

ANL/RERTR/TM-26

ANL/RERTR/TM-26

NUCLEAR MASS INVENTORY, PHOTON DOSE RATE AND THERMAL DECAY HEAT
OF SPENT RESEARCH REACTOR FUEL ASSEMBLIES

R. B. Pond and J. E. Matos
RERTR Program
Argonne National Laboratory
Argonne, IL 60439-4841 USA

RECEIVED

AUG 12 1996

OSTI

May 1996



ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

Operated by The University of Chicago
for the United States Department of Energy
under Contract No. W-31-109-Eng-38.

MASTER

Argonne National Laboratory, with facilities in the states of Illinois and Idaho, is owned by the United States government, and operated by The University of Chicago under the provisions of a contract with the Department of Energy.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Available from the
Reduced Enrichment for Research and Test Reactor (RERTR) Program
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439-4841 USA

**NUCLEAR MASS INVENTORY, PHOTON DOSE RATE AND THERMAL DECAY HEAT
OF SPENT RESEARCH REACTOR FUEL ASSEMBLIES**

**R. B. Pond and J. E. Matos
RERTR Program
Argonne National Laboratory
Argonne, IL 60439-4841 USA**

May 1996

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.



ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

**Operated by The University of Chicago
for the United States Department of Energy
under Contract No. W-31-109-Eng-38.**

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED HH

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

**NUCLEAR MASS INVENTORY, PHOTON DOSE RATE AND THERMAL DECAY HEAT
OF SPENT RESEARCH REACTOR FUEL ASSEMBLIES**

TABLE OF CONTENTS

	<u>Page</u>
Summary	1
Introduction	1
Nuclear Mass Inventory	2
Photon Dose Rate	3
Thermal Decay Heat	6
Conclusions	7
References	7
Appendix A: MTR Model Mass Inventory Sensitivity	18
Appendix B: U-234 And U-236 Mass Inventory Sensitivity	23

NUCLEAR MASS INVENTORY, PHOTON DOSE RATE AND THERMAL DECAY HEAT OF SPENT RESEARCH REACTOR FUEL ASSEMBLIES

**R. B. Pond and J. E. Matos
Argonne National Laboratory
Argonne, IL**

SUMMARY

This document has been prepared to assist research reactor operators possessing spent fuel containing enriched uranium of United States origin to prepare part of the documentation necessary to ship this fuel to the United States. Data are included on the nuclear mass inventory, photon dose rate, and thermal decay heat of spent research reactor fuel assemblies.

Isotopic masses of U, Np, Pu and Am that are present in spent research reactor fuel are estimated for MTR, TRIGA and DIDO fuel assembly types. The isotopic masses of each fuel assembly type are given as functions of U-235 burnup in the spent fuel, and of initial U-235 enrichment and U-235 mass in the fuel assembly.

Photon dose rates of spent MTR, TRIGA and DIDO-type fuel assemblies are estimated for fuel assemblies with up to 80% U-235 burnup and specific power densities between 0.089 and 2.857 MW/kg²³⁵U, and for fission product decay times of up to 20 years.

Thermal decay heat loads are estimated for spent fuel based upon the fuel assembly irradiation history (average assembly power vs. elapsed time) and the spent fuel cooling time.

INTRODUCTION

As part of the Department of Energy's spent nuclear fuel acceptance criteria, the mass of uranium and transuranic elements in spent research reactor fuel must be specified. These data are, however, not always known or readily determined. It is the purpose of this report to provide estimates of these data for some of the more common research reactor fuel assembly types. The specific types considered here are MTR, TRIGA and DIDO fuel assemblies.

The degree of physical protection given to spent fuel assemblies is largely dependent upon the photon dose rate of the spent fuel material. These data also, are not always known or readily determined. Because of a self-protecting dose rate level of radiation (dose rate greater than 100 rem/h at 1 m in air), it is important to know the dose

rate of spent fuel assemblies at all time. Estimates of the photon dose rate for spent MTR, TRIGA and DIDO-type fuel assemblies are given in this report.

For safe spent fuel assembly containment, the thermal heat load generated by the decay of fission products in spent fuel material is an important consideration. This heat load can be estimated by a simple analytical expression that is given in this report.

NUCLEAR MASS INVENTORY

The mass inventory of the heavy metals in research reactor fuels has been calculated using the WIMS code¹ for unit-cell models of MTR, TRIGA and DIDO fuel assembly types. Models of each fuel assembly type were neutronicly burned for a length of time corresponding to typical fuel-cycle lengths and U-235 burnup². Table 1 summarizes the fuel assembly models for which mass inventory calculations were made.

Table 1. Fuel Assembly Models

Assembly Type	U-235 Burnup, %	U-235 Enrichment, %	U-235 Mass, g
MTR (19 fuel plates)	5, 10, 20, 30, 40, 50, 60, 70, 80	93	100 200 300 400
		45	200 300 400
		19.75	100 200 300 400 500
TRIGA (single rod)	5, 10, 15, 20, 25, 30, 35	70 (8.5wt% U)	133
		20 (20wt% U)	98
		20 (12wt% U)	54
		20 (8.5wt% U)	38
TRIGA (25 rod cluster)	10, 20, 30, 40, 50, 60	93.1 (10wt% U)	41.4
		19.7 (45wt% U)	53.6
DIDO (4 fuel tubes)	10, 20, 30, 40, 50, 60	93	150
		80	150
		60	150
		20	200

Mass inventory calculations for MTR models were made for assemblies with up to 80% U-235 burnup, for 93, 45 and 19.75% U-235 enrichments, and for initial U-235 masses of 100 to 500 g. The specific MTR model was for a 19-fuel plate assembly. (Supplemental mass inventory calculations, shown in Appendix A, indicate that the MTR model is not a strong function of the number of fuel plates or the specific fuel-clad-coolant geometry.)

Similar calculations were made for two TRIGA assembly types – a single rod model and a 25-rod cluster model. The maximum U-235 burnup in these models were respectively, 35 and 60%. There were four fuel types for the single rod model and two fuel types for the cluster model.

For DIDO fuel assembly types, mass inventory calculations were made for a 4-fuel tube model with up to 60% U-235 burnup, and for four fuel enrichments and assembly masses.

The results of the mass inventory calculations are shown in the following tables:

Table 2 — MTR Fuel 93% Enrichment, Page 8
Table 3 — MTR Fuel 45% Enrichment, Page 10
Table 4 — MTR Fuel 19.75% Enrichment, Page 12
Table 5 — TRIGA Fuel Single-Rod Model, Page 15
Table 6 — TRIGA Fuel 25-Rod Cluster Model, Page 16
Table 7 — DIDO Fuel, Page 17

The tables show the isotopic masses of U, Np, Pu and Am that are present in spent fuel as functions of the fuel assembly U-235 burnup and initial U-235 mass. As will be noted in the tables for most fuel assembly types, the uranium fuel compositions have excluded initial enrichments of U-234 and U-236. In order to account for initial enrichments of U-234 and/or U-236 in the tables, initial U-234 and U-236 masses can be simply added to the spent fuel mass inventory. (See Appendix B for an assessment of the effect of initial enrichments of U-234 and U-236 upon the overall mass inventory of U, Np, Pu and Am in spent fuel.) Within the uncertainty of the calculations, the results in Tables 2–7 can be used to estimate the spent fuel mass inventory in most MTR, TRIGA and DIDO fuel assembly types.

The mass inventories given in Tables 2–7 are at the time of reactor discharge and therefore do not account for decay of Pu-241 to Am-241 for times after discharge. When necessary to estimate mass inventories after discharge, the Pu-241 mass is decreased and the Am-241 mass is increased by an amount $\Delta M = M_0 \cdot (1 - e^{-\lambda t})$ where M_0 is the Pu-241 mass at discharge, $\lambda = 1.32 \cdot 10^{-4} \text{ d}^{-1}$ (Pu-241 half-life, 14.4 y), and t is the time in days after discharge. No mass inventories are given for U-239 (half-life, 23.5 m) and Np-239 (half life, 2.355 d) as they are assumed to decay instantaneously to Pu-239.

PHOTON DOSE RATE

Calculated dose rates for MTR-type fuel assemblies are shown in Table 8. These dose rates are from Ref. 3 and are for fuel assemblies with up to 80% U-235 burnup, specific power densities between 0.089 and 2.857 MW/kg²³⁵U, and fission product decay times of up to 20 years.

The data in Table 8 are photon dose rates in air that are averaged over a 60-cm long cylindrical surface, located at a radius of 1 m from the fuel assembly axial center line. For MTR-type fuel assemblies, these average dose rates are independent of the assembly rotational orientation and the number of fuel plates in the assembly. These data also can be interpolated for specific decay time, burnup and assembly power density. In all cases, the dose rates must be multiplied by the mass of U-235 burned in the fuel assembly to estimate the fuel assembly dose rate. The mass of U-235 burned per fuel assembly that is necessary for an unshielded, 100 rem/h self-protecting dose rate at 1 m, is shown in Fig. 1.

Additional analyses have shown that the photon dose rates of MTR, TRIGA and DIDO-type fuel assemblies are similar, given the same fuel assembly characteristics of U-235 burnup, fission product decay time, and specific fuel assembly power density. The average dose rates at 1 m in air for TRIGA (25-rod) and DIDO (4-tube) fuel assemblies are respectively, 1.04 and 1.05 times the dose rates given in Table 8 for MTR fuel assemblies. The dose rates of all three fuel assembly types are for fuel assembly models (nominally 8cm by 8cm by 60cm) containing spent fuel in the form of either rods (TRIGA fuel), annuli (DIDO fuel) or plates (MTR fuel). The small difference in the dose rates are due to the different shielding effects of the fuel elements in the fuel assemblies.

Table 8. Photon Dose Rates At 1 M In Air, rem/h per g²³⁵U burned

Decay Time, y	Burnup, % ²³⁵ U	Assembly Power Density, MW/kg ²³⁵ U					
		2.857	1.429	0.714	0.357	0.179	0.089
2	1%	1.84+0	1.84+0	1.83+0	1.80+0	1.77+0	1.70+0
3		1.13+0	1.13+0	1.13+0	1.13+0	1.11+0	1.11+0
4		9.01-1	9.01-1	9.01-1	9.01-1	9.01-1	8.92-1
2	10%	1.89+0	1.87+0	1.80+0	1.64+0	1.50+0	1.28+0
3		1.19+0	1.20+0	1.20+0	1.16+0	1.09+0	9.95-1
4		9.52-1	9.61-1	9.61-1	9.44-1	9.10-1	8.59-1
2	20%	2.01+0	1.98+0	1.86+0	1.66+0	1.42+0	1.19+0
3		1.31+0	1.32+0	1.28+0	1.21+0	1.11+0	9.78-1
4		1.04+0	1.05+0	1.04+0	9.99-1	9.44-1	8.63-1
5		8.97-1	9.10-1	9.05-1	8.80-1	8.46-1	7.95-1
10		6.67-1	6.67-1	6.67-1	6.59-1	6.50-1	6.25-1
15		5.78-1	5.78-1	5.74-1	5.70-1	5.61-1	5.44-1
20		5.10-1	5.10-1	5.10-1	5.06-1	4.97-1	4.85-1
2	40%	2.40+0	2.30+0	2.09+0	1.82+0	1.52+0	1.21+0
3		1.62+0	1.60+0	1.53+0	1.39+0	1.22+0	1.02+0
4		1.27+0	1.27+0	1.22+0	1.14+0	1.03+0	8.99-1
5		1.07+0	1.07+0	1.04+0	9.90-1	9.20-1	8.12-1
10		7.03-1	7.03-1	6.95-1	6.80-1	6.55-1	6.10-1
15		5.87-1	5.84-1	5.80-1	5.70-1	5.53-1	5.23-1
20		5.14-1	5.12-1	5.08-1	5.02-1	4.87-1	4.59-1
2	60%	2.95+0	2.79+0	2.52+0	2.15+0	1.74+0	1.34+0
3		2.05+0	2.00+0	1.87+0	1.66+0	1.40+0	1.12+0
4		1.59+0	1.56+0	1.49+0	1.35+0	1.17+0	9.63-1
5		1.30+0	1.29+0	1.24+0	1.15+0	1.02+0	8.54-1
10		7.55-1	7.51-1	7.37-1	7.07-1	6.70-1	6.02-1
15		5.96-1	5.96-1	5.88-1	5.72-1	5.50-1	5.04-1
20		5.17-1	5.17-1	5.13-1	4.99-1	4.76-1	4.39-1
2	80%	3.85+0	3.62+0	3.26+0	2.76+0	2.21+0	1.64+0
3		2.73+0	2.64+0	2.43+0	2.11+0	1.74+0	1.33+0
4		2.08+0	2.03+0	1.90+0	1.69+0	1.41+0	1.12+0
5		1.66+0	1.63+0	1.54+0	1.39+0	1.19+0	9.57-1
10		8.28-1	8.21-1	8.00-1	7.59-1	6.97-1	6.04-1
15		6.18-1	6.15-1	6.05-1	5.82-1	5.44-1	4.87-1
20		5.27-1	5.20-1	5.13-1	4.97-1	4.66-1	4.20-1

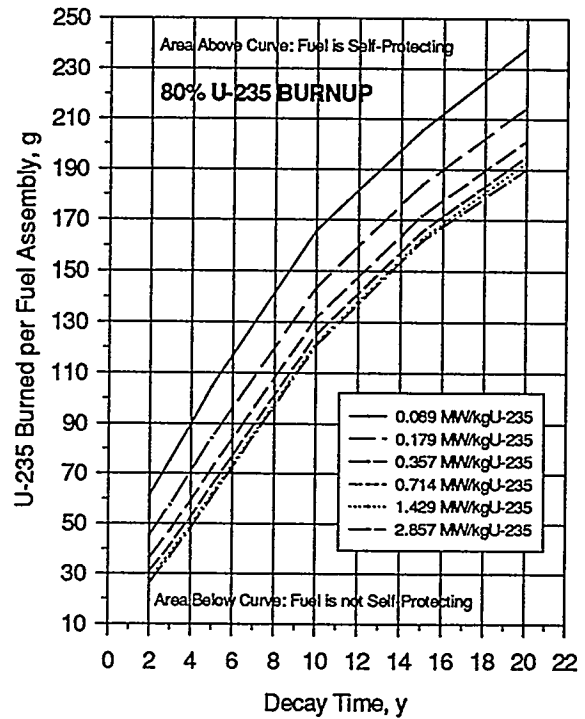
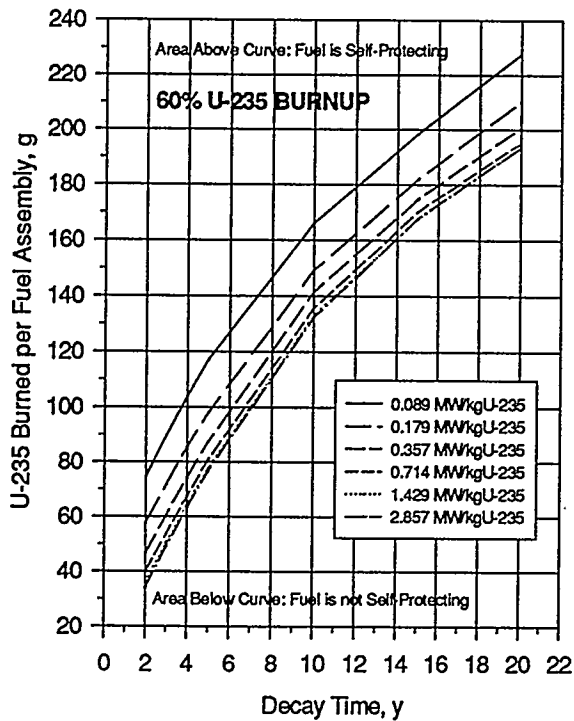
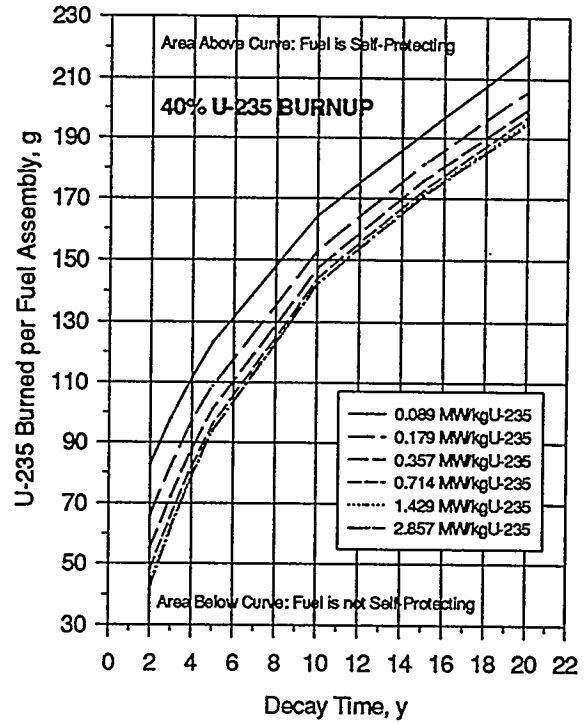
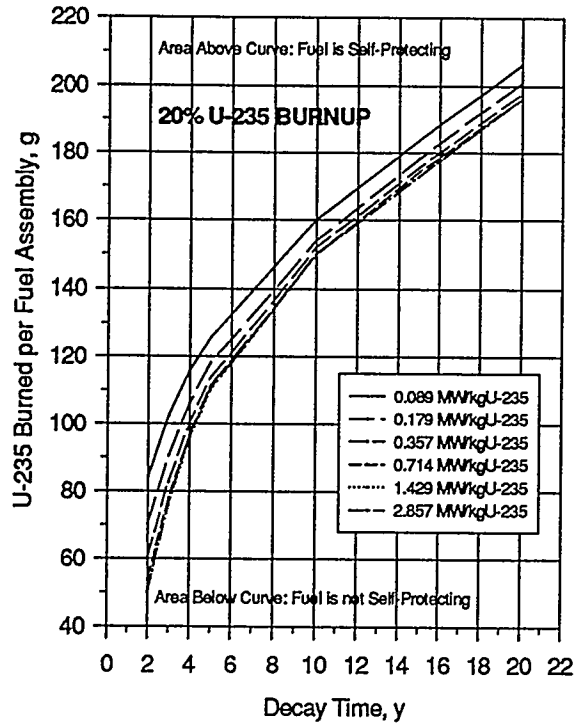


Figure 1. Mass of Burned ^{235}U per Fuel Assembly Necessary for an Unshielded 100 rem/h Dose Rate at 1 m for Fuel Assemblies with 20, 40, 60 and 80% ^{235}U Burnup and Power Densities from 0.089 to 2.857 MW/kg ^{235}U

THERMAL DECAY HEAT

The heat load from decaying fission products in a fuel assembly is proportional to empirical emission rates of beta and gamma radiation. The rates⁴ per U-235 fission, and as a function of decay time t_d in days, are

$$\begin{aligned}\beta(t_d) &= 1.50 \cdot 10^{-6} \cdot t_d^{-1.2} \text{ MeV/s-f} \\ \gamma(t_d) &= 1.67 \cdot 10^{-6} \cdot t_d^{-1.2} \text{ MeV/s-f}\end{aligned}$$

These energy rates are roughly equal for 0.4 MeV mean energy beta particles and 0.7 MeV mean energy gamma-rays.

For a fuel assembly irradiated continuously for t_i days at a constant fuel assembly power (P), the heat (H) load power per assembly, t_d days after irradiation is

$$H = 6.85 \cdot 10^{-3} \cdot P \cdot (t_d^{-0.2} - (t_i + t_d)^{-0.2}) \text{ Watts}$$

This expression⁵ for the heat load is the integral of the above energy rates over the irradiation time, assuming 200 MeV per U-235 fission, and for the fuel assembly power in watts. For a low duty-factor fuel assembly irradiation, the power and irradiation time are replaced by an average power and an elapsed time. With $\bar{P} \cdot t_e = \sum (P \cdot t_i)$ over all irradiation segments, the heat (H) load power per assembly is

$$H \cong 6.85 \cdot 10^{-3} \cdot \bar{P} \cdot (t_d^{-0.2} - (t_e + t_d)^{-0.2}) \text{ Watts}$$

where $\bar{P}$ is the average fuel assembly power in watts and t_e is the elapsed time in days from the initial through the final irradiation segment.

A convenient estimate for the average power ($\bar{P}$) is

$$\bar{P} = (G / t_e) / 1.25 \cdot 10^{-6} \text{ Watts}$$

where G is the mass of U-235 burned in the fuel assembly in grams, and the constant is g²³⁵U burned per Wd.

Fuel assembly decay heat loads calculated with these expressions are expected to be conservative, and within a factor of two or less of measured heat loads. This same conservative heat load estimate also has been found to be true for heat load calculations made with the ORIGEN code⁶. The thermal heat load of a fuel assembly is independent of the fuel assembly type.

CONCLUSIONS

Procedures have been developed to estimate the nuclear mass inventory, the photon dose rate and the thermal decay heat of spent research reactor fuel assemblies. The procedures should provide reasonable estimates based upon known fuel assembly parameters.

Isotopic mass inventories of U, Np, Pu and Am are tabulated in Tables 2-7 for MTR, TRIGA and DIDO fuel assembly types; photon dose rates at 1 m in air are shown in Table 8 for MTR-type fuel assemblies; and an analytical expression is given for the thermal decay heat load of spent uranium fuel. Estimates of TRIGA and DIDO fuel assembly dose rates are respectively, factors of 1.04 and 1.05 times the dose rate for MTR-type fuel assemblies with similar spent fuel material characteristics.

REFERENCES

1. J. R. Deen, W. L. Woodruff and C.I. Costescu, "WIMS-D4M User Manual (Rev. 0)", ANL/RERTR/TM-23, Argonne National Laboratory, Argonne, IL (July 1995).
2. J. E. Matos, "Foreign Research Reactor Irradiated Nuclear Fuel Inventories Containing HEU And LEU Of United States Origin", ANL/RERTR/TM-22, Argonne National Laboratory, Argonne, IL (December 1994).
3. R. B. Pond and J. E. Matos, "Photon Dose Rates From Spent Fuel Assemblies With Relation To Self-Protection (Rev. 1)", ANL/RERTR/TM-25, Argonne National Laboratory, Argonne, IL (February 1996).
4. A. M. Weinberg and E. P. Wigner, "The Physical Theory Of Neutron Chain Reactors", University of Chicago Press, Chicago, IL (1958).
5. S. Glasstone, "Principles Of Nuclear Reactor Engineering", D. Van Nostrand Company, Princeton, NJ (1955).
6. M. J. Bell, "ORIGEN — The ORNL Isotope Generation And Depletion Code," ORNL-4628, Oak Ridge National Laboratory, Oak Ridge, TN (May 1973).

Table 2. MTR Fuel 93% Enrichment

MTR Fuel	93% Enrichment										100 g U-235									
U-235 Burnup, %	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
U-235 Burned, g	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
U-234	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
U-235	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5
U-236	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
U-238	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
U	108	103	99	94	89	84	79	74	69	64	59	54	49	44	39	34	29	24	19	14
Np-237	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Np	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-239	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-240	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

MTR Fuel	93% Enrichment										200 g U-235									
U-235 Burnup, %	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
U-235 Burned, g	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
U-234	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
U-235	200	190	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10
U-236	0	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
U-238	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
U	215	207	198	189	181	172	164	155	147	138	130	121	113	104	96	87	78	69	60	51
Np-237	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Np	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-239	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-240	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 2. MTR Fuel 93% Enrichment (conti.)

MTR Fuel		93% Enrichment										300 g U-235			
U-235 Burnup, %	U-235 Burned, g	0	5	10	15	20	25	30	35	40	45	50	60	70	80
U-234	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
U-235	300	285	270	240	210	180	150	120	90	60	30	0	0	0	0
U-236	0	3	5	10	15	19	24	28	33	37	41	45	49	53	57
U-238	23	23	22	22	22	22	22	21	21	21	21	21	21	21	21
U	323	310	297	272	247	221	196	170	144	118	93	68	43	18	0
Np-237	0	0.0	0.0	0.1	0.2	0.4	0.6	0.8	1.1	1.5	1.9	2.3	2.7	3.1	3.5
Np	0	0.0	0.0	0.1	0.2	0.4	0.6	0.8	1.1	1.5	1.9	2.3	2.7	3.1	3.5
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Pu-239	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
Pu-240	0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4
Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

MTR Fuel		93% Enrichment										400 g U-235			
U-235 Burnup, %	U-235 Burned, g	0	5	10	15	20	25	30	35	40	45	50	60	70	80
U-234	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
U-235	400	380	360	320	280	240	200	160	120	80	40	0	0	0	0
U-236	0	3	7	14	20	26	33	39	44	50	56	62	68	74	80
U-238	30	30	30	30	29	29	29	28	28	27	27	27	27	27	27
U	430	413	397	363	329	295	261	227	192	157	123	89	55	21	0
Np-237	0	0.0	0.0	0.2	0.4	0.6	0.9	1.3	1.7	2.2	2.7	3.1	3.6	4.0	4.5
Np	0	0.0	0.0	0.2	0.4	0.6	0.9	1.3	1.7	2.2	2.7	3.1	3.6	4.0	4.5
Pu-238	0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Pu-239	0	0.1	0.2	0.4	0.6	0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5
Pu-240	0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5
Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu	0	0.1	0.3	0.5	0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3. MTR Fuel 45% Enrichment

MTR Fuel		45% Enrichment				200 g U-235							
U-235 Burnup, %	U-235 Burned, g	0	5	10	20	40	60	80	100	120	140	160	180
U-234	0	0	0	0	0	0	0	0	0	0	0	0	0
U-235	200	190	180	160	140	120	100	80	60	40	20	0	0
U-236	0	2	3	6	10	13	16	19	21	24	27	30	33
U-238	244	244	244	243	242	241	240	239	237	236	235	234	233
U	444	436	427	409	391	374	356	337	319	300	282	264	246
Np-237	0	0.0	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.4
Np	0	0.0	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.4
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3
Pu-239	0	0.4	0.7	1.3	1.7	2.0	2.3	2.4	2.3	2.2	2.1	2.0	1.9
Pu-240	0	0.0	0.0	0.1	0.2	0.3	0.5	0.6	0.8	1.0	1.2	1.4	1.6
Pu-241	0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3
Pu	0	0.4	0.7	1.4	2.0	2.5	2.9	3.3	3.6	3.8	4.0	4.2	4.4
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

MTR Fuel		45% Enrichment				300 g U-235					
U-235 Burnup, %	U-235 Burned, g	0	5	10	20	30	40	50	60	70	80
U-235 Burned, g		0	15	30	60	90	120	150	180	210	240
U-234		0	0	0	0	0	0	0	0	0	0
U-235		300	285	270	240	210	180	150	120	90	60
U-236		0	3	5	10	15	19	24	29	33	37
U-238		367	366	365	364	362	361	359	357	355	352
U		667	654	640	614	587	560	533	505	477	449
Np-237		0	0.0	0.0	0.1	0.2	0.4	0.6	0.9	1.2	1.5
Np		0	0.0	0.0	0.1	0.2	0.4	0.6	0.9	1.2	1.5
Pu-238		0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3
Pu-239		0	0.6	1.2	2.2	2.9	3.4	3.8	3.9	3.8	3.6
Pu-240		0	0.0	0.0	0.2	0.3	0.6	0.8	1.0	1.2	1.4
Pu-241		0	0.0	0.0	0.0	0.1	0.2	0.3	0.5	0.6	0.7
Pu-242		0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3
Pu		0	0.6	1.3	2.4	3.4	4.2	5.0	5.6	6.0	6.3
Am-241		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Am		0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 3. MTR Fuel 45% Enrichment (conti.)

[illegible]

Table 4. MTR Fuel 19.75% Enrichment

MTR Fuel		19.75% Enrichment				100 g U-235						
U-235 Burnup, %	0	5	10	20	30	40	50	60	70	80		
U-235 Burned, g	0	5	10	20	30	40	50	60	70	80		
U-234	0	0	0	0	0	0	0	0	0	0		
U-235	100	95	90	80	70	60	50	40	30	20		
U-236	0	1	2	3	5	6	8	9	11	12		
U-238	406	406	406	405	404	403	402	401	399	398		
U	506	502	497	488	479	469	460	450	440	429		
Np-237	0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3		
Np	0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3		
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1		
Pu-239	0	0.3	0.7	1.2	1.7	2.0	2.3	2.5	2.5	2.5		
Pu-240	0	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.8	1.0		
Pu-241	0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3		
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1		
Pu	0	0.3	0.7	1.3	1.9	2.4	2.9	3.3	3.7	4.0		
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

MTR Fuel	19.75% Enrichment					200 g U-235				
U-235 Burnup, %	0	5	10	20	30	40	50	60	70	80
U-235 Burned, g	0	10	20	40	60	80	100	120	140	160
U-234	0	0	0	0	0	0	0	0	0	0
U-235	200	190	180	160	140	120	100	80	60	40
U-236	0	2	3	6	10	13	16	19	22	24
U-238	813	812	811	809	807	805	802	800	796	792
U	1013	1003	994	975	957	937	918	898	878	856
Np-237	0	0.0	0.0	0.0	0.1	0.2	0.3	0.5	0.6	0.9
Np	0	0.0	0.0	0.0	0.1	0.2	0.3	0.5	0.6	0.9
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2
Pu-239	0	0.8	1.5	2.8	3.8	4.6	5.1	5.4	5.5	5.3
Pu-240	0	0.0	0.1	0.2	0.4	0.7	1.0	1.4	1.7	2.1
Pu-241	0	0.0	0.0	0.0	0.1	0.2	0.3	0.5	0.7	0.9
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4
Pu	0	0.8	1.6	3.1	4.4	5.5	6.6	7.5	8.2	8.8
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4. MTR Fuel 19.75% Enrichment (conti.)

MTR Fuel	19.75% Enrichment					300 g U-235				
	U-235 Burnup, %	U-235 Burned, g	0	5	10	15	20	25	30	35
U-234	0	0	0	0	0	0	0	0	0	0
U-235	300	285	270	240	210	180	150	120	90	60
U-236	0	3	5	10	15	20	25	29	33	37
U-238	1219	1218	1216	1213	1209	1205	1201	1197	1191	1184
U	1519	1505	1491	1463	1434	1405	1375	1345	1314	1281
Np-237	0	0.0	0.0	0.1	0.2	0.4	0.6	0.9	1.2	1.6
Np	0	0.0	0.0	0.1	0.2	0.4	0.6	0.9	1.2	1.6
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3
Pu-239	0	1.3	2.6	4.7	6.3	7.5	8.3	8.7	8.7	8.4
Pu-240	0	0.0	0.1	0.4	0.7	1.2	1.7	2.2	2.7	3.2
Pu-241	0	0.0	0.0	0.1	0.2	0.4	0.7	1.0	1.4	1.6
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.7
Pu	0	1.4	2.7	5.1	7.3	9.2	10.9	12.3	13.4	14.3
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1

MTR Fuel	19.75% Enrichment					400 g U-235				
	U-235 Burnup, %	U-235 Burned, g	0	5	10	15	20	25	30	35
U-234	0	0	0	0	0	0	0	0	0	0
U-235	400	380	360	320	280	240	200	160	120	80
U-236	0	4	7	14	20	27	33	39	45	50
U-238	1625	1623	1621	1616	1611	1605	1599	1592	1584	1574
U	2025	2007	1988	1950	1911	1872	1832	1791	1749	1704
Np-237	0	0.0	0.0	0.2	0.4	0.7	1.0	1.4	1.9	2.5
Np	0	0.0	0.0	0.2	0.4	0.7	1.0	1.4	1.9	2.5
Pu-238	0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4	0.6
Pu-239	0	2.0	3.8	6.8	9.1	10.8	11.8	12.4	12.3	11.7
Pu-240	0	0.0	0.2	0.6	1.1	1.7	2.4	3.1	3.7	4.3
Pu-241	0	0.0	0.0	0.1	0.4	0.7	1.2	1.7	2.2	2.6
Pu-242	0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.7	1.2
Pu	0	2.0	3.9	7.5	10.6	13.4	15.8	17.7	19.3	20.4
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1

Table 4. MTR Fuel 19.75% Enrichment (conti.)

MTR Fuel	19.75% Enrichment										500 g U-235				
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
U-235 Burnup, %	0	475	450	425	400	375	350	325	300	275	250	225	200	175	150
U-235 Burned, g	0	4	9	14	18	23	26	30	34	38	42	46	50	54	57
U-238	2032	2029	2026	2023	2019	2012	2012	2004	2004	1996	1987	1976	1962	1962	1962
U	2532	2508	2484	2460	2437	2388	2388	2338	2338	2288	2236	2183	2126	2126	2126
Np-237	0	0.0	0.1	0.2	0.3	0.6	0.6	1.0	1.0	1.5	2.1	2.8	3.6	3.6	3.6
Np	0	0.0	0.1	0.1	0.3	0.6	0.6	1.0	1.0	1.5	2.1	2.8	3.6	3.6	3.6
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.4	0.6	0.9	0.9	0.9
Pu-239	0	2.6	5.0	5.0	9.0	12.1	12.1	14.3	14.3	15.6	16.2	16.1	15.3	15.3	15.3
Pu-240	0	0.1	0.2	0.2	0.8	1.5	1.5	2.3	2.3	3.2	4.0	4.7	5.4	5.4	5.4
Pu-241	0	0.0	0.0	0.0	0.2	0.6	0.6	1.1	1.1	1.8	2.5	3.2	3.6	3.6	3.6
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.6	1.0	1.7	1.7	1.7
Pu	0	2.7	5.3	5.3	10.0	14.2	14.2	17.9	17.9	21.1	23.7	25.7	27.0	27.0	27.0
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1

Table 5. TRIGA Fuel Single-Rod Model

TRIGA Fuel 8.5wt% U, 70% Enrichment 133 g U-235										TRIGA Fuel 20wt% U, 20% Enrichment 98 g U-235									
U-235 Burnup, %	0	5	10	15	20	25	30	35		U-235 Burnup, %	0	5	10	15	20	25	30	35	
U-235 Burned, g	0	7	13	20	27	33	40	47		U-235 Burned, g	0	5	10	15	20	25	29	34	
U-234	0	0	0	0	0	0	0	0		U-234	0	0	0	0	0	0	0	0	
U-235	133	126	120	113	106	100	93	87		U-235	98	93	88	83	78	74	69	64	
U-236	0	1	3	4	5	6	7	8		U-236	0	1	2	3	4	4	5	6	
U-238	57	57	56	56	56	56	55	55		U-238	392	391	391	390	389	388	388	387	
U	190	184	179	173	167	162	156	150		U	490	485	481	476	471	466	461	457	
Np-237	0	0.0	0.0	0.1	0.1	0.1	0.2	0.3		Np-237	0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	
Np	0	0.0	0.0	0.1	0.1	0.1	0.2	0.3		Np	0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Pu-239	0	0.3	0.5	0.7	0.8	0.9	1.0	1.1		Pu-239	0	0.6	1.1	1.6	2.0	2.4	2.7	2.9	
Pu-240	0	0.0	0.0	0.0	0.1	0.1	0.1	0.2		Pu-240	0	0.0	0.1	0.1	0.2	0.3	0.3	0.4	
Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.1	0.1		Pu-241	0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Pu	0	0.3	0.5	0.7	0.9	1.1	1.2	1.4		Pu	0	0.6	1.2	1.7	2.3	2.7	3.2	3.6	
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

TRIGA Fuel 12wt% U, 20% Enrichment 54 g U-235										TRIGA Fuel 8.5wt% U, 20% Enrichment 38 g U-235									
U-235 Burnup, %	0	5	10	15	20	25	30	35		U-235 Burnup, %	0	5	10	15	20	25	30	35	
U-235 Burned, g	0	3	5	8	11	14	16	19		U-235 Burned, g	0	2	4	6	8	10	11	13	
U-234	0	0	0	0	0	0	0	0		U-234	0	0	0	0	0	0	0	0	
U-235	54	51	49	46	43	41	38	35		U-235	38	36	34	32	30	29	27	25	
U-236	0	0	1	1	2	2	3	3		U-236	0	0	1	1	1	2	2	2	
U-238	216	216	215	215	215	215	214	214		U-238	152	152	152	151	151	151	151	151	
U	270	268	265	262	260	257	255	252		U	190	188	186	185	183	181	179	177	
Np-237	0	0.0	0.0	0.0	0.0	0.0	0.0	0.1		Np-237	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Np	0	0.0	0.0	0.0	0.0	0.0	0.0	0.1		Np	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Pu-239	0	0.3	0.5	0.7	0.9	1.1	1.2	1.3		Pu-239	0	0.2	0.3	0.5	0.6	0.7	0.8	0.9	
Pu-240	0	0.0	0.0	0.0	0.1	0.1	0.1	0.2		Pu-240	0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	
Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.1		Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Pu	0	0.3	0.5	0.8	1.0	1.2	1.4	1.6		Pu	0	0.2	0.3	0.5	0.6	0.8	0.9	1.0	
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

Table 6. TRIGA Fuel 25-Rod Cluster Model

TRIGA Fuel		10wt% U, 93.1% Enrichment						41.4 g U-235						TRIGA Fuel						45wt% U, 19.7% Enrichment						53.6 g U-235						
U-235 Burnup, %	0	10	20	30	40	50	60	U-235 Burnup, %	0	10	20	30	40	50	60	U-235 Burnup, %	0	10	20	30	40	50	60	U-235 Burnup, %	0	10	20	30	40	50	60	
U-235 Burned, g	0.0	4.1	8.3	12.4	16.6	20.7	24.8	U-235 Burned, g	0.0	4.1	8.3	12.4	16.6	20.7	24.8	U-235 Burned, g	0.0	5.4	10.7	16.1	21.4	26.8	32.2	U-235 Burned, g	0.0	5.4	10.7	16.1	21.4	26.8	32.2	
U-234	0.4	0.4	0.4	0.4	0.4	0.3	0.3	U-234	0.4	0.4	0.4	0.4	0.3	0.3	0.3	U-234	0.4	0.4	0.4	0.3	0.3	0.3	0.3	U-234	0.4	0.4	0.4	0.3	0.3	0.3	0.3	
U-235	41.4	37.2	33.1	29.0	24.8	20.7	16.6	U-235	53.6	48.3	42.9	37.5	32.2	26.8	21.4	U-235	53.6	48.3	42.9	37.5	32.2	26.8	21.4	U-235	53.6	48.3	42.9	37.5	32.2	26.8	21.4	
U-236	0.2	1.0	1.7	2.4	3.1	3.8	4.4	U-236	0.7	1.7	2.7	3.7	4.6	5.5	6.4	U-236	0.7	1.7	2.7	3.7	4.6	5.5	6.4	U-236	0.7	1.7	2.7	3.7	4.6	5.5	6.4	
U-238	2.4	2.4	2.4	2.3	2.3	2.2	2.2	U-238	217.4	216.5	215.6	214.6	213.5	212.3	210.9	U-238	217.4	216.5	215.6	214.6	213.5	212.3	210.9	U-238	217.4	216.5	215.6	214.6	213.5	212.3	210.9	
U	44.5	41.0	37.6	34.1	30.6	27.1	23.5	U	272.1	266.9	261.6	256.1	250.6	244.9	239.0	U	272.1	266.9	261.6	256.1	250.6	244.9	239.0	U	272.1	266.9	261.6	256.1	250.6	244.9	239.0	
Np-237	0	0.0	0.0	0.1	0.1	0.2	0.2	Np-237	0	0.0	0.1	0.1	0.2	0.3	0.4	Np-237	0	0.0	0.1	0.1	0.2	0.3	0.4	Np-237	0	0.0	0.1	0.1	0.2	0.3	0.4	
Np	0	0.0	0.0	0.1	0.1	0.2	0.2	Np	0	0.0	0.1	0.1	0.2	0.3	0.4	Np	0	0.0	0.1	0.1	0.2	0.3	0.4	Np	0	0.0	0.1	0.1	0.2	0.3	0.4	
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.1	Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.1	Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.1	
Pu-239	0	0.0	0.1	0.1	0.1	0.1	0.1	Pu-239	0	0.0	0.1	0.1	0.1	0.1	0.1	Pu-239	0	0.7	1.3	1.7	1.9	2.1	2.1	Pu-239	0	0.7	1.3	1.7	1.9	2.1	2.1	
Pu-240	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-240	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-240	0	0.0	0.1	0.2	0.3	0.4	0.5	Pu-240	0	0.0	0.1	0.2	0.3	0.4	0.5	
Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-241	0	0.0	0.0	0.1	0.2	0.3	0.4	Pu-241	0	0.0	0.0	0.1	0.2	0.3	0.4	
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-242	0	0.0	0.0	0.0	0.1	0.2	0.3	0.4	Pu-242	0	0.0	0.0	0.1	0.2	0.3	0.4
Pu	0	0.0	0.1	0.1	0.1	0.1	0.2	Pu	0	0.0	0.1	0.1	0.1	0.1	0.1	Pu	0	0.8	1.4	2.0	2.5	2.9	3.2	Pu	0	0.8	1.4	2.0	2.5	2.9	3.2	
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	Am	0	0.0	0.0	0.0	0.0	0.0	0.0	Am	0	0.0	0.0	0.0	0.0	0.0	0.0	Am	0	0.0	0.0	0.0	0.0	0.0	0.0	

Table 7. DIDO Fuel

DIDO Fuel		93% Enrichment						150 g U-235						80% Enrichment						150 g U-235											
U-235 Burnup, %	0	10	20	30	40	50	60	U-235 Burnup, %	0	10	20	30	40	50	60	U-235 Burnup, %	0	10	20	30	40	50	60	U-235 Burnup, %	0	10	20	30	40	50	60
U-235 Burned, g	0	15	30	45	60	75	90	U-235 Burned, g	0	15	30	45	60	75	90	U-235 Burned, g	0	15	30	45	60	75	90	U-235 Burned, g	0	15	30	45	60	75	90
U-234	0	0	0	0	0	0	0	U-234	0	0	0	0	0	0	0	U-234	0	0	0	0	0	0	0	U-234	0	0	0	0	0	0	0
U-235	150	135	120	105	90	75	60	U-235	150	135	120	105	90	75	60	U-235	150	135	120	105	90	75	60	U-235	150	135	120	105	90	75	60
U-236	0	2	5	7	9	12	14	U-236	0	2	5	7	9	12	14	U-236	0	2	5	7	9	12	14	U-236	0	2	5	7	9	12	14
U-238	11	11	11	11	11	11	11	U-238	11	11	11	11	11	11	11	U-238	38	37	37	37	37	37	37	U-238	38	37	37	37	37	37	37
U	161	149	136	123	110	98	85	U	188	175	162	149	136	123	110	U	188	175	162	149	136	123	110	U	188	175	162	149	136	123	110
Np-237	0	0.0	0.0	0.1	0.1	0.2	0.3	Np-237	0	0.0	0.0	0.1	0.1	0.2	0.3	Np-237	0	0.0	0.0	0.1	0.1	0.2	0.3	Np-237	0	0.0	0.0	0.1	0.1	0.2	0.3
Np	0	0.0	0.0	0.1	0.1	0.2	0.3	Np	0	0.0	0.0	0.1	0.1	0.2	0.3	Np	0	0.0	0.0	0.1	0.1	0.2	0.3	Np	0	0.0	0.0	0.1	0.1	0.2	0.3
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-239	0	0.0	0.1	0.1	0.1	0.1	0.2	Pu-239	0	0.0	0.1	0.1	0.1	0.1	0.2	Pu-239	0	0.1	0.2	0.3	0.3	0.4	0.5	Pu-239	0	0.1	0.2	0.3	0.3	0.4	0.5
Pu-240	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-240	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-240	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-240	0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0
Pu	0	0.0	0.1	0.1	0.2	0.2	0.2	Pu	0	0.0	0.1	0.1	0.2	0.2	0.2	Pu	0	0.1	0.2	0.3	0.4	0.5	0.6	Pu	0	0.1	0.2	0.3	0.4	0.5	0.6
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	Am	0	0.0	0.0	0.0	0.0	0.0	0.0	Am	0	0.0	0.0	0.0	0.0	0.0	0.0	Am	0	0.0	0.0	0.0	0.0	0.0	0.0

DIDO Fuel		60% Enrichment						150 g U-235						20% Enrichment						200 g U-235											
U-235 Burnup, %	0	10	20	30	40	50	60	U-235 Burnup, %	0	10	20	30	40	50	60	U-235 Burnup, %	0	10	20	30	40	50	60	U-235 Burnup, %	0	10	20	30	40	50	60
U-235 Burned, g	0	15	30	45	60	75	90	U-235 Burned, g	0	15	30	45	60	75	90	U-235 Burned, g	0	20	40	60	80	100	120	U-235 Burned, g	0	20	40	60	80	100	120
U-234	0	0	0	0	0	0	0	U-234	0	0	0	0	0	0	0	U-234	0	0	0	0	0	0	0	U-234	0	0	0	0	0	0	0
U-235	150	135	120	105	90	75	60	U-235	200	180	160	140	120	100	80	U-235	200	180	160	140	120	100	80	U-235	200	180	160	140	120	100	80
U-236	0	2	5	7	9	12	14	U-236	0	3	7	10	13	16	19	U-236	0	3	7	10	13	16	19	U-236	0	3	7	10	13	16	19
U-238	100	100	100	99	99	99	98	U-238	800	799	797	796	794	793	791	U-238	800	799	797	796	794	793	791	U-238	800	799	797	796	794	793	791
U	250	237	224	211	198	185	172	U	1000	982	964	946	927	908	890	U	1000	982	964	946	927	908	890	U	1000	982	964	946	927	908	890
Np-237	0	0.0	0.0	0.1	0.1	0.2	0.3	Np-237	0	0.0	0.1	0.1	0.2	0.3	0.4	Np-237	0	0.0	0.1	0.1	0.2	0.3	0.4	Np-237	0	0.0	0.1	0.1	0.2	0.3	0.4
Np	0	0.0	0.0	0.1	0.1	0.2	0.3	Np	0	0.0	0.1	0.1	0.2	0.3	0.4	Np	0	0.0	0.1	0.1	0.2	0.3	0.4	Np	0	0.0	0.1	0.1	0.2	0.3	0.4
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.1	Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.1	Pu-238	0	0.0	0.0	0.0	0.0	0.1	0.1
Pu-239	0	0.2	0.4	0.6	0.7	0.7	0.8	Pu-239	0	0.2	0.4	0.6	0.7	0.7	0.8	Pu-239	0	0.0	0.0	0.0	0.0	0.0	0.1	Pu-239	0	0.0	0.0	0.0	0.0	0.0	0.1
Pu-240	0	0.0	0.0	0.1	0.1	0.2	0.2	Pu-240	0	0.0	0.1	0.1	0.1	0.2	0.2	Pu-240	0	0.0	0.2	0.3	0.6	0.8	1.0	Pu-240	0	0.0	0.2	0.3	0.6	0.8	1.0
Pu-241	0	0.0	0.0	0.0	0.0	0.1	0.1	Pu-241	0	0.0	0.0	0.0	0.0	0.1	0.1	Pu-241	0	0.0	0.0	0.1	0.2	0.3	0.4	Pu-241	0	0.0	0.0	0.1	0.2	0.3	0.4
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.1	Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.1
Pu	0	0.2	0.5	0.7	0.8	1.0	1.1	Pu	0	0.2	0.5	0.7	0.8	1.0	1.1	Pu	0	1.2	2.2	3.1	4.0	4.7	5.3	Pu	0	1.2	2.2	3.1	4.0	4.7	5.3
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	Am	0	0.0	0.0	0.0	0.0	0.0	0.0	Am	0	0.0	0.0	0.0	0.0	0.0	0.0	Am	0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX A

MTR MODEL MASS INVENTORY SENSITIVITY

This appendix examines the sensitivity of MTR-type fuel assemblies to the number of fuel plates in the assembly as well as the fuel element specifications for the fuel, clad and coolant. An examination of many MTR-type fuel assemblies shows that the ratio of the coolant channel thickness to the fuel meat thickness, times the number of fuel plates, is nearly a constant. This constant is also proportional to the H/U-235 atom ratio which can be used to characterize the neutron spectrum in MTR-type fuel assemblies.

Figure A1 shows the H/U-235 atom ratio as a function of the U-235 mass. The upper curve are for 19-plate (0.51mm fuel, 0.38mm clad, 2.95mm coolant) elements and the lower curve are for 23-plate (0.51mm fuel, 0.38mm clad, 2.19mm coolant) elements. Most all MTR-type fuel assemblies as a function of the fuel element specifications are within the range ($\pm 6\%$) of the average H/U-235 ratio.

MTR Fuel Neutron Spectrum Characterization

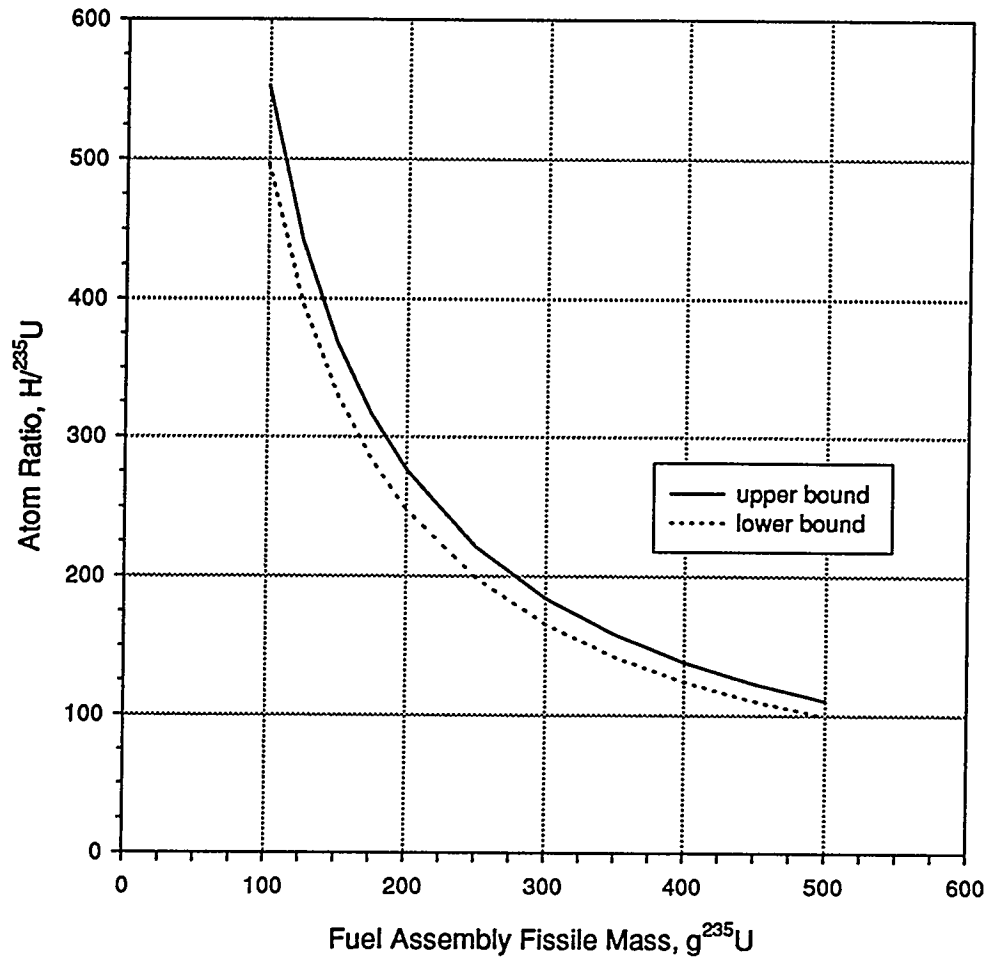


Figure A1. MTR Fuel Assembly Model Sensitivity

Tables A1–A3 show the mass inventory results for MTR fuel assembly types with 300g U-235 and 93, 45 and 19.75% U-235 enrichment. The difference between the upper and lower bound results indicate only small differences in the isotopic masses as a function of fuel element specification.

Table A1. MTR Fuel 93% Enrichment

MTR Upper Bound		93% Enrichment		300 g U-235									
U-235 Burnup, %	0	5	10	15	20	25	30	35	40	45	50	55	60
U-235 Burned, g	0	3	5	10	15	20	25	30	35	40	45	50	55
U-234	0	0	0	0	0	0	0	0	0	0	0	0	0
U-235	300	285	270	240	210	180	150	120	90	60	30	0	0
U-236	0	3	5	10	15	19	24	28	33	37	41	45	49
U-238	23	23	22	22	22	22	22	22	21	21	21	21	21
U	323	310	297	272	247	221	196	170	144	118	90	60	30
Np-237	0	0.0	0.0	0.1	0.2	0.4	0.6	0.8	1.1	1.5	1.9	2.3	2.7
Np	0	0.0	0.0	0.1	0.2	0.4	0.6	0.8	1.1	1.5	1.9	2.3	2.7
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.6
Pu-239	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
Pu-240	0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

MTR Lower Bound		93% Enrichment		300 g U-235									
U-235 Burnup, %	0	5	10	15	20	25	30	35	40	45	50	55	60
U-235 Burned, g	0	3	5	10	15	20	25	30	35	40	45	50	55
U-234	0	0	0	0	0	0	0	0	0	0	0	0	0
U-235	300	285	270	240	210	180	150	120	90	60	30	0	0
U-236	0	3	5	10	15	19	24	28	33	37	41	45	49
U-238	23	23	22	22	22	22	22	22	21	21	21	21	21
U	323	310	297	272	247	221	196	170	144	118	90	60	30
Np-237	0	0.0	0.0	0.1	0.2	0.4	0.6	0.8	1.1	1.5	1.9	2.3	2.7
Np	0	0.0	0.0	0.1	0.2	0.4	0.6	0.8	1.1	1.5	1.9	2.3	2.7
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.6
Pu-239	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
Pu-240	0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table A2. MTR Fuel 45% Enrichment

MTR Upper Bound		45% Enrichment				300 g U-235			
U-235 Burnup, %	U-235 Burned, g	0	5	10	15	20	30	40	50
U-235 Burned, g	0	0	0	0	0	0	0	0	0
U-234	0	0	0	0	0	0	0	0	0
U-235	300	285	270	240	210	180	150	120	90
U-236	0	3	5	10	15	19	24	29	33
U-238	367	366	365	364	362	361	359	357	355
U	667	654	640	614	587	560	533	505	477
Np-237	0	0.0	0.0	0.1	0.2	0.4	0.6	0.9	1.2
Np	0	0.0	0.0	0.1	0.2	0.4	0.6	0.9	1.2
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2
Pu-239	0	0.6	1.2	2.2	2.9	3.4	3.8	3.9	3.8
Pu-240	0	0.0	0.0	0.2	0.3	0.6	0.8	1.0	1.2
Pu-241	0	0.0	0.0	0.0	0.1	0.2	0.3	0.5	0.6
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2
Pu	0	0.6	1.3	2.4	3.4	4.2	5.0	5.6	6.0
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

MTR Lower Bound		45% Enrichment				300 g U-235			
U-235 Burnup, %	U-235 Burned, g	0	5	10	15	20	30	40	50
U-235 Burned, g	0	0	0	0	0	0	0	0	0
U-234	0	0	0	0	0	0	0	0	0
U-235	300	285	270	240	210	180	150	120	90
U-236	0	3	5	10	15	20	24	29	33
U-238	367	366	365	364	362	360	358	356	354
U	667	654	640	614	587	560	532	505	477
Np-237	0	0.0	0.0	0.1	0.2	0.4	0.7	0.9	1.3
Np	0	0.0	0.0	0.1	0.2	0.4	0.7	0.9	1.3
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2
Pu-239	0	0.7	1.3	2.3	3.1	3.7	4.0	4.1	4.0
Pu-240	0	0.0	0.1	0.2	0.4	0.6	0.8	1.0	1.3
Pu-241	0	0.0	0.0	0.0	0.1	0.2	0.4	0.5	0.7
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2
Pu	0	0.7	1.4	2.6	3.6	4.5	5.3	5.9	6.4
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table A3. MTR Fuel 19.75% Enrichment

MTR Upper Bound		19.75% Enrichment										300 g U-235									
U-235 Burnup, %	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
U-235 Burned, g	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
U-234	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
U-235	300	285	270	255	240	225	210	195	180	165	150	135	120	105	90	75	60	45	30	15	0
U-236	0	3	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
U-238	1219	1218	1216	1213	1210	1207	1204	1201	1198	1195	1192	1189	1186	1183	1180	1177	1174	1171	1168	1165	1162
U	1519	1505	1491	1477	1463	1449	1435	1421	1407	1393	1379	1365	1351	1337	1323	1309	1295	1281	1267	1253	1239
Np-237	0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5
Np	0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-239	0	1.3	2.6	4.7	6.3	7.5	8.3	8.7	8.7	8.7	8.3	7.5	6.3	5.0	3.7	2.4	1.1	0.0	0.0	0.0	0.0
Pu-240	0	0.0	0.1	0.4	0.7	1.2	1.7	2.2	2.7	3.2	3.7	4.2	4.7	5.2	5.7	6.2	6.7	7.2	7.7	8.2	8.7
Pu-241	0	0.0	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu	0	1.4	2.7	5.1	7.3	9.2	10.9	12.3	13.4	14.3	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

MTR Lower Bound		19.75% Enrichment										300 g U-235									
U-235 Burnup, %	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
U-235 Burned, g	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
U-234	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
U-235	300	285	270	255	240	225	210	195	180	165	150	135	120	105	90	75	60	45	30	15	0
U-236	0	3	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
U-238	1219	1217	1216	1212	1209	1205	1201	1197	1193	1189	1185	1181	1177	1173	1169	1165	1161	1157	1153	1149	1145
U	1519	1505	1491	1477	1462	1448	1433	1419	1404	1390	1375	1361	1346	1332	1317	1303	1288	1274	1259	1245	1231
Np-237	0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5
Np	0	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu-239	0	1.4	2.8	5.0	6.7	8.0	8.8	9.2	9.2	9.2	8.8	8.0	6.7	5.0	3.7	2.4	1.1	0.0	0.0	0.0	0.0
Pu-240	0	0.0	0.1	0.4	0.8	1.3	1.8	2.3	2.8	3.3	3.8	4.3	4.8	5.3	5.8	6.3	6.8	7.3	7.8	8.3	8.8
Pu-241	0	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pu	0	1.5	2.9	5.5	7.8	9.8	11.6	13.1	14.3	15.1	15.8	16.5	17.2	17.9	18.6	19.3	20.0	20.7	21.4	22.1	22.8
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX B

U-234 AND U-236 MASS INVENTORY SENSITIVITY

The initial fuel composition of some reactor fuels may contain specifications for U-234 and/or U-236 in addition to the usual specifications for U-235 and U-238. It is the purpose of this appendix to evaluate the effect that U-234 and U-236 have on the overall fuel assembly mass inventory when these isotopes are or are not included in the initial fuel assembly composition.

A comparison of the fuel mass inventory for a HEU and a LEU fuel composition, with and without initial enrichments of U-234 and U-236, are shown in Table B1. Typical enrichments of U-234 and U-236 in research reactor fuels are less than 1%; these specific data are for typical TRIGA fuel compositions.

The upper section of Table B1 shows the mass inventory for HEU and LEU fuels with initial enrichments of U-234 and U-236, and the lower section shows similar data for the same fuels but without initial U-234 and U-236 enrichment. The result of this comparison shows that to first-order, any initial mass of U-234 or U-236 can be simply added to the mass inventory for U-234, U-236 and total U at any burnup level. The mass inventory for Np-237 and Pu-238 which are also functions of the U-236 mass, are not substantially affected by an initial enrichment of U-236.

Table B1. TRIGA Fuel 25-Rod Cluster Model

TRIGA Fuel		10wt% U, 93.1% Enrichment					41.4 g U-235					TRIGA Fuel					45wt% U, 19.7% Enrichment					53.6 g U-235				
	U-235 Burnup, %	0	10	20	30	40	50	60					U-235 Burnup, %	0	10	20	30	40	50	60						
	U-235 Burned, g	0.0	4.1	8.3	12.4	16.6	20.7	24.8					U-235 Burned, g	0.0	5.4	10.7	16.1	21.4	26.8	32.2						
U-234	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3					U-234	0.4	0.4	0.4	0.3	0.3	0.3	0.3						
U-235	41.4	37.2	33.1	29.0	24.8	20.7	16.6	16.6					U-235	53.6	48.3	42.9	37.5	32.2	26.8	21.4						
U-236	0.2	1.0	1.7	2.4	3.1	3.8	4.4	4.4					U-236	0.7	1.7	2.7	3.7	4.6	5.5	6.4						
U-238	2.4	2.4	2.4	2.3	2.3	2.2	2.2	2.2					U-238	217.4	216.5	215.6	214.6	213.5	212.3	210.9						
U	44.5	41.0	37.6	34.1	30.6	27.1	23.5	23.5					U	272.1	266.9	261.6	256.1	250.6	244.9	239.0						
Np-237	0	0.0	0.0	0.1	0.1	0.1	0.2	0.2					Np-237	0	0.0	0.1	0.1	0.2	0.3	0.4						
Np	0	0.0	0.0	0.1	0.1	0.1	0.2	0.2					Np	0	0.0	0.1	0.1	0.2	0.3	0.4						
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					Pu-238	0	0.0	0.0	0.0	0.0	0.1	0.1						
Pu-239	0	0.0	0.1	0.1	0.1	0.1	0.1	0.1					Pu-239	0	0.7	1.3	1.7	1.9	2.1	2.1						
Pu-240	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					Pu-240	0	0.0	0.1	0.2	0.3	0.4	0.5						
Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					Pu-241	0	0.0	0.0	0.1	0.2	0.3	0.4						
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					Pu-242	0	0.0	0.0	0.0	0.0	0.1	0.1						
Pu	0	0.0	0.1	0.1	0.1	0.1	0.1	0.2					Pu	0	0.8	1.4	2.0	2.5	2.9	3.2						
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0						
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					Am	0	0.0	0.0	0.0	0.0	0.0	0.0						

TRIGA Fuel		10wt% U, 93.1% Enrichment					41.4 g U-235					TRIGA Fuel		45wt% U, 19.7% Enrichment					53.6 g U-235				
	U-235 Burnup, %	0	10	20	30	40	50	60					U-235 Burnup, %	0	10	20	30	40	50	60			
	U-235 Burned, g	0.0	4.1	8.3	12.4	16.6	20.7	24.8					U-235 Burned, g	0.0	5.4	10.7	16.1	21.4	26.8	32.2			
U-234	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					U-234	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
U-235	41.4	37.2	33.1	29.0	24.8	20.7	16.6	16.6					U-235	53.6	48.3	42.9	37.5	32.2	26.8	21.4			
U-236	0.0	0.8	1.5	2.3	2.9	3.6	4.2	4.2					U-236	0.0	1.1	2.1	3.1	4.0	4.9	5.7			
U-238	2.4	2.4	2.4	2.3	2.3	2.2	2.2	2.2					U-238	217.4	216.5	215.6	214.6	213.5	212.3	211.0			
U	43.8	40.4	37.0	33.5	30.1	26.5	23.0	23.0					U	271.1	265.9	260.6	255.2	249.7	244.0	238.1			
Np-237	0	0.0	0.0	0.1	0.1	0.1	0.1	0.2					Np-237	0	0.0	0.0	0.1	0.2	0.2	0.3			
Np	0	0.0	0.0	0.1	0.1	0.1	0.1	0.2					Np	0	0.0	0.0	0.1	0.2	0.2	0.3			
Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					Pu-238	0	0.0	0.0	0.0	0.0	0.0	0.1			
Pu-239	0	0.0	0.1	0.1	0.1	0.1	0.1	0.1					Pu-239	0	0.7	1.3	1.7	1.9	2.1	2.1			
Pu-240	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					Pu-240	0	0.0	0.1	0.2	0.3	0.4	0.5			
Pu-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					Pu-241	0	0.0	0.0	0.1	0.2	0.3	0.4			
Pu-242	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					Pu-242	0	0.0	0.0	0.0	0.0	0.1	0.1			
Pu	0	0.0	0.1	0.1	0.1	0.1	0.1	0.2					Pu	0	0.8	1.4	2.0	2.5	2.9	3.2			
Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					Am-241	0	0.0	0.0	0.0	0.0	0.0	0.0			
Am	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					Am	0	0.0	0.0	0.0	0.0	0.0	0.0			