855E-05	1.060E-04
97	58140	6.565E-01	0.000E+00	0.000E+00	4.769E-06	6.648E-05	1.036E-04
98	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.249E-05	9.803E-05
99	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.068E-09	1.433E-08
100	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.330E-05	1.007E-04
101	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.215E-05	5.223E-05
102	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.793E-05	2.953E-05
103	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.042E-06	1.175E-05
104	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.864E-06	1.146E-05
105	62152	3.754E-02	0.000E+00	0.000E+00	2.511E-07	3.501E-06	5.921E-06
106	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.086E-07	1.386E-06
107	63151	4.116E-02	0.000E+00	0.000E+00	2.772E-07	3.864E-06	6.493E-06
108	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.737E-06	2.957E-06
109	64154	1.500E-04	0.000E+00	0.000E+00	9.902E-10	1.380E-08	2.366E-08
110	64155	3.255E-03	0.000E+00	0.000E+00	2.135E-08	2.977E-07	5.134E-07
111	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.206E-07	3.830E-07
112	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.396E-08	2.439E-08
113	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.704E-09	6.596E-09
114	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.153E-08	2.040E-08
115	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.008E-09	1.806E-09
116	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.196E-10	3.959E-10
117	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.640E-01	1.183E-01
118	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.546E-05
119	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.180E-09	1.971E-10
120	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.210E-03	2.425E-04
	totals	7.692E+02	4.636E-02	6.027E-05	4.789E-02	6.676E-01	1.213E-01

Step 16 - 1 000 000 years

actinide inventory for material 40000 at end of step 16, time 3.650E+08 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	90230	3.675E-01	7.577E-03	2.062E-02	1.624E-06	2.265E-05	5.807E-05
2	92234	9.202E-01	5.721E-03	6.217E-03	3.996E-06	5.574E-05	1.454E-04
3	91231	4.926E-02	2.327E-03	4.723E-02	2.167E-07	3.023E-06	7.784E-06
4	92235	1.077E+03	2.327E-03	2.161E-06	4.654E-03	6.493E-02	1.701E-01
5	92238	4.474E+03	1.504E-03	3.361E-07	1.910E-02	2.665E-01	7.069E-01
6	92236	7.477E+00	4.835E-04	6.467E-05	3.219E-05	4.490E-04	1.181E-03
7	90229	4.918E-05	9.741E-06	1.981E-01	2.182E-10	3.044E-09	7.770E-09
8	92233	1.008E-03	9.714E-06	9.636E-03	4.396E-09	6.133E-08	1.593E-07
9	93237	1.299E-02	9.154E-06	7.047E-04	5.568E-08	7.768E-07	2.052E-06
10	90232	2.206E-01	2.419E-08	1.097E-07	9.662E-07	1.348E-05	3.486E-05
	totals	5.560E+03	1.997E-02	3.592E-06	2.379E-02	3.319E-01	8.785E-01

nonactinide inventory for material 40000 at end of step 3, time 3.650E+08 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	88226	7.705E-03	7.617E-03	9.885E-01	3.464E-08	4.833E-07	1.217E-06
2	89227	3.217E-05	2.327E-03	7.233E+01	1.440E-10	2.009E-09	5.083E-09
3	40093	2.824E-01	7.104E-04	2.515E-03	3.089E-06	4.310E-05	4.463E-05
4	55135	4.801E-01	5.531E-04	1.152E-03	3.616E-06	5.045E-05	7.585E-05
5	43099	1.712E-02	2.932E-04	1.712E-02	1.759E-07	2.454E-06	2.705E-06
6	53129	5.077E-02	8.968E-06	1.766E-04	4.002E-07	5.583E-06	8.022E-06
7	46107	1.142E-02	5.873E-06	5.145E-04	1.085E-07	1.514E-06	1.804E-06
8	50126	5.251E-06	1.491E-07	2.839E-02	4.238E-11	5.912E-10	8.297E-10
9	37087	1.689E-01	1.447E-08	8.570E-08	1.975E-06	2.755E-05	2.669E-05
10	62147	2.479E-01	5.690E-09	2.296E-08	1.715E-06	2.392E-05	3.917E-05
11	60144	5.994E-01	7.120E-13	1.188E-12	4.233E-06	5.905E-05	9.472E-05
12	57138	3.328E-06	8.217E-14	2.469E-08	2.452E-11	3.421E-10	5.259E-10
13	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.747E-06	7.879E-06
14	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.251E-05	9.886E-05
15	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.203E-05	6.788E-05
16	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.275E-07	1.633E-07
17	64152	2.646E-05	5.765E-16	2.179E-11	1.770E-10	2.469E-09	4.180E-09
18	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.369E-07	2.257E-07
19	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.806E-08	1.234E-07
20	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.465E-06	3.163E-06
21	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.905E-10	2.329E-10
22	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.098E-09	8.922E-10
23	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.659E-09	3.014E-09
24	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.301E-08	2.794E-08
25	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.137E-08	9.493E-09
26	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.463E-08	7.255E-08
27	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.238E-07	1.943E-07
28	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.372E-06	1.222E-06
29	35079	2.657E-03	0.000E+00	0.000E+00	3.422E-08	4.773E-07	4.199E-07
30	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.170E-06	1.957E-06
31	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.793E-10	8.941E-10
32	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.742E-06	5.306E-06
33	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.047E-05	9.790E-06
34	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.244E-05	2.148E-05
35	37085	7.684E-02	0.000E+00	0.000E+00	9.196E-07	1.283E-05	1.214E-05
36	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.114E-10	3.939E-10
37	38087	2.437E-06	0.000E+00	0.000E+00	2.850E-11	3.976E-10	3.851E-10
38	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.788E-05	3.711E-05
39	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.048E-05	5.002E-05
40	40090	3.909E-01	0.000E+00	0.000E+00	4.419E-06	6.164E-05	6.177E-05
41	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.219E-05	6.301E-05
42	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.429E-05	6.585E-05
43	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.911E-05	7.233E-05
44	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.780E-05	7.247E-05
45	41093	1.617E-01	0.000E+00	0.000E+00	1.769E-06	2.468E-05	2.555E-05
46	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.948E-05	7.349E-05
47	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.360E-08	3.592E-08
48	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.452E-05	6.968E-05
49	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.154E-05	6.716E-05
50	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.741E-05	7.506E-05
51	44099	4.385E-01	0.000E+00	0.000E+00	4.506E-06	6.286E-05	6.929E-05
52	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.553E-05	6.245E-05
53	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.604E-05	5.229E-05
54	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.040E-05	2.363E-05
55	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.258E-05	3.736E-05
56	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.059E-05	1.238E-05
57	46106	3.360E-02	0.000E+00	0.000E+00	3.224E-07	4.497E-06	5.308E-06
58	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.283E-07	7.556E-07
59	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.850E-07	3.491E-07
60	47107	1.284E-03	0.000E+00	0.000E+00	1.220E-08	1.703E-07	2.029E-07
61	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.518E-07	4.270E-07
62	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.886E-07	2.331E-07
63	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.429E-07	1.782E-07
64	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.843E-07	2.340E-07
65	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.443E-07	1.864E-07
66	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.025E-10	2.549E-10
67	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.555E-09	8.394E-09
68	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.730E-10	7.402E-10
69	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.385E-07	1.805E-07
70	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.242E-07	1.632E-07
71	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.400E-07	1.855E-07
72	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.373E-07	1.835E-07
73	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.680E-07	2.283E-07
74	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.887E-07	3.987E-07
75	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.340E-07	1.806E-07
76	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.704E-07	2.335E-07
77	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.587E-10	2.192E-10
78	52125	3.202E-03	0.000E+00	0.000E+00	2.605E-08	3.634E-07	5.059E-07
79	52126	5.570E-03	0.000E+00	0.000E+00	4.496E-08	6.272E-07	8.801E-07

80	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.731E-06	5.318E-06
81	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.939E-05	2.808E-05
82	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.647E-06	2.330E-06
83	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.738E-10	3.903E-10
84	54129	2.290E-03	0.000E+00	0.000E+00	1.805E-08	2.519E-07	3.618E-07
85	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.841E-09	7.008E-09
86	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.088E-05	4.506E-05
87	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.636E-05	6.815E-05
88	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.428E-05	1.258E-04
89	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.952E-05	1.053E-04
90	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.159E-05	1.060E-04
91	56134	9.514E-04	0.000E+00	0.000E+00	7.221E-09	1.007E-07	1.503E-07
92	56135	1.687E-01	0.000E+00	0.000E+00	1.271E-06	1.773E-05	2.666E-05
93	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.248E-08	1.098E-07
94	56137	6.394E-01	0.000E+00	0.000E+00	4.746E-06	6.622E-05	1.010E-04
95	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.238E-05	1.113E-04
96	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.860E-05	1.062E-04
97	58140	6.565E-01	0.000E+00	0.000E+00	4.769E-06	6.653E-05	1.037E-04
98	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.253E-05	9.820E-05
99	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.074E-09	1.435E-08
100	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.335E-05	1.009E-04
101	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.217E-05	5.232E-05
102	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.794E-05	2.958E-05
103	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.047E-06	1.178E-05
104	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.869E-06	1.148E-05
105	62152	3.754E-02	0.000E+00	0.000E+00	2.511E-07	3.503E-06	5.931E-06
106	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.091E-07	1.388E-06
107	63151	4.116E-02	0.000E+00	0.000E+00	2.772E-07	3.867E-06	6.504E-06
108	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.738E-06	2.962E-06
109	64154	1.500E-04	0.000E+00	0.000E+00	9.902E-10	1.381E-08	2.370E-08
110	64155	3.255E-03	0.000E+00	0.000E+00	2.135E-08	2.979E-07	5.143E-07
111	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.208E-07	3.837E-07
112	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.397E-08	2.443E-08
113	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.707E-09	6.607E-09
114	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.154E-08	2.044E-08
115	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.009E-09	1.809E-09
116	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.198E-10	3.966E-10
117	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.645E-01	1.185E-01
118	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.404E-04	4.554E-05
119	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.181E-09	1.974E-10
120	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.211E-03	2.429E-04
	totals	7.691E+02	1.152E-02	1.497E-05	4.789E-02	6.681E-01	1.215E-01

Step 17 - 10 000 000 years

actinide inventory for material 40000 at end of step 4, time 3.650E+09 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	91231	4.883E-02	2.306E-03	4.723E-02	2.148E-07	2.999E-06	7.736E-06
2	92235	1.067E+03	2.306E-03	2.161E-06	4.613E-03	6.442E-02	1.690E-01
3	90230	7.284E-02	1.502E-03	2.062E-02	3.218E-07	4.494E-06	1.154E-05
4	92234	2.416E-01	1.502E-03	6.217E-03	1.049E-06	1.465E-05	3.827E-05
5	92238	4.468E+03	1.502E-03	3.361E-07	1.907E-02	2.663E-01	7.078E-01
6	92236	5.729E+00	3.705E-04	6.467E-05	2.466E-05	3.444E-04	9.077E-04
7	90229	2.721E-06	5.390E-07	1.981E-01	1.207E-11	1.686E-10	4.311E-10
8	92233	5.573E-05	5.370E-07	9.636E-03	2.430E-10	3.394E-09	8.830E-09
9	93237	7.054E-04	4.971E-07	7.047E-04	3.024E-09	4.223E-08	1.118E-07
10	90232	1.938E+00	2.125E-07	1.097E-07	8.486E-06	1.185E-04	3.070E-04
	totals	5.543E+03	9.490E-03	1.712E-06	2.372E-02	3.313E-01	8.781E-01

nonactinide inventory for material 40000 at end of step 4, time 3.650E+09 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	89227	3.188E-05	2.306E-03	7.233E+01	1.427E-10	1.993E-09	5.051E-09
2	88226	1.519E-03	1.502E-03	9.885E-01	6.830E-09	9.538E-08	2.407E-07
3	55135	3.192E-02	3.678E-05	1.152E-03	2.405E-07	3.358E-06	5.058E-06
4	40093	4.801E-03	1.207E-05	2.515E-03	5.251E-08	7.334E-07	7.606E-07
5	53129	3.413E-02	6.029E-06	1.766E-04	2.691E-07	3.757E-06	5.407E-06
6	46107	4.375E-03	2.251E-06	5.145E-04	4.159E-08	5.808E-07	6.932E-07
7	37087	1.689E-01	1.447E-08	8.570E-08	1.974E-06	2.757E-05	2.675E-05
8	62147	2.479E-01	5.690E-09	2.296E-08	1.714E-06	2.394E-05	3.927E-05
9	60144	5.994E-01	7.120E-13	1.188E-12	4.233E-06	5.911E-05	9.497E-05
10	57138	3.328E-06	8.216E-14	2.469E-08	2.452E-11	3.425E-10	5.273E-10
11	62149	4.986E-02	5.985E-14	1.200E-12	3.403E-07	4.752E-06	7.900E-06
12	58142	6.257E-01	3.154E-14	5.042E-14	4.480E-06	6.257E-05	9.912E-05
13	60145	4.296E-01	1.766E-14	4.112E-14	3.013E-06	4.207E-05	6.806E-05
14	49115	1.033E-03	7.290E-15	7.055E-12	9.139E-09	1.276E-07	1.637E-07
15	64152	2.646E-05	5.765E-16	2.179E-11	1.770E-10	2.471E-09	4.191E-09
16	62148	1.428E-03	4.358E-16	3.051E-13	9.814E-09	1.370E-07	2.263E-07

17	48113	7.810E-04	2.659E-16	3.405E-13	7.029E-09	9.816E-08	1.237E-07
18	34082	2.002E-02	6.266E-19	3.130E-17	2.483E-07	3.468E-06	3.171E-06
19	32072	1.474E-06	0.000E+00	0.000E+00	2.082E-11	2.908E-10	2.335E-10
20	32073	5.647E-06	0.000E+00	0.000E+00	7.869E-11	1.099E-09	8.946E-10
21	32074	1.908E-05	0.000E+00	0.000E+00	2.623E-10	3.662E-09	3.022E-09
22	32076	1.768E-04	0.000E+00	0.000E+00	2.366E-09	3.305E-08	2.801E-08
23	33075	6.008E-05	0.000E+00	0.000E+00	8.149E-10	1.138E-08	9.518E-09
24	34077	4.592E-04	0.000E+00	0.000E+00	6.066E-09	8.472E-08	7.275E-08
25	34078	1.230E-03	0.000E+00	0.000E+00	1.604E-08	2.240E-07	1.948E-07
26	34080	7.734E-03	0.000E+00	0.000E+00	9.834E-08	1.373E-06	1.225E-06
27	35079	2.657E-03	0.000E+00	0.000E+00	3.422E-08	4.778E-07	4.210E-07
28	35081	1.238E-02	0.000E+00	0.000E+00	1.555E-07	2.172E-06	1.962E-06
29	36082	5.658E-06	0.000E+00	0.000E+00	7.020E-11	9.803E-10	8.964E-10
30	36083	3.358E-02	0.000E+00	0.000E+00	4.116E-07	5.748E-06	5.320E-06
31	36084	6.196E-02	0.000E+00	0.000E+00	7.503E-07	1.048E-05	9.816E-06
32	36086	1.360E-01	0.000E+00	0.000E+00	1.608E-06	2.246E-05	2.154E-05
33	37085	7.684E-02	0.000E+00	0.000E+00	9.196E-07	1.284E-05	1.217E-05
34	38086	2.493E-06	0.000E+00	0.000E+00	2.949E-11	4.118E-10	3.950E-10
35	38087	2.437E-05	0.000E+00	0.000E+00	2.850E-10	3.980E-09	3.861E-09
36	38088	2.349E-01	0.000E+00	0.000E+00	2.715E-06	3.792E-05	3.721E-05
37	39089	3.165E-01	0.000E+00	0.000E+00	3.618E-06	5.053E-05	5.015E-05
38	40090	3.909E-01	0.000E+00	0.000E+00	4.419E-06	6.171E-05	6.193E-05
39	40091	3.988E-01	0.000E+00	0.000E+00	4.458E-06	6.225E-05	6.318E-05
40	40092	4.168E-01	0.000E+00	0.000E+00	4.608E-06	6.435E-05	6.602E-05
41	40094	4.578E-01	0.000E+00	0.000E+00	4.954E-06	6.918E-05	7.252E-05
42	40096	4.587E-01	0.000E+00	0.000E+00	4.860E-06	6.787E-05	7.267E-05
43	41093	4.394E-01	0.000E+00	0.000E+00	4.806E-06	6.711E-05	6.961E-05
44	42095	4.651E-01	0.000E+00	0.000E+00	4.980E-06	6.955E-05	7.369E-05
45	42096	2.273E-04	0.000E+00	0.000E+00	2.409E-09	3.364E-08	3.601E-08
46	42097	4.410E-01	0.000E+00	0.000E+00	4.625E-06	6.458E-05	6.987E-05
47	42098	4.250E-01	0.000E+00	0.000E+00	4.412E-06	6.161E-05	6.734E-05
48	42100	4.750E-01	0.000E+00	0.000E+00	4.832E-06	6.748E-05	7.526E-05
49	44099	4.556E-01	0.000E+00	0.000E+00	4.682E-06	6.538E-05	7.219E-05
50	44101	3.952E-01	0.000E+00	0.000E+00	3.980E-06	5.559E-05	6.262E-05
51	44102	3.310E-01	0.000E+00	0.000E+00	3.300E-06	4.609E-05	5.243E-05
52	44104	1.496E-01	0.000E+00	0.000E+00	1.463E-06	2.043E-05	2.369E-05
53	45103	2.365E-01	0.000E+00	0.000E+00	2.335E-06	3.261E-05	3.746E-05
54	46105	7.838E-02	0.000E+00	0.000E+00	7.593E-07	1.060E-05	1.242E-05
55	46106	3.360E-02	0.000E+00	0.000E+00	3.224E-07	4.502E-06	5.322E-06
56	46108	4.782E-03	0.000E+00	0.000E+00	4.503E-08	6.289E-07	7.576E-07
57	46110	2.209E-03	0.000E+00	0.000E+00	2.043E-08	2.853E-07	3.500E-07
58	47107	8.325E-03	0.000E+00	0.000E+00	7.914E-08	1.105E-06	1.319E-06
59	47109	2.702E-03	0.000E+00	0.000E+00	2.521E-08	3.521E-07	4.281E-07
60	48111	1.475E-03	0.000E+00	0.000E+00	1.352E-08	1.888E-07	2.338E-07
61	48112	1.128E-03	0.000E+00	0.000E+00	1.024E-08	1.430E-07	1.787E-07
62	48114	1.481E-03	0.000E+00	0.000E+00	1.321E-08	1.845E-07	2.346E-07
63	48116	1.180E-03	0.000E+00	0.000E+00	1.034E-08	1.444E-07	1.869E-07
64	49113	1.613E-06	0.000E+00	0.000E+00	1.452E-11	2.028E-10	2.556E-10
65	50115	5.313E-05	0.000E+00	0.000E+00	4.698E-10	6.561E-09	8.417E-09
66	50116	4.685E-06	0.000E+00	0.000E+00	4.107E-11	5.736E-10	7.422E-10
67	50117	1.142E-03	0.000E+00	0.000E+00	9.928E-09	1.386E-07	1.809E-07
68	50118	1.033E-03	0.000E+00	0.000E+00	8.902E-09	1.243E-07	1.636E-07
69	50119	1.174E-03	0.000E+00	0.000E+00	1.004E-08	1.401E-07	1.860E-07
70	50120	1.161E-03	0.000E+00	0.000E+00	9.842E-09	1.374E-07	1.840E-07
71	50122	1.445E-03	0.000E+00	0.000E+00	1.204E-08	1.682E-07	2.289E-07
72	50124	2.523E-03	0.000E+00	0.000E+00	2.069E-08	2.890E-07	3.998E-07
73	51121	1.143E-03	0.000E+00	0.000E+00	9.605E-09	1.341E-07	1.810E-07
74	51123	1.478E-03	0.000E+00	0.000E+00	1.222E-08	1.706E-07	2.341E-07
75	52124	1.387E-06	0.000E+00	0.000E+00	1.138E-11	1.589E-10	2.198E-10
76	52125	3.202E-03	0.000E+00	0.000E+00	2.605E-08	3.638E-07	5.072E-07
77	52126	5.575E-03	0.000E+00	0.000E+00	4.500E-08	6.284E-07	8.833E-07
78	52128	3.366E-02	0.000E+00	0.000E+00	2.674E-07	3.734E-06	5.332E-06
79	52130	1.777E-01	0.000E+00	0.000E+00	1.390E-06	1.941E-05	2.815E-05
80	53127	1.474E-02	0.000E+00	0.000E+00	1.181E-07	1.649E-06	2.336E-06
81	54128	2.470E-06	0.000E+00	0.000E+00	1.963E-11	2.741E-10	3.913E-10
82	54129	1.893E-02	0.000E+00	0.000E+00	1.492E-07	2.084E-06	2.999E-06
83	54130	4.435E-05	0.000E+00	0.000E+00	3.470E-10	4.845E-09	7.027E-09
84	54131	2.852E-01	0.000E+00	0.000E+00	2.214E-06	3.091E-05	4.518E-05
85	54132	4.313E-01	0.000E+00	0.000E+00	3.323E-06	4.641E-05	6.834E-05
86	54134	7.961E-01	0.000E+00	0.000E+00	6.041E-06	8.437E-05	1.261E-04
87	54136	6.665E-01	0.000E+00	0.000E+00	4.983E-06	6.959E-05	1.056E-04
88	55133	6.711E-01	0.000E+00	0.000E+00	5.131E-06	7.166E-05	1.063E-04
89	56134	9.514E-04	0.000E+00	0.000E+00	7.221E-09	1.008E-07	1.507E-07
90	56135	6.168E-01	0.000E+00	0.000E+00	4.646E-06	6.489E-05	9.772E-05
91	56136	6.948E-04	0.000E+00	0.000E+00	5.195E-09	7.255E-08	1.101E-07
92	56137	6.394E-01	0.000E+00	0.000E+00	4.746E-06	6.628E-05	1.013E-04
93	56138	7.041E-01	0.000E+00	0.000E+00	5.188E-06	7.246E-05	1.115E-04
94	57139	6.721E-01	0.000E+00	0.000E+00	4.917E-06	6.867E-05	1.065E-04
95	58140	6.565E-01	0.000E+00	0.000E+00	4.769E-06	6.659E-05	1.040E-04
96	59141	6.215E-01	0.000E+00	0.000E+00	4.482E-06	6.259E-05	9.846E-05
97	60142	9.082E-05	0.000E+00	0.000E+00	6.504E-10	9.083E-09	1.439E-08
98	60143	6.386E-01	0.000E+00	0.000E+00	4.541E-06	6.341E-05	1.012E-04

99	60146	3.311E-01	0.000E+00	0.000E+00	2.306E-06	3.221E-05	5.246E-05
100	60148	1.872E-01	0.000E+00	0.000E+00	1.286E-06	1.796E-05	2.966E-05
101	60150	7.452E-02	0.000E+00	0.000E+00	5.051E-07	7.054E-06	1.181E-05
102	62150	7.264E-02	0.000E+00	0.000E+00	4.924E-07	6.876E-06	1.151E-05
103	62152	3.754E-02	0.000E+00	0.000E+00	2.511E-07	3.506E-06	5.947E-06
104	62154	8.784E-03	0.000E+00	0.000E+00	5.800E-08	8.099E-07	1.392E-06
105	63151	4.116E-02	0.000E+00	0.000E+00	2.772E-07	3.870E-06	6.521E-06
106	63153	1.875E-02	0.000E+00	0.000E+00	1.246E-07	1.740E-06	2.970E-06
107	64154	1.500E-04	0.000E+00	0.000E+00	9.902E-10	1.383E-08	2.376E-08
108	64155	3.255E-03	0.000E+00	0.000E+00	2.135E-08	2.982E-07	5.157E-07
109	64156	2.428E-03	0.000E+00	0.000E+00	1.583E-08	2.210E-07	3.847E-07
110	64157	1.546E-04	0.000E+00	0.000E+00	1.001E-09	1.398E-08	2.450E-08
111	64160	4.181E-05	0.000E+00	0.000E+00	2.657E-10	3.710E-09	6.625E-09
112	65159	1.293E-04	0.000E+00	0.000E+00	8.271E-10	1.155E-08	2.049E-08
113	66161	1.145E-05	0.000E+00	0.000E+00	7.231E-11	1.010E-09	1.814E-09
114	66162	2.510E-06	0.000E+00	0.000E+00	1.575E-11	2.200E-10	3.977E-10
115	8016	7.497E+02	0.000E+00	0.000E+00	4.763E-02	6.651E-01	1.188E-01
116	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.406E-04	4.566E-05
117	7015	1.249E-06	0.000E+00	0.000E+00	8.464E-11	1.182E-09	1.979E-10
118	8018	1.537E+00	0.000E+00	0.000E+00	8.680E-05	1.212E-03	2.436E-04
	totals	7.691E+02	3.865E-03	5.025E-06	4.789E-02	6.687E-01	1.219E-01

Annex X

Decay Results

CINDER Module Output File Excerpt

Full Power (20 kW_t)

Step 1 - 5 years

actinide inventory for material 40000 at end of step 1, time 1.825E+03 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	94239	2.251E+00	1.396E-01	6.203E-02	9.567E-06	1.333E-04	3.549E-04
2	94241	8.094E-04	8.365E-02	1.033E+02	3.412E-09	4.754E-08	1.276E-07
3	92234	1.154E+01	7.175E-02	6.217E-03	5.011E-05	6.981E-04	1.820E-03
4	94240	3.204E-02	7.269E-03	2.269E-01	1.356E-07	1.889E-06	5.052E-06
5	94238	3.217E-04	5.509E-03	1.712E+01	1.373E-09	1.913E-08	5.074E-08
6	92235	1.056E+03	2.283E-03	2.161E-06	4.566E-03	6.361E-02	1.666E-01
7	92238	4.474E+03	1.504E-03	3.361E-07	1.910E-02	2.660E-01	7.055E-01
8	95241	2.200E-04	7.541E-04	3.427E+00	9.275E-10	1.292E-08	3.470E-08
9	92236	1.114E+01	7.204E-04	6.467E-05	4.796E-05	6.681E-04	1.757E-03
10	93237	4.151E-02	2.925E-05	7.047E-04	1.779E-07	2.479E-06	6.546E-06
11	90230	3.084E-04	6.359E-06	2.062E-02	1.363E-09	1.898E-08	4.864E-08
12	91231	1.083E-05	5.117E-07	4.723E-02	4.765E-11	6.638E-10	1.708E-09
13	92233	7.457E-06	7.185E-08	9.636E-03	3.252E-11	4.530E-10	1.176E-09
14	94242	6.430E-06	2.543E-08	3.954E-03	2.699E-11	3.761E-10	1.014E-09
	totals	5.555E+03	3.131E-01	5.636E-05	2.377E-02	3.312E-01	8.760E-01

nonactinide inventory for material 40000 at end of step 1, time 1.825E+03 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	1.077E+00	9.376E+01	8.704E+01	7.996E-06	1.114E-04	1.699E-04
2	39090	1.693E-04	9.205E+01	5.438E+05	1.913E-09	2.666E-08	2.670E-08
3	38090	6.515E-01	9.203E+01	1.413E+02	7.364E-06	1.026E-04	1.027E-04
4	61147	7.636E-02	7.083E+01	9.276E+02	5.282E-07	7.358E-06	1.204E-05
5	58144	3.309E-03	1.054E+01	3.185E+03	2.337E-08	3.256E-07	5.219E-07
6	36085	2.184E-02	8.579E+00	3.927E+02	2.614E-07	3.642E-06	3.445E-06
7	44106	6.688E-04	2.219E+00	3.318E+03	6.417E-09	8.940E-08	1.055E-07
8	62151	6.709E-02	1.766E+00	2.632E+01	4.517E-07	6.293E-06	1.058E-05
9	51125	1.066E-03	1.118E+00	1.048E+03	8.675E-09	1.209E-07	1.682E-07
10	63155	2.245E-03	1.107E+00	4.931E+02	1.473E-08	2.052E-07	3.541E-07
11	55134	4.498E-04	5.823E-01	1.295E+03	3.413E-09	4.755E-08	7.093E-08
12	63154	3.539E-04	9.566E-02	2.703E+02	2.336E-09	3.255E-08	5.581E-08
13	43099	9.105E-01	1.559E-02	1.712E-02	9.354E-06	1.303E-04	1.436E-04
14	63152	8.608E-05	1.520E-02	1.765E+02	5.758E-10	8.022E-09	1.358E-08
15	40093	8.861E-01	2.229E-03	2.515E-03	9.692E-06	1.350E-04	1.397E-04
16	55135	1.259E+00	1.450E-03	1.152E-03	9.482E-06	1.321E-04	1.985E-04
17	34079	5.302E-03	7.278E-04	1.373E-01	6.827E-08	9.511E-07	8.361E-07
18	50126	1.076E-02	3.056E-04	2.839E-02	8.687E-08	1.210E-06	1.697E-06
19	53129	1.056E-01	1.866E-05	1.766E-04	8.328E-07	1.160E-05	1.666E-05
20	46107	2.523E-02	1.298E-05	5.145E-04	2.398E-07	3.341E-06	3.978E-06
21	37087	3.377E-01	2.894E-08	8.570E-08	3.949E-06	5.501E-05	5.326E-05
22	62147	4.160E-01	9.551E-09	2.296E-08	2.878E-06	4.009E-05	6.561E-05
23	60144	1.199E+00	1.425E-12	1.188E-12	8.470E-06	1.180E-04	1.892E-04
24	57138	6.742E-06	1.665E-13	2.469E-08	4.968E-11	6.921E-10	1.063E-09
25	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.214E-06	8.649E-06
26	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.250E-04	1.976E-04
27	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.372E-05	1.351E-04
28	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.500E-07	3.201E-07
29	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.361E-07	8.834E-07
30	64152	6.638E-05	1.446E-15	2.179E-11	4.440E-10	6.186E-09	1.047E-08
31	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.340E-07	1.686E-07
32	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.911E-06	6.307E-06
33	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.880E-10	1.486E-10
34	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.811E-10	4.656E-10
35	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.190E-09	1.779E-09
36	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.301E-09	6.012E-09
37	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.581E-08	5.566E-08
38	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.270E-08	1.895E-08
39	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.690E-07	1.448E-07
40	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.471E-07	3.881E-07
41	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.740E-06	2.440E-06
42	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.331E-06	3.904E-06
43	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.750E-09	2.510E-09
44	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.140E-05	1.053E-05
45	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.090E-05	1.954E-05
46	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.471E-05	4.279E-05
47	37085	1.319E-01	0.000E+00	0.000E+00	1.579E-06	2.199E-05	2.080E-05
48	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.480E-09	1.417E-09
49	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.561E-05	7.404E-05
50	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.007E-04	9.970E-05
51	40090	1.283E-01	0.000E+00	0.000E+00	1.450E-06	2.020E-05	2.023E-05
52	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.241E-04	1.257E-04
53	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.280E-04	1.311E-04
54	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.380E-04	1.444E-04

55	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.350E-04	1.443E-04
56	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.385E-04	1.464E-04
57	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.230E-07	1.314E-07
58	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.290E-04	1.393E-04
59	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.230E-04	1.342E-04
60	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.340E-04	1.492E-04
61	44099	5.155E-05	0.000E+00	0.000E+00	5.296E-10	7.379E-09	8.130E-09
62	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.790E-10	1.992E-10
63	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.110E-04	1.248E-04
64	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.182E-05	1.042E-04
65	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.071E-05	4.712E-05
66	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.465E-05	7.411E-05
67	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.113E-05	2.470E-05
68	46106	6.667E-02	0.000E+00	0.000E+00	6.397E-07	8.912E-06	1.051E-05
69	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.250E-06	1.503E-06
70	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.681E-07	6.955E-07
71	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.981E-07	8.469E-07
72	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.630E-10	3.220E-10
73	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.764E-07	4.650E-07
74	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.851E-07	3.553E-07
75	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.301E-07	5.457E-07
76	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.881E-07	3.719E-07
77	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.171E-10	3.988E-10
78	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.310E-08	1.677E-08
79	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.270E-09	2.931E-09
80	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.760E-07	3.595E-07
81	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.480E-07	3.258E-07
82	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.801E-07	3.709E-07
83	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.740E-07	3.660E-07
84	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.351E-07	4.550E-07
85	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.771E-07	7.966E-07
86	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.670E-07	3.597E-07
87	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.399E-07	4.654E-07
88	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.071E-10	4.170E-10
89	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.221E-10	5.826E-10
90	52125	5.331E-03	0.000E+00	0.000E+00	4.337E-08	6.042E-07	8.407E-07
91	52126	4.487E-04	0.000E+00	0.000E+00	3.621E-09	5.045E-08	7.076E-08
92	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.441E-06	1.060E-05
93	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.871E-05	5.601E-05
94	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.301E-06	4.666E-06
95	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.630E-09	3.748E-09
96	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.470E-08	2.128E-08
97	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.143E-05	8.958E-05
98	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.277E-05	1.363E-04
99	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.680E-04	2.506E-04
100	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.420E-04	2.150E-04
101	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.427E-04	2.112E-04
102	56134	3.363E-03	0.000E+00	0.000E+00	2.552E-08	3.555E-07	5.303E-07
103	56135	2.934E-06	0.000E+00	0.000E+00	2.210E-11	3.079E-10	4.628E-10
104	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.706E-07	2.583E-07
105	56137	1.984E-01	0.000E+00	0.000E+00	1.472E-06	2.051E-05	3.128E-05
106	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.440E-04	2.213E-04
107	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.370E-04	2.120E-04
108	58140	1.309E+00	0.000E+00	0.000E+00	9.506E-06	1.324E-04	2.064E-04
109	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.244E-04	1.953E-04
110	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.181E-08	5.028E-08
111	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.256E-04	2.000E-04
112	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.431E-05	1.045E-04
113	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.581E-05	5.900E-05
114	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.410E-05	2.355E-05
115	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.790E-05	2.990E-05
116	62152	8.577E-02	0.000E+00	0.000E+00	5.737E-07	7.993E-06	1.353E-05
117	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.610E-06	2.761E-06
118	63151	3.805E-03	0.000E+00	0.000E+00	2.562E-08	3.569E-07	6.001E-07
119	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.527E-06	6.008E-06
120	64154	2.430E-04	0.000E+00	0.000E+00	1.604E-09	2.235E-08	3.832E-08
121	64155	3.412E-03	0.000E+00	0.000E+00	2.238E-08	3.118E-07	5.381E-07
122	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.205E-07	9.041E-07
123	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.400E-08	2.448E-08
124	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.411E-09	1.320E-08
125	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.320E-08	4.108E-08
126	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.970E-09	3.532E-09
127	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.131E-10	9.255E-10
128	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.760E-10	3.195E-10
129	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.631E-01	1.182E-01
130	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.400E-04	4.546E-05
131	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.350E-09	3.927E-10
132	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.210E-03	2.427E-04
	totals	7.862E+02	3.747E+02	4.766E-01	4.801E-02	6.688E-01	1.240E-01

Step 2 - 10 years

actinide inventory for material 40000 at end of step 2, time 3.650E+03 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	94239	2.250E+00	1.396E-01	6.203E-02	9.566E-06	1.333E-04	3.549E-04
2	92234	1.154E+01	7.175E-02	6.217E-03	5.011E-05	6.981E-04	1.820E-03
3	94241	6.358E-04	6.571E-02	1.033E+02	2.680E-09	3.734E-08	1.003E-07
4	94240	3.202E-02	7.266E-03	2.269E-01	1.355E-07	1.888E-06	5.050E-06
5	94238	3.093E-04	5.296E-03	1.712E+01	1.320E-09	1.839E-08	4.877E-08
6	92235	1.056E+03	2.283E-03	2.161E-06	4.566E-03	6.361E-02	1.666E-01
7	92238	4.474E+03	1.504E-03	3.361E-07	1.910E-02	2.660E-01	7.055E-01
8	95241	3.911E-04	1.340E-03	3.427E+00	1.649E-09	2.297E-08	6.168E-08
9	92236	1.114E+01	7.204E-04	6.467E-05	4.796E-05	6.681E-04	1.757E-03
10	93237	4.151E-02	2.925E-05	7.047E-04	1.780E-07	2.479E-06	6.547E-06
11	90230	4.683E-04	9.655E-06	2.062E-02	2.069E-09	2.882E-08	7.386E-08
12	91231	1.594E-05	7.529E-07	4.723E-02	7.012E-11	9.768E-10	2.514E-09
13	92233	7.523E-06	7.249E-08	9.636E-03	3.280E-11	4.570E-10	1.186E-09
14	94242	6.430E-06	2.543E-08	3.954E-03	2.699E-11	3.761E-10	1.014E-09
15	90232	3.239E-06	3.552E-13	1.097E-07	1.418E-11	1.976E-10	5.108E-10
	totals	5.555E+03	2.955E-01	5.320E-05	2.377E-02	3.312E-01	8.760E-01

nonactinide inventory for material 40000 at end of step 2, time 3.650E+03 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	9.598E-01	8.354E+01	8.704E+01	7.124E-06	9.925E-05	1.514E-04
2	39090	1.497E-04	8.140E+01	5.438E+05	1.692E-09	2.357E-08	2.361E-08
3	38090	5.761E-01	8.137E+01	1.413E+02	6.511E-06	9.071E-05	9.085E-05
4	61147	2.039E-02	1.892E+01	9.276E+02	1.411E-07	1.965E-06	3.216E-06
5	36085	1.581E-02	6.210E+00	3.927E+02	1.892E-07	2.636E-06	2.494E-06
6	62151	6.455E-02	1.699E+00	2.632E+01	4.347E-07	6.056E-06	1.018E-05
7	63155	1.071E-03	5.282E-01	4.931E+02	7.027E-09	9.790E-08	1.689E-07
8	51125	2.998E-04	3.144E-01	1.048E+03	2.439E-09	3.398E-08	4.729E-08
9	58144	3.903E-05	1.243E-01	3.185E+03	2.756E-10	3.840E-09	6.155E-09
10	55134	8.385E-05	1.086E-01	1.295E+03	6.363E-10	8.865E-09	1.322E-08
11	44106	2.222E-05	7.374E-02	3.318E+03	2.132E-10	2.971E-09	3.505E-09
12	63154	2.365E-04	6.393E-02	2.703E+02	1.561E-09	2.175E-08	3.730E-08
13	43099	9.104E-01	1.559E-02	1.712E-02	9.354E-06	1.303E-04	1.436E-04
14	63152	6.639E-05	1.172E-02	1.765E+02	4.440E-10	6.186E-09	1.047E-08
15	40093	8.861E-01	2.229E-03	2.515E-03	9.692E-06	1.350E-04	1.397E-04
16	55135	1.259E+00	1.450E-03	1.152E-03	9.482E-06	1.321E-04	1.985E-04
17	34079	5.301E-03	7.277E-04	1.373E-01	6.826E-08	9.510E-07	8.360E-07
18	50126	1.076E-02	3.056E-04	2.839E-02	8.686E-08	1.210E-06	1.697E-06
19	53129	1.056E-01	1.866E-05	1.766E-04	8.328E-07	1.160E-05	1.666E-05
20	46107	2.523E-02	1.298E-05	5.145E-04	2.398E-07	3.341E-06	3.978E-06
21	37087	3.377E-01	2.894E-08	8.570E-08	3.949E-06	5.501E-05	5.326E-05
22	62147	4.720E-01	1.084E-08	2.296E-08	3.265E-06	4.548E-05	7.444E-05
23	60144	1.203E+00	1.429E-12	1.188E-12	8.493E-06	1.183E-04	1.897E-04
24	57138	6.742E-06	1.665E-13	2.469E-08	4.968E-11	6.921E-10	1.063E-09
25	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.214E-06	8.649E-06
26	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.250E-04	1.976E-04
27	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.372E-05	1.351E-04
28	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.500E-07	3.201E-07
29	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.361E-07	8.834E-07
30	64152	7.188E-05	1.566E-15	2.179E-11	4.808E-10	6.698E-09	1.134E-08
31	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.340E-07	1.686E-07
32	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.911E-06	6.307E-06
33	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.880E-10	1.486E-10
34	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.811E-10	4.656E-10
35	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.190E-09	1.779E-09
36	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.301E-09	6.012E-09
37	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.581E-08	5.566E-08
38	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.270E-08	1.895E-08
39	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.690E-07	1.448E-07
40	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.471E-07	3.881E-07
41	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.740E-06	2.440E-06
42	35079	1.113E-06	0.000E+00	0.000E+00	1.433E-11	1.996E-10	1.755E-10
43	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.331E-06	3.904E-06
44	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.750E-09	2.510E-09
45	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.140E-05	1.053E-05
46	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.090E-05	1.954E-05
47	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.471E-05	4.279E-05
48	37085	1.379E-01	0.000E+00	0.000E+00	1.651E-06	2.300E-05	2.175E-05
49	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.480E-09	1.417E-09
50	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.561E-05	7.404E-05
51	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.007E-04	9.970E-05
52	40090	2.035E-01	0.000E+00	0.000E+00	2.300E-06	3.205E-05	3.210E-05
53	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.241E-04	1.257E-04
54	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.280E-04	1.311E-04

55	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.380E-04	1.444E-04
56	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.350E-04	1.443E-04
57	41093	7.503E-07	0.000E+00	0.000E+00	8.206E-12	1.143E-10	1.183E-10
58	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.385E-04	1.464E-04
59	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.230E-07	1.314E-07
60	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.290E-04	1.393E-04
61	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.230E-04	1.342E-04
62	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.340E-04	1.492E-04
63	44099	6.649E-05	0.000E+00	0.000E+00	6.831E-10	9.517E-09	1.049E-08
64	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.790E-10	1.992E-10
65	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.110E-04	1.248E-04
66	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.182E-05	1.042E-04
67	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.071E-05	4.712E-05
68	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.465E-05	7.411E-05
69	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.113E-05	2.470E-05
70	46106	6.731E-02	0.000E+00	0.000E+00	6.459E-07	8.999E-06	1.062E-05
71	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.250E-06	1.503E-06
72	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.681E-07	6.955E-07
73	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.981E-07	8.469E-07
74	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.630E-10	3.220E-10
75	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.764E-07	4.650E-07
76	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.851E-07	3.553E-07
77	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.301E-07	5.457E-07
78	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.881E-07	3.719E-07
79	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.171E-10	3.988E-10
80	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.310E-08	1.677E-08
81	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.270E-09	2.931E-09
82	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.760E-07	3.595E-07
83	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.480E-07	3.258E-07
84	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.801E-07	3.709E-07
85	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.740E-07	3.660E-07
86	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.351E-07	4.550E-07
87	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.771E-07	7.966E-07
88	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.670E-07	3.597E-07
89	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.399E-07	4.654E-07
90	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.071E-10	4.170E-10
91	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.221E-10	5.826E-10
92	52125	6.108E-03	0.000E+00	0.000E+00	4.970E-08	6.923E-07	9.633E-07
93	52126	4.490E-04	0.000E+00	0.000E+00	3.624E-09	5.049E-08	7.082E-08
94	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.441E-06	1.060E-05
95	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.871E-05	5.601E-05
96	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.301E-06	4.666E-06
97	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.630E-09	3.748E-09
98	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.470E-08	2.128E-08
99	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.143E-05	8.958E-05
100	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.277E-05	1.363E-04
101	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.680E-04	2.506E-04
102	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.420E-04	2.150E-04
103	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.427E-04	2.112E-04
104	56134	3.729E-03	0.000E+00	0.000E+00	2.830E-08	3.942E-07	5.880E-07
105	56135	4.830E-06	0.000E+00	0.000E+00	3.638E-11	5.069E-10	7.617E-10
106	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.706E-07	2.583E-07
107	56137	3.158E-01	0.000E+00	0.000E+00	2.344E-06	3.266E-05	4.981E-05
108	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.440E-04	2.213E-04
109	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.370E-04	2.120E-04
110	58140	1.309E+00	0.000E+00	0.000E+00	9.506E-06	1.324E-04	2.064E-04
111	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.244E-04	1.953E-04
112	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.181E-08	5.028E-08
113	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.256E-04	2.000E-04
114	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.431E-05	1.045E-04
115	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.581E-05	5.900E-05
116	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.410E-05	2.355E-05
117	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.790E-05	2.990E-05
118	62152	8.579E-02	0.000E+00	0.000E+00	5.738E-07	7.994E-06	1.353E-05
119	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.610E-06	2.761E-06
120	63151	6.338E-03	0.000E+00	0.000E+00	4.267E-08	5.945E-07	9.995E-07
121	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.527E-06	6.008E-06
122	64154	3.603E-04	0.000E+00	0.000E+00	2.379E-09	3.314E-08	5.683E-08
123	64155	4.586E-03	0.000E+00	0.000E+00	3.008E-08	4.191E-07	7.233E-07
124	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.205E-07	9.041E-07
125	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.400E-08	2.448E-08
126	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.411E-09	1.320E-08
127	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.320E-08	4.108E-08
128	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.970E-09	3.532E-09
129	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.131E-10	9.255E-10
130	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.760E-10	3.195E-10
131	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.631E-01	1.182E-01
132	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.400E-04	4.546E-05
133	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.350E-09	3.927E-10
134	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.210E-03	2.427E-04
	totals	7.862E+02	2.744E+02	3.490E-01	4.801E-02	6.688E-01	1.240E-01

Step 3 - 15 years

actinide inventory for material 40000 at end of step 3, time 5.475E+03 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	94239	2.250E+00	1.396E-01	6.203E-02	9.564E-06	1.332E-04	3.548E-04
2	92234	1.154E+01	7.175E-02	6.217E-03	5.011E-05	6.981E-04	1.820E-03
3	94241	4.995E-04	5.162E-02	1.033E+02	2.106E-09	2.933E-08	7.877E-08
4	94240	3.200E-02	7.262E-03	2.269E-01	1.355E-07	1.887E-06	5.047E-06
5	94238	2.973E-04	5.091E-03	1.712E+01	1.269E-09	1.768E-08	4.688E-08
6	92235	1.056E+03	2.283E-03	2.161E-06	4.566E-03	6.361E-02	1.666E-01
7	95241	5.238E-04	1.795E-03	3.427E+00	2.208E-09	3.076E-08	8.260E-08
8	92238	4.474E+03	1.504E-03	3.361E-07	1.910E-02	2.660E-01	7.055E-01
9	92236	1.114E+01	7.204E-04	6.467E-05	4.796E-05	6.681E-04	1.757E-03
10	93237	4.152E-02	2.926E-05	7.047E-04	1.780E-07	2.479E-06	6.547E-06
11	90230	6.282E-04	1.295E-05	2.062E-02	2.775E-09	3.866E-08	9.907E-08
12	91231	2.105E-05	9.942E-07	4.723E-02	9.258E-11	1.290E-09	3.319E-09
13	92233	7.589E-06	7.312E-08	9.636E-03	3.309E-11	4.610E-10	1.197E-09
14	94242	6.430E-06	2.543E-08	3.954E-03	2.699E-11	3.761E-10	1.014E-09
15	90232	4.858E-06	5.327E-13	1.097E-07	2.128E-11	2.964E-10	7.662E-10
	totals	5.555E+03	2.816E-01	5.070E-05	2.377E-02	3.312E-01	8.760E-01

nonactinide inventory for material 40000 at end of step 3, time 5.475E+03 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	8.551E-01	7.443E+01	8.704E+01	6.347E-06	8.842E-05	1.349E-04
2	39090	1.324E-04	7.197E+01	5.438E+05	1.496E-09	2.084E-08	2.087E-08
3	38090	5.094E-01	7.195E+01	1.413E+02	5.758E-06	8.021E-05	8.034E-05
4	61147	5.447E-03	5.052E+00	9.276E+02	3.767E-08	5.248E-07	8.590E-07
5	36085	1.145E-02	4.496E+00	3.927E+02	1.370E-07	1.909E-06	1.805E-06
6	62151	6.212E-02	1.635E+00	2.632E+01	4.183E-07	5.827E-06	9.796E-06
7	63155	5.111E-04	2.520E-01	4.931E+02	3.353E-09	4.671E-08	8.060E-08
8	51125	8.432E-05	8.840E-02	1.048E+03	6.860E-10	9.557E-09	1.330E-08
9	63154	1.580E-04	4.272E-02	2.703E+02	1.043E-09	1.454E-08	2.492E-08
10	55134	1.563E-05	2.024E-02	1.295E+03	1.186E-10	1.653E-09	2.465E-09
11	43099	9.104E-01	1.559E-02	1.712E-02	9.354E-06	1.303E-04	1.436E-04
12	63152	5.120E-05	9.038E-03	1.765E+02	3.424E-10	4.771E-09	8.074E-09
13	40093	8.861E-01	2.229E-03	2.515E-03	9.692E-06	1.350E-04	1.397E-04
14	55135	1.259E+00	1.450E-03	1.152E-03	9.482E-06	1.321E-04	1.985E-04
15	34079	5.301E-03	7.276E-04	1.373E-01	6.825E-08	9.509E-07	8.359E-07
16	50126	1.076E-02	3.056E-04	2.839E-02	8.686E-08	1.210E-06	1.697E-06
17	53129	1.056E-01	1.866E-05	1.766E-04	8.328E-07	1.160E-05	1.666E-05
18	46107	2.523E-02	1.298E-05	5.145E-04	2.398E-07	3.341E-06	3.978E-06
19	37087	3.377E-01	2.894E-08	8.570E-08	3.949E-06	5.501E-05	5.326E-05
20	62147	4.869E-01	1.118E-08	2.296E-08	3.368E-06	4.692E-05	7.679E-05
21	60144	1.203E+00	1.429E-12	1.188E-12	8.493E-06	1.183E-04	1.897E-04
22	57138	6.742E-06	1.665E-13	2.469E-08	4.968E-11	6.921E-10	1.063E-09
23	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.214E-06	8.649E-06
24	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.250E-04	1.976E-04
25	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.372E-05	1.351E-04
26	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.500E-07	3.201E-07
27	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.361E-07	8.834E-07
28	64152	7.612E-05	1.659E-15	2.179E-11	5.091E-10	7.093E-09	1.200E-08
29	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.340E-07	1.686E-07
30	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.911E-06	6.307E-06
31	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.880E-10	1.486E-10
32	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.811E-10	4.656E-10
33	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.190E-09	1.779E-09
34	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.301E-09	6.012E-09
35	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.581E-08	5.566E-08
36	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.270E-08	1.895E-08
37	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.690E-07	1.448E-07
38	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.471E-07	3.881E-07
39	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.740E-06	2.440E-06
40	35079	1.669E-06	0.000E+00	0.000E+00	2.149E-11	2.994E-10	2.632E-10
41	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.331E-06	3.904E-06
42	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.750E-09	2.510E-09
43	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.140E-05	1.053E-05
44	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.090E-05	1.954E-05
45	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.471E-05	4.279E-05
46	37085	1.423E-01	0.000E+00	0.000E+00	1.703E-06	2.373E-05	2.244E-05
47	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.480E-09	1.417E-09
48	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.561E-05	7.404E-05
49	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.007E-04	9.970E-05
50	40090	2.701E-01	0.000E+00	0.000E+00	3.053E-06	4.253E-05	4.259E-05
51	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.241E-04	1.257E-04
52	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.280E-04	1.311E-04
53	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.380E-04	1.444E-04
54	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.350E-04	1.443E-04

55	41093	1.581E-06	0.000E+00	0.000E+00	1.730E-11	2.409E-10	2.494E-10
56	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.385E-04	1.464E-04
57	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.230E-07	1.314E-07
58	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.290E-04	1.393E-04
59	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.230E-04	1.342E-04
60	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.340E-04	1.492E-04
61	44099	8.142E-05	0.000E+00	0.000E+00	8.366E-10	1.165E-08	1.284E-08
62	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.790E-10	1.992E-10
63	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.110E-04	1.248E-04
64	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.182E-05	1.042E-04
65	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.071E-05	4.712E-05
66	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.465E-05	7.411E-05
67	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.113E-05	2.470E-05
68	46106	6.734E-02	0.000E+00	0.000E+00	6.461E-07	9.002E-06	1.062E-05
69	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.250E-06	1.503E-06
70	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.681E-07	6.955E-07
71	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.981E-07	8.469E-07
72	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.630E-10	3.220E-10
73	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.764E-07	4.650E-07
74	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.851E-07	3.553E-07
75	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.301E-07	5.457E-07
76	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.881E-07	3.719E-07
77	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.171E-10	3.988E-10
78	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.310E-08	1.677E-08
79	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.270E-09	2.931E-09
80	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.760E-07	3.595E-07
81	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.480E-07	3.258E-07
82	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.801E-07	3.709E-07
83	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.740E-07	3.660E-07
84	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.351E-07	4.550E-07
85	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.771E-07	7.966E-07
86	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.670E-07	3.597E-07
87	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.399E-07	4.654E-07
88	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.071E-10	4.170E-10
89	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.221E-10	5.826E-10
90	52125	6.327E-03	0.000E+00	0.000E+00	5.147E-08	7.171E-07	9.978E-07
91	52126	4.494E-04	0.000E+00	0.000E+00	3.627E-09	5.053E-08	7.088E-08
92	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.441E-06	1.060E-05
93	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.871E-05	5.601E-05
94	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.301E-06	4.666E-06
95	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.630E-09	3.748E-09
96	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.470E-08	2.128E-08
97	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.143E-05	8.958E-05
98	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.277E-05	1.363E-04
99	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.680E-04	2.506E-04
100	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.420E-04	2.150E-04
101	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.427E-04	2.112E-04
102	56134	3.797E-03	0.000E+00	0.000E+00	2.881E-08	4.014E-07	5.988E-07
103	56135	6.725E-06	0.000E+00	0.000E+00	5.066E-11	7.058E-10	1.061E-09
104	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.706E-07	2.583E-07
105	56137	4.205E-01	0.000E+00	0.000E+00	3.121E-06	4.348E-05	6.631E-05
106	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.440E-04	2.213E-04
107	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.370E-04	2.120E-04
108	58140	1.309E+00	0.000E+00	0.000E+00	9.506E-06	1.324E-04	2.064E-04
109	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.244E-04	1.953E-04
110	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.181E-08	5.028E-08
111	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.256E-04	2.000E-04
112	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.431E-05	1.045E-04
113	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.581E-05	5.900E-05
114	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.410E-05	2.355E-05
115	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.790E-05	2.990E-05
116	62152	8.580E-02	0.000E+00	0.000E+00	5.739E-07	7.995E-06	1.353E-05
117	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.610E-06	2.761E-06
118	63151	8.775E-03	0.000E+00	0.000E+00	5.908E-08	8.231E-07	1.384E-06
119	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.527E-06	6.008E-06
120	64154	4.388E-04	0.000E+00	0.000E+00	2.897E-09	4.036E-08	6.920E-08
121	64155	5.146E-03	0.000E+00	0.000E+00	3.376E-08	4.703E-07	8.116E-07
122	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.205E-07	9.041E-07
123	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.400E-08	2.448E-08
124	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.411E-09	1.320E-08
125	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.320E-08	4.108E-08
126	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.970E-09	3.532E-09
127	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.131E-10	9.255E-10
128	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.760E-10	3.195E-10
129	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.631E-01	1.182E-01
130	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.400E-04	4.546E-05
131	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.350E-09	3.927E-10
132	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.210E-03	2.427E-04
	totals	7.862E+02	2.300E+02	2.925E-01	4.801E-02	6.688E-01	1.240E-01

Step 4 - 20 years

actinide inventory for material 40000 at end of step 4, time 7.300E+03 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	94239	2.250E+00	1.395E-01	6.203E-02	9.563E-06	1.332E-04	3.548E-04
2	92234	1.154E+01	7.175E-02	6.217E-03	5.011E-05	6.981E-04	1.820E-03
3	94241	3.924E-04	4.055E-02	1.033E+02	1.654E-09	2.304E-08	6.188E-08
4	94240	3.199E-02	7.258E-03	2.269E-01	1.354E-07	1.886E-06	5.044E-06
5	94238	2.858E-04	4.894E-03	1.712E+01	1.220E-09	1.700E-08	4.507E-08
6	92235	1.056E+03	2.283E-03	2.161E-06	4.566E-03	6.361E-02	1.666E-01
7	95241	6.262E-04	2.146E-03	3.427E+00	2.640E-09	3.678E-08	9.876E-08
8	92238	4.474E+03	1.504E-03	3.361E-07	1.910E-02	2.660E-01	7.055E-01
9	92236	1.114E+01	7.204E-04	6.467E-05	4.796E-05	6.681E-04	1.757E-03
10	93237	4.152E-02	2.926E-05	7.047E-04	1.780E-07	2.480E-06	6.548E-06
11	90230	7.880E-04	1.625E-05	2.062E-02	3.481E-09	4.850E-08	1.243E-07
12	91231	2.615E-05	1.235E-06	4.723E-02	1.150E-10	1.603E-09	4.125E-09
13	92233	7.654E-06	7.376E-08	9.636E-03	3.338E-11	4.650E-10	1.207E-09
14	94242	6.430E-06	2.543E-08	3.954E-03	2.699E-11	3.761E-10	1.014E-09
15	90232	6.478E-06	7.103E-13	1.097E-07	2.837E-11	3.952E-10	1.022E-09
	totals	5.555E+03	2.707E-01	4.873E-05	2.377E-02	3.312E-01	8.760E-01

nonactinide inventory for material 40000 at end of step 4, time 7.300E+03 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	7.619E-01	6.631E+01	8.704E+01	5.655E-06	7.878E-05	1.202E-04
2	39090	1.170E-04	6.364E+01	5.438E+05	1.323E-09	1.843E-08	1.846E-08
3	38090	4.504E-01	6.362E+01	1.413E+02	5.091E-06	7.093E-05	7.104E-05
4	36085	8.287E-03	3.255E+00	3.927E+02	9.917E-08	1.382E-06	1.307E-06
5	62151	5.977E-02	1.573E+00	2.632E+01	4.025E-07	5.607E-06	9.427E-06
6	61147	1.455E-03	1.349E+00	9.276E+02	1.006E-08	1.402E-07	2.294E-07
7	63155	2.438E-04	1.202E-01	4.931E+02	1.599E-09	2.228E-08	3.846E-08
8	63154	1.056E-04	2.855E-02	2.703E+02	6.972E-10	9.713E-09	1.665E-08
9	51125	2.371E-05	2.486E-02	1.048E+03	1.929E-10	2.687E-09	3.739E-09
10	43099	9.104E-01	1.559E-02	1.712E-02	9.354E-06	1.303E-04	1.436E-04
11	63152	3.948E-05	6.970E-03	1.765E+02	2.641E-10	3.679E-09	6.226E-09
12	55134	2.915E-06	3.774E-03	1.295E+03	2.212E-11	3.081E-10	4.597E-10
13	40093	8.861E-01	2.229E-03	2.515E-03	9.692E-06	1.350E-04	1.397E-04
14	55135	1.259E+00	1.450E-03	1.152E-03	9.482E-06	1.321E-04	1.985E-04
15	34079	5.300E-03	7.275E-04	1.373E-01	6.825E-08	9.508E-07	8.359E-07
16	50126	1.076E-02	3.056E-04	2.839E-02	8.686E-08	1.210E-06	1.697E-06
17	53129	1.056E-01	1.866E-05	1.766E-04	8.328E-07	1.160E-05	1.666E-05
18	46107	2.523E-02	1.298E-05	5.145E-04	2.398E-07	3.341E-06	3.978E-06
19	37087	3.377E-01	2.894E-08	8.570E-08	3.949E-06	5.501E-05	5.326E-05
20	62147	4.909E-01	1.127E-08	2.296E-08	3.396E-06	4.731E-05	7.742E-05
21	60144	1.203E+00	1.429E-12	1.188E-12	8.493E-06	1.183E-04	1.897E-04
22	57138	6.742E-06	1.665E-13	2.469E-08	4.968E-11	6.921E-10	1.063E-09
23	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.214E-06	8.649E-06
24	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.250E-04	1.976E-04
25	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.372E-05	1.351E-04
26	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.500E-07	3.201E-07
27	64152	7.939E-05	1.730E-15	2.179E-11	5.310E-10	7.398E-09	1.252E-08
28	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.361E-07	8.834E-07
29	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.340E-07	1.686E-07
30	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.911E-06	6.307E-06
31	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.880E-10	1.486E-10
32	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.811E-10	4.656E-10
33	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.190E-09	1.779E-09
34	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.301E-09	6.012E-09
35	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.581E-08	5.566E-08
36	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.270E-08	1.895E-08
37	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.690E-07	1.448E-07
38	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.471E-07	3.881E-07
39	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.740E-06	2.440E-06
40	35079	2.225E-06	0.000E+00	0.000E+00	2.866E-11	3.992E-10	3.510E-10
41	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.331E-06	3.904E-06
42	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.750E-09	2.510E-09
43	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.140E-05	1.053E-05
44	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.090E-05	1.954E-05
45	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.471E-05	4.279E-05
46	37085	1.455E-01	0.000E+00	0.000E+00	1.741E-06	2.425E-05	2.294E-05
47	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.480E-09	1.417E-09
48	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.561E-05	7.404E-05
49	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.007E-04	9.970E-05
50	40090	3.289E-01	0.000E+00	0.000E+00	3.718E-06	5.180E-05	5.188E-05
51	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.241E-04	1.257E-04
52	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.280E-04	1.311E-04
53	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.380E-04	1.444E-04
54	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.350E-04	1.443E-04

55	41093	2.639E-06	0.000E+00	0.000E+00	2.887E-11	4.022E-10	4.162E-10
56	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.385E-04	1.464E-04
57	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.230E-07	1.314E-07
58	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.290E-04	1.393E-04
59	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.230E-04	1.342E-04
60	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.340E-04	1.492E-04
61	44099	9.636E-05	0.000E+00	0.000E+00	9.901E-10	1.379E-08	1.520E-08
62	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.790E-10	1.992E-10
63	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.110E-04	1.248E-04
64	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.182E-05	1.042E-04
65	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.071E-05	4.712E-05
66	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.465E-05	7.411E-05
67	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.113E-05	2.470E-05
68	46106	6.734E-02	0.000E+00	0.000E+00	6.461E-07	9.002E-06	1.062E-05
69	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.250E-06	1.503E-06
70	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.681E-07	6.955E-07
71	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.981E-07	8.469E-07
72	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.630E-10	3.220E-10
73	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.764E-07	4.650E-07
74	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.851E-07	3.553E-07
75	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.301E-07	5.457E-07
76	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.881E-07	3.719E-07
77	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.171E-10	3.988E-10
78	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.310E-08	1.677E-08
79	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.270E-09	2.931E-09
80	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.760E-07	3.595E-07
81	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.480E-07	3.258E-07
82	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.801E-07	3.709E-07
83	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.740E-07	3.660E-07
84	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.351E-07	4.550E-07
85	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.771E-07	7.966E-07
86	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.670E-07	3.597E-07
87	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.399E-07	4.654E-07
88	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.071E-10	4.170E-10
89	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.221E-10	5.826E-10
90	52125	6.388E-03	0.000E+00	0.000E+00	5.197E-08	7.241E-07	1.007E-06
91	52126	4.498E-04	0.000E+00	0.000E+00	3.630E-09	5.058E-08	7.093E-08
92	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.441E-06	1.060E-05
93	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.871E-05	5.601E-05
94	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.301E-06	4.666E-06
95	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.630E-09	3.748E-09
96	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.470E-08	2.128E-08
97	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.143E-05	8.958E-05
98	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.277E-05	1.363E-04
99	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.680E-04	2.506E-04
100	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.420E-04	2.150E-04
101	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.427E-04	2.112E-04
102	56134	3.810E-03	0.000E+00	0.000E+00	2.891E-08	4.028E-07	6.008E-07
103	56135	8.621E-06	0.000E+00	0.000E+00	6.494E-11	9.047E-10	1.360E-09
104	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.706E-07	2.583E-07
105	56137	5.137E-01	0.000E+00	0.000E+00	3.813E-06	5.312E-05	8.101E-05
106	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.440E-04	2.213E-04
107	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.370E-04	2.120E-04
108	58140	1.309E+00	0.000E+00	0.000E+00	9.506E-06	1.324E-04	2.064E-04
109	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.244E-04	1.953E-04
110	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.181E-08	5.028E-08
111	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.256E-04	2.000E-04
112	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.431E-05	1.045E-04
113	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.581E-05	5.900E-05
114	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.410E-05	2.355E-05
115	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.790E-05	2.990E-05
116	62152	8.581E-02	0.000E+00	0.000E+00	5.740E-07	7.996E-06	1.353E-05
117	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.610E-06	2.761E-06
118	63151	1.112E-02	0.000E+00	0.000E+00	7.487E-08	1.043E-06	1.754E-06
119	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.527E-06	6.008E-06
120	64154	4.912E-04	0.000E+00	0.000E+00	3.243E-09	4.518E-08	7.747E-08
121	64155	5.414E-03	0.000E+00	0.000E+00	3.551E-08	4.947E-07	8.538E-07
122	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.205E-07	9.041E-07
123	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.400E-08	2.448E-08
124	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.411E-09	1.320E-08
125	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.320E-08	4.108E-08
126	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.970E-09	3.532E-09
127	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.131E-10	9.255E-10
128	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.760E-10	3.195E-10
129	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.631E-01	1.182E-01
130	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.400E-04	4.546E-05
131	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.350E-09	3.927E-10
132	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.210E-03	2.427E-04
	totals	7.862E+02	2.000E+02	2.543E-01	4.801E-02	6.688E-01	1.240E-01

Step 5 - 30 years

actinide inventory for material 40000 at end of step 5, time 1.095E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	94239	2.249E+00	1.395E-01	6.203E-02	9.560E-06	1.332E-04	3.547E-04
2	92234	1.154E+01	7.175E-02	6.217E-03	5.011E-05	6.981E-04	1.820E-03
3	94241	2.421E-04	2.502E-02	1.033E+02	1.021E-09	1.422E-08	3.819E-08
4	94240	3.195E-02	7.250E-03	2.269E-01	1.353E-07	1.884E-06	5.039E-06
5	94238	2.641E-04	4.522E-03	1.712E+01	1.127E-09	1.570E-08	4.165E-08
6	95241	7.652E-04	2.623E-03	3.427E+00	3.226E-09	4.494E-08	1.207E-07
7	92235	1.056E+03	2.283E-03	2.161E-06	4.566E-03	6.361E-02	1.666E-01
8	92238	4.474E+03	1.504E-03	3.361E-07	1.910E-02	2.660E-01	7.055E-01
9	92236	1.114E+01	7.204E-04	6.467E-05	4.796E-05	6.681E-04	1.757E-03
10	93237	4.153E-02	2.927E-05	7.047E-04	1.780E-07	2.480E-06	6.550E-06
11	90230	1.108E-03	2.284E-05	2.062E-02	4.894E-09	6.817E-08	1.747E-07
12	91231	3.637E-05	1.718E-06	4.723E-02	1.600E-10	2.228E-09	5.735E-09
13	92233	7.786E-06	7.503E-08	9.636E-03	3.395E-11	4.730E-10	1.228E-09
14	94242	6.430E-06	2.543E-08	3.954E-03	2.699E-11	3.760E-10	1.014E-09
15	90232	9.717E-06	1.066E-12	1.097E-07	4.255E-11	5.928E-10	1.532E-09
	totals	5.555E+03	2.552E-01	4.595E-05	2.377E-02	3.312E-01	8.760E-01

nonactinide inventory for material 40000 at end of step 5, time 1.095E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	6.048E-01	5.264E+01	8.704E+01	4.489E-06	6.254E-05	9.538E-05
2	39090	9.151E-05	4.976E+01	5.438E+05	1.034E-09	1.441E-08	1.443E-08
3	38090	3.522E-01	4.975E+01	1.413E+02	3.981E-06	5.545E-05	5.554E-05
4	36085	4.343E-03	1.706E+00	3.927E+02	5.197E-08	7.241E-07	6.849E-07
5	62151	5.534E-02	1.457E+00	2.632E+01	3.727E-07	5.192E-06	8.728E-06
6	61147	1.038E-04	9.625E-02	9.276E+02	7.177E-10	9.999E-09	1.636E-08
7	63155	5.551E-05	2.737E-02	4.931E+02	3.641E-10	5.072E-09	8.754E-09
8	43099	9.104E-01	1.559E-02	1.712E-02	9.354E-06	1.303E-04	1.436E-04
9	63154	4.716E-05	1.275E-02	2.703E+02	3.113E-10	4.337E-09	7.437E-09
10	63152	2.348E-05	4.145E-03	1.765E+02	1.571E-10	2.188E-09	3.703E-09
11	40093	8.861E-01	2.228E-03	2.515E-03	9.692E-06	1.350E-04	1.397E-04
12	51125	1.875E-06	1.966E-03	1.048E+03	1.525E-11	2.125E-10	2.957E-10
13	55135	1.259E+00	1.450E-03	1.152E-03	9.482E-06	1.321E-04	1.985E-04
14	34079	5.299E-03	7.274E-04	1.373E-01	6.823E-08	9.506E-07	8.357E-07
15	50126	1.076E-02	3.055E-04	2.839E-02	8.685E-08	1.210E-06	1.697E-06
16	53129	1.056E-01	1.866E-05	1.766E-04	8.328E-07	1.160E-05	1.666E-05
17	46107	2.523E-02	1.298E-05	5.145E-04	2.398E-07	3.341E-06	3.978E-06
18	37087	3.377E-01	2.894E-08	8.570E-08	3.949E-06	5.501E-05	5.326E-05
19	62147	4.923E-01	1.130E-08	2.296E-08	3.405E-06	4.744E-05	7.764E-05
20	60144	1.203E+00	1.429E-12	1.188E-12	8.493E-06	1.183E-04	1.897E-04
21	57138	6.742E-06	1.665E-13	2.469E-08	4.968E-11	6.921E-10	1.063E-09
22	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.214E-06	8.649E-06
23	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.250E-04	1.976E-04
24	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.372E-05	1.351E-04
25	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.500E-07	3.201E-07
26	64152	8.385E-05	1.827E-15	2.179E-11	5.609E-10	7.814E-09	1.322E-08
27	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.361E-07	8.834E-07
28	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.340E-07	1.686E-07
29	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.911E-06	6.307E-06
30	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.880E-10	1.486E-10
31	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.811E-10	4.656E-10
32	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.190E-09	1.779E-09
33	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.301E-09	6.012E-09
34	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.581E-08	5.566E-08
35	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.270E-08	1.895E-08
36	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.690E-07	1.448E-07
37	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.471E-07	3.881E-07
38	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.740E-06	2.440E-06
39	35079	3.338E-06	0.000E+00	0.000E+00	4.298E-11	5.988E-10	5.264E-10
40	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.331E-06	3.904E-06
41	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.750E-09	2.510E-09
42	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.140E-05	1.053E-05
43	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.090E-05	1.954E-05
44	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.471E-05	4.279E-05
45	37085	1.494E-01	0.000E+00	0.000E+00	1.788E-06	2.491E-05	2.356E-05
46	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.480E-09	1.417E-09
47	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.561E-05	7.404E-05
48	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.007E-04	9.970E-05
49	40090	4.271E-01	0.000E+00	0.000E+00	4.827E-06	6.725E-05	6.736E-05
50	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.241E-04	1.257E-04
51	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.280E-04	1.311E-04
52	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.380E-04	1.444E-04
53	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.350E-04	1.443E-04
54	41093	5.269E-06	0.000E+00	0.000E+00	5.763E-11	8.029E-10	8.310E-10

55	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.385E-04	1.464E-04
56	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.230E-07	1.314E-07
57	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.290E-04	1.393E-04
58	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.230E-04	1.342E-04
59	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.340E-04	1.492E-04
60	44099	1.262E-04	0.000E+00	0.000E+00	1.297E-09	1.807E-08	1.991E-08
61	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.790E-10	1.992E-10
62	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.110E-04	1.248E-04
63	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.182E-05	1.042E-04
64	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.071E-05	4.712E-05
65	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.465E-05	7.411E-05
66	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.113E-05	2.470E-05
67	46106	6.734E-02	0.000E+00	0.000E+00	6.461E-07	9.002E-06	1.062E-05
68	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.250E-06	1.503E-06
69	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.681E-07	6.955E-07
70	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.981E-07	8.469E-07
71	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.630E-10	3.220E-10
72	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.764E-07	4.650E-07
73	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.851E-07	3.553E-07
74	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.301E-07	5.457E-07
75	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.881E-07	3.719E-07
76	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.171E-10	3.988E-10
77	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.310E-08	1.677E-08
78	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.270E-09	2.931E-09
79	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.760E-07	3.595E-07
80	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.480E-07	3.258E-07
81	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.801E-07	3.709E-07
82	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.740E-07	3.660E-07
83	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.351E-07	4.550E-07
84	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.771E-07	7.966E-07
85	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.670E-07	3.597E-07
86	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.399E-07	4.654E-07
87	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.071E-10	4.170E-10
88	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.221E-10	5.826E-10
89	52125	6.410E-03	0.000E+00	0.000E+00	5.215E-08	7.265E-07	1.011E-06
90	52126	4.505E-04	0.000E+00	0.000E+00	3.636E-09	5.066E-08	7.105E-08
91	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.441E-06	1.060E-05
92	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.871E-05	5.601E-05
93	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.301E-06	4.666E-06
94	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.630E-09	3.748E-09
95	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.470E-08	2.128E-08
96	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.143E-05	8.958E-05
97	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.277E-05	1.363E-04
98	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.680E-04	2.506E-04
99	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.420E-04	2.150E-04
100	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.427E-04	2.112E-04
101	56134	3.812E-03	0.000E+00	0.000E+00	2.893E-08	4.031E-07	6.012E-07
102	56135	1.241E-05	0.000E+00	0.000E+00	9.349E-11	1.303E-09	1.957E-09
103	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.706E-07	2.583E-07
104	56137	6.708E-01	0.000E+00	0.000E+00	4.979E-06	6.936E-05	1.058E-04
105	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.440E-04	2.213E-04
106	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.370E-04	2.120E-04
107	58140	1.309E+00	0.000E+00	0.000E+00	9.506E-06	1.324E-04	2.064E-04
108	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.244E-04	1.953E-04
109	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.181E-08	5.028E-08
110	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.256E-04	2.000E-04
111	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.431E-05	1.045E-04
112	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.581E-05	5.900E-05
113	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.410E-05	2.355E-05
114	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.790E-05	2.990E-05
115	62152	8.582E-02	0.000E+00	0.000E+00	5.740E-07	7.997E-06	1.353E-05
116	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.610E-06	2.761E-06
117	63151	1.555E-02	0.000E+00	0.000E+00	1.047E-07	1.458E-06	2.452E-06
118	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.527E-06	6.008E-06
119	64154	5.496E-04	0.000E+00	0.000E+00	3.629E-09	5.055E-08	8.668E-08
120	64155	5.602E-03	0.000E+00	0.000E+00	3.675E-08	5.119E-07	8.835E-07
121	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.205E-07	9.041E-07
122	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.400E-08	2.448E-08
123	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.411E-09	1.320E-08
124	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.320E-08	4.108E-08
125	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.970E-09	3.532E-09
126	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.131E-10	9.255E-10
127	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.760E-10	3.195E-10
128	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.631E-01	1.182E-01
129	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.400E-04	4.546E-05
130	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.350E-09	3.927E-10
131	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.210E-03	2.427E-04
	totals	7.862E+02	1.555E+02	1.977E-01	4.801E-02	6.688E-01	1.240E-01

Step 6 - 40 years

actinide inventory for material 40000 at end of step 6, time 1.460E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	94239	2.248E+00	1.395E-01	6.203E-02	9.558E-06	1.332E-04	3.546E-04
2	92234	1.154E+01	7.174E-02	6.217E-03	5.011E-05	6.981E-04	1.820E-03
3	94241	1.494E-04	1.544E-02	1.033E+02	6.299E-10	8.776E-09	2.357E-08
4	94240	3.192E-02	7.243E-03	2.269E-01	1.351E-07	1.882E-06	5.034E-06
5	94238	2.440E-04	4.179E-03	1.712E+01	1.042E-09	1.451E-08	3.848E-08
6	95241	8.450E-04	2.896E-03	3.427E+00	3.562E-09	4.963E-08	1.333E-07
7	92235	1.056E+03	2.283E-03	2.161E-06	4.566E-03	6.361E-02	1.666E-01
8	92238	4.474E+03	1.504E-03	3.361E-07	1.910E-02	2.660E-01	7.055E-01
9	92236	1.114E+01	7.204E-04	6.467E-05	4.796E-05	6.681E-04	1.757E-03
10	90230	1.427E-03	2.943E-05	2.062E-02	6.306E-09	8.785E-08	2.251E-07
11	93237	4.154E-02	2.928E-05	7.047E-04	1.781E-07	2.481E-06	6.552E-06
12	91231	4.658E-05	2.200E-06	4.723E-02	2.049E-10	2.854E-09	7.345E-09
13	92233	7.918E-06	7.630E-08	9.636E-03	3.453E-11	4.810E-10	1.249E-09
14	94242	6.430E-06	2.542E-08	3.954E-03	2.699E-11	3.760E-10	1.014E-09
15	90232	1.296E-05	1.421E-12	1.097E-07	5.674E-11	7.904E-10	2.043E-09
	totals	5.555E+03	2.455E-01	4.420E-05	2.377E-02	3.312E-01	8.760E-01

nonactinide inventory for material 40000 at end of step 6, time 1.460E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	4.801E-01	4.179E+01	8.704E+01	3.564E-06	4.965E-05	7.572E-05
2	39090	7.155E-05	3.890E+01	5.438E+05	8.087E-10	1.127E-08	1.128E-08
3	38090	2.754E-01	3.889E+01	1.413E+02	3.112E-06	4.336E-05	4.343E-05
4	62151	5.124E-02	1.349E+00	2.632E+01	3.450E-07	4.807E-06	8.082E-06
5	36085	2.276E-03	8.938E-01	3.927E+02	2.724E-08	3.794E-07	3.589E-07
6	43099	9.104E-01	1.559E-02	1.712E-02	9.353E-06	1.303E-04	1.436E-04
7	61147	7.401E-06	6.865E-03	9.276E+02	5.119E-11	7.132E-10	1.167E-09
8	63155	1.263E-05	6.229E-03	4.931E+02	8.287E-11	1.155E-09	1.993E-09
9	63154	2.106E-05	5.693E-03	2.703E+02	1.390E-10	1.937E-09	3.321E-09
10	63152	1.396E-05	2.465E-03	1.765E+02	9.341E-11	1.301E-09	2.202E-09
11	40093	8.861E-01	2.228E-03	2.515E-03	9.692E-06	1.350E-04	1.397E-04
12	55135	1.259E+00	1.450E-03	1.152E-03	9.482E-06	1.321E-04	1.985E-04
13	34079	5.298E-03	7.272E-04	1.373E-01	6.822E-08	9.504E-07	8.355E-07
14	50126	1.076E-02	3.055E-04	2.839E-02	8.684E-08	1.210E-06	1.697E-06
15	53129	1.056E-01	1.866E-05	1.766E-04	8.328E-07	1.160E-05	1.666E-05
16	46107	2.523E-02	1.298E-05	5.145E-04	2.398E-07	3.341E-06	3.978E-06
17	37087	3.377E-01	2.894E-08	8.570E-08	3.949E-06	5.501E-05	5.326E-05
18	62147	4.924E-01	1.130E-08	2.296E-08	3.406E-06	4.745E-05	7.765E-05
19	60144	1.203E+00	1.429E-12	1.188E-12	8.493E-06	1.183E-04	1.897E-04
20	57138	6.742E-06	1.665E-13	2.469E-08	4.968E-11	6.921E-10	1.063E-09
21	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.214E-06	8.649E-06
22	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.250E-04	1.976E-04
23	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.372E-05	1.351E-04
24	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.500E-07	3.201E-07
25	64152	8.651E-05	1.885E-15	2.179E-11	5.787E-10	8.062E-09	1.364E-08
26	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.361E-07	8.834E-07
27	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.340E-07	1.686E-07
28	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.911E-06	6.307E-06
29	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.880E-10	1.486E-10
30	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.811E-10	4.656E-10
31	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.190E-09	1.779E-09
32	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.301E-09	6.012E-09
33	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.581E-08	5.566E-08
34	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.270E-08	1.895E-08
35	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.690E-07	1.448E-07
36	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.471E-07	3.881E-07
37	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.740E-06	2.440E-06
38	35079	4.450E-06	0.000E+00	0.000E+00	5.730E-11	7.983E-10	7.018E-10
39	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.331E-06	3.904E-06
40	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.750E-09	2.510E-09
41	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.140E-05	1.053E-05
42	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.090E-05	1.954E-05
43	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.471E-05	4.279E-05
44	37085	1.515E-01	0.000E+00	0.000E+00	1.813E-06	2.526E-05	2.389E-05
45	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.480E-09	1.417E-09
46	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.561E-05	7.404E-05
47	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.007E-04	9.970E-05
48	40090	5.038E-01	0.000E+00	0.000E+00	5.695E-06	7.934E-05	7.946E-05
49	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.241E-04	1.257E-04
50	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.280E-04	1.311E-04
51	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.380E-04	1.444E-04
52	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.350E-04	1.443E-04
53	41093	8.382E-06	0.000E+00	0.000E+00	9.168E-11	1.277E-09	1.322E-09
54	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.385E-04	1.464E-04

55	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.230E-07	1.314E-07
56	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.290E-04	1.393E-04
57	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.230E-04	1.342E-04
58	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.340E-04	1.492E-04
59	44099	1.561E-04	0.000E+00	0.000E+00	1.604E-09	2.234E-08	2.462E-08
60	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.790E-10	1.992E-10
61	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.110E-04	1.248E-04
62	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.182E-05	1.042E-04
63	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.071E-05	4.712E-05
64	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.465E-05	7.411E-05
65	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.113E-05	2.470E-05
66	46106	6.734E-02	0.000E+00	0.000E+00	6.461E-07	9.002E-06	1.062E-05
67	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.250E-06	1.503E-06
68	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.681E-07	6.955E-07
69	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.981E-07	8.469E-07
70	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.630E-10	3.220E-10
71	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.764E-07	4.650E-07
72	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.851E-07	3.553E-07
73	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.301E-07	5.457E-07
74	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.881E-07	3.719E-07
75	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.171E-10	3.988E-10
76	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.310E-08	1.677E-08
77	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.270E-09	2.931E-09
78	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.760E-07	3.595E-07
79	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.480E-07	3.258E-07
80	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.801E-07	3.709E-07
81	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.740E-07	3.660E-07
82	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.351E-07	4.550E-07
83	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.771E-07	7.966E-07
84	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.670E-07	3.597E-07
85	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.399E-07	4.654E-07
86	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.071E-10	4.170E-10
87	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.221E-10	5.826E-10
88	52125	6.412E-03	0.000E+00	0.000E+00	5.217E-08	7.267E-07	1.011E-06
89	52126	4.513E-04	0.000E+00	0.000E+00	3.642E-09	5.074E-08	7.117E-08
90	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.441E-06	1.060E-05
91	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.871E-05	5.601E-05
92	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.301E-06	4.666E-06
93	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.630E-09	3.748E-09
94	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.470E-08	2.128E-08
95	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.143E-05	8.958E-05
96	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.277E-05	1.363E-04
97	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.680E-04	2.506E-04
98	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.420E-04	2.150E-04
99	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.427E-04	2.112E-04
100	56134	3.812E-03	0.000E+00	0.000E+00	2.893E-08	4.031E-07	6.012E-07
101	56135	1.620E-05	0.000E+00	0.000E+00	1.221E-10	1.700E-09	2.555E-09
102	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.706E-07	2.583E-07
103	56137	7.955E-01	0.000E+00	0.000E+00	5.904E-06	8.226E-05	1.255E-04
104	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.440E-04	2.213E-04
105	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.370E-04	2.120E-04
106	58140	1.309E+00	0.000E+00	0.000E+00	9.506E-06	1.324E-04	2.064E-04
107	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.244E-04	1.953E-04
108	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.181E-08	5.028E-08
109	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.256E-04	2.000E-04
110	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.431E-05	1.045E-04
111	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.581E-05	5.900E-05
112	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.410E-05	2.355E-05
113	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.790E-05	2.990E-05
114	62152	8.583E-02	0.000E+00	0.000E+00	5.741E-07	7.998E-06	1.354E-05
115	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.610E-06	2.761E-06
116	63151	1.965E-02	0.000E+00	0.000E+00	1.323E-07	1.843E-06	3.099E-06
117	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.527E-06	6.008E-06
118	64154	5.757E-04	0.000E+00	0.000E+00	3.801E-09	5.295E-08	9.080E-08
119	64155	5.645E-03	0.000E+00	0.000E+00	3.703E-08	5.158E-07	8.902E-07
120	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.205E-07	9.041E-07
121	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.400E-08	2.448E-08
122	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.411E-09	1.320E-08
123	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.320E-08	4.108E-08
124	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.970E-09	3.532E-09
125	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.131E-10	9.255E-10
126	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.760E-10	3.195E-10
127	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.631E-01	1.182E-01
128	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.400E-04	4.546E-05
129	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.350E-09	3.927E-10
130	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.210E-03	2.427E-04
	totals	7.862E+02	1.219E+02	1.550E-01	4.801E-02	6.688E-01	1.240E-01

Step 7 - 50 years

actinide inventory for material 40000 at end of step 7, time 1.825E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	94239	2.248E+00	1.394E-01	6.203E-02	9.555E-06	1.331E-04	3.545E-04
2	92234	1.154E+01	7.174E-02	6.217E-03	5.010E-05	6.980E-04	1.820E-03
3	94241	9.221E-05	9.530E-03	1.033E+02	3.887E-10	5.416E-09	1.454E-08
4	94240	3.188E-02	7.235E-03	2.269E-01	1.350E-07	1.880E-06	5.028E-06
5	94238	2.255E-04	3.861E-03	1.712E+01	9.625E-10	1.341E-08	3.556E-08
6	95241	8.883E-04	3.045E-03	3.427E+00	3.745E-09	5.217E-08	1.401E-07
7	92235	1.056E+03	2.283E-03	2.161E-06	4.566E-03	6.361E-02	1.666E-01
8	92238	4.474E+03	1.504E-03	3.361E-07	1.910E-02	2.660E-01	7.055E-01
9	92236	1.114E+01	7.204E-04	6.467E-05	4.796E-05	6.681E-04	1.757E-03
10	90230	1.747E-03	3.602E-05	2.062E-02	7.718E-09	1.075E-07	2.755E-07
11	93237	4.156E-02	2.929E-05	7.047E-04	1.782E-07	2.482E-06	6.554E-06
12	91231	5.678E-05	2.682E-06	4.723E-02	2.498E-10	3.480E-09	8.955E-09
13	92233	8.050E-06	7.757E-08	9.636E-03	3.510E-11	4.890E-10	1.270E-09
14	94242	6.429E-06	2.542E-08	3.954E-03	2.699E-11	3.760E-10	1.014E-09
15	90232	1.619E-05	1.776E-12	1.097E-07	7.092E-11	9.881E-10	2.554E-09
	totals	5.555E+03	2.394E-01	4.310E-05	2.377E-02	3.312E-01	8.760E-01

nonactinide inventory for material 40000 at end of step 7, time 1.825E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	3.811E-01	3.317E+01	8.704E+01	2.829E-06	3.941E-05	6.010E-05
2	39090	5.594E-05	3.042E+01	5.438E+05	6.323E-10	8.808E-09	8.822E-09
3	38090	2.153E-01	3.041E+01	1.413E+02	2.433E-06	3.390E-05	3.395E-05
4	62151	4.745E-02	1.249E+00	2.632E+01	3.195E-07	4.451E-06	7.483E-06
5	36085	1.193E-03	4.684E-01	3.927E+02	1.427E-08	1.988E-07	1.881E-07
6	43099	9.103E-01	1.559E-02	1.712E-02	9.353E-06	1.303E-04	1.436E-04
7	63154	9.404E-06	2.542E-03	2.703E+02	6.208E-11	8.649E-10	1.483E-09
8	40093	8.861E-01	2.228E-03	2.515E-03	9.692E-06	1.350E-04	1.397E-04
9	63152	8.305E-06	1.466E-03	1.765E+02	5.555E-11	7.739E-10	1.310E-09
10	55135	1.259E+00	1.450E-03	1.152E-03	9.482E-06	1.321E-04	1.985E-04
11	63155	2.876E-06	1.418E-03	4.931E+02	1.886E-11	2.628E-10	4.535E-10
12	34079	5.297E-03	7.271E-04	1.373E-01	6.820E-08	9.502E-07	8.353E-07
13	50126	1.076E-02	3.055E-04	2.839E-02	8.684E-08	1.210E-06	1.697E-06
14	53129	1.056E-01	1.866E-05	1.766E-04	8.328E-07	1.160E-05	1.666E-05
15	46107	2.523E-02	1.298E-05	5.145E-04	2.398E-07	3.341E-06	3.978E-06
16	37087	3.377E-01	2.894E-08	8.570E-08	3.949E-06	5.501E-05	5.326E-05
17	62147	4.924E-01	1.130E-08	2.296E-08	3.406E-06	4.745E-05	7.765E-05
18	60144	1.203E+00	1.429E-12	1.188E-12	8.493E-06	1.183E-04	1.897E-04
19	57138	6.742E-06	1.665E-13	2.469E-08	4.968E-11	6.921E-10	1.063E-09
20	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.214E-06	8.649E-06
21	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.250E-04	1.976E-04
22	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.372E-05	1.351E-04
23	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.500E-07	3.201E-07
24	64152	8.809E-05	1.919E-15	2.179E-11	5.892E-10	8.209E-09	1.389E-08
25	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.361E-07	8.834E-07
26	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.340E-07	1.686E-07
27	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.911E-06	6.307E-06
28	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.880E-10	1.486E-10
29	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.811E-10	4.656E-10
30	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.190E-09	1.779E-09
31	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.301E-09	6.012E-09
32	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.581E-08	5.566E-08
33	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.270E-08	1.895E-08
34	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.690E-07	1.448E-07
35	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.471E-07	3.881E-07
36	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.740E-06	2.440E-06
37	35079	5.562E-06	0.000E+00	0.000E+00	7.162E-11	9.977E-10	8.771E-10
38	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.331E-06	3.904E-06
39	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.750E-09	2.510E-09
40	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.140E-05	1.053E-05
41	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.090E-05	1.954E-05
42	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.471E-05	4.279E-05
43	37085	1.526E-01	0.000E+00	0.000E+00	1.826E-06	2.544E-05	2.406E-05
44	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.480E-09	1.417E-09
45	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.561E-05	7.404E-05
46	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.007E-04	9.970E-05
47	40090	5.638E-01	0.000E+00	0.000E+00	6.373E-06	8.879E-05	8.892E-05
48	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.241E-04	1.257E-04
49	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.280E-04	1.311E-04
50	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.380E-04	1.444E-04
51	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.350E-04	1.443E-04
52	41093	1.181E-05	0.000E+00	0.000E+00	1.292E-10	1.799E-09	1.862E-09
53	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.385E-04	1.464E-04
54	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.230E-07	1.314E-07

55	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.290E-04	1.393E-04
56	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.230E-04	1.342E-04
57	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.340E-04	1.492E-04
58	44099	1.860E-04	0.000E+00	0.000E+00	1.911E-09	2.662E-08	2.933E-08
59	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.790E-10	1.992E-10
60	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.110E-04	1.248E-04
61	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.182E-05	1.042E-04
62	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.071E-05	4.712E-05
63	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.465E-05	7.411E-05
64	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.113E-05	2.470E-05
65	46106	6.734E-02	0.000E+00	0.000E+00	6.461E-07	9.002E-06	1.062E-05
66	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.250E-06	1.503E-06
67	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.681E-07	6.955E-07
68	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.981E-07	8.469E-07
69	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.630E-10	3.220E-10
70	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.764E-07	4.650E-07
71	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.851E-07	3.553E-07
72	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.301E-07	5.457E-07
73	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.881E-07	3.719E-07
74	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.171E-10	3.988E-10
75	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.310E-08	1.677E-08
76	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.270E-09	2.931E-09
77	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.760E-07	3.595E-07
78	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.480E-07	3.258E-07
79	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.801E-07	3.709E-07
80	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.740E-07	3.660E-07
81	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.351E-07	4.550E-07
82	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.771E-07	7.966E-07
83	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.670E-07	3.597E-07
84	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.399E-07	4.654E-07
85	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.071E-10	4.170E-10
86	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.221E-10	5.826E-10
87	52125	6.412E-03	0.000E+00	0.000E+00	5.217E-08	7.268E-07	1.011E-06
88	52126	4.520E-04	0.000E+00	0.000E+00	3.648E-09	5.083E-08	7.129E-08
89	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.441E-06	1.060E-05
90	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.871E-05	5.601E-05
91	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.301E-06	4.666E-06
92	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.630E-09	3.748E-09
93	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.470E-08	2.128E-08
94	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.143E-05	8.958E-05
95	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.277E-05	1.363E-04
96	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.680E-04	2.506E-04
97	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.420E-04	2.150E-04
98	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.427E-04	2.112E-04
99	56134	3.812E-03	0.000E+00	0.000E+00	2.893E-08	4.031E-07	6.012E-07
100	56135	1.999E-05	0.000E+00	0.000E+00	1.506E-10	2.098E-09	3.153E-09
101	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.706E-07	2.583E-07
102	56137	8.945E-01	0.000E+00	0.000E+00	6.639E-06	9.249E-05	1.411E-04
103	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.440E-04	2.213E-04
104	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.370E-04	2.120E-04
105	58140	1.309E+00	0.000E+00	0.000E+00	9.506E-06	1.324E-04	2.064E-04
106	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.244E-04	1.953E-04
107	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.181E-08	5.028E-08
108	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.256E-04	2.000E-04
109	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.431E-05	1.045E-04
110	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.581E-05	5.900E-05
111	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.410E-05	2.355E-05
112	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.790E-05	2.990E-05
113	62152	8.583E-02	0.000E+00	0.000E+00	5.741E-07	7.998E-06	1.354E-05
114	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.610E-06	2.761E-06
115	63151	2.344E-02	0.000E+00	0.000E+00	1.579E-07	2.199E-06	3.697E-06
116	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.527E-06	6.008E-06
117	64154	5.874E-04	0.000E+00	0.000E+00	3.878E-09	5.403E-08	9.263E-08
118	64155	5.655E-03	0.000E+00	0.000E+00	3.709E-08	5.167E-07	8.918E-07
119	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.205E-07	9.041E-07
120	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.400E-08	2.448E-08
121	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.411E-09	1.320E-08
122	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.320E-08	4.108E-08
123	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.970E-09	3.532E-09
124	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.131E-10	9.255E-10
125	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.760E-10	3.195E-10
126	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.631E-01	1.182E-01
127	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.400E-04	4.546E-05
128	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.350E-09	3.927E-10
129	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.210E-03	2.427E-04
	totals	7.862E+02	9.574E+01	1.218E-01	4.801E-02	6.688E-01	1.240E-01

Step 8 - 70 years

actinide inventory for material 40000 at end of step 8, time 2.555E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	94239	2.246E+00	1.393E-01	6.203E-02	9.549E-06	1.330E-04	3.543E-04
2	92234	1.154E+01	7.174E-02	6.217E-03	5.010E-05	6.980E-04	1.820E-03
3	94240	3.182E-02	7.220E-03	2.269E-01	1.347E-07	1.876E-06	5.018E-06
4	94241	3.512E-05	3.629E-03	1.033E+02	1.480E-10	2.062E-09	5.538E-09
5	94238	1.925E-04	3.297E-03	1.712E+01	8.219E-10	1.145E-08	3.036E-08
6	95241	9.164E-04	3.141E-03	3.427E+00	3.863E-09	5.382E-08	1.445E-07
7	92235	1.056E+03	2.283E-03	2.161E-06	4.566E-03	6.361E-02	1.666E-01
8	92238	4.474E+03	1.504E-03	3.361E-07	1.910E-02	2.660E-01	7.055E-01
9	92236	1.114E+01	7.204E-04	6.467E-05	4.796E-05	6.681E-04	1.757E-03
10	90230	2.386E-03	4.919E-05	2.062E-02	1.054E-08	1.469E-07	3.763E-07
11	93237	4.159E-02	2.931E-05	7.047E-04	1.783E-07	2.484E-06	6.558E-06
12	91231	7.719E-05	3.646E-06	4.723E-02	3.395E-10	4.730E-09	1.217E-08
13	92233	8.314E-06	8.011E-08	9.636E-03	3.625E-11	5.051E-10	1.311E-09
14	94242	6.429E-06	2.542E-08	3.954E-03	2.699E-11	3.760E-10	1.014E-09
15	90232	2.267E-05	2.486E-12	1.097E-07	9.929E-11	1.383E-09	3.576E-09
	totals	5.555E+03	2.330E-01	4.194E-05	2.377E-02	3.312E-01	8.760E-01

nonactinide inventory for material 40000 at end of step 8, time 2.555E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	2.402E-01	2.090E+01	8.704E+01	1.783E-06	2.483E-05	3.787E-05
2	39090	3.420E-05	1.860E+01	5.438E+05	3.865E-10	5.385E-09	5.393E-09
3	38090	1.316E-01	1.859E+01	1.413E+02	1.488E-06	2.072E-05	2.076E-05
4	62151	4.068E-02	1.071E+00	2.632E+01	2.739E-07	3.816E-06	6.415E-06
5	36085	3.275E-04	1.286E-01	3.927E+02	3.920E-09	5.461E-08	5.166E-08
6	43099	9.103E-01	1.559E-02	1.712E-02	9.352E-06	1.303E-04	1.436E-04
7	40093	8.861E-01	2.228E-03	2.515E-03	9.692E-06	1.350E-04	1.397E-04
8	55135	1.259E+00	1.450E-03	1.152E-03	9.482E-06	1.321E-04	1.985E-04
9	34079	5.294E-03	7.268E-04	1.373E-01	6.817E-08	9.498E-07	8.350E-07
10	63152	2.938E-06	5.186E-04	1.765E+02	1.965E-11	2.737E-10	4.633E-10
11	63154	1.875E-06	5.069E-04	2.703E+02	1.238E-11	1.725E-10	2.957E-10
12	50126	1.076E-02	3.055E-04	2.839E-02	8.683E-08	1.210E-06	1.697E-06
13	53129	1.056E-01	1.866E-05	1.766E-04	8.328E-07	1.160E-05	1.666E-05
14	46107	2.523E-02	1.298E-05	5.145E-04	2.398E-07	3.341E-06	3.978E-06
15	37087	3.377E-01	2.894E-08	8.570E-08	3.949E-06	5.501E-05	5.326E-05
16	62147	4.924E-01	1.130E-08	2.296E-08	3.406E-06	4.745E-05	7.765E-05
17	60144	1.203E+00	1.429E-12	1.188E-12	8.493E-06	1.183E-04	1.897E-04
18	57138	6.742E-06	1.665E-13	2.469E-08	4.968E-11	6.921E-10	1.063E-09
19	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.214E-06	8.649E-06
20	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.250E-04	1.976E-04
21	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.372E-05	1.351E-04
22	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.500E-07	3.201E-07
23	64152	8.959E-05	1.952E-15	2.179E-11	5.993E-10	8.349E-09	1.413E-08
24	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.361E-07	8.834E-07
25	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.340E-07	1.686E-07
26	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.911E-06	6.307E-06
27	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.880E-10	1.486E-10
28	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.811E-10	4.656E-10
29	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.190E-09	1.779E-09
30	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.301E-09	6.012E-09
31	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.581E-08	5.566E-08
32	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.270E-08	1.895E-08
33	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.690E-07	1.448E-07
34	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.471E-07	3.881E-07
35	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.740E-06	2.440E-06
36	35079	7.785E-06	0.000E+00	0.000E+00	1.002E-10	1.397E-09	1.228E-09
37	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.331E-06	3.904E-06
38	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.750E-09	2.510E-09
39	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.140E-05	1.053E-05
40	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.090E-05	1.954E-05
41	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.471E-05	4.279E-05
42	37085	1.534E-01	0.000E+00	0.000E+00	1.836E-06	2.558E-05	2.420E-05
43	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.480E-09	1.417E-09
44	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.561E-05	7.404E-05
45	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.007E-04	9.970E-05
46	40090	6.475E-01	0.000E+00	0.000E+00	7.319E-06	1.020E-04	1.021E-04
47	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.241E-04	1.257E-04
48	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.280E-04	1.311E-04
49	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.380E-04	1.444E-04
50	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.350E-04	1.443E-04
51	41093	1.920E-05	0.000E+00	0.000E+00	2.100E-10	2.926E-09	3.028E-09
52	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.385E-04	1.464E-04
53	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.230E-07	1.314E-07
54	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.290E-04	1.393E-04

55	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.230E-04	1.342E-04
56	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.340E-04	1.492E-04
57	44099	2.457E-04	0.000E+00	0.000E+00	2.525E-09	3.517E-08	3.875E-08
58	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.790E-10	1.992E-10
59	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.110E-04	1.248E-04
60	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.182E-05	1.042E-04
61	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.071E-05	4.712E-05
62	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.465E-05	7.411E-05
63	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.113E-05	2.470E-05
64	46106	6.734E-02	0.000E+00	0.000E+00	6.461E-07	9.002E-06	1.062E-05
65	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.250E-06	1.503E-06
66	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.681E-07	6.955E-07
67	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.981E-07	8.469E-07
68	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.630E-10	3.220E-10
69	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.764E-07	4.650E-07
70	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.851E-07	3.553E-07
71	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.301E-07	5.457E-07
72	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.881E-07	3.719E-07
73	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.171E-10	3.988E-10
74	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.310E-08	1.677E-08
75	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.270E-09	2.931E-09
76	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.760E-07	3.595E-07
77	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.480E-07	3.258E-07
78	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.801E-07	3.709E-07
79	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.740E-07	3.660E-07
80	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.351E-07	4.550E-07
81	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.771E-07	7.966E-07
82	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.670E-07	3.597E-07
83	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.399E-07	4.654E-07
84	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.071E-10	4.170E-10
85	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.221E-10	5.826E-10
86	52125	6.412E-03	0.000E+00	0.000E+00	5.217E-08	7.268E-07	1.011E-06
87	52126	4.535E-04	0.000E+00	0.000E+00	3.660E-09	5.100E-08	7.152E-08
88	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.441E-06	1.060E-05
89	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.871E-05	5.601E-05
90	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.301E-06	4.666E-06
91	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.630E-09	3.748E-09
92	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.470E-08	2.128E-08
93	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.143E-05	8.958E-05
94	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.277E-05	1.363E-04
95	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.680E-04	2.506E-04
96	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.420E-04	2.150E-04
97	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.427E-04	2.112E-04
98	56134	3.812E-03	0.000E+00	0.000E+00	2.893E-08	4.031E-07	6.012E-07
99	56135	2.758E-05	0.000E+00	0.000E+00	2.077E-10	2.894E-09	4.349E-09
100	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.706E-07	2.583E-07
101	56137	1.035E+00	0.000E+00	0.000E+00	7.685E-06	1.071E-04	1.633E-04
102	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.440E-04	2.213E-04
103	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.370E-04	2.120E-04
104	58140	1.309E+00	0.000E+00	0.000E+00	9.506E-06	1.324E-04	2.064E-04
105	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.244E-04	1.953E-04
106	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.181E-08	5.028E-08
107	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.256E-04	2.000E-04
108	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.431E-05	1.045E-04
109	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.581E-05	5.900E-05
110	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.410E-05	2.355E-05
111	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.790E-05	2.990E-05
112	62152	8.583E-02	0.000E+00	0.000E+00	5.741E-07	7.999E-06	1.354E-05
113	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.610E-06	2.761E-06
114	63151	3.021E-02	0.000E+00	0.000E+00	2.034E-07	2.834E-06	4.765E-06
115	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.527E-06	6.008E-06
116	64154	5.949E-04	0.000E+00	0.000E+00	3.928E-09	5.472E-08	9.382E-08
117	64155	5.657E-03	0.000E+00	0.000E+00	3.711E-08	5.170E-07	8.922E-07
118	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.205E-07	9.041E-07
119	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.400E-08	2.448E-08
120	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.411E-09	1.320E-08
121	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.320E-08	4.108E-08
122	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.970E-09	3.532E-09
123	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.131E-10	9.255E-10
124	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.760E-10	3.195E-10
125	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.631E-01	1.182E-01
126	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.400E-04	4.546E-05
127	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.350E-09	3.927E-10
128	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.210E-03	2.427E-04
	totals	7.862E+02	5.931E+01	7.544E-02	4.801E-02	6.688E-01	1.240E-01

Step 9 - 100 years

actinide inventory for material 40000 at end of step 9, time 3.650E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	94239	2.244E+00	1.392E-01	6.203E-02	9.541E-06	1.329E-04	3.540E-04
2	92234	1.154E+01	7.173E-02	6.217E-03	5.010E-05	6.979E-04	1.820E-03
3	94240	3.172E-02	7.197E-03	2.269E-01	1.343E-07	1.870E-06	5.002E-06
4	95241	8.995E-04	3.083E-03	3.427E+00	3.792E-09	5.283E-08	1.419E-07
5	94238	1.519E-04	2.601E-03	1.712E+01	6.485E-10	9.034E-09	2.396E-08
6	92235	1.056E+03	2.283E-03	2.161E-06	4.566E-03	6.361E-02	1.666E-01
7	92238	4.474E+03	1.504E-03	3.361E-07	1.910E-02	2.660E-01	7.055E-01
8	94241	8.253E-06	8.529E-04	1.033E+02	3.479E-11	4.847E-10	1.301E-09
9	92236	1.114E+01	7.204E-04	6.467E-05	4.796E-05	6.681E-04	1.757E-03
10	90230	3.345E-03	6.895E-05	2.062E-02	1.477E-08	2.058E-07	5.275E-07
11	93237	4.163E-02	2.934E-05	7.047E-04	1.785E-07	2.486E-06	6.565E-06
12	91231	1.078E-04	5.091E-06	4.723E-02	4.741E-10	6.605E-09	1.700E-08
13	92233	8.710E-06	8.393E-08	9.636E-03	3.798E-11	5.291E-10	1.374E-09
14	94242	6.429E-06	2.542E-08	3.954E-03	2.699E-11	3.760E-10	1.014E-09
15	90232	3.239E-05	3.552E-12	1.097E-07	1.418E-10	1.976E-09	5.108E-09
	totals	5.555E+03	2.293E-01	4.128E-05	2.377E-02	3.312E-01	8.760E-01

nonactinide inventory for material 40000 at end of step 9, time 3.650E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	1.201E-01	1.046E+01	8.704E+01	8.917E-07	1.242E-05	1.895E-05
2	39090	1.635E-05	8.888E+00	5.438E+05	1.847E-10	2.574E-09	2.578E-09
3	38090	6.291E-02	8.886E+00	1.413E+02	7.110E-07	9.905E-06	9.921E-06
4	62151	3.229E-02	8.499E-01	2.632E+01	2.174E-07	3.029E-06	5.093E-06
5	36085	4.714E-05	1.851E-02	3.927E+02	5.641E-10	7.859E-09	7.434E-09
6	43099	9.102E-01	1.558E-02	1.712E-02	9.351E-06	1.303E-04	1.435E-04
7	40093	8.861E-01	2.228E-03	2.515E-03	9.692E-06	1.350E-04	1.397E-04
8	55135	1.259E+00	1.450E-03	1.152E-03	9.482E-06	1.321E-04	1.985E-04
9	34079	5.291E-03	7.263E-04	1.373E-01	6.813E-08	9.492E-07	8.344E-07
10	50126	1.076E-02	3.054E-04	2.839E-02	8.681E-08	1.209E-06	1.696E-06
11	53129	1.056E-01	1.866E-05	1.766E-04	8.328E-07	1.160E-05	1.666E-05
12	46107	2.523E-02	1.298E-05	5.145E-04	2.398E-07	3.341E-06	3.978E-06
13	37087	3.377E-01	2.894E-08	8.570E-08	3.949E-06	5.501E-05	5.326E-05
14	62147	4.924E-01	1.130E-08	2.296E-08	3.406E-06	4.745E-05	7.765E-05
15	60144	1.203E+00	1.429E-12	1.188E-12	8.493E-06	1.183E-04	1.897E-04
16	57138	6.742E-06	1.665E-13	2.469E-08	4.968E-11	6.921E-10	1.063E-09
17	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.214E-06	8.649E-06
18	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.250E-04	1.976E-04
19	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.372E-05	1.351E-04
20	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.500E-07	3.201E-07
21	64152	9.024E-05	1.966E-15	2.179E-11	6.036E-10	8.409E-09	1.423E-08
22	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.361E-07	8.834E-07
23	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.340E-07	1.686E-07
24	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.911E-06	6.307E-06
25	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.880E-10	1.486E-10
26	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.811E-10	4.656E-10
27	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.190E-09	1.779E-09
28	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.301E-09	6.012E-09
29	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.581E-08	5.566E-08
30	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.270E-08	1.895E-08
31	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.690E-07	1.448E-07
32	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.471E-07	3.881E-07
33	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.740E-06	2.440E-06
34	35079	1.112E-05	0.000E+00	0.000E+00	1.432E-10	1.994E-09	1.753E-09
35	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.331E-06	3.904E-06
36	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.750E-09	2.510E-09
37	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.140E-05	1.053E-05
38	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.090E-05	1.954E-05
39	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.471E-05	4.279E-05
40	37085	1.537E-01	0.000E+00	0.000E+00	1.839E-06	2.563E-05	2.424E-05
41	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.480E-09	1.417E-09
42	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.561E-05	7.404E-05
43	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.007E-04	9.970E-05
44	40090	7.162E-01	0.000E+00	0.000E+00	8.095E-06	1.128E-04	1.129E-04
45	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.241E-04	1.257E-04
46	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.280E-04	1.311E-04
47	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.380E-04	1.444E-04
48	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.350E-04	1.443E-04
49	41093	3.090E-05	0.000E+00	0.000E+00	3.380E-10	4.709E-09	4.873E-09
50	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.385E-04	1.464E-04
51	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.230E-07	1.314E-07
52	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.290E-04	1.393E-04
53	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.230E-04	1.342E-04
54	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.340E-04	1.492E-04

55	44099	3.353E-04	0.000E+00	0.000E+00	3.445E-09	4.800E-08	5.288E-08
56	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.790E-10	1.992E-10
57	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.110E-04	1.248E-04
58	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.182E-05	1.042E-04
59	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.071E-05	4.712E-05
60	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.465E-05	7.411E-05
61	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.113E-05	2.470E-05
62	46106	6.734E-02	0.000E+00	0.000E+00	6.461E-07	9.002E-06	1.062E-05
63	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.250E-06	1.503E-06
64	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.681E-07	6.955E-07
65	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.981E-07	8.469E-07
66	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.630E-10	3.220E-10
67	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.764E-07	4.650E-07
68	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.851E-07	3.553E-07
69	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.301E-07	5.457E-07
70	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.881E-07	3.719E-07
71	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.171E-10	3.988E-10
72	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.310E-08	1.677E-08
73	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.270E-09	2.931E-09
74	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.760E-07	3.595E-07
75	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.480E-07	3.258E-07
76	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.801E-07	3.709E-07
77	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.740E-07	3.660E-07
78	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.351E-07	4.550E-07
79	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.771E-07	7.966E-07
80	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.670E-07	3.597E-07
81	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.399E-07	4.654E-07
82	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.071E-10	4.170E-10
83	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.221E-10	5.826E-10
84	52125	6.412E-03	0.000E+00	0.000E+00	5.217E-08	7.268E-07	1.011E-06
85	52126	4.557E-04	0.000E+00	0.000E+00	3.678E-09	5.125E-08	7.187E-08
86	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.441E-06	1.060E-05
87	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.871E-05	5.601E-05
88	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.301E-06	4.666E-06
89	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.630E-09	3.748E-09
90	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.470E-08	2.128E-08
91	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.143E-05	8.958E-05
92	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.277E-05	1.363E-04
93	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.680E-04	2.506E-04
94	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.420E-04	2.150E-04
95	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.427E-04	2.112E-04
96	56134	3.812E-03	0.000E+00	0.000E+00	2.893E-08	4.031E-07	6.012E-07
97	56135	3.895E-05	0.000E+00	0.000E+00	2.934E-10	4.087E-09	6.142E-09
98	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.706E-07	2.583E-07
99	56137	1.155E+00	0.000E+00	0.000E+00	8.576E-06	1.195E-04	1.822E-04
100	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.440E-04	2.213E-04
101	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.370E-04	2.120E-04
102	58140	1.309E+00	0.000E+00	0.000E+00	9.506E-06	1.324E-04	2.064E-04
103	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.244E-04	1.953E-04
104	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.181E-08	5.028E-08
105	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.256E-04	2.000E-04
106	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.431E-05	1.045E-04
107	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.581E-05	5.900E-05
108	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.410E-05	2.355E-05
109	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.790E-05	2.990E-05
110	62152	8.584E-02	0.000E+00	0.000E+00	5.742E-07	7.999E-06	1.354E-05
111	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.610E-06	2.761E-06
112	63151	3.860E-02	0.000E+00	0.000E+00	2.599E-07	3.621E-06	6.088E-06
113	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.527E-06	6.008E-06
114	64154	5.966E-04	0.000E+00	0.000E+00	3.939E-09	5.487E-08	9.409E-08
115	64155	5.657E-03	0.000E+00	0.000E+00	3.711E-08	5.170E-07	8.922E-07
116	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.205E-07	9.041E-07
117	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.400E-08	2.448E-08
118	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.411E-09	1.320E-08
119	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.320E-08	4.108E-08
120	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.970E-09	3.532E-09
121	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.131E-10	9.255E-10
122	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.760E-10	3.195E-10
123	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.631E-01	1.182E-01
124	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.400E-04	4.546E-05
125	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.350E-09	3.927E-10
126	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.210E-03	2.427E-04
	totals	7.862E+02	2.912E+01	3.704E-02	4.801E-02	6.688E-01	1.240E-01

Step 10 - 200 years

actinide inventory for material 40000 at end of step 10, time 7.300E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	94239	2.238E+00	1.388E-01	6.203E-02	9.514E-06	1.325E-04	3.530E-04

2	92234	1.154E+01	7.171E-02	6.217E-03	5.008E-05	6.978E-04	1.819E-03
3	94240	3.138E-02	7.121E-03	2.269E-01	1.329E-07	1.851E-06	4.949E-06
4	95241	7.736E-04	2.651E-03	3.427E+00	3.261E-09	4.543E-08	1.220E-07
5	92235	1.056E+03	2.283E-03	2.161E-06	4.566E-03	6.361E-02	1.666E-01
6	92238	4.474E+03	1.504E-03	3.361E-07	1.910E-02	2.660E-01	7.055E-01
7	94238	6.896E-05	1.181E-03	1.712E+01	2.944E-10	4.101E-09	1.087E-08
8	92236	1.114E+01	7.204E-04	6.467E-05	4.796E-05	6.682E-04	1.757E-03
9	90230	6.537E-03	1.348E-04	2.062E-02	2.888E-08	4.023E-07	1.031E-06
10	93237	4.176E-02	2.943E-05	7.047E-04	1.790E-07	2.494E-06	6.586E-06
11	91231	2.096E-04	9.902E-06	4.723E-02	9.221E-10	1.285E-08	3.306E-08
12	92233	1.003E-05	9.667E-08	9.636E-03	4.375E-11	6.095E-10	1.582E-09
13	94242	6.428E-06	2.542E-08	3.954E-03	2.698E-11	3.759E-10	1.014E-09
14	90232	6.478E-05	7.104E-12	1.097E-07	2.837E-10	3.952E-09	1.022E-08
	totals	5.555E+03	2.262E-01	4.072E-05	2.377E-02	3.312E-01	8.760E-01

nonactinide inventory for material 40000 at end of step 10, time 7.300E+04 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	55137	1.194E-02	1.039E+00	8.704E+01	8.861E-08	1.234E-06	1.883E-06
2	39090	1.395E-06	7.588E-01	5.438E+05	1.577E-11	2.197E-10	2.201E-10
3	38090	5.371E-03	7.586E-01	1.413E+02	6.070E-08	8.457E-07	8.470E-07
4	62151	1.496E-02	3.937E-01	2.632E+01	1.007E-07	1.403E-06	2.359E-06
5	43099	9.099E-01	1.558E-02	1.712E-02	9.348E-06	1.302E-04	1.435E-04
6	40093	8.860E-01	2.228E-03	2.515E-03	9.691E-06	1.350E-04	1.397E-04
7	55135	1.259E+00	1.450E-03	1.152E-03	9.481E-06	1.321E-04	1.985E-04
8	34079	5.280E-03	7.248E-04	1.373E-01	6.799E-08	9.472E-07	8.327E-07
9	50126	1.075E-02	3.052E-04	2.839E-02	8.675E-08	1.209E-06	1.695E-06
10	53129	1.056E-01	1.866E-05	1.766E-04	8.328E-07	1.160E-05	1.666E-05
11	46107	2.523E-02	1.298E-05	5.145E-04	2.398E-07	3.341E-06	3.978E-06
12	88226	5.864E-06	5.797E-06	9.885E-01	2.636E-11	3.673E-10	9.248E-10
13	37087	3.377E-01	2.894E-08	8.570E-08	3.949E-06	5.501E-05	5.326E-05
14	62147	4.924E-01	1.130E-08	2.296E-08	3.406E-06	4.745E-05	7.765E-05
15	60144	1.203E+00	1.429E-12	1.188E-12	8.493E-06	1.183E-04	1.897E-04
16	57138	6.742E-06	1.665E-13	2.469E-08	4.968E-11	6.921E-10	1.063E-09
17	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.214E-06	8.649E-06
18	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.250E-04	1.976E-04
19	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.372E-05	1.351E-04
20	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.500E-07	3.201E-07
21	64152	9.041E-05	1.970E-15	2.179E-11	6.048E-10	8.425E-09	1.426E-08
22	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.361E-07	8.834E-07
23	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.340E-07	1.686E-07
24	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.911E-06	6.307E-06
25	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.880E-10	1.486E-10
26	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.811E-10	4.656E-10
27	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.190E-09	1.779E-09
28	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.301E-09	6.012E-09
29	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.581E-08	5.566E-08
30	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.270E-08	1.895E-08
31	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.690E-07	1.448E-07
32	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.471E-07	3.881E-07
33	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.740E-06	2.440E-06
34	35079	2.221E-05	0.000E+00	0.000E+00	2.860E-10	3.985E-09	3.503E-09
35	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.331E-06	3.904E-06
36	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.750E-09	2.510E-09
37	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.140E-05	1.053E-05
38	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.090E-05	1.954E-05
39	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.471E-05	4.279E-05
40	37085	1.538E-01	0.000E+00	0.000E+00	1.840E-06	2.563E-05	2.425E-05
41	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.480E-09	1.417E-09
42	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.561E-05	7.404E-05
43	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.007E-04	9.970E-05
44	40090	7.737E-01	0.000E+00	0.000E+00	8.745E-06	1.218E-04	1.220E-04
45	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.241E-04	1.257E-04
46	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.280E-04	1.311E-04
47	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.380E-04	1.444E-04
48	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.350E-04	1.443E-04
49	41093	7.089E-05	0.000E+00	0.000E+00	7.754E-10	1.080E-08	1.118E-08
50	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.385E-04	1.464E-04
51	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.230E-07	1.314E-07
52	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.290E-04	1.393E-04
53	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.230E-04	1.342E-04
54	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.340E-04	1.492E-04
55	44099	6.339E-04	0.000E+00	0.000E+00	6.513E-09	9.074E-08	9.997E-08
56	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.790E-10	1.992E-10
57	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.110E-04	1.248E-04
58	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.182E-05	1.042E-04
59	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.071E-05	4.712E-05
60	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.465E-05	7.411E-05
61	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.113E-05	2.470E-05
62	46106	6.734E-02	0.000E+00	0.000E+00	6.461E-07	9.002E-06	1.062E-05
63	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.250E-06	1.503E-06

64	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.681E-07	6.955E-07
65	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.981E-07	8.469E-07
66	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.630E-10	3.220E-10
67	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.764E-07	4.650E-07
68	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.851E-07	3.553E-07
69	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.301E-07	5.457E-07
70	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.881E-07	3.719E-07
71	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.171E-10	3.988E-10
72	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.310E-08	1.677E-08
73	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.270E-09	2.931E-09
74	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.760E-07	3.595E-07
75	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.480E-07	3.258E-07
76	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.801E-07	3.709E-07
77	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.740E-07	3.660E-07
78	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.351E-07	4.550E-07
79	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.771E-07	7.966E-07
80	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.670E-07	3.597E-07
81	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.399E-07	4.654E-07
82	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.071E-10	4.170E-10
83	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.221E-10	5.826E-10
84	52125	6.412E-03	0.000E+00	0.000E+00	5.217E-08	7.268E-07	1.011E-06
85	52126	4.632E-04	0.000E+00	0.000E+00	3.739E-09	5.208E-08	7.305E-08
86	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.441E-06	1.060E-05
87	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.871E-05	5.601E-05
88	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.301E-06	4.666E-06
89	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.630E-09	3.748E-09
90	54129	9.322E-07	0.000E+00	0.000E+00	7.349E-12	1.024E-10	1.470E-10
91	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.470E-08	2.128E-08
92	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.143E-05	8.958E-05
93	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.277E-05	1.363E-04
94	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.680E-04	2.506E-04
95	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.420E-04	2.150E-04
96	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.427E-04	2.112E-04
97	56134	3.812E-03	0.000E+00	0.000E+00	2.893E-08	4.031E-07	6.012E-07
98	56135	7.686E-05	0.000E+00	0.000E+00	5.789E-10	8.065E-09	1.212E-08
99	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.706E-07	2.583E-07
100	56137	1.264E+00	0.000E+00	0.000E+00	9.379E-06	1.307E-04	1.993E-04
101	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.440E-04	2.213E-04
102	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.370E-04	2.120E-04
103	58140	1.309E+00	0.000E+00	0.000E+00	9.506E-06	1.324E-04	2.064E-04
104	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.244E-04	1.953E-04
105	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.181E-08	5.028E-08
106	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.256E-04	2.000E-04
107	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.431E-05	1.045E-04
108	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.581E-05	5.900E-05
109	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.410E-05	2.355E-05
110	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.790E-05	2.990E-05
111	62152	8.584E-02	0.000E+00	0.000E+00	5.742E-07	7.999E-06	1.354E-05
112	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.610E-06	2.761E-06
113	63151	5.594E-02	0.000E+00	0.000E+00	3.766E-07	5.247E-06	8.821E-06
114	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.527E-06	6.008E-06
115	64154	5.968E-04	0.000E+00	0.000E+00	3.940E-09	5.489E-08	9.412E-08
116	64155	5.657E-03	0.000E+00	0.000E+00	3.711E-08	5.170E-07	8.922E-07
117	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.205E-07	9.041E-07
118	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.400E-08	2.448E-08
119	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.411E-09	1.320E-08
120	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.320E-08	4.108E-08
121	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.970E-09	3.532E-09
122	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.131E-10	9.255E-10
123	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.760E-10	3.195E-10
124	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.631E-01	1.182E-01
125	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.400E-04	4.546E-05
126	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.350E-09	3.927E-10
127	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.210E-03	2.427E-04
	totals	7.862E+02	2.970E+00	3.778E-03	4.801E-02	6.688E-01	1.240E-01

Step 11 - 300 years

actinide inventory for material 40000 at end of step 11, time 1.095E+05 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	94239	2.232E+00	1.384E-01	6.203E-02	9.486E-06	1.322E-04	3.519E-04
2	92234	1.153E+01	7.169E-02	6.217E-03	5.007E-05	6.976E-04	1.819E-03
3	94240	3.105E-02	7.047E-03	2.269E-01	1.315E-07	1.831E-06	4.897E-06
4	92235	1.056E+03	2.283E-03	2.161E-06	4.566E-03	6.361E-02	1.666E-01
5	95241	6.592E-04	2.259E-03	3.427E+00	2.779E-09	3.872E-08	1.040E-07
6	92238	4.474E+03	1.504E-03	3.361E-07	1.910E-02	2.660E-01	7.055E-01
7	92236	1.114E+01	7.204E-04	6.467E-05	4.796E-05	6.682E-04	1.757E-03
8	94238	3.130E-05	5.360E-04	1.712E+01	1.336E-10	1.861E-09	4.936E-09
9	90230	9.725E-03	2.005E-04	2.062E-02	4.296E-08	5.985E-07	1.534E-06

10	93237	4.187E-02	2.951E-05	7.047E-04	1.795E-07	2.501E-06	6.603E-06
11	91231	3.113E-04	1.470E-05	4.723E-02	1.369E-09	1.907E-08	4.909E-08
12	92233	1.136E-05	1.095E-07	9.636E-03	4.953E-11	6.900E-10	1.791E-09
13	94242	6.426E-06	2.541E-08	3.954E-03	2.698E-11	3.759E-10	1.013E-09
14	90232	9.717E-05	1.066E-11	1.097E-07	4.255E-10	5.929E-09	1.532E-08
	totals	5.555E+03	2.247E-01	4.045E-05	2.377E-02	3.312E-01	8.760E-01

nonactinide inventory for material 40000 at end of step 11, time 1.095E+05 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	62151	6.928E-03	1.823E-01	2.632E+01	4.665E-08	6.498E-07	1.093E-06
2	55137	1.186E-03	1.032E-01	8.704E+01	8.804E-09	1.227E-07	1.871E-07
3	38090	4.585E-04	6.477E-02	1.413E+02	5.182E-09	7.220E-08	7.231E-08
4	43099	9.096E-01	1.557E-02	1.712E-02	9.345E-06	1.302E-04	1.434E-04
5	40093	8.860E-01	2.228E-03	2.515E-03	9.691E-06	1.350E-04	1.397E-04
6	55135	1.259E+00	1.450E-03	1.152E-03	9.481E-06	1.321E-04	1.985E-04
7	34079	5.269E-03	7.233E-04	1.373E-01	6.785E-08	9.452E-07	8.310E-07
8	50126	1.074E-02	3.050E-04	2.839E-02	8.669E-08	1.208E-06	1.694E-06
9	53129	1.056E-01	1.866E-05	1.766E-04	8.328E-07	1.160E-05	1.666E-05
10	46107	2.523E-02	1.298E-05	5.145E-04	2.398E-07	3.340E-06	3.978E-06
11	88226	1.281E-05	1.266E-05	9.885E-01	5.760E-11	8.024E-10	2.020E-09
12	37087	3.377E-01	2.894E-08	8.570E-08	3.949E-06	5.501E-05	5.326E-05
13	62147	4.924E-01	1.130E-08	2.296E-08	3.406E-06	4.745E-05	7.765E-05
14	60144	1.203E+00	1.429E-12	1.188E-12	8.493E-06	1.183E-04	1.897E-04
15	57138	6.742E-06	1.665E-13	2.469E-08	4.968E-11	6.921E-10	1.063E-09
16	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.214E-06	8.649E-06
17	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.250E-04	1.976E-04
18	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.372E-05	1.351E-04
19	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.500E-07	3.201E-07
20	64152	9.041E-05	1.970E-15	2.179E-11	6.048E-10	8.425E-09	1.426E-08
21	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.361E-07	8.834E-07
22	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.340E-07	1.686E-07
23	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.911E-06	6.307E-06
24	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.880E-10	1.486E-10
25	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.811E-10	4.656E-10
26	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.190E-09	1.779E-09
27	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.301E-09	6.012E-09
28	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.581E-08	5.566E-08
29	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.270E-08	1.895E-08
30	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.690E-07	1.448E-07
31	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.471E-07	3.881E-07
32	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.740E-06	2.440E-06
33	35079	3.328E-05	0.000E+00	0.000E+00	4.286E-10	5.971E-09	5.249E-09
34	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.331E-06	3.904E-06
35	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.750E-09	2.510E-09
36	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.140E-05	1.053E-05
37	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.090E-05	1.954E-05
38	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.471E-05	4.279E-05
39	37085	1.538E-01	0.000E+00	0.000E+00	1.840E-06	2.563E-05	2.425E-05
40	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.480E-09	1.417E-09
41	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.561E-05	7.404E-05
42	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.007E-04	9.970E-05
43	40090	7.786E-01	0.000E+00	0.000E+00	8.801E-06	1.226E-04	1.228E-04
44	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.241E-04	1.257E-04
45	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.280E-04	1.311E-04
46	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.380E-04	1.444E-04
47	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.350E-04	1.443E-04
48	41093	1.110E-04	0.000E+00	0.000E+00	1.214E-09	1.691E-08	1.751E-08
49	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.385E-04	1.464E-04
50	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.230E-07	1.314E-07
51	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.290E-04	1.393E-04
52	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.230E-04	1.342E-04
53	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.340E-04	1.492E-04
54	44099	9.324E-04	0.000E+00	0.000E+00	9.580E-09	1.335E-07	1.471E-07
55	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.790E-10	1.992E-10
56	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.110E-04	1.248E-04
57	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.182E-05	1.042E-04
58	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.071E-05	4.712E-05
59	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.465E-05	7.411E-05
60	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.113E-05	2.470E-05
61	46106	6.734E-02	0.000E+00	0.000E+00	6.461E-07	9.002E-06	1.062E-05
62	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.250E-06	1.503E-06
63	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.681E-07	6.955E-07
64	47107	8.065E-07	0.000E+00	0.000E+00	7.666E-12	1.068E-10	1.272E-10
65	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.981E-07	8.469E-07
66	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.630E-10	3.220E-10
67	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.764E-07	4.650E-07
68	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.851E-07	3.553E-07
69	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.301E-07	5.457E-07
70	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.881E-07	3.719E-07
71	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.171E-10	3.988E-10

72	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.310E-08	1.677E-08
73	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.270E-09	2.931E-09
74	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.760E-07	3.595E-07
75	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.480E-07	3.258E-07
76	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.801E-07	3.709E-07
77	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.740E-07	3.660E-07
78	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.351E-07	4.550E-07
79	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.771E-07	7.966E-07
80	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.670E-07	3.597E-07
81	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.399E-07	4.654E-07
82	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.071E-10	4.170E-10
83	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.221E-10	5.826E-10
84	52125	6.412E-03	0.000E+00	0.000E+00	5.217E-08	7.268E-07	1.011E-06
85	52126	4.706E-04	0.000E+00	0.000E+00	3.799E-09	5.292E-08	7.422E-08
86	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.441E-06	1.060E-05
87	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.871E-05	5.601E-05
88	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.301E-06	4.666E-06
89	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.630E-09	3.748E-09
90	54129	1.398E-06	0.000E+00	0.000E+00	1.102E-11	1.536E-10	2.205E-10
91	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.470E-08	2.128E-08
92	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.143E-05	8.958E-05
93	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.277E-05	1.363E-04
94	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.680E-04	2.506E-04
95	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.420E-04	2.150E-04
96	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.427E-04	2.112E-04
97	56134	3.812E-03	0.000E+00	0.000E+00	2.893E-08	4.031E-07	6.012E-07
98	56135	1.148E-04	0.000E+00	0.000E+00	8.645E-10	1.204E-08	1.810E-08
99	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.706E-07	2.583E-07
100	56137	1.274E+00	0.000E+00	0.000E+00	9.459E-06	1.318E-04	2.010E-04
101	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.440E-04	2.213E-04
102	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.370E-04	2.120E-04
103	58140	1.309E+00	0.000E+00	0.000E+00	9.506E-06	1.324E-04	2.064E-04
104	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.244E-04	1.953E-04
105	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.181E-08	5.028E-08
106	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.256E-04	2.000E-04
107	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.431E-05	1.045E-04
108	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.581E-05	5.900E-05
109	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.410E-05	2.355E-05
110	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.790E-05	2.990E-05
111	62152	8.584E-02	0.000E+00	0.000E+00	5.742E-07	7.999E-06	1.354E-05
112	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.610E-06	2.761E-06
113	63151	6.396E-02	0.000E+00	0.000E+00	4.307E-07	6.000E-06	1.009E-05
114	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.527E-06	6.008E-06
115	64154	5.968E-04	0.000E+00	0.000E+00	3.940E-09	5.489E-08	9.412E-08
116	64155	5.657E-03	0.000E+00	0.000E+00	3.711E-08	5.170E-07	8.922E-07
117	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.205E-07	9.041E-07
118	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.400E-08	2.448E-08
119	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.411E-09	1.320E-08
120	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.320E-08	4.108E-08
121	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.970E-09	3.532E-09
122	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.131E-10	9.255E-10
123	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.760E-10	3.195E-10
124	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.631E-01	1.182E-01
125	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.400E-04	4.546E-05
126	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.350E-09	3.927E-10
127	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.210E-03	2.427E-04
	totals	7.862E+02	3.707E-01	4.715E-04	4.801E-02	6.688E-01	1.240E-01

Step 12 – 500 years

actinide inventory for material 40000 at end of step 12, time 1.825E+05 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	94239	2.219E+00	1.376E-01	6.203E-02	9.432E-06	1.314E-04	3.499E-04
2	92234	1.153E+01	7.165E-02	6.217E-03	5.004E-05	6.972E-04	1.818E-03
3	94240	3.041E-02	6.899E-03	2.269E-01	1.287E-07	1.793E-06	4.795E-06
4	92235	1.056E+03	2.283E-03	2.161E-06	4.566E-03	6.361E-02	1.666E-01
5	95241	4.786E-04	1.640E-03	3.427E+00	2.018E-09	2.811E-08	7.548E-08
6	92238	4.474E+03	1.504E-03	3.361E-07	1.910E-02	2.660E-01	7.055E-01
7	92236	1.114E+01	7.205E-04	6.467E-05	4.796E-05	6.682E-04	1.757E-03
8	90230	1.609E-02	3.317E-04	2.062E-02	7.108E-08	9.903E-07	2.538E-06
9	94238	6.449E-06	1.104E-04	1.712E+01	2.753E-11	3.835E-10	1.017E-09
10	93237	4.204E-02	2.963E-05	7.047E-04	1.802E-07	2.511E-06	6.631E-06
11	91231	5.139E-04	2.427E-05	4.723E-02	2.260E-09	3.149E-08	8.105E-08
12	92233	1.402E-05	1.351E-07	9.636E-03	6.113E-11	8.516E-10	2.211E-09
13	94242	6.424E-06	2.540E-08	3.954E-03	2.697E-11	3.757E-10	1.013E-09
14	90232	1.620E-04	1.776E-11	1.097E-07	7.093E-10	9.881E-09	2.554E-08
	totals	5.555E+03	2.228E-01	4.011E-05	2.377E-02	3.312E-01	8.760E-01

nonactinide inventory for material 40000 at end of step 12, time 1.825E+05 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	62151	1.486E-03	3.912E-02	2.632E+01	1.001E-08	1.394E-07	2.344E-07
2	43099	9.090E-01	1.556E-02	1.712E-02	9.339E-06	1.301E-04	1.434E-04
3	40093	8.859E-01	2.228E-03	2.515E-03	9.690E-06	1.350E-04	1.397E-04
4	55135	1.259E+00	1.450E-03	1.152E-03	9.480E-06	1.321E-04	1.985E-04
5	55137	1.171E-05	1.019E-03	8.704E+01	8.693E-11	1.211E-09	1.847E-09
6	34079	5.247E-03	7.202E-04	1.373E-01	6.756E-08	9.412E-07	8.275E-07
7	38090	3.342E-06	4.721E-04	1.413E+02	3.778E-11	5.263E-10	5.271E-10
8	50126	1.073E-02	3.045E-04	2.839E-02	8.657E-08	1.206E-06	1.692E-06
9	88226	3.416E-05	3.377E-05	9.885E-01	1.536E-10	2.140E-09	5.387E-09
10	53129	1.056E-01	1.866E-05	1.766E-04	8.328E-07	1.160E-05	1.666E-05
11	46107	2.522E-02	1.298E-05	5.145E-04	2.398E-07	3.340E-06	3.978E-06
12	37087	3.377E-01	2.894E-08	8.570E-08	3.949E-06	5.501E-05	5.326E-05
13	62147	4.924E-01	1.130E-08	2.296E-08	3.406E-06	4.745E-05	7.765E-05
14	60144	1.203E+00	1.429E-12	1.188E-12	8.493E-06	1.183E-04	1.897E-04
15	57138	6.742E-06	1.665E-13	2.469E-08	4.968E-11	6.921E-10	1.063E-09
16	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.214E-06	8.649E-06
17	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.250E-04	1.976E-04
18	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.372E-05	1.351E-04
19	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.500E-07	3.201E-07
20	64152	9.041E-05	1.970E-15	2.179E-11	6.048E-10	8.425E-09	1.426E-08
21	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.361E-07	8.834E-07
22	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.340E-07	1.686E-07
23	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.911E-06	6.307E-06
24	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.880E-10	1.486E-10
25	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.811E-10	4.656E-10
26	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.190E-09	1.779E-09
27	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.301E-09	6.012E-09
28	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.581E-08	5.566E-08
29	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.270E-08	1.895E-08
30	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.690E-07	1.448E-07
31	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.471E-07	3.881E-07
32	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.740E-06	2.440E-06
33	35079	5.536E-05	0.000E+00	0.000E+00	7.128E-10	9.930E-09	8.730E-09
34	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.331E-06	3.904E-06
35	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.750E-09	2.510E-09
36	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.140E-05	1.053E-05
37	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.090E-05	1.954E-05
38	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.471E-05	4.279E-05
39	37085	1.538E-01	0.000E+00	0.000E+00	1.840E-06	2.563E-05	2.425E-05
40	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.480E-09	1.417E-09
41	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.561E-05	7.404E-05
42	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.007E-04	9.970E-05
43	40090	7.791E-01	0.000E+00	0.000E+00	8.806E-06	1.227E-04	1.229E-04
44	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.241E-04	1.257E-04
45	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.280E-04	1.311E-04
46	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.380E-04	1.444E-04
47	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.350E-04	1.443E-04
48	41093	1.912E-04	0.000E+00	0.000E+00	2.092E-09	2.914E-08	3.016E-08
49	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.385E-04	1.464E-04
50	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.230E-07	1.314E-07
51	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.290E-04	1.393E-04
52	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.230E-04	1.342E-04
53	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.340E-04	1.492E-04
54	44099	1.529E-03	0.000E+00	0.000E+00	1.571E-08	2.189E-07	2.412E-07
55	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.790E-10	1.992E-10
56	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.110E-04	1.248E-04
57	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.182E-05	1.042E-04
58	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.071E-05	4.712E-05
59	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.465E-05	7.411E-05
60	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.113E-05	2.470E-05
61	46106	6.734E-02	0.000E+00	0.000E+00	6.461E-07	9.002E-06	1.062E-05
62	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.250E-06	1.503E-06
63	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.681E-07	6.955E-07
64	47107	1.344E-06	0.000E+00	0.000E+00	1.278E-11	1.780E-10	2.120E-10
65	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.981E-07	8.469E-07
66	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.630E-10	3.220E-10
67	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.764E-07	4.650E-07
68	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.851E-07	3.553E-07
69	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.301E-07	5.457E-07
70	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.881E-07	3.719E-07
71	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.171E-10	3.988E-10
72	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.310E-08	1.677E-08
73	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.270E-09	2.931E-09
74	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.760E-07	3.595E-07
75	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.480E-07	3.258E-07
76	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.801E-07	3.709E-07
77	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.740E-07	3.660E-07
78	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.351E-07	4.550E-07

79	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.771E-07	7.966E-07
80	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.670E-07	3.597E-07
81	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.399E-07	4.654E-07
82	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.071E-10	4.170E-10
83	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.221E-10	5.826E-10
84	52125	6.412E-03	0.000E+00	0.000E+00	5.217E-08	7.268E-07	1.011E-06
85	52126	4.855E-04	0.000E+00	0.000E+00	3.919E-09	5.459E-08	7.657E-08
86	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.441E-06	1.060E-05
87	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.871E-05	5.601E-05
88	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.301E-06	4.666E-06
89	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.630E-09	3.748E-09
90	54129	2.330E-06	0.000E+00	0.000E+00	1.837E-11	2.559E-10	3.675E-10
91	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.470E-08	2.128E-08
92	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.143E-05	8.958E-05
93	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.277E-05	1.363E-04
94	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.680E-04	2.506E-04
95	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.420E-04	2.150E-04
96	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.427E-04	2.112E-04
97	56134	3.812E-03	0.000E+00	0.000E+00	2.893E-08	4.031E-07	6.012E-07
98	56135	1.906E-04	0.000E+00	0.000E+00	1.436E-09	2.000E-08	3.005E-08
99	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.706E-07	2.583E-07
100	56137	1.276E+00	0.000E+00	0.000E+00	9.468E-06	1.319E-04	2.012E-04
101	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.440E-04	2.213E-04
102	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.370E-04	2.120E-04
103	58140	1.309E+00	0.000E+00	0.000E+00	9.506E-06	1.324E-04	2.064E-04
104	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.244E-04	1.953E-04
105	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.181E-08	5.028E-08
106	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.256E-04	2.000E-04
107	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.431E-05	1.045E-04
108	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.581E-05	5.900E-05
109	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.410E-05	2.355E-05
110	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.790E-05	2.990E-05
111	62152	8.584E-02	0.000E+00	0.000E+00	5.742E-07	7.999E-06	1.354E-05
112	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.610E-06	2.761E-06
113	63151	6.941E-02	0.000E+00	0.000E+00	4.673E-07	6.511E-06	1.095E-05
114	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.527E-06	6.008E-06
115	64154	5.968E-04	0.000E+00	0.000E+00	3.940E-09	5.489E-08	9.412E-08
116	64155	5.657E-03	0.000E+00	0.000E+00	3.711E-08	5.170E-07	8.922E-07
117	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.205E-07	9.041E-07
118	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.400E-08	2.448E-08
119	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.411E-09	1.320E-08
120	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.320E-08	4.108E-08
121	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.970E-09	3.532E-09
122	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.131E-10	9.255E-10
123	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.760E-10	3.195E-10
124	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.631E-01	1.182E-01
125	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.400E-04	4.546E-05
126	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.350E-09	3.927E-10
127	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.210E-03	2.427E-04
	totals	7.862E+02	6.094E-02	7.751E-05	4.801E-02	6.688E-01	1.240E-01

Step 13 – 1 000 years

actinide inventory for material 40000 at end of step 13, time 3.650E+05 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	94239	2.187E+00	1.357E-01	6.203E-02	9.298E-06	1.295E-04	3.449E-04
2	92234	1.151E+01	7.156E-02	6.217E-03	4.997E-05	6.962E-04	1.815E-03
3	94240	2.884E-02	6.545E-03	2.269E-01	1.221E-07	1.701E-06	4.549E-06
4	92235	1.056E+03	2.283E-03	2.161E-06	4.566E-03	6.362E-02	1.666E-01
5	92238	4.474E+03	1.504E-03	3.361E-07	1.910E-02	2.660E-01	7.055E-01
6	95241	2.150E-04	7.368E-04	3.427E+00	9.063E-10	1.263E-08	3.390E-08
7	92236	1.114E+01	7.206E-04	6.467E-05	4.797E-05	6.683E-04	1.757E-03
8	90230	3.194E-02	6.585E-04	2.062E-02	1.411E-07	1.966E-06	5.037E-06
9	91231	1.017E-03	4.802E-05	4.723E-02	4.472E-09	6.230E-08	1.603E-07
10	93237	4.230E-02	2.981E-05	7.047E-04	1.813E-07	2.526E-06	6.671E-06
11	92233	2.069E-05	1.994E-07	9.636E-03	9.023E-11	1.257E-09	3.263E-09
12	94242	6.418E-06	2.538E-08	3.954E-03	2.694E-11	3.754E-10	1.012E-09
13	90232	3.239E-04	3.552E-11	1.097E-07	1.419E-09	1.976E-08	5.109E-08
	totals	5.555E+03	2.197E-01	3.956E-05	2.377E-02	3.312E-01	8.760E-01

nonactinide inventory for material 40000 at end of step 13, time 3.650E+05 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	43099	9.075E-01	1.554E-02	1.712E-02	9.324E-06	1.299E-04	1.431E-04
2	40093	8.857E-01	2.228E-03	2.515E-03	9.688E-06	1.350E-04	1.397E-04
3	55135	1.258E+00	1.450E-03	1.152E-03	9.479E-06	1.321E-04	1.985E-04
4	62151	3.168E-05	8.338E-04	2.632E+01	2.133E-10	2.972E-09	4.996E-09

5	34079	5.192E-03	7.127E-04	1.373E-01	6.686E-08	9.314E-07	8.188E-07
6	50126	1.069E-02	3.035E-04	2.839E-02	8.627E-08	1.202E-06	1.686E-06
7	88226	1.262E-04	1.247E-04	9.885E-01	5.673E-10	7.904E-09	1.990E-08
8	53129	1.056E-01	1.866E-05	1.766E-04	8.328E-07	1.160E-05	1.666E-05
9	46107	2.522E-02	1.298E-05	5.145E-04	2.398E-07	3.340E-06	3.978E-06
10	37087	3.377E-01	2.894E-08	8.570E-08	3.949E-06	5.501E-05	5.326E-05
11	62147	4.924E-01	1.130E-08	2.296E-08	3.406E-06	4.745E-05	7.765E-05
12	60144	1.203E+00	1.429E-12	1.188E-12	8.493E-06	1.183E-04	1.897E-04
13	57138	6.742E-06	1.665E-13	2.469E-08	4.968E-11	6.921E-10	1.063E-09
14	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.214E-06	8.649E-06
15	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.250E-04	1.976E-04
16	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.372E-05	1.351E-04
17	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.500E-07	3.201E-07
18	64152	9.041E-05	1.970E-15	2.179E-11	6.048E-10	8.425E-09	1.426E-08
19	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.361E-07	8.834E-07
20	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.340E-07	1.686E-07
21	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.911E-06	6.307E-06
22	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.880E-10	1.486E-10
23	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.811E-10	4.656E-10
24	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.190E-09	1.779E-09
25	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.301E-09	6.012E-09
26	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.581E-08	5.566E-08
27	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.270E-08	1.895E-08
28	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.690E-07	1.448E-07
29	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.471E-07	3.881E-07
30	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.740E-06	2.440E-06
31	35079	1.101E-04	0.000E+00	0.000E+00	1.418E-09	1.976E-08	1.737E-08
32	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.331E-06	3.904E-06
33	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.750E-09	2.510E-09
34	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.140E-05	1.053E-05
35	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.090E-05	1.954E-05
36	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.471E-05	4.279E-05
37	37085	1.538E-01	0.000E+00	0.000E+00	1.840E-06	2.563E-05	2.425E-05
38	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.480E-09	1.417E-09
39	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.561E-05	7.404E-05
40	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.007E-04	9.970E-05
41	40090	7.791E-01	0.000E+00	0.000E+00	8.806E-06	1.227E-04	1.229E-04
42	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.241E-04	1.257E-04
43	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.280E-04	1.311E-04
44	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.380E-04	1.444E-04
45	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.350E-04	1.443E-04
46	41093	3.917E-04	0.000E+00	0.000E+00	4.285E-09	5.969E-08	6.178E-08
47	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.385E-04	1.464E-04
48	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.230E-07	1.314E-07
49	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.290E-04	1.393E-04
50	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.230E-04	1.342E-04
51	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.340E-04	1.492E-04
52	44099	3.019E-03	0.000E+00	0.000E+00	3.102E-08	4.322E-07	4.762E-07
53	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.790E-10	1.992E-10
54	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.110E-04	1.248E-04
55	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.182E-05	1.042E-04
56	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.071E-05	4.712E-05
57	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.465E-05	7.411E-05
58	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.113E-05	2.470E-05
59	46106	6.734E-02	0.000E+00	0.000E+00	6.461E-07	9.002E-06	1.062E-05
60	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.250E-06	1.503E-06
61	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.681E-07	6.955E-07
62	47107	2.688E-06	0.000E+00	0.000E+00	2.555E-11	3.560E-10	4.239E-10
63	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.981E-07	8.469E-07
64	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.630E-10	3.220E-10
65	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.764E-07	4.650E-07
66	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.851E-07	3.553E-07
67	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.301E-07	5.457E-07
68	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.881E-07	3.719E-07
69	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.171E-10	3.988E-10
70	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.310E-08	1.677E-08
71	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.270E-09	2.931E-09
72	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.760E-07	3.595E-07
73	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.480E-07	3.258E-07
74	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.801E-07	3.709E-07
75	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.740E-07	3.660E-07
76	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.351E-07	4.550E-07
77	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.771E-07	7.966E-07
78	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.670E-07	3.597E-07
79	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.399E-07	4.654E-07
80	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.071E-10	4.170E-10
81	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.221E-10	5.826E-10
82	52125	6.412E-03	0.000E+00	0.000E+00	5.217E-08	7.268E-07	1.011E-06
83	52126	5.226E-04	0.000E+00	0.000E+00	4.218E-09	5.876E-08	8.242E-08
84	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.441E-06	1.060E-05
85	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.871E-05	5.601E-05
86	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.301E-06	4.666E-06

87	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.630E-09	3.748E-09
88	54129	4.661E-06	0.000E+00	0.000E+00	3.674E-11	5.119E-10	7.350E-10
89	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.470E-08	2.128E-08
90	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.143E-05	8.958E-05
91	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.277E-05	1.363E-04
92	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.680E-04	2.506E-04
93	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.420E-04	2.150E-04
94	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.427E-04	2.112E-04
95	56134	3.812E-03	0.000E+00	0.000E+00	2.893E-08	4.031E-07	6.012E-07
96	56135	3.801E-04	0.000E+00	0.000E+00	2.863E-09	3.989E-08	5.994E-08
97	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.706E-07	2.583E-07
98	56137	1.276E+00	0.000E+00	0.000E+00	9.468E-06	1.319E-04	2.012E-04
99	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.440E-04	2.213E-04
100	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.370E-04	2.120E-04
101	58140	1.309E+00	0.000E+00	0.000E+00	9.506E-06	1.324E-04	2.064E-04
102	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.244E-04	1.953E-04
103	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.181E-08	5.028E-08
104	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.256E-04	2.000E-04
105	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.431E-05	1.045E-04
106	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.581E-05	5.900E-05
107	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.410E-05	2.355E-05
108	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.790E-05	2.990E-05
109	62152	8.584E-02	0.000E+00	0.000E+00	5.742E-07	7.999E-06	1.354E-05
110	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.610E-06	2.761E-06
111	63151	7.086E-02	0.000E+00	0.000E+00	4.771E-07	6.647E-06	1.118E-05
112	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.527E-06	6.008E-06
113	64154	5.968E-04	0.000E+00	0.000E+00	3.940E-09	5.489E-08	9.412E-08
114	64155	5.657E-03	0.000E+00	0.000E+00	3.711E-08	5.170E-07	8.922E-07
115	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.205E-07	9.041E-07
116	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.400E-08	2.448E-08
117	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.411E-09	1.320E-08
118	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.320E-08	4.108E-08
119	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.970E-09	3.532E-09
120	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.131E-10	9.255E-10
121	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.760E-10	3.195E-10
122	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.631E-01	1.182E-01
123	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.400E-04	4.546E-05
124	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.350E-09	3.927E-10
125	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.210E-03	2.427E-04
	totals	7.862E+02	2.122E-02	2.699E-05	4.801E-02	6.688E-01	1.240E-01

Step 14 – 10 000 years

actinide inventory for material 40000 at end of step 14, time 3.650E+06 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	94239	1.689E+00	1.048E-01	6.203E-02	7.179E-06	1.000E-04	2.663E-04
2	92234	1.123E+01	6.980E-02	6.217E-03	4.875E-05	6.791E-04	1.771E-03
3	90230	3.015E-01	6.215E-03	2.062E-02	1.332E-06	1.855E-05	4.754E-05
4	94240	1.116E-02	2.531E-03	2.269E-01	4.723E-08	6.579E-07	1.759E-06
5	92235	1.057E+03	2.284E-03	2.161E-06	4.568E-03	6.364E-02	1.666E-01
6	92238	4.474E+03	1.504E-03	3.361E-07	1.910E-02	2.660E-01	7.055E-01
7	92236	1.116E+01	7.215E-04	6.467E-05	4.803E-05	6.692E-04	1.760E-03
8	91231	9.218E-03	4.354E-04	4.723E-02	4.054E-08	5.648E-07	1.454E-06
9	93237	4.239E-02	2.987E-05	7.047E-04	1.817E-07	2.531E-06	6.684E-06
10	92233	1.391E-04	1.340E-06	9.636E-03	6.064E-10	8.449E-09	2.193E-08
11	90229	2.366E-06	4.688E-07	1.981E-01	1.050E-11	1.463E-10	3.732E-10
12	94242	6.312E-06	2.496E-08	3.954E-03	2.650E-11	3.692E-10	9.954E-10
13	90232	3.242E-03	3.555E-10	1.097E-07	1.420E-08	1.978E-07	5.113E-07
	totals	5.555E+03	1.883E-01	3.390E-05	2.377E-02	3.312E-01	8.760E-01

nonactinide inventory for material 40000 at end of step 14, time 3.650E+06 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	43099	8.811E-01	1.509E-02	1.712E-02	9.053E-06	1.261E-04	1.390E-04
2	88226	4.903E-03	4.847E-03	9.885E-01	2.204E-08	3.071E-07	7.733E-07
3	40093	8.821E-01	2.218E-03	2.515E-03	9.648E-06	1.344E-04	1.391E-04
4	55135	1.255E+00	1.446E-03	1.152E-03	9.453E-06	1.317E-04	1.979E-04
5	34079	4.298E-03	5.900E-04	1.373E-01	5.535E-08	7.711E-07	6.779E-07
6	89227	6.002E-06	4.341E-04	7.233E+01	2.687E-11	3.743E-10	9.466E-10
7	50126	1.004E-02	2.852E-04	2.839E-02	8.106E-08	1.129E-06	1.584E-06
8	53129	1.056E-01	1.865E-05	1.766E-04	8.324E-07	1.160E-05	1.665E-05
9	46107	2.520E-02	1.296E-05	5.145E-04	2.395E-07	3.337E-06	3.974E-06
10	37087	3.377E-01	2.894E-08	8.570E-08	3.949E-06	5.501E-05	5.326E-05
11	62147	4.924E-01	1.130E-08	2.296E-08	3.406E-06	4.745E-05	7.765E-05
12	60144	1.203E+00	1.429E-12	1.188E-12	8.493E-06	1.183E-04	1.897E-04
13	57138	6.742E-06	1.665E-13	2.469E-08	4.968E-11	6.921E-10	1.063E-09
14	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.214E-06	8.649E-06
15	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.250E-04	1.976E-04

16	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.372E-05	1.351E-04
17	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.500E-07	3.201E-07
18	64152	9.041E-05	1.970E-15	2.179E-11	6.048E-10	8.425E-09	1.426E-08
19	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.361E-07	8.834E-07
20	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.340E-07	1.686E-07
21	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.911E-06	6.307E-06
22	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.880E-10	1.486E-10
23	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.811E-10	4.656E-10
24	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.190E-09	1.779E-09
25	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.301E-09	6.012E-09
26	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.581E-08	5.566E-08
27	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.270E-08	1.895E-08
28	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.690E-07	1.448E-07
29	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.471E-07	3.881E-07
30	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.740E-06	2.440E-06
31	35079	1.004E-03	0.000E+00	0.000E+00	1.293E-08	1.801E-07	1.583E-07
32	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.331E-06	3.904E-06
33	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.750E-09	2.510E-09
34	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.140E-05	1.053E-05
35	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.090E-05	1.954E-05
36	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.471E-05	4.279E-05
37	37085	1.538E-01	0.000E+00	0.000E+00	1.840E-06	2.563E-05	2.425E-05
38	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.480E-09	1.417E-09
39	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.561E-05	7.404E-05
40	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.007E-04	9.970E-05
41	40090	7.791E-01	0.000E+00	0.000E+00	8.806E-06	1.227E-04	1.229E-04
42	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.241E-04	1.257E-04
43	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.280E-04	1.311E-04
44	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.380E-04	1.444E-04
45	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.350E-04	1.443E-04
46	41093	3.984E-03	0.000E+00	0.000E+00	4.358E-08	6.071E-07	6.283E-07
47	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.385E-04	1.464E-04
48	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.230E-07	1.314E-07
49	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.290E-04	1.393E-04
50	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.230E-04	1.342E-04
51	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.340E-04	1.492E-04
52	44099	2.943E-02	0.000E+00	0.000E+00	3.023E-07	4.212E-06	4.641E-06
53	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.790E-10	1.992E-10
54	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.110E-04	1.248E-04
55	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.182E-05	1.042E-04
56	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.071E-05	4.712E-05
57	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.465E-05	7.411E-05
58	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.113E-05	2.470E-05
59	46106	6.734E-02	0.000E+00	0.000E+00	6.461E-07	9.002E-06	1.062E-05
60	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.250E-06	1.503E-06
61	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.681E-07	6.955E-07
62	47107	2.687E-05	0.000E+00	0.000E+00	2.554E-10	3.558E-09	4.237E-09
63	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.981E-07	8.469E-07
64	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.630E-10	3.220E-10
65	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.764E-07	4.650E-07
66	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.851E-07	3.553E-07
67	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.301E-07	5.457E-07
68	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.881E-07	3.719E-07
69	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.171E-10	3.988E-10
70	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.310E-08	1.677E-08
71	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.270E-09	2.931E-09
72	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.760E-07	3.595E-07
73	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.480E-07	3.258E-07
74	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.801E-07	3.709E-07
75	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.740E-07	3.660E-07
76	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.351E-07	4.550E-07
77	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.771E-07	7.966E-07
78	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.670E-07	3.597E-07
79	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.399E-07	4.654E-07
80	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.071E-10	4.170E-10
81	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.221E-10	5.826E-10
82	52125	6.412E-03	0.000E+00	0.000E+00	5.217E-08	7.268E-07	1.011E-06
83	52126	1.169E-03	0.000E+00	0.000E+00	9.432E-09	1.314E-07	1.843E-07
84	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.441E-06	1.060E-05
85	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.871E-05	5.601E-05
86	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.301E-06	4.666E-06
87	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.630E-09	3.748E-09
88	54129	4.660E-05	0.000E+00	0.000E+00	3.674E-10	5.118E-09	7.349E-09
89	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.470E-08	2.128E-08
90	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.143E-05	8.958E-05
91	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.277E-05	1.363E-04
92	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.680E-04	2.506E-04
93	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.420E-04	2.150E-04
94	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.427E-04	2.112E-04
95	56134	3.812E-03	0.000E+00	0.000E+00	2.893E-08	4.031E-07	6.012E-07
96	56135	3.786E-03	0.000E+00	0.000E+00	2.852E-08	3.973E-07	5.971E-07
97	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.706E-07	2.583E-07

98	56137	1.276E+00	0.000E+00	0.000E+00	9.468E-06	1.319E-04	2.012E-04
99	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.440E-04	2.213E-04
100	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.370E-04	2.120E-04
101	58140	1.309E+00	0.000E+00	0.000E+00	9.506E-06	1.324E-04	2.064E-04
102	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.244E-04	1.953E-04
103	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.181E-08	5.028E-08
104	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.256E-04	2.000E-04
105	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.431E-05	1.045E-04
106	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.581E-05	5.900E-05
107	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.410E-05	2.355E-05
108	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.790E-05	2.990E-05
109	62152	8.584E-02	0.000E+00	0.000E+00	5.742E-07	7.999E-06	1.354E-05
110	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.610E-06	2.761E-06
111	63151	7.089E-02	0.000E+00	0.000E+00	4.773E-07	6.650E-06	1.118E-05
112	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.527E-06	6.008E-06
113	64154	5.968E-04	0.000E+00	0.000E+00	3.940E-09	5.489E-08	9.412E-08
114	64155	5.657E-03	0.000E+00	0.000E+00	3.711E-08	5.170E-07	8.922E-07
115	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.205E-07	9.041E-07
116	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.400E-08	2.448E-08
117	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.411E-09	1.320E-08
118	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.320E-08	4.108E-08
119	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.970E-09	3.532E-09
120	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.131E-10	9.255E-10
121	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.760E-10	3.195E-10
122	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.631E-01	1.182E-01
123	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.400E-04	4.546E-05
124	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.350E-09	3.928E-10
125	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.210E-03	2.427E-04
	totals	7.862E+02	2.494E-02	3.172E-05	4.801E-02	6.688E-01	1.240E-01

Step 15 – 100 000 years

actinide inventory for material 40000 at end of step 15, time 3.650E+07 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	92234	8.765E+00	5.449E-02	6.217E-03	3.806E-05	5.303E-04	1.383E-03
2	90230	1.791E+00	3.692E-02	2.062E-02	7.911E-06	1.102E-04	2.825E-04
3	94239	1.272E-01	7.892E-03	6.203E-02	5.409E-07	7.536E-06	2.007E-05
4	92235	1.058E+03	2.287E-03	2.161E-06	4.575E-03	6.373E-02	1.669E-01
5	91231	4.256E-02	2.010E-03	4.723E-02	1.872E-07	2.608E-06	6.714E-06
6	92238	4.473E+03	1.504E-03	3.361E-07	1.910E-02	2.661E-01	7.056E-01
7	92236	1.114E+01	7.203E-04	6.467E-05	4.795E-05	6.681E-04	1.757E-03
8	93237	4.117E-02	2.901E-05	7.047E-04	1.765E-07	2.459E-06	6.494E-06
9	92233	1.083E-03	1.044E-05	9.636E-03	4.723E-09	6.580E-08	1.708E-07
10	90229	4.777E-05	9.463E-06	1.981E-01	2.120E-10	2.953E-09	7.535E-09
11	94242	5.341E-06	2.112E-08	3.954E-03	2.242E-11	3.124E-10	8.425E-10
12	90232	3.242E-02	3.555E-09	1.097E-07	1.420E-07	1.978E-06	5.114E-06
	totals	5.554E+03	1.059E-01	1.906E-05	2.377E-02	3.311E-01	8.760E-01

nonactinide inventory for material 40000 at end of step 15, time 3.650E+07 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	88226	3.695E-02	3.653E-02	9.885E-01	1.661E-07	2.315E-06	5.829E-06
2	43099	6.558E-01	1.123E-02	1.712E-02	6.738E-06	9.387E-05	1.034E-04
3	40093	8.469E-01	2.130E-03	2.515E-03	9.263E-06	1.291E-04	1.336E-04
4	89227	2.779E-05	2.010E-03	7.233E+01	1.244E-10	1.733E-09	4.384E-09
5	55135	1.221E+00	1.407E-03	1.152E-03	9.201E-06	1.282E-04	1.927E-04
6	50126	5.384E-03	1.529E-04	2.839E-02	4.345E-08	6.054E-07	8.493E-07
7	34079	6.499E-04	8.922E-05	1.373E-01	8.369E-09	1.166E-07	1.025E-07
8	53129	1.052E-01	1.858E-05	1.766E-04	8.291E-07	1.155E-05	1.659E-05
9	46107	2.496E-02	1.284E-05	5.145E-04	2.372E-07	3.305E-06	3.937E-06
10	37087	3.377E-01	2.894E-08	8.570E-08	3.949E-06	5.501E-05	5.327E-05
11	62147	4.924E-01	1.130E-08	2.296E-08	3.406E-06	4.745E-05	7.767E-05
12	60144	1.203E+00	1.429E-12	1.188E-12	8.493E-06	1.183E-04	1.897E-04
13	57138	6.742E-06	1.665E-13	2.469E-08	4.968E-11	6.922E-10	1.063E-09
14	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.214E-06	8.651E-06
15	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.250E-04	1.977E-04
16	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.372E-05	1.352E-04
17	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.501E-07	3.201E-07
18	64152	9.041E-05	1.970E-15	2.179E-11	6.048E-10	8.426E-09	1.426E-08
19	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.361E-07	8.835E-07
20	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.340E-07	1.686E-07
21	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.912E-06	6.308E-06
22	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.880E-10	1.486E-10
23	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.811E-10	4.657E-10
24	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.191E-09	1.780E-09
25	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.302E-09	6.013E-09
26	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.582E-08	5.567E-08
27	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.271E-08	1.895E-08

28	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.690E-07	1.449E-07
29	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.471E-07	3.881E-07
30	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.741E-06	2.440E-06
31	35079	4.652E-03	0.000E+00	0.000E+00	5.991E-08	8.346E-07	7.338E-07
32	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.331E-06	3.904E-06
33	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.751E-09	2.510E-09
34	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.140E-05	1.053E-05
35	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.091E-05	1.954E-05
36	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.471E-05	4.279E-05
37	37085	1.538E-01	0.000E+00	0.000E+00	1.840E-06	2.564E-05	2.425E-05
38	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.480E-09	1.417E-09
39	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.562E-05	7.406E-05
40	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.007E-04	9.972E-05
41	40090	7.799E-01	0.000E+00	0.000E+00	8.815E-06	1.228E-04	1.230E-04
42	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.241E-04	1.257E-04
43	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.280E-04	1.311E-04
44	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.380E-04	1.444E-04
45	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.350E-04	1.443E-04
46	41093	3.920E-02	0.000E+00	0.000E+00	4.288E-07	5.974E-06	6.184E-06
47	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.385E-04	1.465E-04
48	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.230E-07	1.315E-07
49	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.290E-04	1.393E-04
50	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.230E-04	1.342E-04
51	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.340E-04	1.492E-04
52	44099	2.547E-01	0.000E+00	0.000E+00	2.617E-06	3.646E-05	4.018E-05
53	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.790E-10	1.993E-10
54	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.110E-04	1.248E-04
55	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.182E-05	1.042E-04
56	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.071E-05	4.713E-05
57	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.466E-05	7.413E-05
58	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.113E-05	2.470E-05
59	46106	6.734E-02	0.000E+00	0.000E+00	6.461E-07	9.002E-06	1.062E-05
60	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.250E-06	1.503E-06
61	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.681E-07	6.957E-07
62	47107	2.674E-04	0.000E+00	0.000E+00	2.542E-09	3.541E-08	4.218E-08
63	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.982E-07	8.471E-07
64	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.631E-10	3.221E-10
65	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.764E-07	4.651E-07
66	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.851E-07	3.554E-07
67	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.301E-07	5.458E-07
68	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.881E-07	3.720E-07
69	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.171E-10	3.988E-10
70	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.310E-08	1.677E-08
71	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.271E-09	2.932E-09
72	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.761E-07	3.596E-07
73	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.481E-07	3.258E-07
74	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.801E-07	3.710E-07
75	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.741E-07	3.661E-07
76	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.351E-07	4.551E-07
77	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.771E-07	7.967E-07
78	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.671E-07	3.597E-07
79	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.399E-07	4.654E-07
80	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.071E-10	4.170E-10
81	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.221E-10	5.827E-10
82	52125	6.412E-03	0.000E+00	0.000E+00	5.217E-08	7.268E-07	1.011E-06
83	52126	5.827E-03	0.000E+00	0.000E+00	4.703E-08	6.553E-07	9.192E-07
84	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.442E-06	1.060E-05
85	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.871E-05	5.602E-05
86	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.301E-06	4.667E-06
87	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.631E-09	3.749E-09
88	54129	4.651E-04	0.000E+00	0.000E+00	3.666E-09	5.108E-08	7.336E-08
89	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.470E-08	2.128E-08
90	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.143E-05	8.959E-05
91	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.277E-05	1.363E-04
92	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.680E-04	2.507E-04
93	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.420E-04	2.151E-04
94	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.427E-04	2.112E-04
95	56134	3.812E-03	0.000E+00	0.000E+00	2.893E-08	4.031E-07	6.014E-07
96	56135	3.735E-02	0.000E+00	0.000E+00	2.813E-07	3.919E-06	5.891E-06
97	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.706E-07	2.584E-07
98	56137	1.276E+00	0.000E+00	0.000E+00	9.468E-06	1.319E-04	2.012E-04
99	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.440E-04	2.213E-04
100	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.370E-04	2.121E-04
101	58140	1.311E+00	0.000E+00	0.000E+00	9.519E-06	1.326E-04	2.067E-04
102	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.244E-04	1.953E-04
103	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.181E-08	5.029E-08
104	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.256E-04	2.000E-04
105	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.432E-05	1.046E-04
106	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.581E-05	5.901E-05
107	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.410E-05	2.356E-05
108	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.790E-05	2.990E-05
109	62152	8.584E-02	0.000E+00	0.000E+00	5.742E-07	7.999E-06	1.354E-05

110	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.610E-06	2.762E-06
111	63151	7.089E-02	0.000E+00	0.000E+00	4.773E-07	6.651E-06	1.118E-05
112	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.527E-06	6.009E-06
113	64154	5.968E-04	0.000E+00	0.000E+00	3.940E-09	5.489E-08	9.413E-08
114	64155	5.657E-03	0.000E+00	0.000E+00	3.711E-08	5.170E-07	8.924E-07
115	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.205E-07	9.043E-07
116	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.400E-08	2.448E-08
117	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.412E-09	1.321E-08
118	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.321E-08	4.109E-08
119	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.970E-09	3.533E-09
120	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.131E-10	9.257E-10
121	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.760E-10	3.196E-10
122	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.632E-01	1.182E-01
123	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.401E-04	4.546E-05
124	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.351E-09	3.928E-10
125	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.210E-03	2.427E-04
	totals	7.862E+02	5.358E-02	6.815E-05	4.801E-02	6.689E-01	1.240E-01

Step 16 – 1 000 000 years

actinide inventory for material 40000 at end of step 16, time 3.650E+08 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	90230	3.656E-01	7.538E-03	2.062E-02	1.615E-06	2.252E-05	5.777E-05
2	92234	9.159E-01	5.694E-03	6.217E-03	3.977E-06	5.544E-05	1.447E-04
3	91231	4.838E-02	2.285E-03	4.723E-02	2.128E-07	2.967E-06	7.645E-06
4	92235	1.057E+03	2.285E-03	2.161E-06	4.571E-03	6.373E-02	1.671E-01
5	92238	4.473E+03	1.503E-03	3.361E-07	1.909E-02	2.662E-01	7.067E-01
6	92236	1.085E+01	7.014E-04	6.467E-05	4.669E-05	6.510E-04	1.714E-03
7	90229	1.165E-04	2.307E-05	1.981E-01	5.168E-10	7.205E-09	1.840E-08
8	92233	2.388E-03	2.301E-05	9.636E-03	1.041E-08	1.451E-07	3.772E-07
9	93237	3.076E-02	2.168E-05	7.047E-04	1.319E-07	1.839E-06	4.861E-06
10	90232	3.200E-01	3.509E-08	1.097E-07	1.402E-06	1.954E-05	5.057E-05
	totals	5.543E+03	2.007E-02	3.622E-06	2.372E-02	3.307E-01	8.758E-01

nonactinide inventory for material 40000 at end of step 16, time 3.650E+08 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	88226	7.665E-03	7.577E-03	9.885E-01	3.446E-08	4.805E-07	1.211E-06
2	89227	3.159E-05	2.285E-03	7.233E+01	1.414E-10	1.972E-09	4.992E-09
3	40093	5.635E-01	1.417E-03	2.515E-03	6.163E-06	8.592E-05	8.903E-05
4	55135	9.314E-01	1.073E-03	1.152E-03	7.016E-06	9.782E-05	1.472E-04
5	43099	3.421E-02	5.858E-04	1.712E-02	3.515E-07	4.901E-06	5.406E-06
6	53129	1.011E-01	1.786E-05	1.766E-04	7.968E-07	1.111E-05	1.597E-05
7	46107	2.268E-02	1.167E-05	5.145E-04	2.155E-07	3.005E-06	3.583E-06
8	50126	1.056E-05	2.998E-07	2.839E-02	8.523E-11	1.188E-09	1.668E-09
9	37087	3.377E-01	2.894E-08	8.570E-08	3.949E-06	5.505E-05	5.336E-05
10	62147	4.924E-01	1.130E-08	2.296E-08	3.406E-06	4.748E-05	7.780E-05
11	60144	1.203E+00	1.429E-12	1.188E-12	8.493E-06	1.184E-04	1.900E-04
12	57138	6.742E-06	1.665E-13	2.469E-08	4.968E-11	6.926E-10	1.065E-09
13	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.217E-06	8.665E-06
14	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.251E-04	1.980E-04
15	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.378E-05	1.354E-04
16	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.502E-07	3.207E-07
17	64152	9.041E-05	1.970E-15	2.179E-11	6.048E-10	8.431E-09	1.429E-08
18	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.365E-07	8.850E-07
19	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.341E-07	1.689E-07
20	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.916E-06	6.319E-06
21	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.882E-10	1.488E-10
22	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.815E-10	4.665E-10
23	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.192E-09	1.783E-09
24	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.307E-09	6.024E-09
25	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.586E-08	5.577E-08
26	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.272E-08	1.898E-08
27	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.692E-07	1.451E-07
28	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.474E-07	3.888E-07
29	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.742E-06	2.444E-06
30	35079	5.302E-03	0.000E+00	0.000E+00	6.827E-08	9.519E-07	8.378E-07
31	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.334E-06	3.911E-06
32	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.752E-09	2.515E-09
33	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.141E-05	1.055E-05
34	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.092E-05	1.958E-05
35	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.474E-05	4.287E-05
36	37085	1.538E-01	0.000E+00	0.000E+00	1.840E-06	2.565E-05	2.429E-05
37	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.481E-09	1.419E-09
38	38087	4.873E-06	0.000E+00	0.000E+00	5.698E-11	7.944E-10	7.700E-10
39	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.567E-05	7.418E-05
40	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.007E-04	9.989E-05
41	40090	7.799E-01	0.000E+00	0.000E+00	8.815E-06	1.229E-04	1.232E-04

42	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.242E-04	1.259E-04
43	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.281E-04	1.313E-04
44	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.381E-04	1.447E-04
45	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.351E-04	1.445E-04
46	41093	3.226E-01	0.000E+00	0.000E+00	3.529E-06	4.920E-05	5.098E-05
47	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.386E-04	1.467E-04
48	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.231E-07	1.317E-07
49	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.291E-04	1.395E-04
50	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.231E-04	1.344E-04
51	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.341E-04	1.494E-04
52	44099	8.763E-01	0.000E+00	0.000E+00	9.003E-06	1.255E-04	1.385E-04
53	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.792E-10	1.996E-10
54	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.111E-04	1.250E-04
55	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.188E-05	1.044E-04
56	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.074E-05	4.721E-05
57	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.470E-05	7.425E-05
58	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.115E-05	2.474E-05
59	46106	6.734E-02	0.000E+00	0.000E+00	6.461E-07	9.008E-06	1.064E-05
60	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.251E-06	1.506E-06
61	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.685E-07	6.969E-07
62	47107	2.550E-03	0.000E+00	0.000E+00	2.424E-08	3.379E-07	4.029E-07
63	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.986E-07	8.485E-07
64	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.632E-10	3.227E-10
65	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.767E-07	4.659E-07
66	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.853E-07	3.560E-07
67	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.304E-07	5.467E-07
68	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.883E-07	3.726E-07
69	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.173E-10	3.995E-10
70	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.311E-08	1.680E-08
71	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.272E-09	2.937E-09
72	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.762E-07	3.602E-07
73	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.482E-07	3.264E-07
74	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.803E-07	3.716E-07
75	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.742E-07	3.667E-07
76	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.353E-07	4.559E-07
77	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.775E-07	7.981E-07
78	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.672E-07	3.604E-07
79	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.401E-07	4.662E-07
80	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.073E-10	4.178E-10
81	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.224E-10	5.837E-10
82	52125	6.412E-03	0.000E+00	0.000E+00	5.217E-08	7.273E-07	1.013E-06
83	52126	1.120E-02	0.000E+00	0.000E+00	9.040E-08	1.260E-06	1.770E-06
84	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.447E-06	1.062E-05
85	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.873E-05	5.612E-05
86	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.303E-06	4.675E-06
87	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.632E-09	3.755E-09
88	54129	4.560E-03	0.000E+00	0.000E+00	3.594E-08	5.011E-07	7.204E-07
89	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.471E-08	2.132E-08
90	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.147E-05	8.975E-05
91	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.283E-05	1.366E-04
92	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.682E-04	2.511E-04
93	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.421E-04	2.154E-04
94	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.428E-04	2.116E-04
95	56134	3.812E-03	0.000E+00	0.000E+00	2.893E-08	4.034E-07	6.024E-07
96	56135	3.273E-01	0.000E+00	0.000E+00	2.466E-06	3.438E-05	5.172E-05
97	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.708E-07	2.588E-07
98	56137	1.276E+00	0.000E+00	0.000E+00	9.468E-06	1.320E-04	2.015E-04
99	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.441E-04	2.217E-04
100	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.371E-04	2.124E-04
101	58140	1.311E+00	0.000E+00	0.000E+00	9.519E-06	1.327E-04	2.071E-04
102	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.245E-04	1.957E-04
103	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.183E-08	5.037E-08
104	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.257E-04	2.003E-04
105	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.436E-05	1.047E-04
106	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.583E-05	5.911E-05
107	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.411E-05	2.360E-05
108	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.792E-05	2.996E-05
109	62152	8.584E-02	0.000E+00	0.000E+00	5.742E-07	8.005E-06	1.356E-05
110	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.611E-06	2.766E-06
111	63151	7.089E-02	0.000E+00	0.000E+00	4.773E-07	6.655E-06	1.120E-05
112	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.529E-06	6.019E-06
113	64154	5.968E-04	0.000E+00	0.000E+00	3.940E-09	5.493E-08	9.429E-08
114	64155	5.657E-03	0.000E+00	0.000E+00	3.711E-08	5.174E-07	8.939E-07
115	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.209E-07	9.058E-07
116	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.401E-08	2.452E-08
117	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.417E-09	1.323E-08
118	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.322E-08	4.116E-08
119	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.972E-09	3.539E-09
120	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.135E-10	9.273E-10
121	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.762E-10	3.201E-10
122	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.636E-01	1.184E-01
123	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.402E-04	4.554E-05

124	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.352E-09	3.935E-10
125	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.211E-03	2.431E-04
	totals	7.862E+02	1.297E-02	1.649E-05	4.801E-02	6.693E-01	1.242E-01

Step 17 – 10 000 000 years

actinide inventory for material 40000 at end of step 17, time 3.650E+09 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	91231	4.796E-02	2.265E-03	4.723E-02	2.109E-07	2.944E-06	7.597E-06
2	92235	1.048E+03	2.265E-03	2.161E-06	4.531E-03	6.323E-02	1.660E-01
3	90230	7.282E-02	1.501E-03	2.062E-02	3.217E-07	4.490E-06	1.154E-05
4	92234	2.415E-01	1.501E-03	6.217E-03	1.049E-06	1.463E-05	3.826E-05
5	92238	4.467E+03	1.501E-03	3.361E-07	1.907E-02	2.661E-01	7.076E-01
6	92236	8.311E+00	5.375E-04	6.467E-05	3.578E-05	4.993E-04	1.317E-03
7	90229	6.445E-06	1.277E-06	1.981E-01	2.860E-11	3.991E-10	1.021E-09
8	92233	1.320E-04	1.272E-06	9.636E-03	5.756E-10	8.033E-09	2.091E-08
9	93237	1.671E-03	1.177E-06	7.047E-04	7.162E-09	9.994E-08	2.647E-07
10	90232	2.811E+00	3.082E-07	1.097E-07	1.231E-05	1.718E-04	4.453E-04
	totals	5.526E+03	9.576E-03	1.733E-06	2.365E-02	3.300E-01	8.754E-01

nonactinide inventory for material 40000 at end of step 17, time 3.650E+09 (days), power 0.000E+00 (MW)

no.	zaid	mass (gm)	activity (Ci)	spec.act. (Ci/gm)	atom den. (a/b-cm)	atom fr.	mass fr.
1	89227	3.131E-05	2.265E-03	7.233E+01	1.402E-10	1.956E-09	4.961E-09
2	88226	1.519E-03	1.501E-03	9.885E-01	6.828E-09	9.529E-08	2.406E-07
3	55135	6.194E-02	7.137E-05	1.152E-03	4.666E-07	6.511E-06	9.813E-06
4	40093	9.578E-03	2.409E-05	2.515E-03	1.048E-07	1.462E-06	1.517E-06
5	53129	6.795E-02	1.200E-05	1.766E-04	5.357E-07	7.476E-06	1.077E-05
6	46107	8.690E-03	4.471E-06	5.145E-04	8.261E-08	1.153E-06	1.377E-06
7	37087	3.377E-01	2.894E-08	8.570E-08	3.948E-06	5.510E-05	5.349E-05
8	62147	4.924E-01	1.130E-08	2.296E-08	3.406E-06	4.753E-05	7.800E-05
9	60144	1.203E+00	1.429E-12	1.188E-12	8.493E-06	1.185E-04	1.905E-04
10	57138	6.742E-06	1.664E-13	2.469E-08	4.968E-11	6.933E-10	1.068E-09
11	62149	5.484E-02	6.583E-14	1.200E-12	3.742E-07	5.223E-06	8.688E-06
12	58142	1.253E+00	6.318E-14	5.042E-14	8.974E-06	1.252E-04	1.985E-04
13	60145	8.569E-01	3.523E-14	4.112E-14	6.009E-06	8.386E-05	1.358E-04
14	49115	2.029E-03	1.432E-14	7.055E-12	1.795E-08	2.505E-07	3.215E-07
15	64152	9.041E-05	1.970E-15	2.179E-11	6.048E-10	8.440E-09	1.432E-08
16	62148	5.601E-03	1.709E-15	3.051E-13	3.848E-08	5.370E-07	8.874E-07
17	48113	1.069E-03	3.639E-16	3.405E-13	9.620E-09	1.343E-07	1.693E-07
18	34082	3.999E-02	1.252E-18	3.130E-17	4.961E-07	6.923E-06	6.335E-06
19	31071	9.420E-07	0.000E+00	0.000E+00	1.350E-11	1.884E-10	1.492E-10
20	32072	2.952E-06	0.000E+00	0.000E+00	4.171E-11	5.821E-10	4.677E-10
21	32073	1.128E-05	0.000E+00	0.000E+00	1.572E-10	2.194E-09	1.787E-09
22	32074	3.812E-05	0.000E+00	0.000E+00	5.241E-10	7.314E-09	6.040E-09
23	32076	3.529E-04	0.000E+00	0.000E+00	4.724E-09	6.592E-08	5.591E-08
24	33075	1.202E-04	0.000E+00	0.000E+00	1.630E-09	2.274E-08	1.903E-08
25	34077	9.184E-04	0.000E+00	0.000E+00	1.213E-08	1.693E-07	1.455E-07
26	34078	2.461E-03	0.000E+00	0.000E+00	3.209E-08	4.478E-07	3.898E-07
27	34080	1.547E-02	0.000E+00	0.000E+00	1.967E-07	2.745E-06	2.451E-06
28	35079	5.302E-03	0.000E+00	0.000E+00	6.827E-08	9.528E-07	8.400E-07
29	35081	2.475E-02	0.000E+00	0.000E+00	3.109E-07	4.338E-06	3.921E-06
30	36082	1.591E-05	0.000E+00	0.000E+00	1.974E-10	2.755E-09	2.521E-09
31	36083	6.678E-02	0.000E+00	0.000E+00	8.184E-07	1.142E-05	1.058E-05
32	36084	1.239E-01	0.000E+00	0.000E+00	1.500E-06	2.094E-05	1.963E-05
33	36086	2.713E-01	0.000E+00	0.000E+00	3.209E-06	4.478E-05	4.298E-05
34	37085	1.538E-01	0.000E+00	0.000E+00	1.840E-06	2.568E-05	2.436E-05
35	38086	8.983E-06	0.000E+00	0.000E+00	1.063E-10	1.483E-09	1.423E-09
36	38087	4.873E-05	0.000E+00	0.000E+00	5.698E-10	7.952E-09	7.720E-09
37	38088	4.695E-01	0.000E+00	0.000E+00	5.428E-06	7.574E-05	7.438E-05
38	39089	6.322E-01	0.000E+00	0.000E+00	7.226E-06	1.008E-04	1.002E-04
39	40090	7.799E-01	0.000E+00	0.000E+00	8.815E-06	1.230E-04	1.236E-04
40	40091	7.968E-01	0.000E+00	0.000E+00	8.907E-06	1.243E-04	1.262E-04
41	40092	8.311E-01	0.000E+00	0.000E+00	9.189E-06	1.282E-04	1.317E-04
42	40094	9.155E-01	0.000E+00	0.000E+00	9.907E-06	1.383E-04	1.450E-04
43	40096	9.147E-01	0.000E+00	0.000E+00	9.692E-06	1.353E-04	1.449E-04
44	41093	8.765E-01	0.000E+00	0.000E+00	9.587E-06	1.338E-04	1.389E-04
45	42095	9.285E-01	0.000E+00	0.000E+00	9.942E-06	1.387E-04	1.471E-04
46	42096	8.334E-04	0.000E+00	0.000E+00	8.830E-09	1.232E-07	1.320E-07
47	42097	8.832E-01	0.000E+00	0.000E+00	9.261E-06	1.292E-04	1.399E-04
48	42098	8.508E-01	0.000E+00	0.000E+00	8.830E-06	1.232E-04	1.348E-04
49	42100	9.458E-01	0.000E+00	0.000E+00	9.620E-06	1.343E-04	1.498E-04
50	44099	9.105E-01	0.000E+00	0.000E+00	9.355E-06	1.306E-04	1.442E-04
51	44100	1.263E-06	0.000E+00	0.000E+00	1.285E-11	1.793E-10	2.001E-10
52	44101	7.913E-01	0.000E+00	0.000E+00	7.969E-06	1.112E-04	1.254E-04
53	44102	6.609E-01	0.000E+00	0.000E+00	6.591E-06	9.197E-05	1.047E-04
54	44104	2.988E-01	0.000E+00	0.000E+00	2.922E-06	4.078E-05	4.733E-05
55	45103	4.699E-01	0.000E+00	0.000E+00	4.641E-06	6.476E-05	7.445E-05

56	46105	1.566E-01	0.000E+00	0.000E+00	1.517E-06	2.117E-05	2.481E-05
57	46106	6.734E-02	0.000E+00	0.000E+00	6.461E-07	9.017E-06	1.067E-05
58	46108	9.529E-03	0.000E+00	0.000E+00	8.974E-08	1.252E-06	1.510E-06
59	46110	4.410E-03	0.000E+00	0.000E+00	4.078E-08	5.691E-07	6.987E-07
60	47107	1.654E-02	0.000E+00	0.000E+00	1.572E-07	2.194E-06	2.620E-06
61	47109	5.370E-03	0.000E+00	0.000E+00	5.011E-08	6.993E-07	8.508E-07
62	48110	2.042E-06	0.000E+00	0.000E+00	1.888E-11	2.635E-10	3.235E-10
63	48111	2.949E-03	0.000E+00	0.000E+00	2.702E-08	3.770E-07	4.671E-07
64	48112	2.253E-03	0.000E+00	0.000E+00	2.046E-08	2.855E-07	3.569E-07
65	48114	3.460E-03	0.000E+00	0.000E+00	3.087E-08	4.308E-07	5.482E-07
66	48116	2.358E-03	0.000E+00	0.000E+00	2.068E-08	2.885E-07	3.736E-07
67	49113	2.529E-06	0.000E+00	0.000E+00	2.276E-11	3.176E-10	4.006E-10
68	50115	1.063E-04	0.000E+00	0.000E+00	9.405E-10	1.312E-08	1.685E-08
69	50116	1.859E-05	0.000E+00	0.000E+00	1.630E-10	2.274E-09	2.945E-09
70	50117	2.279E-03	0.000E+00	0.000E+00	1.981E-08	2.765E-07	3.611E-07
71	50118	2.066E-03	0.000E+00	0.000E+00	1.780E-08	2.485E-07	3.273E-07
72	50119	2.352E-03	0.000E+00	0.000E+00	2.010E-08	2.805E-07	3.726E-07
73	50120	2.321E-03	0.000E+00	0.000E+00	1.967E-08	2.745E-07	3.677E-07
74	50122	2.885E-03	0.000E+00	0.000E+00	2.405E-08	3.356E-07	4.571E-07
75	50124	5.051E-03	0.000E+00	0.000E+00	4.142E-08	5.781E-07	8.002E-07
76	51121	2.281E-03	0.000E+00	0.000E+00	1.917E-08	2.675E-07	3.613E-07
77	51123	2.951E-03	0.000E+00	0.000E+00	2.440E-08	3.405E-07	4.675E-07
78	52122	2.644E-06	0.000E+00	0.000E+00	2.204E-11	3.076E-10	4.189E-10
79	52124	3.694E-06	0.000E+00	0.000E+00	3.030E-11	4.228E-10	5.852E-10
80	52125	6.412E-03	0.000E+00	0.000E+00	5.217E-08	7.280E-07	1.016E-06
81	52126	1.121E-02	0.000E+00	0.000E+00	9.049E-08	1.263E-06	1.776E-06
82	52128	6.723E-02	0.000E+00	0.000E+00	5.341E-07	7.454E-06	1.065E-05
83	52130	3.552E-01	0.000E+00	0.000E+00	2.778E-06	3.877E-05	5.627E-05
84	53127	2.959E-02	0.000E+00	0.000E+00	2.369E-07	3.306E-06	4.687E-06
85	54128	2.377E-05	0.000E+00	0.000E+00	1.888E-10	2.635E-09	3.765E-09
86	54129	3.769E-02	0.000E+00	0.000E+00	2.971E-07	4.146E-06	5.970E-06
87	54130	1.349E-04	0.000E+00	0.000E+00	1.055E-09	1.473E-08	2.137E-08
88	54131	5.680E-01	0.000E+00	0.000E+00	4.409E-06	6.153E-05	8.998E-05
89	54132	8.643E-01	0.000E+00	0.000E+00	6.659E-06	9.293E-05	1.369E-04
90	54134	1.589E+00	0.000E+00	0.000E+00	1.206E-05	1.683E-04	2.518E-04
91	54136	1.363E+00	0.000E+00	0.000E+00	1.019E-05	1.423E-04	2.160E-04
92	55133	1.339E+00	0.000E+00	0.000E+00	1.024E-05	1.429E-04	2.122E-04
93	56134	3.812E-03	0.000E+00	0.000E+00	2.893E-08	4.038E-07	6.040E-07
94	56135	1.197E+00	0.000E+00	0.000E+00	9.015E-06	1.258E-04	1.896E-04
95	56136	1.638E-03	0.000E+00	0.000E+00	1.225E-08	1.709E-07	2.595E-07
96	56137	1.276E+00	0.000E+00	0.000E+00	9.468E-06	1.321E-04	2.021E-04
97	56138	1.403E+00	0.000E+00	0.000E+00	1.034E-05	1.443E-04	2.223E-04
98	57139	1.344E+00	0.000E+00	0.000E+00	9.836E-06	1.373E-04	2.130E-04
99	58140	1.311E+00	0.000E+00	0.000E+00	9.519E-06	1.328E-04	2.076E-04
100	59141	1.238E+00	0.000E+00	0.000E+00	8.930E-06	1.246E-04	1.962E-04
101	60142	3.188E-04	0.000E+00	0.000E+00	2.283E-09	3.186E-08	5.051E-08
102	60143	1.268E+00	0.000E+00	0.000E+00	9.016E-06	1.258E-04	2.009E-04
103	60146	6.628E-01	0.000E+00	0.000E+00	4.616E-06	6.442E-05	1.050E-04
104	60148	3.741E-01	0.000E+00	0.000E+00	2.570E-06	3.587E-05	5.927E-05
105	60150	1.493E-01	0.000E+00	0.000E+00	1.012E-06	1.413E-05	2.366E-05
106	62150	1.896E-01	0.000E+00	0.000E+00	1.285E-06	1.793E-05	3.003E-05
107	62152	8.584E-02	0.000E+00	0.000E+00	5.742E-07	8.013E-06	1.360E-05
108	62154	1.751E-02	0.000E+00	0.000E+00	1.156E-07	1.613E-06	2.774E-06
109	63151	7.089E-02	0.000E+00	0.000E+00	4.773E-07	6.662E-06	1.123E-05
110	63153	3.809E-02	0.000E+00	0.000E+00	2.531E-07	3.533E-06	6.035E-06
111	64154	5.968E-04	0.000E+00	0.000E+00	3.940E-09	5.498E-08	9.454E-08
112	64155	5.657E-03	0.000E+00	0.000E+00	3.711E-08	5.179E-07	8.963E-07
113	64156	5.733E-03	0.000E+00	0.000E+00	3.736E-08	5.214E-07	9.082E-07
114	64157	1.552E-04	0.000E+00	0.000E+00	1.005E-09	1.403E-08	2.459E-08
115	64160	8.372E-05	0.000E+00	0.000E+00	5.320E-10	7.424E-09	1.326E-08
116	65159	2.605E-04	0.000E+00	0.000E+00	1.666E-09	2.324E-08	4.127E-08
117	66161	2.240E-05	0.000E+00	0.000E+00	1.414E-10	1.974E-09	3.548E-09
118	66162	5.869E-06	0.000E+00	0.000E+00	3.683E-11	5.140E-10	9.297E-10
119	66163	2.026E-06	0.000E+00	0.000E+00	1.264E-11	1.763E-10	3.209E-10
120	8016	7.492E+02	0.000E+00	0.000E+00	4.760E-02	6.643E-01	1.187E-01
121	8017	2.882E-01	0.000E+00	0.000E+00	1.723E-05	2.405E-04	4.566E-05
122	7015	2.490E-06	0.000E+00	0.000E+00	1.687E-10	2.354E-09	3.945E-10
123	8018	1.539E+00	0.000E+00	0.000E+00	8.687E-05	1.212E-03	2.438E-04
	totals	7.862E+02	3.878E-03	4.933E-06	4.801E-02	6.700E-01	1.246E-01