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MCC
Materials Characterization Center

Characterization of Spent Fuel Approved Testing Material—ATM-104

December 1991

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

PNL-5109-104

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CHARACTERIZATION OF SPENT FUEL APPROVED TESTING MATERIAL--ATM-104

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PWR

ABSTRACT

The characterization data obtained to date are described for Approved Testing Material 104 (ATM-104), which is spent fuel from Assembly D047 of the Calvert Cliffs Nuclear Power Plant (Unit 1), a pressurized-water reactor. This report is one in a series being prepared by the Materials Characterization Center at Pacific Northwest Laboratory (PNL) on spent fuel ATMs. The ATMs are receiving extensive examinations to provide a source of well-characterized spent fuel for testing in the U.S. Department of Energy Office of Civilian Radioactive Waste Management (OCRWM) Program. ATM-104 consists of 128 full-length irradiated fuel rods with rod-average burnups of about 42 MWd/kgM and expected fission gas release of about 1%.

A variety of analyses were performed to investigate cladding characteristics, radionuclide inventory, and redistribution of fission products. Characterization data include 1) fabricated fuel design, irradiation history, and subsequent storage and handling history; 2) isotopic gamma scans; 3) fission gas analyses; 4) ceramography of the fuel and metallography of the cladding; 5) special fuel studies involving analytical transmission electron microscopy (AEM) and electron probe microanalyses (EPMA); 6) calculated nuclide inventories and radioactivities in the fuel and cladding; and 7) radiochemical analyses of the fuel and cladding.

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ACKNOWLEDGMENTS

The characterization of ATM-104 fuel was achieved through the efforts of a large number of people. The authors extend their appreciation to the following individuals who provided valuable assistance in making this report possible.

Assistance with startup and initial operation of the gamma scanning system was provided by M. L. Elliott and R. W. Goles. R. S. Holeman and L. J. Dunn conducted the in-cell fuel rod gamma scanning, fission gas sampling, and fuel rod sectioning operations. N. J. Wildung provided the graphics for the gamma scan and radiochemical data. C. E. Clement verified calculations and reviewed analytical results for correctness in the report.

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ACRONYMS

AEM	analytical transmission electron microscopy
ATM-104	Approved Testing Material 104
BG&E	Baltimore Gas and Electric
BOL	beginning-of-life
BWR	boiling water reactors
CC-1	Calvert Cliffs No. 1
C-E	Combustion Engineering
DOE	U.S. Department of Energy
EDS	energy-dispersive X-ray spectrometry
EOL	end-of-life
EPA	Environmental Protection Agency
EPMA	electron probe microanalyses
LHGRs	linear heat generation rates
LWR	light water reactor
MCC	Materials Characterization Center
NRC	Nuclear Regulatory Commission
OCRWM	Office of Civilian Radioactive Waste Management
ORNL	Oak Ridge National Laboratory
PNL	Pacific Northwest Laboratory
PWR	pressurized-water reactor
PWRU	ORIGEN2 PWR Cross-section Libraries moderate burnup
PWRUD50	ORIGEN2 PWR Cross-section Libraries high burnup
RSIC	Radiation Shielding Information Center
SSMS	spark-source mass spectrometry
STP	standard temperature and pressure
YMP	Yucca Mountain Site Characterization Project

KEY WORD DEFINITIONS

Burnup: a) the process of fuel being consumed by fissioning; b) the amount of energy obtained from the fuel as the fuel fissions, which is expressed as the amount of energy produced per unit of fuel weight, such as MWd/kgM, or the percentage of fissile atoms consumed during irradiation, atom% (at%)

Fission Gas Release: a) the process of fission gas (xenon and krypton) being released from the fuel matrix to the void spaces (pores, plenum, etc.) within the fuel rod; b) the amount of fission gas that has been released as a percentage of the amount of fission gas produced in the fuel at a given point in time.

Linear Heat Generation Rate: the amount of energy produced in a unit length of the fuel rod, kW/m (kW/ft).

Power Density: the amount of energy produced per unit volume of fuel, W/g

1.0 INTRODUCTION

The Materials Characterization Center (MCC) at Pacific Northwest Laboratory (PNL)[a] has the responsibility to provide spent fuel test material (samples) for laboratory investigations of nuclear waste forms by the U.S. Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM) Program. This MCC reference report describes the characterization of Approved Testing Material 104 (ATM-104), one of six spent fuel ATMs that are being characterized. The first four reports in the series are on ATM-101 (Barner 1985), ATM-103 (Guenther et al. 1988a), ATM-105 (Guenther et al. 1991), and ATM-106 (Guenther et al. 1988b). General descriptions of the six spent fuel ATMs presently being characterized by the MCC are provided in Table 1.1. Additional spent fuel with burnable poisons, rods from newer high-burnup designs, and rods with stainless steel cladding are being considered as future ATMs.

ATM-104 has UO_2-fueled rods that achieved moderately high burnups of about 42 MWd/kgM. These rods were expected to have only minor fission gas release from the UO_2 fuel during irradiation. The fuel rods were fabricated by Combustion Engineering (C-E) and irradiated in the Calvert Cliffs No. 1 (CC-1) pressurized water reactor (PWR), which is operated by Baltimore Gas and Electric (BG&E) in Maryland. ATM-104 consists of 128 full-length fuel rods from Assembly D047. Of the original 176 rods irradiated in Assembly D047, 41 rods were removed for other uses by BG&E. The remaining 135 rods were received by the MCC, but insufficient data was available on the fuel fabrication specifications of seven of the rods to include them as part of ATM-104.

The MCC spent fuel ATMS were selected to represent the typical end-of-life (EOL) fuel conditions, potential extremes in EOL spent fuel conditions, or differences between PWR and BWR spent fuel from United States commercial nuclear reactors. The ATM-104 spent fuel, with moderately high burnup and low fission gas release, is representative of one type of spent fuel condition for

(a) Operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

TABLE 1.1. Summary of Spent Fuel ATMs Being Characterized by the MCC

ATM	Fuel Type	Reactor	Burnup Range, MWd/kgM(a)	Range of Fission Gas Release, %(a)	No. of Rods
101	PWR	H. B. Robinson, No. 1	16-32	0.2-0.3	9 as 27 1.2-m (4-ft) segments
103	PWR	Calvert Cliffs, No. 1	13-33	0.25	176 full length
104	PWR	Calvert Cliffs, No. 1	20-44	0.4-1.1	128 full length
105	BWR	Cooper	18-34	0.6-7.9	88 full length
106	PWR	Calvert Cliffs, No. 1	27-47	7.8-18	20 full length
108	BWR	Cooper	~12-28 (estimated)	~9 (estimated)	10 full length

(a) Measured in the fuel rods examined to date. These ranges may expand as more rods are examined.

PWR reactors operating in the United States. ATM-104 fuel has higher burnups than accumulated in ATMs 101 and 103, but the rods from all three ATMs had low fission gas release from the fuel. The examination of fuel with burnups over 40 MWD/kgM, such as in ATM-104, is important because discharge burnup has been increased over the years and will be even higher in the future (Andrews and Lobre 1988).

Characterization of the moderate burnup fuel from ATM-105 will provide data for one type of spent fuel condition for boiling water reactors (BWR) operating in the United States. These data will also be useful for comparing any differences between the conditions of irradiated PWR and BWR fuel rods. ATM-106 (moderately high burnup, high fission gas release) will provide characterization data on spent fuel where operating conditions have caused significant changes in the fuel condition, such as fuel grain growth and redistribution of volatile fission products.

This report describes the characterizations completed to date for Rods MKP028, MKP059, MKP063, MKP070, MKP106, and MKP109 of ATM-104. Rod MKP109 is the only ATM-104 rod for which detailed destructive examinations are available. All of the characterizations have been conducted at DOE's Hanford Site near Richland, Washington. A portion of an ATM-104 characterized fuel rod has been made available to the Yucca Mountain Site Characterization Project (YMP) for spent fuel testing. Additional quantities of ATM-104 are available for distribution to experimenters.

This report presents the results of the characterization of ATM-104 spent fuel including fuel rod and assembly designs, the irradiation history, postirradiation handling and transportation, and a variety of destructive and nondestructive examinations conducted on Rod MKP109 from ATM-104. Information is provided in Section 3.0 on the fabricated fuel design, irradiation histories, and subsequent storage and handling of the 128 fuel rods in Assembly D047 that comprise ATM-104. A characterization plan was developed for all of the MCC ATMs (Barner 1984) and is described in Section 4.0 with specific emphasis on the characterizations planned for ATM-104. Calculated nuclide inventories and radioactivities in the fuel and cladding are discussed in Section 5.0 for later comparison with measured inventories in the fuel and cladding.

The examinations conducted on Rod MKP109 include gamma scanning, fission gas analyses, ceramography of the fuel, metallography of the cladding, electron probe microanalyses (EPMA) of the fuel, analytical transmission electron microscopy of the fuel (AEM), fuel burnup analysis, and radiochemical analyses of the fuel and cladding. Cladding characteristics, including radiochemical analyses and metallographic examinations, are discussed in Section 6.0. The fuel burnup, bulk-average inventory of fission products and actinides in the fuel, and their distribution across the fuel radius are discussed in Section 7.0. Data from fission gas analyses, fuel ceramography, radiochemistry, and AEM are drawn upon in Section 8.0 to define the extent of fission product redistribution and how it compares with other spent fuel ATMs.

2.0 SUMMARY AND CONCLUSIONS

Representative fuel rods from ATM-104 were selected for characterization with the expectation that this fuel achieved a moderately high burnup of 42 MWd/kgM (assembly average) and fission gas release from the fuel of about one percent (rod average). This level of burnup is now considered moderately high because utilities are extending burnups to 50 to 55 MWd/kgM in future discharged fuel compared with typical past burnups of 25 to 35 MWd/kgM. Burnup is an ATM selection criteria because fission product and actinide inventories in the fuel are proportional to burnup. Other characteristics, such as the inventory of ^{14}C, maximum cladding oxide thickness, and cladding hydriding, are also related to burnup. Fission gas release is a major criteria for selecting spent fuel ATMs because the amount of fission gas release is indicative of the microstructural changes and the amount of redistribution of fission products in the fuel. Other experimenters have related the initial release of cesium and other volatile fission products during leach testing to fission gas release.

Based on the examinations conducted on the ATM-104 fuel rods and comparison with previous results for other ATMs, the following major conclusions can be made regarding fuel burnup and characteristics related to fuel burnup:

- ATM-104 does have moderately high burnup. For Rod MKP109, the rod-average burnup was 39.6 MWd/kgM, which is 2.0% lower than predicted by C-E. The pellet-average burnup in the peak-power region was 44.3 MWd/kgM. Comparison of measured fuel burnups and gamma scan data indicate that other ATM-104 rods had comparable burnups. EPMA of fuel from the peak-power region of Rod MKP109 indicated that the burnup increased from ~42 MWd/kgM at the pellet center to ~70 MWd/kgM at the fuel edge. (See Sections 7.1 and 7.3.2.)
- The inventory of radionuclides measured in the fuel is a function of fuel burnup, as expected. Measured values for ^{243}Cm plus 244Cm, ^{135}Cs, ^{137}Cs, ^{90}Sr, ^{99}Tc, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Am, ^{241}Pu, ^{242}Pu, ^{234}U, ^{235}U, ^{236}U, and ^{238}U agreed within about $\pm$10% of the ORIGEN2 predictions. The ^{79}Se and ^{126}Sn measured values were about 15% and

22% of their respective values predicted by ORIGEN2; similar results were obtained for fuel from all of the MCC ATMs. (See Sections 7.1 and 7.2.)

- The ^{14}C inventory in the fuel rod increases with burnup and initial nitrogen content. There are insignificant amounts of ^{14}C in the gas, while about 75% of the ^{14}C inventory in the rod is contained in the fuel with the balance in the cladding. Based on these results from PWR and BWR rods with 15 to 44 MWd/kgM burnup, it is possible to estimate the upper bound for the ^{14}C inventory in the fuel and cladding from a range of fuel types. (See Sections 6.1.2, 7.2, and 8.1.1.)

- The maximum oxide thicknesses on the exterior surfaces of cladding from ATMs 103, 104, and 106 are in agreement with extensive data for other C-E rods with equivalent or higher burnups. The oxide thickness on the exterior surface of the cladding increased from 2 to 4 μm at the bottom of Rod MKP109 to a maximum of 21 μm near the top of the rod, which is consistent with the coolant and fuel operating temperatures. In comparison to the other ATMs, the oxide thickness is reasonably consistent with exposure times. (See Section 6.2.1.)

- The hydriding and hydrogen content of the cladding followed the trend of measured oxide thicknesses. Photomicrography indicated that the number of circumferentially oriented hydrides in cladding increased from the bottom to the top of fuel rods. The hydrogen level was found to vary linearly with oxide thickness, as expected, and peaked at about 120 ppm, which is well below potential levels in high burnups fuels. Given sufficient data, the linear relationship between hydrogen content and oxide thickness could be used to relate hydrogen content to burnup. (See Sections 6.1.3 and 6.2.1.)

- The radial distributions of fission products and actinides in ATM-104 were typical of spent fuel with moderately high burnup and low fission gas release based on comparisons with ATM-103 (moderate burnup, low fission gas release), ATM-106 (moderately high burnup, high fission gas release), and data for other fuels. Autoradiography indicated preferential production of alpha-emitting material near the fuel edge and no redistribution of volatile fission products. EPMA indicated that the concentrations of neodymium, plutonium, americium, cesium, and ruthenium were all relatively constant across the fuel radius to within a few hundred micrometers of the fuel edge, after which the concentrations increased in concert with the variation in local burnup across the fuel radius. Iodine was below detection limits, and technetium was relatively constant except for a possible decrease near the fuel edge. Uranium concentrations decreased near the fuel edge inversely proportional to the change in burnup across the fuel pellet. (See Section 7.3.2.)

- Xenon concentrations determined by EPMA appeared to decrease near the fuel edge, contrary to the burnup profile. This decrease in xenon concentration was similar to that for ATM-106 fuel with burnups comparable to ATM-104. On the other hand, xenon levels increased near the edge of ATM-103 fuel with 33 MWd/kgM burnup. The region with an apparent loss of xenon includes fuel with a high density of 1- to 2-μm pores. These results are consistent with work by other experimenters who attributed enhanced fission gas release in fuels with burnups above 40 MWd/kgM to gas release from the porous fuel rim. (See Section 7.3.2.)

Similarly, based on the examinations conducted on the ATM-104 fuel rods, the following major conclusions can be made regarding fission gas release and characteristics related to fission gas release:

- As expected, ATM-104 fuel does have low fission gas release. The fission gas releases ranged from 0.38 to 1.1% for three ATM-104 rods. Gas analyses for three other rods indicated comparable releases of xenon and krypton. Based on EPMA, xenon concentrations were nearly constant and equivalent to expected levels across the center of ATM-104 fuel, indicating minimal fission gas release. (See Sections 8.1.2 and 7.3.2.)

- The xenon/krypton ratios determined for gas samples from the ATM-104 rods tend to support the decrease in xenon from the porous rim of the fuel observed by EPMA. The xenon/krypton ratios of gas samples averaged 11.4 for the six ATM-104 rods compared with a predicted ratio of 9.9. Because the xenon/krypton ratios from plutonium fissions are about twice that from uranium fissions, release of fission gas from the porous rim where more plutonium fissions occur would cause higher than expected xenon/krypton ratios in rods with little gas release from the fuel center. (See Section 8.1.1.)

- The microstructures of the ATM-104 fuel were typical of fuel with low fission gas release. Fuel grain growth, the amount by which the grains grow, was 30% or less in the peak-power region. Only a few grain boundary bubbles characteristic of fission gas were observed in the center of peak-power pellets and metallic ingots were too small to be seen by optical microscopy. (See Sections 8.2.1 and 8.2.2.)

- The amount of cesium and iodine deposited on the interior surface of the cladding can be related to the maximum fuel grain growth in the fuel or the rod-average fission gas release. The preferential release of cesium and iodine observed during leach tests on spent fuel have been related by other experimenters to the rod-average fission gas release. Examination of MCC fuels indicates that the cesium and iodine inventories deposited on the cladding interior surface approach a 1:1 relationship with fission gas release at higher release levels. Leach testing of spent fuel will be necessary to determine how much of the gap inventory comes from cesium and iodine deposited on the interior surface of the cladding. (See Section 8.3.2.)

- Except for molybdenum, ruthenium, technetium, rhodium, and palladium in the metallic ϵ-phase and the fission gases xenon and krypton, the fission products remain finely dispersed in the UO_2 matrix. AEM on ATM-104 and other fuels with low fission gas release has consistently indicated this absence of detectable fission product aggregates other than the ϵ-phase and xenon plus krypton. As in the other ATMs with low fission gas release, some of the xenon and krypton near the fuel center is concentrated under high local pressure at large ϵ-phase particles. Particle size generally increases toward the fuel center from the fuel edge and very small bubbles appear to form on the grain boundaries at the fuel mid-radius. (See Section 8.4.2.)

3.0 FABRICATION, IRRADIATION, AND HANDLING HISTORY FOR ATM-104

The characteristics of spent fuel prior to emplacement in a geologic repository are determined by the combined effects of fuel rod design, fabrication, irradiation, handling, and decay time. During the fabrication of the fuel rods, the cladding and fuel materials are selected, cladding dimensions and fuel enrichments are established, and concentrations of impurity elements such as nitrogen are set. During irradiation, the fuel assemblies are repositioned within the reactor core to maximize fuel burnup and operating conditions. Operating power during the life of the fuel determines the final burnup and inventory of actinides, fission products, and activation products. During irradiation, fuel temperatures and fission gas release combine to define the as-irradiated characteristics of the fuel rods, such as fuel grain growth and redistribution of volatile fission products. After irradiation, spent fuel is typically stored in water pools at the reactor site with generally benign effects on the spent fuel rods (Van Luik et al. 1987). Some spent fuel is scheduled for dry storage or other post-irradiation activities, such as shipment to interim storage facilities. The handling operations conducted on the spent fuel assemblies can affect the integrity of the cladding, although the frequency of significant occurrences has been low (Bailey and Johnson 1983). The remainder of this section describes the fabrication data for ATM-104 fuel rods and their irradiation and handling history as provided by C-E to the MCC.

3.1 ASSEMBLY AND FUEL ROD DESCRIPTIONS

ATM-104 consists of part of one fuel assembly (D047) that was fabricated by C-E and irradiated during four cycles in the CC-1 PWR operated by BG&E near Lusby, Maryland. The assembly was fabricated in the mid 1970s and irradiated from March of 1977 until it was discharged from the reactor in April 1982. The fuel assembly was transported from the reactor cooling basin to PNL in September 1985.

Assembly D047 is a standard C-E 14 x 14 fuel assembly that contained 176 fuel rods during irradiation. The fuel assembly is constructed with five guide tubes, upper and lower end fittings, and eight spacer grids to form a structural cage to support the fuel rods (Figure 3.1). All structural components except the lower Inconel grid and the stainless steel upper and lower end fittings are fabricated from Zircaloy-4.

The 176 fuel rods in the standard 14 x 14 fuel assembly rest on the flow plate, which is part of the lower end fitting. Zircaloy-4 grid strips with integral springs align the rods with each other and provide axial, lateral, and rotational restraint against fuel rod motion during operation. Combustion Engineering's standard fuel assembly is reconstitutable. Any or all fuel rods can be easily removed and replaced using the proper remote handling tools.

The ATM-104 fuel rod and pellet dimensions are shown in Figure 3.2. The pellets have the same geometric design as that used for the ATM-103 fuel, which achieved moderate burnup (Guenther et al. 1988a). The fuel pellets in the ATM-104 rods are about two thirds the length of the pellets in ATM-106 rods, which achieved comparable EOL burnups but had higher fission gas release than the ATM-104 rods (Guenther et al. 1988b). The fuel pellet certification data for Assembly D047 are provided in Table 3.1. All of the fuel pellets were fabricated using a standard cold-pressing and sintering process. The 128 ATM-104 rods were fabricated from Fuel Lot B-71-GB; the seven rods not included in ATM-104 (NBD005, NBD067, NBD112, AHS040, AHS044, AHS060, and AHS077) were made from other fuel lots and will not be used for testing.

All ATM-104 rods are clad with Zircaloy-4 tubing (Lot Numbers 5GD12, 5GD31, and 5FP65) fabricated by Sandvik Special Metals. Cladding certification data are listed in Table 3.2.

In fabricating the fuel rods, the pellet stacks were laid out on a V-trough. The stacks were weighed and the stack lengths measured. The pellet stacks were then dried in a vacuum furnace and cooled in a flowing helium atmosphere. An Al_2O_3 spacer was added to each stack at the top and bottom, and the stacks were loaded into the Zircaloy-4 tubes with bottom end caps already welded on. The tubes were then closed with temporary caps to minimize exposure to the environment prior to welding the upper end caps. The

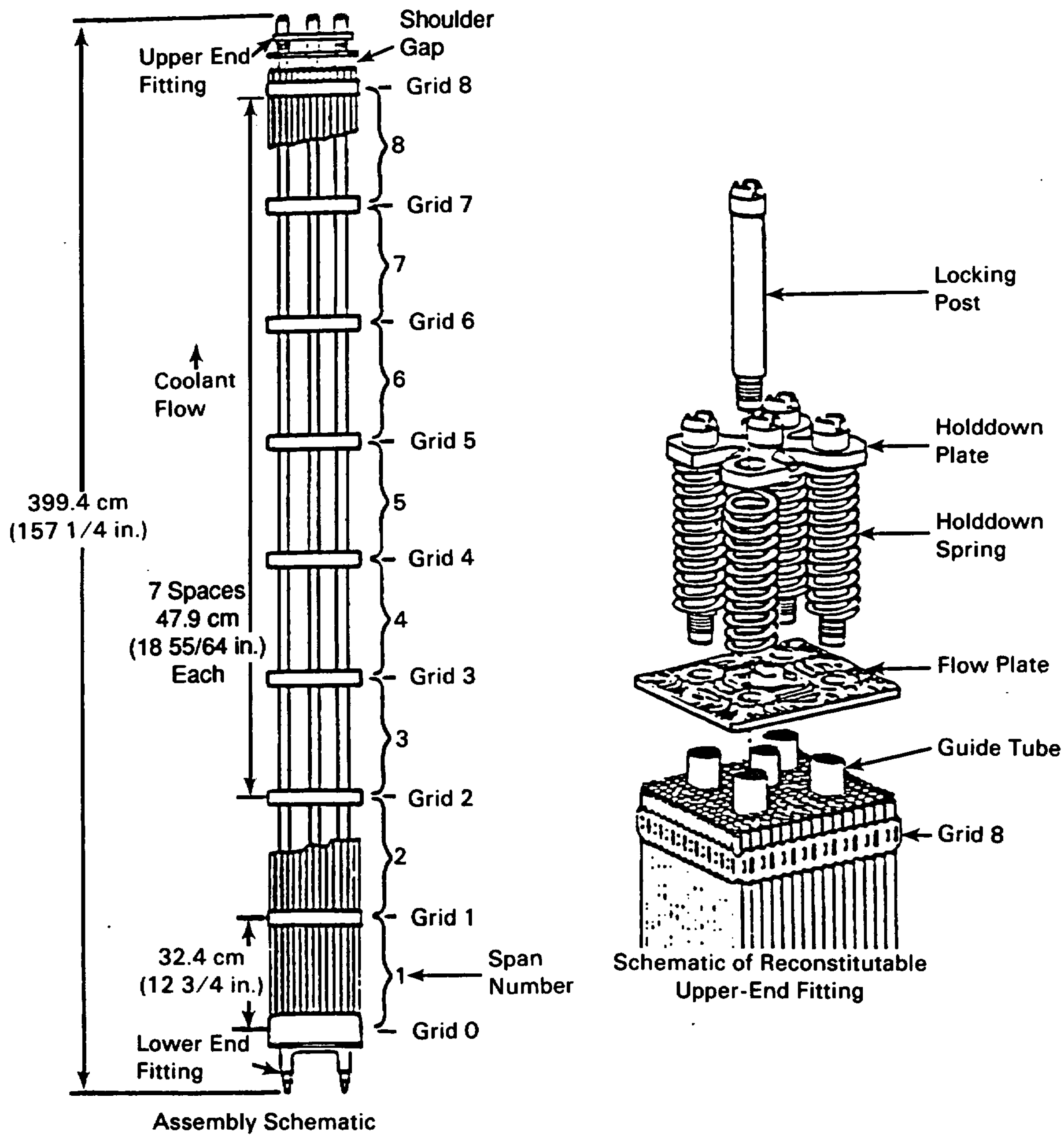


FIGURE 3.1. Combustion Engineering 14 x 14 Fuel Assembly Schematic

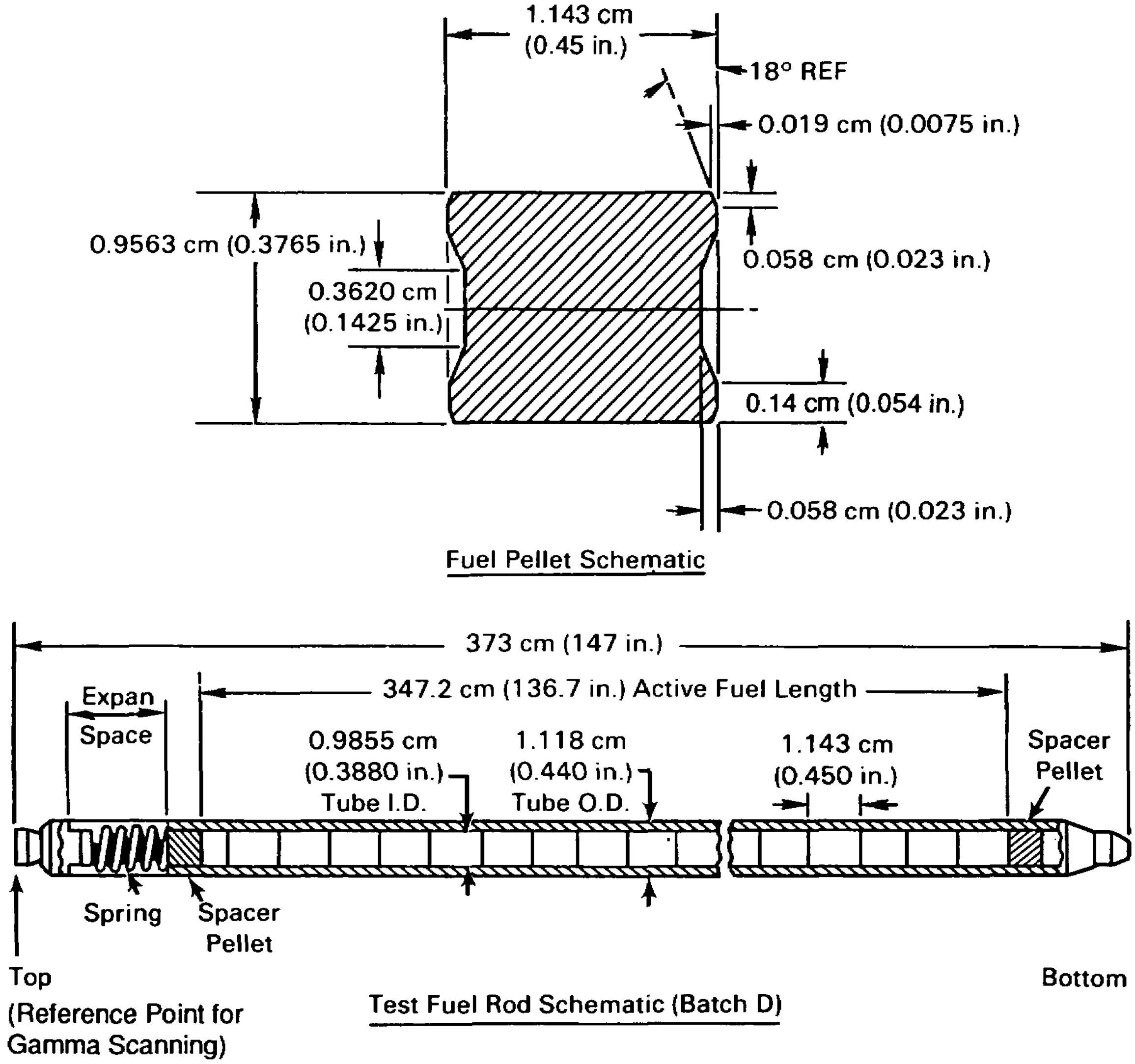


FIGURE 3.2. ATM-104 Pellet and Fuel Rod Dimensions

TABLE 3.1. ATM-104 Fuel Pellet Certification Data

Chemical Attribute	Fuel Lot B-71-GB Analysis Results			
Total uranium, wt%	88.15	88.148	88.146	88.129
Carbon, ppm	23	22	15	<10
Nitrogen, ppm	21	14	34	24
Fluorine, ppm	<5	<5	<5	<5
Chlorine & fluorine, ppm	<10	<10	<10	<10
Iron, ppm	<45	<45	<45	<45
Silver, ppm	<1	<1	<1	<1
Calcium, ppm; Aluminum, ppm; Silicon, ppm	<97	<115	<115	<115
O:U ratio	2.000	2.000	2.000	2.003
Nickel, ppm	<25	<25	<25	<25
Mass spec. analysis	3.038 wt% U-235			
Density	10.36-10.48 g/cm^3			
Grain size	≥5 μm			

plenum springs and permanent upper end caps were inserted, the rods were pressurized with helium to 3.1 MPa (450 psi), and the end caps were welded into place. The end cap welds were made using a magnetic force welding machine, which provides for pressurizing the rods to the required level.

In July 1985, some rods were removed from Assembly D047 at the reactor pool and rods from another assembly were inserted before Assembly D047 was shipped to PNL. Forty-one of the 176 original rods were removed; and 20 rods selected from Assembly BT03 were inserted into 20 of the vacancies in Assembly D047. The 20 rods from Assembly BT03 compose ATM-106 and were put in Assembly D047 only to facilitate their shipment to PNL. Characterization data reported to date on ATM-106 is described by Guenther et al. (1988b). The locations of the ATM-104 rods, as shipped to PNL, are shown in Figure 3.3; the locations of

TABLE 3.2. ATM-104 Fuel Rod Cladding Certification Data

Fuel Assembly: D047	ROD LOT: MKN CLADDING LOT: 5GD12		ROD LOT: MKN/MKP CLADDING LOT: 5GD31		ROD LOT: MKP CLADDING LOT: 5FP65	
<u>Tensile Properties</u>						
Room UTS, psi	101300	102500	100900	102200	102000	98700
0.2% YS, psi	75200	75600	74100	75800	76400	74400
Elong. 2 in., %	24	24	18	24	26	26
750°F UTS, psi	54800	54400	54700	55300	57700	53200
0.2% YS, psi	41100	39200	41100	44500	40600	40200
Elong. 2 in., %	29	28	29	28	26	31
<u>Burst Test</u> (closed end with mandrel at room temperature)						
Pressure, psi	17800	17700	17900	18000	17800	17400
Circ. Elong., %	19	24	15	13	13	22
<u>Hydride Orientation</u>						
OD	0.16	0.05	0.03	0.02	0.06	0.05
Fn Mid	0.01	0.04	0.02	0.05	0.07	0.10
ID	0.02	0.03	0.03	0.01	0.03	0.00

<u>Corrosion Test</u> (3 day, 750°F steam)

	Etched			Etched			Etched		
Sample wt/dm^2	14.9	15.6		16.6	16		12.9	13.3	
Color	Lustrous Black			Lustrous Black			Lustrous Black		
Std. wt/dm^2	15.5	15.8	15.2	14.9	15.2	16.4	15.6	15.9	12.9
Std. No.	C423(T)	C437(C)	C458(B)	C407(T)	C416(C)	C448(B)	C312(T)	C348(C)	C371(B)
	Unetched			Unetched			Unetched		
Sample wt/dm^2	18.8	17.1		17.6	18.8		17.3	16.7	
Color	Slightly gray			Slightly gray			Slightly gray		

<u>Chemical Analysis</u>, ppm						
Hydrogen	13	13	17	16	11	11
Nitrogen	25	22	30	32	20	20
Oxygen	1135	1195	1200	1210	1100	1150
Carbon	102	119	102	102	125	142
<u>Grain Size</u>						
Long. ASTM	12	12	11	12	12.5	12
Trans. ASTM	12	12	11	12	12	12.5
Recrystallization Data	1100°F, 45 min		1100°F, 45 min		1100°F, 45 min	
<u>Surface Roughness</u>						
OD, RMS, microinch	18	18	18	20	18	18
ID, RMS, microinch	16	17	17	22	18	18

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	MKP 033	MKP 030	MKP 061	MKP 007	MKP 034	MKP 043	MKP 081	MKP 039	MKP 067	MKP 080	MKP 079	MKP 092		MKP 029
B	MKP 047	MKP 051	MKP 032	MKP 017	MKP 073		MKP 063	MKP 106		MKP 118	MKP 116	MKP 005	MKP 124	
C	MKN 011	MKN 160			MKP 119	MKN 047	MKP 109	MKP 054	MKP 056	MKP 112				MKP 025
D	MKN 002	MKP 001			MKP 042	MKN 033	MKP 070	MKP 087	MKP 045	MKP 108			MKP 090	
E	MKN 150	MKP 019	MKP 014	MKN 104	MKP 110	MKP 150	MKP 083	MKP 103	MKP 026	MKP 077		MKP 115		MKP 048
F	MKN 139		MKP 018	NBD 112	MKP 057	MKP 060	MKP 059	MKP 068	MKP 101	MKP 096	NBD 067			
G	MKP 003	MKN 073	MKP 013	MKP 072	MKP 050	MKP 020			MKP 069	MKP 100		MKP 120		MKP 028
H	MKN 153	MKP 021	MKP 046	MKP 075	MKP 015	MKP 011			MKP 093		MKP 125	NBD 005	MKP 044	
I	MKP 002	AHS 040	MKP 035	AHS 044	MKP 008	MKP 041	MKP 038	MKP 058	MKP 104	MKP 111	AHS 040	MKP 121	MKP 005	MKP 053
J	MKP 076	MKP 071	MKP 009	MKP 036	MKP 004	MKP 010	MKP 086	MKP 126	MKP 085		MKP 102		MKP 127	
K	MKP 037	MKP 040				MKP 062		MKP 117	AHS 077	MKP 105				MKP 024
L	MKP 184				MKP 022		MKP 052		MKP 084				MKP 082	
M		MKP 016		MKP 031				MKP 065	AHS 060	MKP 074		MKP 122		MKP 012
N	MKN 169		MKP 023		MKP 078		MKP 064		MKP 107		MKP 091		MKP 099	

R9004195.1

FIGURE 3.3. Locations of 128 ATM-104 Rods in Assembly D047 (characterized rods denoted in highlighted boxes)

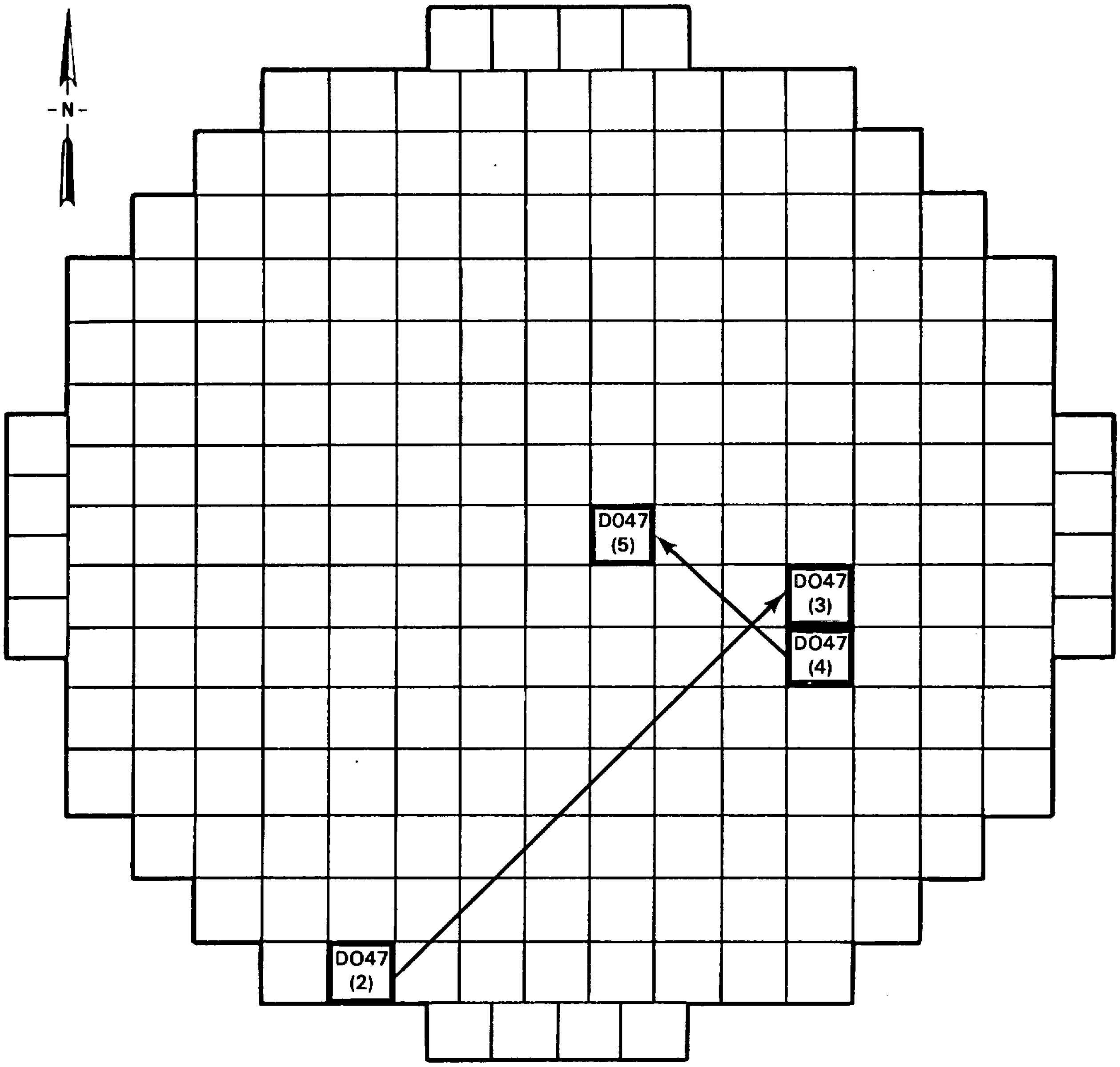
the seven rods not used for ATM-104 from Assembly D047 are also shown. Rod MKP109, the first ATM-104 rod to receive detailed characterization, was located at position C7 approximately equidistant from three guide tube holes and a fuel assembly edge.

3.2 IRRADIATION AND HANDLING HISTORY

The position of Assembly D047 in the core of CC-1 during each cycle of irradiation is shown in Figure 3.4. Assembly D047 was irradiated in Cycles 2, 3, 4, and 5 of operation of CC-1 between March 22, 1977, and April 17, 1982 (Figure 3.5). The core thermal power rating at CC-1 was 2560 MWt from beginning-of-life (BOL) until midway through Cycle 2 (September 9, 1977), when a new license was issued to increase the power rating to 2700 MWt. Except for a period of about 5 months at reduced power during reactor Cycle 4, the reactor operated at essentially full power during Cycles 2, 3, 4, and 5.

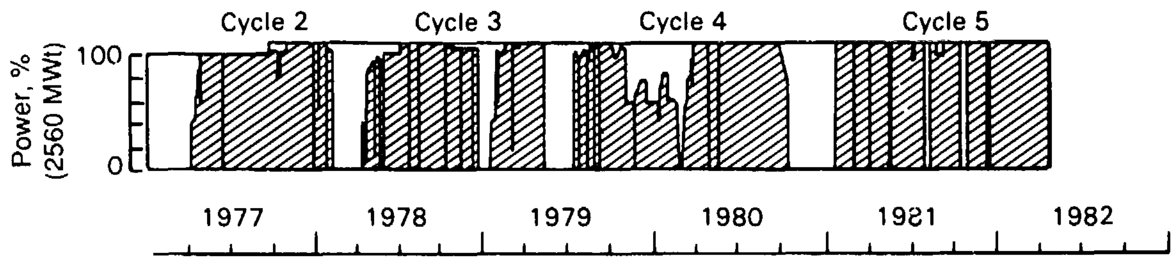
The CC-1 reactor contains a total of 217 fuel assemblies. The linear heat generation rates (LHGRs) given in Figure 3.5 are average values for the entire core. The LHGRs for specific rods vary significantly from core-average LHGRs. This is a typical effect of loading fresh fuel at the beginning of each cycle and moving the fuel assemblies to different core locations to optimally utilize the fissile fuel and maintain the required power distribution across the reactor core. As an example, the core-average LHGR was relatively constant at about 20.3 kW/m (6.2 kW/ft) during Cycles 2, 3, 4, and 5. In comparison with the core-average LHGRs, the steady-state, average LHGR for Rod MKP104 decreased from a high of about 24.1 kW/m (7.4 kW/ft) at the beginning of Cycle 2 to a low of about 15.4 kW/m (4 kW/ft) at the end of Cycle 5. Rod MKP104 (cell I9 in Figure 3.3) was expected to have an EOL burnup equivalent to the assembly average burnup according to calculations by C-E. The power history for Rod MKP104 in Assembly D047 is shown in Figure 3.6 and is listed in tabular form in Appendix A.

Following discharge, Assembly D047 was stored in the fuel storage basin at CC-1 until September 1985, when it was loaded into a National Assurance Corporation NLI-1/2 cask and shipped dry to PNL. Since that time, it has been stored in air in B-cell in the 324 Building. There have been no unusual incidents associated with this fuel. Nine rods (see Table 3.3) were removed from the assembly in August 1986 and transferred to D-cell, 324 Building, where the intact fuel rods are stored in air at an ambient cell temperature of about 25°C. These rods are being characterized by the MCC (see Sections 6.0 through 8.0) and are available for use in the repository testing program.



*Bracketed Numbers Indicate the Cycle of Operation at the Indicated Location

FIGURE 3.4. Core Map Showing the Location of Assembly D047 (ATM-104) in Calvert Cliffs No. 1 for Cycles 2, 3, 4, and 5



Dates	Cycle 2	Cycle3	Cycle 4	Cycle 5
Beginning of Cycle	3-22-77	4-3-78	7-10-79	1-11-81
End of Cycle	1-22-78	4-20-79	10-18-80	4-17-82
Burnups and Powers				
Cycle Average Burnup at Shutdown, MWd/kgM	8.3	9.0	11.0	13.0
Cumulative D047 Assembly Average Burnup, MWd/kgM	9.4	20.3	31.5	41.8
Cycle Average Linear Heat Generation Rate,kW/m (kW/ft)	19.97 (6.086) 21.06 (6.419*)	20.37 (6.209)	20.37 (6.209)	20.58 (6.274)

*After Increase to Stretch Power

FIGURE 3.5. Calvert Cliffs No. 1 Operating History

Cycle No.	2	3	4	5
Start/End of Cycle	3-22-77/1-22-78	4-3-78/4-20-79	7-10-79/10-18-80	1-11-81/4-17-82
Cycle Duration	~10 months	~12.5 months	~15 months	~15.5 months
Cycle Burnup MWd/kgM	10.06	10.90	11.02	9.87
Cumulative Burnup, MWd/kgM	10.06	20.96	31.98	41.85

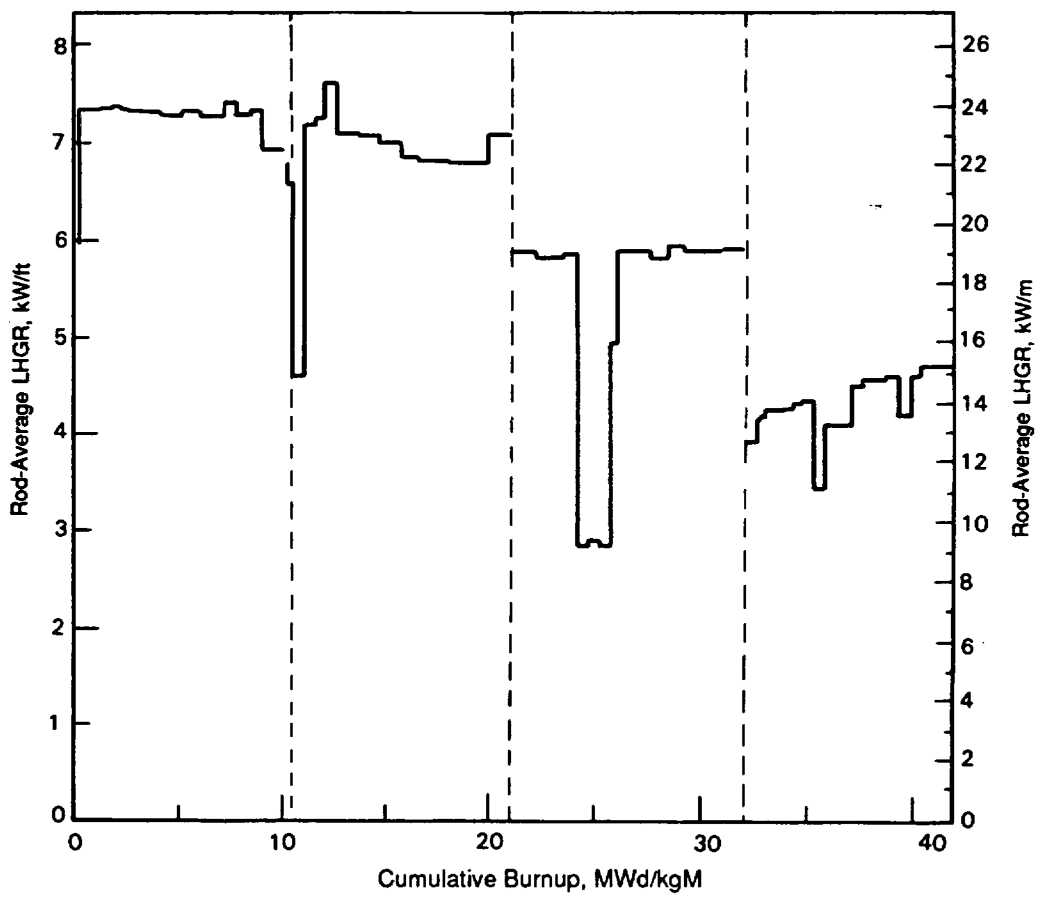


FIGURE 3.6. Power History for Rod MKP104 from Assembly D047

TABLE 3.3. Initial ATM-104 Fuel Rods to be Characterized

Rod Number	Rod Location[(a)]	Comments
MKP028	G14	Fission gas sampled only to test system.
MKP054	C8	Not yet examined.
MKP059	F7	Gamma scan reference rod, gas sampled.
MKP063	B7	Gamma scanned and fission gas sampled.
MKP070	D7	Receiving detailed characterization.
MKP081	A7	To be gamma scanned and fission gas sampled only.
MKP087	D8	Not yet examined.
MKP106	B8	Not yet examined.
MKP109	C7	In-depth characterization of this rod described in this report

(a) Locations refer to Figure 3.3.

4.0 CHARACTERIZATION PLAN FOR ATM-104

The characterization plan for ATM-104 was prepared by the MCC and approved by the repository project. The plan describes standard examinations that are performed on all rods and detailed examinations that are expected to be performed on a representative number of rods from each ATM. Information is provided below on the types of analyses conducted on rods receiving standard or detailed examinations, the criteria for selecting rods for detailed characterization, and an explanation of the sectioning of rods for detailed examination.

4.1 STANDARD EXAMINATIONS

Characterization of the spent fuel rods can be separated into two categories, namely, standard (those MCC characterizations applicable to all fuel rods) and detailed (those MCC characterizations applicable to samples or specimens from a few representative fuel rods). Standard examinations consist of gamma scanning and fission gas sampling, the first two examinations listed in Figure 4.1.

The first step in the MCC's characterization of spent fuel ATMs is to perform a full-length gamma scan on a selection of fuel rods from the ATM. Axial gamma scan data have been used along with measured fuel burnups to develop correlations for predicting burnups in the samples of sectioned rods from ATM-101 through ATM-108 and to estimate burnups in fuel rods that were not destructively analyzed from these ATMs. The gamma scan data also provide valuable information on fission product movement in the rod (such as cesium migration) and on axial gaps or shifts, if any, in the fuel column.

After gamma scanning, each rod other than the rod used as a gamma scan reference is normally punctured and a gas sample is taken. Analysis of the gas provides an estimate of the fission gas released from the fuel during irradiation. The magnitude of the fission gas release is an indication of the extent of the microstructural changes that have occurred in the fuel. These microstructural changes may be important to the dissolution of fuel in a repository (Oversby 1987a). The magnitude of fission gas release is also indicative of the fraction of volatile fission products, such as cesium and iodine, that have migrated to the grain boundaries and the gap between the fuel and cladding (Johnson et al. 1983). Quantifying the inventory of fission products in the gap and at the grain boundaries is important; after repository waste package barriers are breached, fission products will be released from these locations first and the release rates will be independent of the dissolution rate of the matrix.

Thus, gamma scanning and fission gas analyses, combined with limited destructive examinations, can serve to define the variation in fuel burnups and, possibly, the fission gas release along the length of the rods if a representative number of fuel rods are examined. Gamma scanning and fission gas data also facilitate the selection of fuel rods for detailed examinations. Characteristics of fuel rods receiving only standard examinations (gamma scanning and fission gas analyses) can be approximated by correlations expected to be developed from detailed examination of a few selected rods from each ATM.

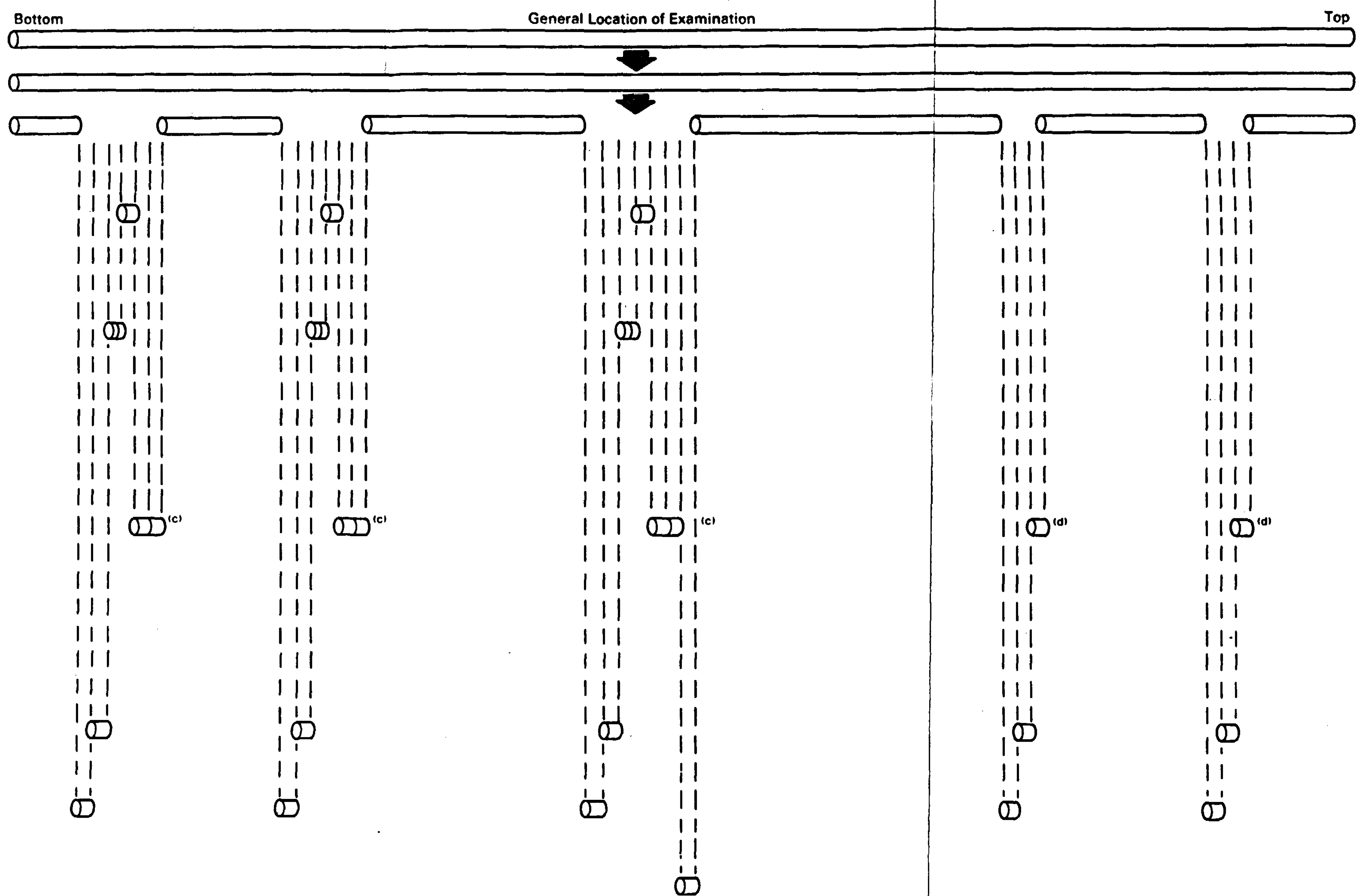
It is planned to gamma scan and fission gas sample a number of ATM-104 rods to 1) have a backlog of ATM-104 material that can be made available immediately upon request, 2) document the homogeneity of, or differences among, the ATM-104 rods, and 3) provide a means of correlating measured data from fully characterized fuel rods with the gamma scan and fission gas release data that will be obtained from other ATM-104 fuel rods.

4.2 DETAILED EXAMINATIONS

Detailed characterizations of spent fuel ATMs involve fuel examinations, cladding examinations, or a combination of the two. Detailed characterizations are conducted on a limited number of spent fuel rods from each ATM, depending on the number of rods in the assembly and known or observed variations in the characteristics of the fuel rods. Three rods were scheduled for detailed characterization from each of ATMs-103, -104, -105, and -106.

As shown in Figure 4.1, samples are taken from several locations along the length of a rod receiving detailed characterization. Samples are scheduled to be taken for radiochemical analysis of the fuel and cladding,

Report Sections	Type of Characterization	Description
Sec. 4.41 & Append. B & C	Gamma Scan [(a)]	Selected isotopes, e.g., Cs-137, Cs-134, etc.
Sec. 8.1 & Append. G	Fission Gas [(a)]	H_2, Ar, Kr, Xe, N_2, O_2, CO_2 (C-14), etc.
Sec. 7.1	Burnup	Nd-148 method, isotopes of U and Pu
Sec. 7.2	Specific Radionuclides	Se-79, Sr-90, Tc-99, Sn-126, Cs-135, Cs-137, Np-237, Am-241, Cm-244, C-14, H_3, and Hydrogen
	Spark Source Mass Spectroscopy (ORNL)	Radial distribution (six points on radius) of most fission products and actinides, plus bulk concentration of same radionuclides (adjacent sample)
Sec. 8.2 & Append. E	Fuel Ceramography	Amount and type of cracking, grain size and structure, porosity and noble metal fission product particles
Sec. 6.2 & Append. E	Cladding Metallography	Hydride orientation, inner and outer surface oxidation, crud on outer surface, if present
Sec. 7.3.2 & Append. F	Microprobe	Radial distribution of selected elements
Sec. 7.3.1 & Append. E	Autoradiography	Alpha and beta-gamma intensity maps
Sec. 7.2 and 8.3	I-129 Distribution	Bulk concentration in fuel and chemically stripped from inner cladding surface
Sec. 8.3	Cs-135 and Cs-137 on Cladding	Chemically stripped from inner and outer cladding surfaces
Sec. 7.2 and 6.1.1	C-14 Distribution	Bulk concentration in fuel and cladding
Sec. 8.4	Transmission Electron Microscopy	Fission product distribution within grains and at grain boundaries
	Activation Products in Assembly Hardware	C-14, Ni-59, Ni-63 and Nb-94
	Crud Analyses [(b)]	C-14 and selected radionuclides



(a) Conducted on all rods selected for characterization
(b) Conducted on one rod per ATM
(c) Transverse and longitudinal examinations
(d) Transverse section examinations only

FIGURE 4.1. General Characterization for Spent Fuel ATMs

metallography of the cladding, ceramography of the fuel, analysis of the assembly hardware, and special examinations involving spark-source mass spectrometry (SSMS), electron probe microanalyses (EPMA), and analytical transmission electron microscopy (AEM). The actual number and location of samples in a given rod or rods from an ATM may vary from the generic plan shown in Figure 4.1 depending on the results of the gamma scans, fission gas analyses, additional requests for samples, or other factors.

A principal purpose of sampling the fuel rod at different locations is to determine the bulk inventory of long-lived radionuclides in fuel with different burnups. The fission products, actinides, and activation products of interest in assessments of geologic disposal are analyzed. Samples are taken from the peak-power region of the rod, which corresponds with the region of maximum gamma activity, and from additional locations of lower power near the rod ends. Generally, the radionuclide concentrations are obtained from radiochemical measurements of dissolved or, in the case of ^{14}C, thermally decomposed samples. In addition to the radiochemical measurements, thermal ionization and SSMS are being considered for obtaining the bulk concentration of selected isotopes to supplement the data obtained from radiochemical methods or as overchecks on the determined values.

One major type of examination involves radiochemical analyses of the bulk concentrations of the radionuclides of interest to geologic disposal. These results are compared with calculations made using the ORIGEN2 computer code. The ORIGEN2 calculations are based on measured and estimated burnups for samples from the rods and a representative power history for rods from the ATM. Comparison of the measured and predicted values serves to validate the ORIGEN2 code for use in predicting the radionuclide inventory in samples from other locations or other rods from the spent fuel ATMs at any decay time of interest.

In addition to determining the bulk concentrations of radionuclides in the fuel and cladding, characterization is also directed towards obtaining information on the radionuclide distribution in the fuel. Information on the nonuniform distribution of radionuclides will assist in providing an understanding of the preferential release of certain radionuclides that is observed in leach testing of spent fuel (Oversby and Wilson 1985). Special emphasis is being placed on determining the ^{14}C distribution in the fuel, cladding, crud, and assembly hardware because less is known about the actual concentrations of this radionuclide than most of the other radionuclides. Because of a similar interest in tritium distribution in the fuel and cladding, techniques are being developed to analyze tritium in the MCC spent fuel rods. Several mutually supportive techniques are being used to evaluate nonuniform distribution, including autoradiography, EPMA, AEM, SSMS of small radial samples from fuel pellets, and radiochemical analyses of material chemically stripped from the interior cladding surfaces.

Another major type of examination conducted by the MCC involves metallography and ceramography of samples from the peak-power and other lower-power regions of the fuel rod. Metallography is conducted because cladding corrosion varies along the entire length of the rod under the influence of reactor coolant temperatures and the fuel operating temperatures. An understanding of cladding characteristics is needed because the cladding may serve as an important barrier during geologic disposal. Cladding corrosion on both the water side and fuel side is evaluated, along with hydriding, hydrogen content, and any obvious crud deposition. Ceramography of the fuel is conducted to evaluate 1) the amount and location of fuel grain growth, 2) fission gas bubble formation and distribution, 3) the amount and distribution of fuel pellet cracking, 4) as-fabricated porosity and changes caused during irradiation, and 5) the formation of noble metal fission product agglomerates. Ceramography is used to determine the fuel grain sizes and grain growth, a parameter that is important to interpreting differences in the behavior of fuel in leach tests and oxidation tests. Ceramography is also important in establishing the characteristics of the individual spent fuel ATMs for comparison with the overall spent fuel population.

As indicated in Figure 4.1, selected samples from the spent fuel ATM assembly hardware are scheduled to be analyzed for specific activation products. To interpret this information, it will also be necessary to analyze for the precursor isotopes (N, Ni, Co, Nb, and Eu). The inventory of activation products in hardware is an important part of the evaluation of repository performance (Oversby 1987b); however, work has not yet been initiated by the MCC to analyze crud or hardware, although hardware samples from ATM-103 (PWR) and ATM-105 (BWR) have been examined by Luksic et al. (1986).

Special examinations consisting of SSMS, EPMA, and AEM are planned for selected samples from the rods that are receiving detailed characterization. As previously noted, SSMS is being evaluated for use in confirming the bulk measurements made by radiochemistry and providing measurements of nuclides for which radiochemistry is not conducted. EPMA is used to determine the distribution of elements across the fuel radius. AEM provides a method for examining the fuel on a scale approaching the atomic level; it can identify phases and structures that are not discernible in normal ceramography but are important to understanding the distribution of fission products in the fuel.

4.3 SELECTION OF RODS FOR DETAILED EXAMINATION

Because all of the ATM-104 rods had similar burnups according to data provided by the vendor, it was desired to perform detailed examination on ATM-104 rods that would adequately define the range in characteristics for fuel rods in the assembly. Nine fuel rods were initially removed from the assembly; detailed characterization was to be performed on three rods. Eight of the ATM-104 rods removed from the assembly were in two rows positioned about halfway between guide tubes (see Table 3.3 and Figure 3.3); one rod (MKP028) from another part of the assembly was removed for use in testing the fission gas collection system. Examination of these rods was expected to indicate whether there were any significant burnup and/or fission gas variations from the fuel assembly edge to the central guide tube. The rods were withdrawn from the locations indicated in Figure 3.3 because almost all of the rods originally irradiated in this portion of Assembly D047 were available for examination, if necessary (41 of the original rods were removed by C-E and fabrication data was insufficient for seven other rods). Removal of rods in a row from the assembly edge to the central guide tube also follows the pattern of examination for the ATM-103 rods irradiated to a moderate burnup in the same reactor (Guenther et al. 1988a).

Gamma scanning and fission gas sampling were used to confirm the choice of rods to receive detailed characterization. Rod MKP109 was proposed as the first rod for detailed characterization because of its central location between the guide tubes and the assembly face (see Figure 3.3). Results of the gamma scanning did not indicate any apparent cesium movement in any of the ATM-104 rods, which would have been indicative of high fission gas release. Analyses of the gas samples from the ATM-104 rods confirmed the expected low fission gas releases and the suitability of Rod MKP109 for detailed characterization.

Additional ATM-104 fuel rods will be gamma scanned and fission gas sampled to select the remaining rods for detailed characterization and to establish the rod-to-rod variability among the ATM-104 fuel rods. The results of the detailed examinations of Rod MKP109 and the available results for limited examinations conducted on Rods MKP028, MKP059 (the reference rod for ATM-104), MKP063, MKP070, and MKP106 are discussed in Sections 6.0, 7.0, and 8.0.

4.4 ROD SECTIONING

Once a rod has been gamma scanned, fission gas sampled, and selected for detailed characterization, a sectioning diagram is developed based on the number of samples required for MCC characterization and any samples requested by experimenters. Brief explanations of the gamma scanning process and how gamma scan plots are used to prepare a sectioning diagram are provided below.

4.4.1 Gamma Scans

Each fuel rod was gamma scanned axially using a germanium-lithium gamma ray detector. Details on the gamma scanning equipment and procedure are provided in Appendix B. In general, the same counting geometry, counting equipment, analyzing equipment, and data storage equipment were used for each measurement. During a few of the gamma scans (involving Rods MKP063 and MKP106), a temporary detector was used as described in Appendix B. The gamma scanning system is the same one used to measure the gamma activity in the ATM-103, ATM-105, and ATM-106 fuel rods. As in the gamma scans for other MCC spent fuel rods, the gamma scans for standard rods in ATM-104 are preceded and followed by gamma scans of short portions of a reference rod. The reference rod for ATM-104 is MKP059.

Initial spectral counting of the high-activity regions of reference Rod MKP059 showed significant gamma ray peaks at 605 keV (^{134}Cs), 662 keV (^{137}Cs), and 796 keV (^{134}Cs), as was the case for previous ATMs. The ^{137}Cs activity of the ATM-104 fuel was approximately 30% higher than for ATM-103 at the time of gamma scanning. The higher radioactivity occurred because the ATM-104 fuel achieved a higher burnup and was out of the reactor 2 years less than the ATM-103 fuel. There was no difficulty in obtaining adequate counting statistics. A ^{60}Co signal was also detected during scanning because a sample of this material was placed in the detection system as a reference point. The detailed results of the gamma scanning are provided in Appendix B for Rods MKP059, MKP063, MKP070, MKP106, and MKP109.

An example of the ^{137}Cs gamma activity along the length of Rod MKP109 is shown in Figure 4.2. As was the case for ATM-103 spent fuel (moderate burnup and low fission gas release), the pellet/pellet interfaces are readily indicated in the gamma scans by the sharp dips in the gamma activity on a pitch equal to the pellet length of approximately 1.14 cm (0.45 in.). The ^{137}Cs gamma activity also decreased regularly (~5%) on intervals equal to the distance between the grid spacers (47.9 cm, 18.9 in.). There were no indications of fuel relocation in any of the rods that were gamma scanned; nor were there any indications of cesium movement to the pellet-pellet interfaces, which is associated with high fuel temperatures and fission gas release. A small portion of the gamma scan data near the center of Rod MKP109 was deleted because of an electronic shift during scanning (see Appendix B).

The gamma scanning procedure requires the measurement of the length of the irradiated fuel rod from one end cap to the other. The as-measured fuel rod lengths are summarized in Table 4.1 for the reported ATM-104 rods. The rod lengths are similar to the fuel rods in ATM-103 and ATM-106 and may be compared with the nominal design length of 3.73 m (147 in.). The permanent axial strains of about 0.5% fall in the range that is typical for these rods (Andrews, Smith, and Shubert 1988).

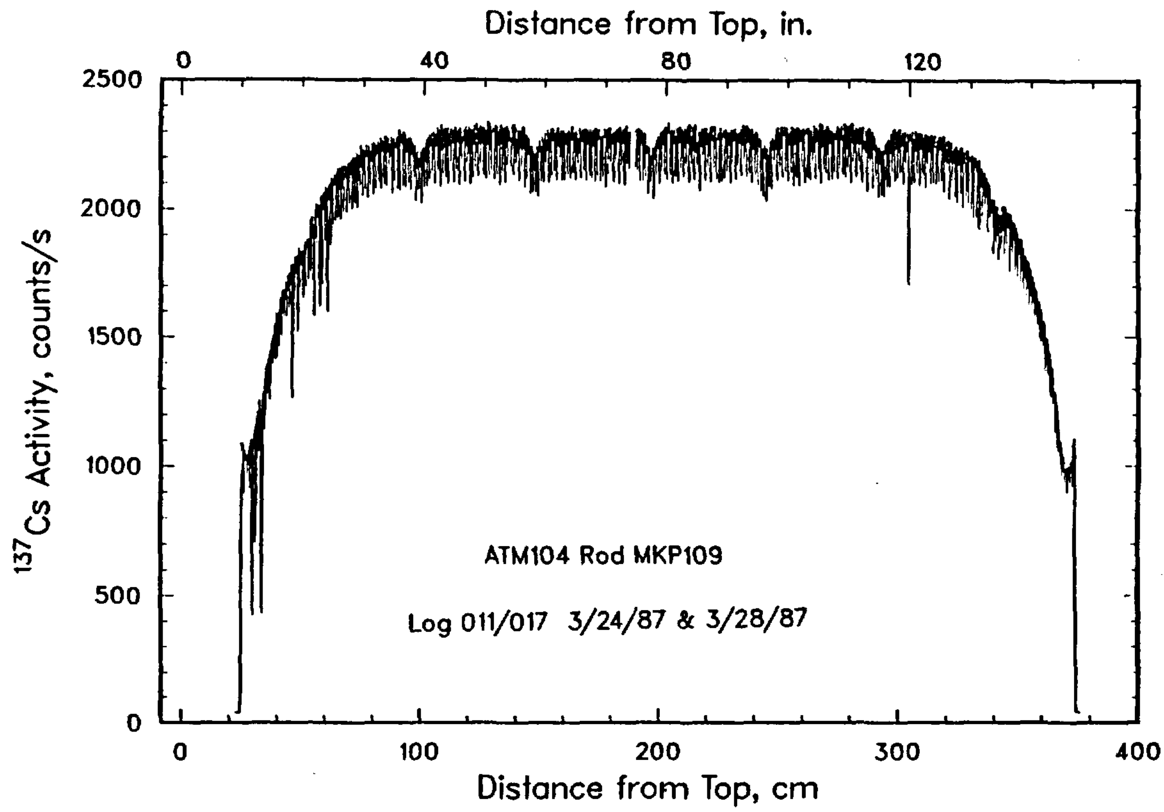


FIGURE 4.2. Gamma Scan for ^{137}Cs - Rod MKP109

TABLE 4.1. Fuel Rod Lengths Measured During Gamma Scanning

Fuel Rod Number	As-Irradiated Fuel Rod Length, m (in.)
MKP059	3.758 ± 0.003 (148.0 ± 0.2)
MKP063	3.754 ± 0.003 (147.8 ± 0.2)
MKP070	3.75 avg[(a)] (147.9 avg)[(a)]
MKP106	3.762 ± 0.003 (148.1 ± 0.2)
MKP109	3.757 ± 0.003 (147.9 ± 0.2)

(a) Assumed to be equal to average of length measurements for the other rods because of technical difficulties in the measurement system.

4.4.2 Rod Sectioning and Sample Selection

After gamma scanning and fission gas sampling, a sectioning diagram was prepared for Rod MKP109, as will be done for all spent fuel rods that are to receive detailed characterization. The sectioning was based on the characterization plan, results of the ^{137}Cs gamma scan of the entire length of the rod, and requests by experimenters.

The sections used for radiochemical, ceramographic, and metallographic analysis were 0.63 to 2.54 cm (0.25 to 1.0 in.) in length. Each sample was designated with an alpha-numeric symbol in order of sectioning from the top of the fuel rod. Details on the sectioning process, descriptions of each fuel section, their lengths, and locations in the rod are given in Appendix C. The majority of the samples were taken for either ceramographic/metallographic examinations (Figure 4.3) or radiochemical analyses (Figure 4.4).

Selected fuel samples were sectioned from Rod MKP109 for ceramographic examination of the irradiated fuel, metallographic examination of the irradiated cladding at the same location, and alpha and beta/gamma autoradiography of each sample. These fuel samples were taken in coordination with several other samples for radiochemistry, AEM, distribution to experimenters, and archiving. As indicated in Figure 4.3, five transverse and three longitudinal fuel sections were taken from Rod MKP109 to provide detailed characterization across the fuel radius and at fuel axial locations with a variety of cladding temperatures and fuel burnups. The fuel rod sections taken from the low-power regions of the fuel rod also provide information on as-fabricated fuel data, such as grain size and porosity.

Similarly, as indicated in Figure 4.4, additional samples were taken at several locations in Rod MKP109 for radiochemical analyses. The analyses were conducted primarily to verify or identify deficiencies in the results of the ORIGEN2 calculations. Secondary reasons for radiochemical analyses were to 1) characterize radionuclide migration (which ORIGEN2 cannot predict), and 2) characterize inventories of radionuclides for which input information is unknown or uncertain, such as ^{14}C, tritium, or other activation products.

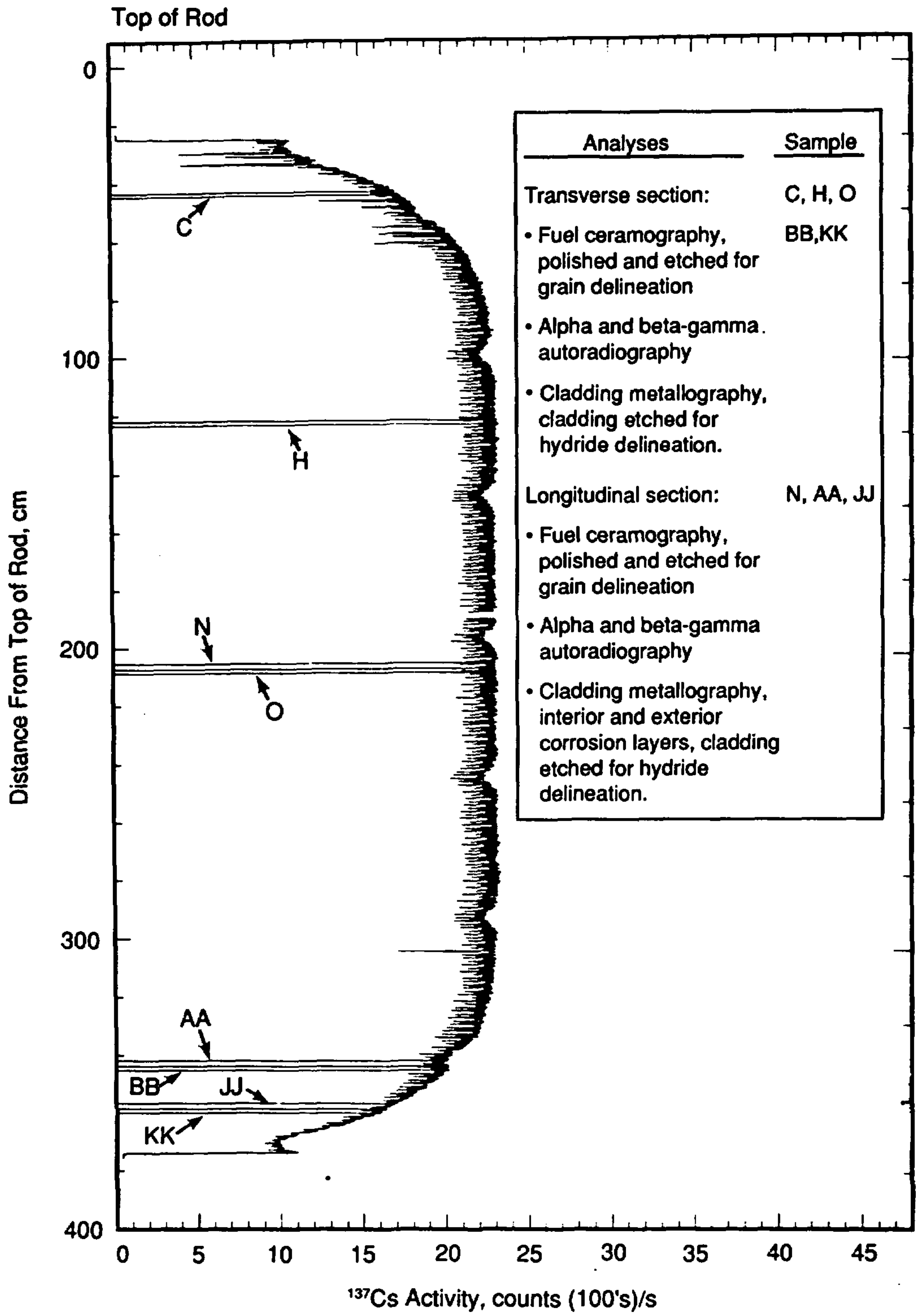


FIGURE 4.3. Locations and Types of Metallographic/Ceramographic Samples from Rod MKP109 of ATM-104

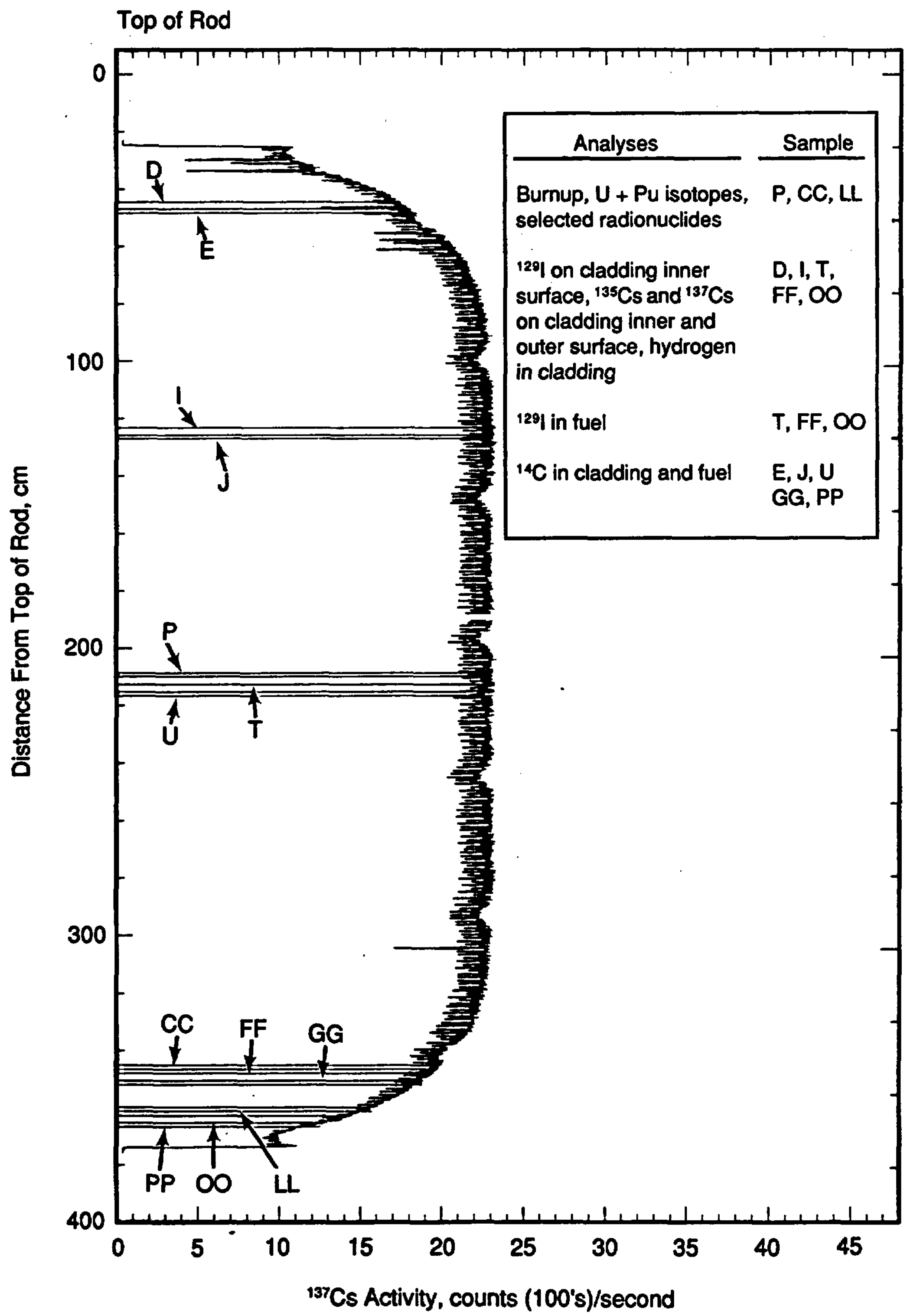


FIGURE 4.4. Locations and Types of Radiochemical Samples from Rod MKP109 of ATM-104

Thus, analytical samples were taken from the rod at locations representative of various burnups and fuel and cladding operating temperature levels. Two pairs of fuel samples were taken from the upper half of Rod MKP109, and three sets of three fuel sections were taken from the lower half. The main difference between the lower three sets and the upper pairs of specimens is the inclusion of fuel samples for obtaining the fuel burnup, the isotopes of uranium and plutonium, and specific nuclides: ^{79}Se, ^{90}Sr, ^{99}Tc, ^{126}Sn, ^{135}Cs, ^{137}Cs, ^{237}Np, ^{241}Am, and ^{243}Cm plus ^{244}Cm.

5.0 NUCLIDE INVENTORY AND RADIOACTIVITY CALCULATIONS

Because of the large number of radionuclides and the long times considered for repository calculations, computer codes such as ORIGEN2 (Croff 1980a, Croff 1980b) are used to predict the nuclide inventories and radioactivities in fuel rods over a range of fuel burnups (exposures) and decay times (times since discharge from the reactor). To compare radiochemically measured concentrations in the fuel with values predicted by the ORIGEN2 computer code, burnup and decay calculations were made with the ORIGEN2 computer code[a] to estimate the nuclide inventories in the ATM-104 fuel and cladding as a function of exposure and decay times (see Appendix D). The comparison of measured and predicted values of radionuclides in the fuel and cladding provides a means of cross checking the validity of the predictions as well as the measurements. The input used for the ORIGEN2 calculations is explained below in Section 5.1. An evaluation of ORIGEN2 libraries for moderate and high burnup fuel is provided in Section 5.2.

5.1 INPUT DATA FOR ORIGEN2 CALCULATIONS

The input data for making the ORIGEN2 calculations for ATM-104, include fuel composition, cladding composition, and power history. The fuel composition given in Table 5.1 was used as a basis for ORIGEN2 input. It is based on information reported by C-E and reproduced in Section 3.1. The ^{234}U content was estimated by interpolating between published values for fuels of various ^{235}U enrichments (Glasstone and Sesonske 1967; Garber 1984).

The cladding composition given in Table 5.2 was used as a basis for ORIGEN2 input. It is also based on information provided by C-E and reported in Section 3.1, plus nominal values assumed for the cladding. There are 4.514 grams of uranium for each gram of cladding over the UO_2-bearing length of the ATM-104 rod.

(a) The VAX version of the ORIGEN2 code and the decay, photon, and cross-section libraries (Croff, Haese, and Gove 1979; Croff et al. 1978) were obtained from the Radiation Shielding Information Center (RSIC) at Oak Ridge National Laboratory (ORNL) in July 1986.

TABLE 5.1. Fuel Composition of ATM-104 Assumed for ORIGEN2 Calculations

Parameter	Value[a]
Enrichment, wt%	3.038
^{234}U, ppm	246[b]
Total Uranium, wt%	88.143
Oxygen, wt%	11.857
Carbon, ppm	18
Nitrogen, ppm	23
Fluorine, ppm	5
Chlorine, ppm	5
Iron, ppm	45
Silver, ppm	1
Calcium, ppm	32
Aluminum, ppm	32
Silicon, ppm	32
Nickel	25

(a) Based on measured value unless otherwise noted (see Table 3.1).
(b) Based on other fuel enrichments.

The irradiation history for Rod MKP104 shown in Figure 3.6 and tabulated in Appendix A was used as the basis for ORIGEN2 input. Rod MKP104 was located in the center of the fuel assembly and was expected to have had a rod-average burnup of 41.9 MWd/kgM at discharge compared with the expected assembly-average burnup of 41.8 MWd/kgM. Rod MKP109, the rod that received detailed characterization, was expected to have had a slightly lower discharge burnup of 40.4 MWd/kgM. The power densities for Rod MKP104 were normalized to give EOL burnup exposures of 20, 25, 30, 35, 40, 45, and 50 MWd/kgM in order to correctly predict radionuclide inventories in fuel samples that achieved different discharge burnups over the same time.

TABLE 5.2. Cladding Composition of ATM-104 Assumed for ORIGEN2 Calculations

Parameter	Value [a]
Zirconium, wt%	98.0
Tin, wt%	1.5
Iron, wt%	0.2
Chromium	0.1
Aluminum, ppm	40
Hafnium, ppm	55
Silicon, ppm	80
Oxygen, ppm	1165 [b]
Carbon, ppm	115 [b]
Nitrogen, ppm	25 [b]
Hydrogen, ppm	14 [b]

(a) Nominal values unless otherwise noted.
(b) Average of measured values (see Table 3.2).

Nuclide inventories were calculated for decay times of 4, 6, 8, 10, 15, 20, and 1000 years after discharge from the reactor. These times bracket the period during which experimenters may be evaluating this fuel and approximate a common time at which long-term repository calculations are made. Sample inputs for irradiation and decay calculations are provided in Appendix D. Appendix D contains extensive tables of ORIGEN2 output for use in determining the predicted values of radionuclide inventory for fuel and cladding samples from Rod MKP109.

5.2 EVALUATION OF ORIGEN2 LIBRARIES FOR MODERATE AND HIGH BURNUPS

As explained above, the ORIGEN2 computer code was used to calculate the expected inventory of actinides, fission products, and activation products in MCC spent fuels. Because the discharge burnups of the ATM-104 (and ATM-106) fuel rods are about 30% higher than the discharge burnup of ATM-101 and ATM-103 fuel, it is reasonable to consider using the ORIGEN2 libraries associated with high burnup fuel for ATM-104 calculations instead of the library associated with moderate burnup fuel. This question of which library is best to use has been addressed by comparing the inventories predicted with both libraries for the ATM-104 fuel samples that had measured burnups up to 44 MWd/kgM.

The ORIGEN2 code package obtained from ORNL/RSIC in 1986 included enriched uranium, PWR cross-section libraries for moderate burnup (PWRU) and high burnup (PWRUD50). Characteristics of the libraries are summarized in Table 5.3. The ORIGEN2 calculations reported in the MCC series of characterization reports have used the PWRU library.

The ORIGEN2 libraries were designed to reproduce the quantities of the major actinides at the burnups listed in Table 5.3. These burnups are typical discharge burnups for the enrichments indicated in Table 5.3. Actinide quantities at burnups less than "discharge burnup" should be reproducible because ORIGEN2 is encoded to change the cross sections for the major actinides as a function of burnup in order to match detailed neutronics calculations. The actinide quantities beyond "discharge burnup" are expected to become less accurate with increasing burnup because the "discharge-burnup" cross sections are used for all burnups beyond "discharge burnup."

Calculations made for three ATM-104 fuel samples[a] using the two cross-section libraries assumed a postirradiation decay time of 5.08 years and an initial enrichment of 3.038 wt% ^{235}U. Results of the predictions are compared against measured values in Figure 5.1 for Sample 104-MKP109-P with a burnup of 44.34 MWd/kgM and in Figure 5.2 for Sample 104-MKP109-LL with a burnup of 27.35 MWd/kgM. Results for Sample 104-MKP109-CC with a burnup of 37.12 MWd/kgM are not shown, but the PWRU cross-section library also provided the best overall predictions for this sample.

(a) Radiochemical analyses of these three samples are described in detail in Section 7.0.

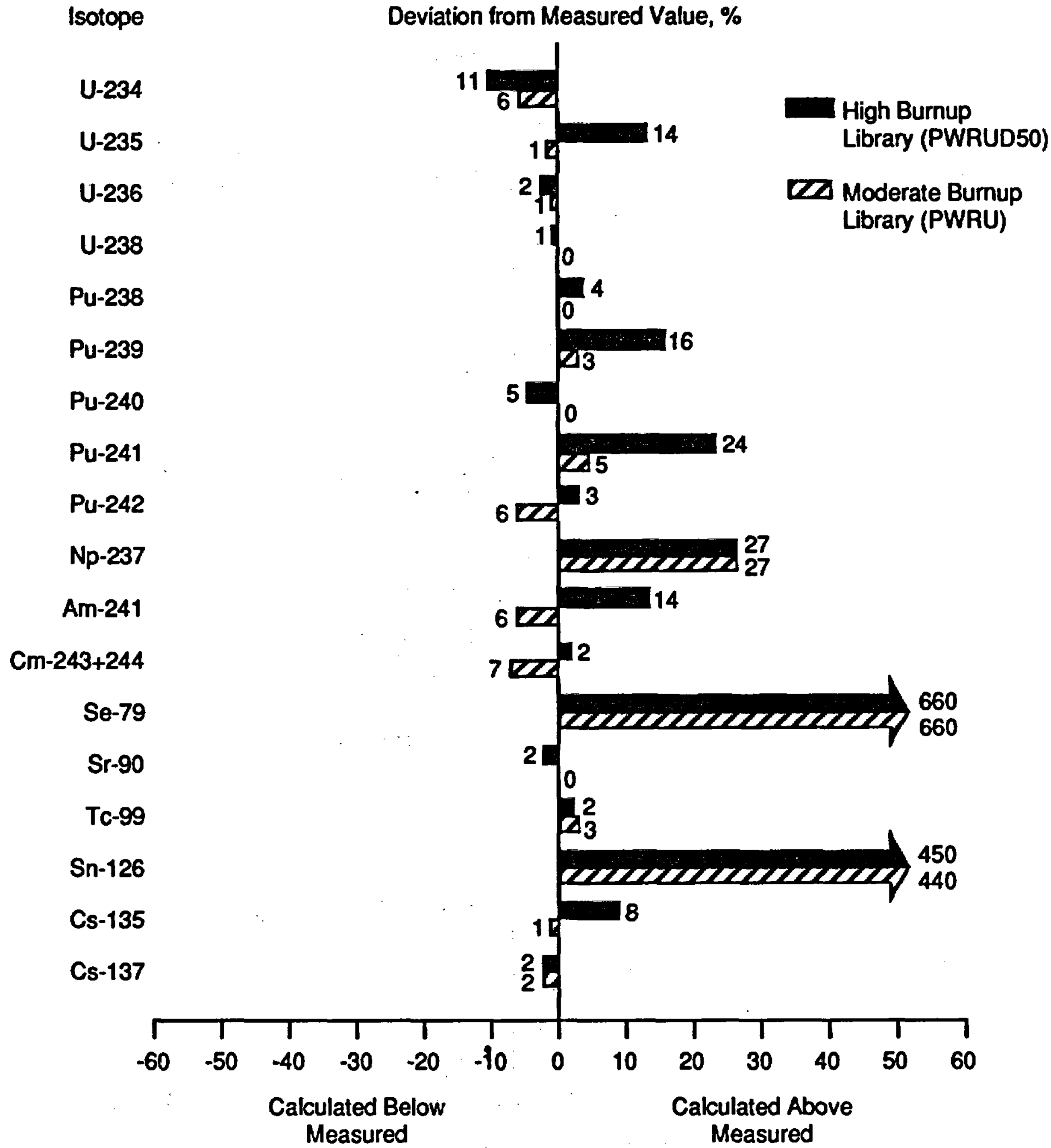


FIGURE 5.1. Isotope Concentrations Predicted by ORIGEN2 Cross-Section Libraries Compared with Values Measured in Sample 104-MKP109-P with a Burnup of 44.34 MWd/kgM

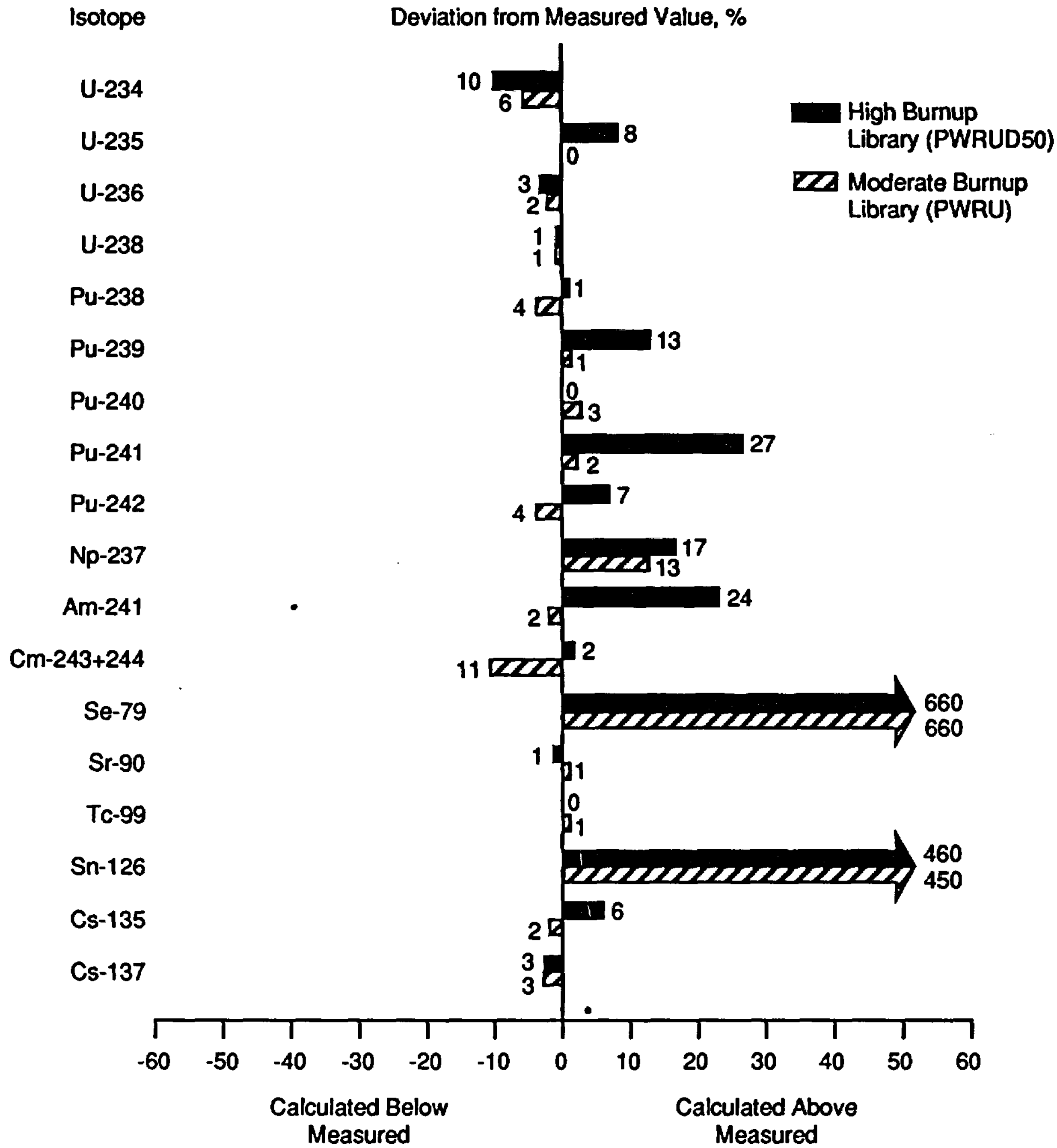


FIGURE 5.2. Isotope Concentrations Predicted by ORIGEN2 Cross-Section Libraries Compared with Values Measured in Sample 104-MKP109-LL with a Burnup of 27.35 MWd/kgM

TABLE 5.3. ORIGEN2 PWR Cross-Section Libraries

Parameter	Moderate Burnup (PWRU)	High Burnup (PWRUD50)
Enrichment, wt%	3.2	4.15
Burnup, MWd/kgM	33.0	50.0
Power Density, W/KgM	37.5	37.5
Boron Content, ppm	550.0	550.0

For the peak burnup sample (Figure 5.1), one would expect the PWRUD50 library to do better than the PWRU library because of the high burnup. For most isotopes this was not the case. The actinide isotopics calculated with the PWRU library are in better agreement with the measured isotopics except for ^{237}Np, ^{242}Pu, and ^{243}Cm plus ^{244}Cm. The cause of the discrepancies for the PWRUD50 library may be due to the much higher initial enrichment used to generate the library than is actually contained in the ATM-104 fuel samples.

It was expected that the PWRU library would do better than the PWRUD50 library in predicting the radionuclide inventory for Sample 104-MKP109-LL (Figure 5.2) because the measured burnup is 27.35 MWd/kgM. This is borne out for most isotopes, especially the isotopes in greatest quantity (^{235}U, ^{238}U, ^{239}Pu, and ^{241}Pu). The exception is ^{240}Pu; however, the discrepancy is not very large.

The ratio of calculated-to-measured values for the fission products is nearly the same for the two libraries except for ^{135}Cs. More ^{135}Cs is formed when using the PWRUD50 library than with the PWRU library because the ^{135}Xe cross section is lower on the PWRUD50 library than on the PWRU library. Consequently, the neutron capture rate of ^{135}Xe is lower and the rate of decay to ^{135}Cs is higher. The fission products that affect the production of ^{79}Se, ^{90}Sr, ^{99}Tc, ^{126}Sn, and ^{137}Cs all have small cross sections; hence, the amount of each isotope is essentially the same using the two libraries.

Comparison of the results using the two cross-section libraries for ORIGEN2 shows that the PWRU library gives the best results when comparing measured and predicted inventories for the ATM-104 fuel samples. It may prove necessary to use the PWRUD50 library when the MCC acquires ATMs with higher initial enrichments and higher discharge burnups than those in ATMs 101 through 108.

6.0 CLADDING CHARACTERIZATION

The cladding can provide a barrier to release of fission products from the fuel rod during irradiation and subsequent storage or disposal. The extent to which the cladding provides this barrier depends on the condition of the cladding as well as the environmental conditions to which the fuel rod is exposed. During the disposal period in a nuclear waste repository, disposal containers and/or overpacks will be relied upon to provide the primary barrier against release to the environment. However, undefected or essentially intact cladding could provide an additional barrier to release of many radionuclides (Wilson and Shaw 1987).

In characterizing the cladding, the MCC has used both radiochemical and metallographic examinations to determine the amount and distribution of selected elements and isotopes that are important to the characteristics of spent fuel rods. A schematic representation of these examinations is presented in Figure 6.1. Radiochemical examinations have been conducted on cladding samples from several locations along Rod MKP109 to determine the distribution of cesium on the exterior and interior surfaces of the cladding, the distribution of iodine on the interior surfaces of the cladding, total ^{14}C in the cladding (i.e., in the cladding as well as any deposits on the surfaces), and the hydrogen content in the cladding. Analyses are planned for determining the amount of tritium, a radioisotope of interest during handling operations at the repository, but these analyses have not yet been conducted. Metallographic examinations have also been conducted on additional samples from several locations along the fuel rod to provide a general view of the deposits on the exterior and interior surfaces, a means of determining the thicknesses of these deposits, and the relative amount, distribution, and orientation of hydrides. Results of the radiochemical and metallographic examinations are presented in Sections 6.1 and 6.2, respectively.

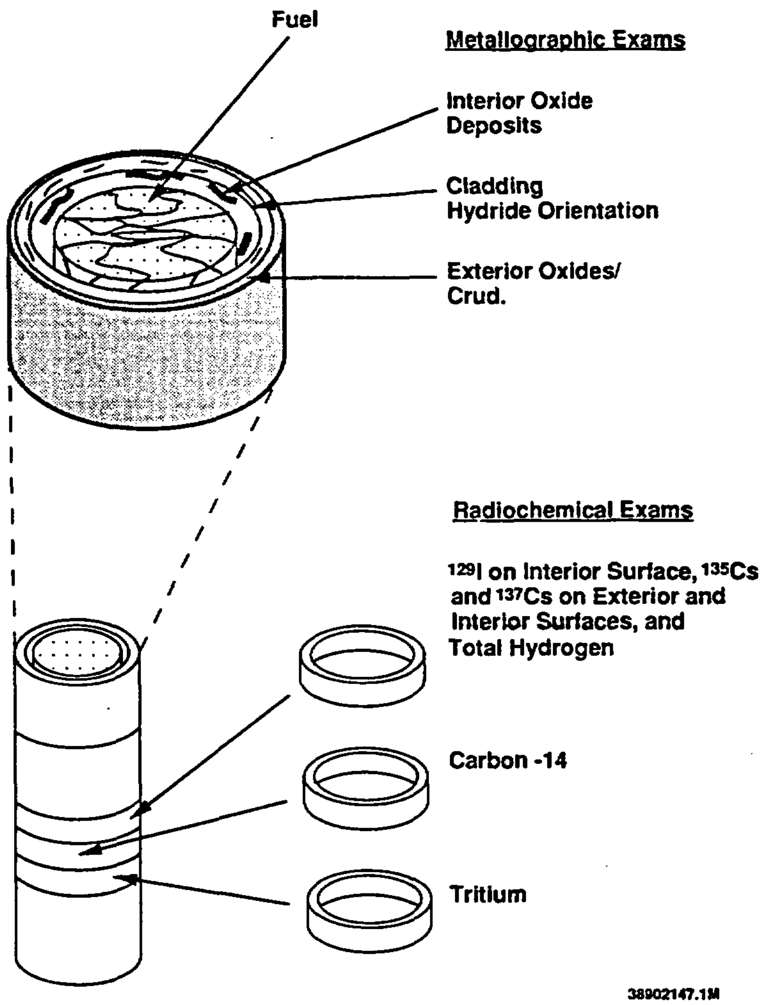


FIGURE 6.1. Schematic of Cladding Examinations

6.1 RADIOCHEMICAL ANALYSES

Radiochemical analyses of the cladding have consisted primarily of measuring the cesium on the exterior and interior surfaces of the cladding, iodine on the interior surfaces of the cladding, and the total amount of ^{14}C in the cladding. Rod MKP109 from ATM-104 was the first MCC spent fuel to also have the hydrogen content measured in cladding samples. Measurement of the hydrogen content in the cladding was added to the list of analyses for comparison with photomicrographs of the etched cladding and correlation with the measured oxide thicknesses on the cladding exterior surfaces. A brief description of the procedures used to obtain these results is provided in

Table 6.1. The results of these examinations are provided below, except for the analyses of deposits of cesium and iodine on the cladding interior surfaces; results for the analysis of cesium and iodine on the cladding interior surfaces are included with the description of fission product redistribution in Section 8.

6.1.1 Cesium on the Cladding Exterior Surface

The levels of ^{135}Cs and ^{137}Cs on the cladding exterior surface are of interest in handling operations where large quantitites of dispersible radioactivity could be an issue. These and other radionuclides that deposit on the exterior surface of the cladding come from defected fuel rods or the corrosion of assembly or reactor system hardware.

TABLE 6.1. Description of Radiochemical Analysis Procedures for Cladding Samples

Analysis	Description
^{14}C	The carbon in the cladding is evolved by total combustion in pure oxygen, the CO_2 collected, and the ^{14}C measured by liquid scintillation counting. Uncertainty: ±5.6%.
^{135}Cs Interior and Exterior Surfaces	The cesium is leached from (interior or exterior) surface and separated from other elements by chromatographic elution from a cation exchange column. Isotope abundance of cesium isotopes is determined by mass spectrometry. Uncertainty: ±14%.
^{137}Cs Interior and Exterior Surfaces	The cesium is leached from (interior or exterior) surface and determined by gamma ray spectrometry on an aliquot of the leachate. Uncertainty: ±3.7%.
^{129}I Interior Surface	The cladding interior surface is leached in nitric acid. The iodine is separated from the nitric acid leachate by distillation and precipitation as AgI. Iodine-129 is determined in a GeLi well detector. Uncertainty: ±2.8%.
Hydrogen in Cladding	A weighed cladding sample is melted under a flowing inert cover gas and analyzed by gas chromotography. Uncertainty: ± 10%.

Radiochemical analyses for cesium (and iodine) were obtained from 2.5-cm (1.0-in.) cladding sections taken from five locations along the length of Rod MKP109 (see Figure 4.4). The fuel was removed from the cladding with a specially constructed punch, and the cladding interior surface was wiped four to five times with fresh, dry cotton to remove loose particles. The first cotton swabs were black-streaked; thus, it may be inferred that some "loose" cesium and iodine may have been removed by the swabs. After stoppering the open ends of the cladding sample, it was immersed in 8N HNO_3, and the resulting solution was analyzed for ^{137}Cs and ^{135}Cs to obtain the exterior surface values for cesium.

Results of the analyses for ^{135}Cs and ^{137}Cs on the cladding exterior surface are provided in Table 6.2. The ^{137}Cs concentrations on the exterior surface of samples were relatively uniform over the full rod length and about 10% of the ^{137}Cs deposited on the interior surface in the peak-power region (see Table 8.9). The ratio of ^{135}Cs and ^{137}Cs activities are approximately as expected from the predicted values listed in Appendix D. The amounts of these two isotopes are somewhat similar in terms of grams, but the shorter half life for ^{137}Cs results in a much greater activity than for ^{135}Cs. The amount of cesium deposited on the exterior surface of the cladding is about 10 times higher than that on the ATM-103 samples (Guenther et al. 1988a), possibly due to the additional cycle of irradiation and/or slight contamination during hot cell handling. The measured amounts of deposits on the ATM-104 exterior cladding surface are comparable to those measured on ATM-106 cladding (Guenther et al. 1988b). Longer irradiation allows greater time for deposits of radionuclides to accumulate on the cladding exterior surface. This possible explanation is suggested by the oxide thickness being roughly twice as thick on ATM-104 cladding as observed for the ATM-103 cladding (see below). Analyses of the cesium deposits on the cladding exterior surfaces will be discontinued for subsequent rods because of similar results for all of the MCC ATMs (Guenther et al. 1988a, Guenther et al. 1988b, Guenther et al. 1990).

TABLE 6.2. Radiochemical Analyses of Cesium on the Cladding Exterior Surface

Sample No.[(a)]	Activity, μCi/cm² ^{137}Cs	^{135}Cs
104-MKP109-D	12.8	7.25×10^{-5}
104-MKP109-I	16.4	7.61×10^{-5}
104-MKP109-T	13.1	5.99×10^{-5}
104-MKP109-FF	13.8	7.21×10^{-5}
104-MKP109-OO	10.9	7.21×10^{-5}

(a) See Figure 4.4 for sample location.

6.1.2 Carbon-14 In the Cladding

Carbon-14 is of interest in repository performance evaluations even for undefected cladding because ^{14}C release has been observed in heated storage tests where ^{14}C on the cladding exterior surface was oxidized and released as a gas (Van Konynenburg et al. 1987). Both the Environmental Protection Agency (EPA 1985)[(a)] and the Nuclear Regulatory Commission (NRC 1983) limit ^{14}C release from the proposed repository to the environment. Carbon-14 released from the fuel may migrate as CO_2 because the proposed repository site will be located above the water table in the unsaturated zone (Van Konynenburg et al. 1987; Ross 1988). With a 5730-yr half life, ^{14}C contributes less than 0.1% of the total 1000-yr inventory in a PWR spent fuel assembly (Wilson and Oversby 1985). The significance of the ^{14}C inventory in the cladding will depend on the distribution and release of the radionuclide after the containment period.

Carbon-14 in the cladding results primarily from the activation of ^{14}N, although very small amounts of ^{14}C come from n-α reactions with ^{17}O and n-γ reactions with ^{13}C (Van Konynenburg et al. 1987). The nitrogen content in the MCC ATMs varies over a range of values; the nitrogen content averages 24.8 ± 5.1 ppm in the as-fabricated ATM-104 cladding (see Table 3.2). The ^{14}C in the cladding constitutes about 25% of the total ^{14}C in the irradiated fuel rod.

(a) EPA 1985 references a regulation that has been remanded for repromulgation.

Analyses were performed on five samples from Rod MKP109 to determine the ^{14}C content in cladding sections taken from locations along the length of the rod (see Figure 4.3). The fuel was removed from these 1-cm (0.5-in.) samples, and the cladding was broken into two portions that were analyzed separately. The analytical results are compared with ORIGEN2 predictions in Table 6.3.

The average concentrations of ^{14}C are consistent with the levels predicted by ORIGEN2 using an initial nitrogen level of 25 ppm. The amount of ^{14}C in the ATM-104 cladding is comparable to the values reported by Barner (1985) for ATM-101 cladding and by Van Konynenburg et al. (1987) for Turkey Point cladding. The ATM-104 cladding, with an initial nitrogen content only 5 ppm less than in the ATM-103 cladding, had ^{14}C levels very similar to those in ATM-103 cladding with a peak burnup of about 33 MWd/kgM. The amount of ^{14}C measured in ATM-104 cladding ranged between 69% and 98% of the predicted values. In comparison, the amount of ^{14}C measured in the cladding from ATM-103 and ATM-106 samples averaged about 65% and 120%, respectively, of the predicted levels for these two ATMs.

Carbon-14 levels should increase with burnup and initial nitrogen content as is indicated in Figure 6.2 where data are presented for cladding from the first rod characterized from each of ATM-103, ATM-104, and ATM-106. The increase in ^{14}C content with increasing burnup is readily seen from the data for each of the three rods in Figure 6.2. The ATM-106 rod had about twice the initial nitrogen content as in the ATM-104 rod resulting in roughly twice as much ^{14}C content in the ATM-106 rod at a given burnup.

The ^{14}C levels measured in the ATM-104 cladding varied about as much as previously observed in the first rods from ATM-103 and ATM-106, although the range of ^{14}C values in the peak-burnup region was greatest in the ATM-106 fuel with 11% fission gas release. Some of the variation in measured ^{14}C content may be explained by the range in initial nitrogen level, such as the 20% variance indicated in Table 3.2 for the ATM-104 cladding. The greater disparity between measured and predicted values for the ATM-106 rod with high fission gas release suggests that some of the ^{14}C in the hot fuel may have migrated to the cladding, thus increasing the amount of ^{14}C measured. It is possible that some ^{14}C was also released from the fuel center in the peak-burnup regions of

TABLE 6.3. Radiochemical Analyses of Carbon-14 in Cladding and Comparison with ORIGEN2 Predictions

Sample No.	Analyzed Activities, μCi/g Cladding(a)	Average of Analyzed Activities, μCi/g Cladding	Interpolated ORIGEN2 Activity, μCi/g Cladding(b)	Ratio, Average Analytical Activity to ORIGEN2
104-MKP109-E	0.389, 0.378	0.384	0.52	0.74
104-MKP109-J	0.659, 0.334	0.497	0.72	0.69
104-MKP109-U	0.955, 0.457	0.706	0.72	0.98
104-MKP109-GG	0.521, 0.356	0.439	0.53	0.83
104-MKP109-PP	0.392, 0.147	0.270	0.29	0.93

(a) Each cladding sample was separated for duplicate analyses.
(b) Interpolated ORIGEN2 values obtained from Appendix D using estimated burnup from equation in Section 7.1 and ^{137}Cs activity in Appendix C.

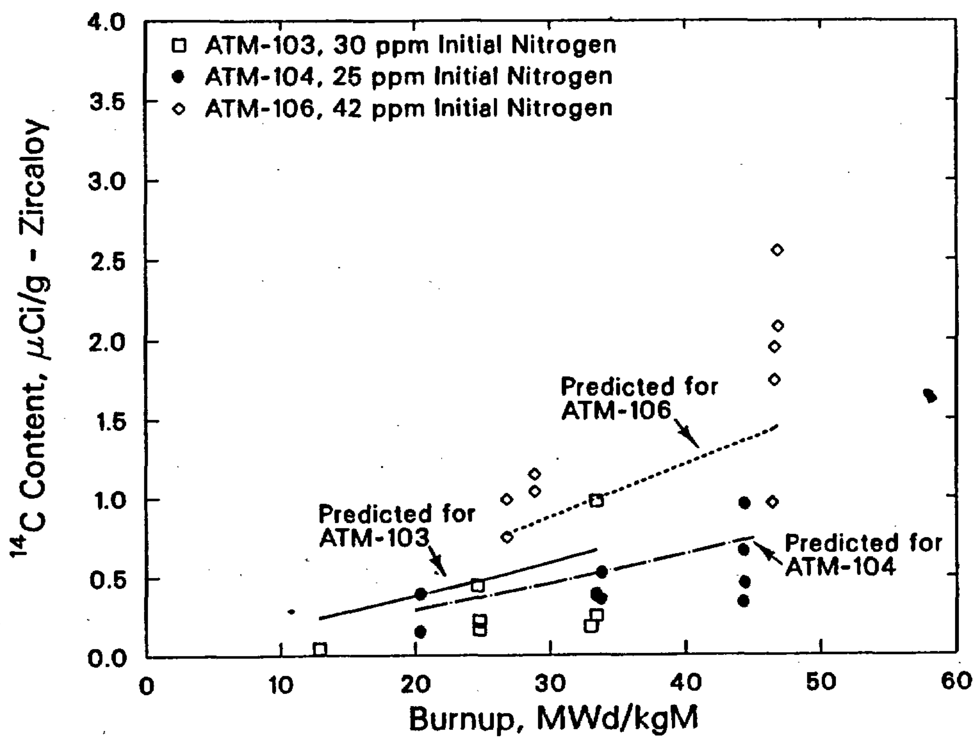


FIGURE 6.2. Comparison of ^{14}C Content in Zircaloy-4 Cladding from ATM-103, ATM-104, and ATM-106

the ATM-104 fuel with low fission gas release; however, gas analyses indicate no increase in ^{14}C release to the void space in any of the rods with high release. If ^{14}C is released at operating temperatures, then it may form a solid compound and deposit on the fuel and/or cladding surfaces and not be present in the cover gas.

6.1.3 Cladding Hydrogen Content

Hydrogen is an impurity typically found in low amounts in fabricated cladding; the ATM-104 cladding had 13.5 ±2.5 ppm hydrogen prior to irradiation (see Table 3.2). As the cladding reacts with the reactor coolant, typically less than 20% of the hydrogen liberated from the corrosion process is absorbed into the cladding (Pyecha et al. 1985). The hydriding level in the cladding is known to increase with increasing corrosion of the cladding exterior surface, but hydriding also depends on neutron fluence, cladding prefilms, and other factors (Lanning et. al. 1984; Johnson and Lanning 1985). Any residual hydrogen in the fuel can also be released and absorbed in the cladding, although hydrogen in the fuel is intentionally kept low. The nuclear industry's desire to improve uranium utilization and increase plant efficiency is leading to longer irradiation times, greater discharge burnups, higher operating temperatures, and increased LHGRs (Pyecha et al. 1985). All of these factors can increase the oxidation of the cladding and result in higher hydrogen levels in the fuel rods.

At reactor operating conditions, cladding temperatures (~300°C) are sufficiently high for hydrogen to remain soluble in the cladding at concentrations up to about 200 ppm; however, zirconium hydrides precipitate at hydrogen levels above 30 ppm and temperatures of about 250°C (Johnson, Gilbert, and Guenther 1983). The increase in hydrogen levels combined with radiation damage decreases the cladding ductility (Andrews and Lobre 1988), although the hydride platelets are ductile at typical operating temperatures. Design limits of about 500 ppm hydrogen at discharge have been suggested for PWRs (Stehle et al. 1975).

Hydrogen concentrations were not originally scheduled to be determined for the cladding samples. However, during metallographic examination of the cladding (see Section 6.2), an apparently significant concentration of hydrides was observed with the concentrating increasing from the bottom to top of rods in several ATMs (Guenther et al. 1988b, Guenther et al. 1990). Such an increase in hydriding from the bottom to the top of PWR rods would be consistent with increasing coolant temperatures that were typically 284°C at the inlet and 312°C at the outlet of the Calvert Cliffs reactor core; actual cladding temperatures also depend on the oxide thickness and the fuel operating temperatures. Because of the apparent variation in hydrogen concentration along the fuel rod and the potential effect on cladding characteristics, hydrogen analyses were made on five ATM-104 cladding samples previously examined for cesium and iodine concentrations on the cladding surfaces. Results of the hydrogen analyses for Rod MKP109 are provided in Table 6.4.

The hydrogen concentrations in the cladding are plotted against axial position along the rod along Figure 6.3. The hydrogen level increases from about the as-fabricated value near the bottom of the rod to a peak of about 120 ppm towards the top of the rod after which the hydrogen level drops slightly. The slight decrease at the top of the rod is consistent with data from Pyecha et al. (1985) and is attributed to the maximum time-averaged temperature occurring near the second span from the top of the rods, i.e., between the 2nd and 3rd grid spacers. This results because the cladding temperature at the top end of the rod decreases along with the fuel operating temperatures, even though the coolant temperature peaks at the top of the rod.

The hydrogen levels in the cladding of the ATM-104 fuel rod are well below the solubility limit during reactor operation, but essentially all of the hydrogen has precipitated as zirconium hydrides at the examination temperatures. The hydrogen may redissolve in the cladding once the fuel rod is emplaced in a repository, but the hydrogen would probably reprecipitate and exist as hydrides during most of the containment period in a repository because the fuel temperatures are estimated to decrease to below 100°C after several hundred years of disposal (Soo 1985).

6.2 METALLOGRAPHIC EXAMINATIONS

The thickness of deposits on exterior and interior surfaces of the cladding and hydride orientations within the cladding were evaluated from the

TABLE 6.4. Hydrogen Concentrations Measured in Cladding from Rod MKP109

Sample No.	Axial Distance from Rod Top(a), cm (in.)	Hydrogen Content(b), ppm
104-MKP109-D	45.9 (18.1)	103, 122
104-MKP109-I	124.5 (49.0)	118, 126
104-MKP109-T	214.0 (84.3)	72.9, 70.4, 82.1, 73.4
104-MKP109-FF	349.4 (137.6)	16.6, 22.8
104-MKP109-OO	364.1 (143.3)	30.7, 29.8

(a) Distance is measured from the top end of the fuel rod to the center of the sample.
(b) Duplicate analyses were made for all samples except for quadruplicate analyses in Sample 104-MKP109-T.

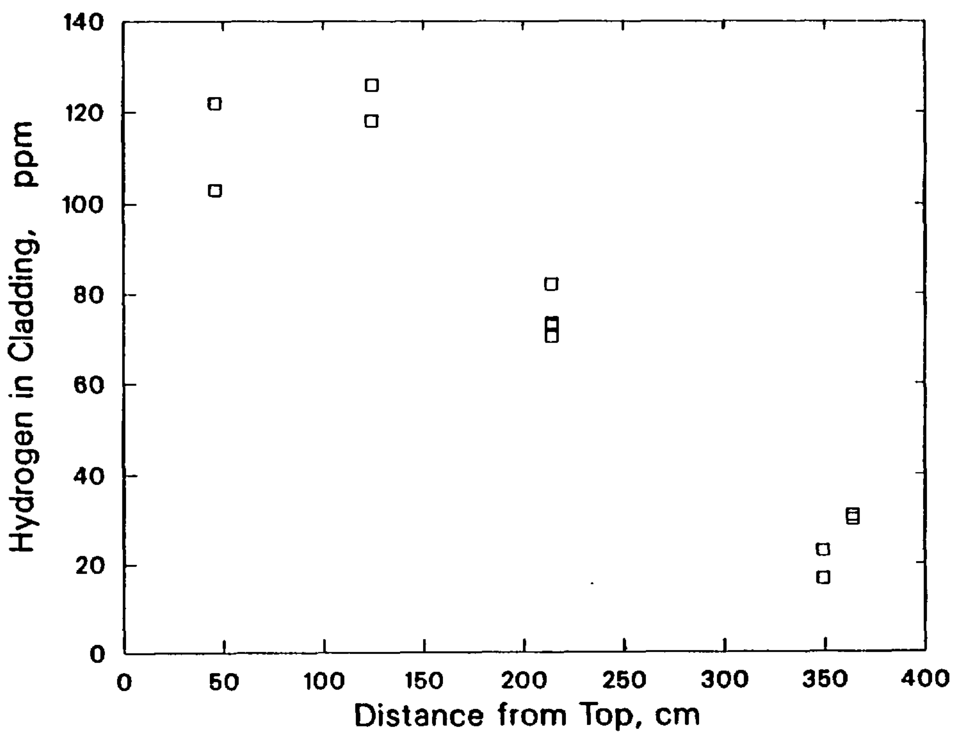


FIGURE 6.3. Axial Variation of Hydrogen in Cladding from Rod MKP109

results of metallographic examinations conducted on cladding in the same mounted samples as those used for the fuel ceramographic examinations (see Figure 4.3). Results of these examinations for Rod MKP109 are provided below. Photographic details of all metallographic samples examined are provided in Appendix E.

6.2.1 Cladding Oxide Examinations

The cladding is an important barrier to the release of radionuclides during reactor operation and may serve as an additional barrier to the release of radionuclides in a nuclear waste repository. The effective stress in the cladding of fuel rods under internal pressurization increases as the cladding is thinned by corrosion of either the exterior or interior surfaces. Information on the exterior zirconium oxide layer is useful in evaluating the amount of corrosion that has occurred on the cladding surfaces. Analyses of the oxide layer and any crud deposits are also useful in evaluating the potential for airborne contamination during handling operations and potential interactions with the exterior environment during disposal. As explained above, it is also known that hydrogen content correlates with the thickness of the oxide layer formed on the exterior surface of the cladding (see Section 6.1.1). Oxide layers can also affect the heat transfer characteristics of the fuel rod (Pyecha et al. 1985).

The interior oxide layer or deposits are of interest for correlating fission product deposits with structural changes in the fuel, such as grain growth. These correlations are possible clues to fission product redistributions. The cladding thickness may also be decreased by oxidation of the interior surface of the cladding where deposits are observed.

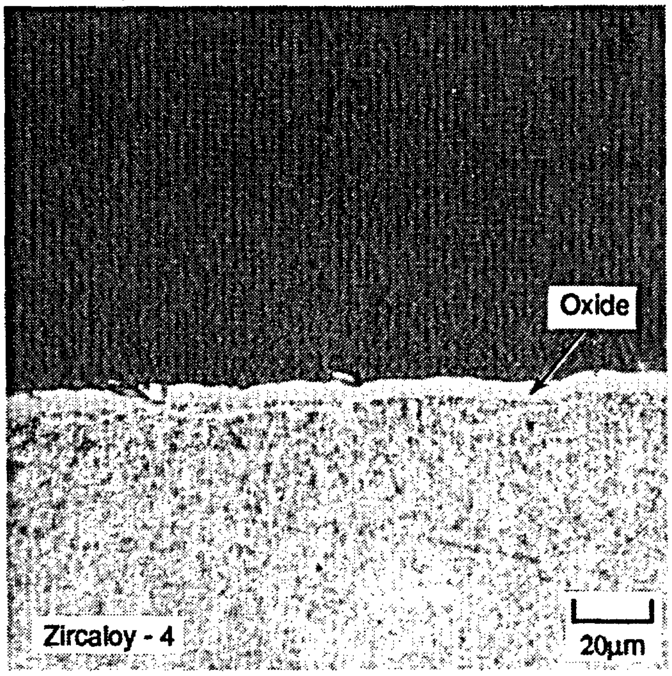
Films of ZrO_2 are formed on the cladding exterior surface during reactor operation, although some cladding has entered the reactor with a thin prefilm. Oxidation of the cladding can also occur during wet or dry storage, depending on the temperatures and amount of available oxidant. Zircaloy oxidation is described as involving two phases: 1) pretransition, where a black and highly protective $ZrO_{1.95}$ forms under parabolic or cubic kinetics; and 2) post-transition, where a less protective oxide forms that progresses from a dark (black or mottled gray) to light (beige or white) under linear kinetics (Johnson, Gilbert, and Guenther 1983). Hillner (1977) describes equations for these two regimes of cladding oxidation.

Work by Bryner (1979) has indicated that the oxidation of Zircaloy cladding at reactor operating temperatures consists of a series of cyclical steps with initially fast oxidation followed by a decreasing corrosion rate. During each cycle, a protective layer forms at the metal-oxide surface until a critical thickness is reached when the layer loses its protective nature; this is followed by another cycle with an initially rapid oxidation rate. The first cycle is equivalent to the pretransition phase; the second and subsequent cycles include the post-transition oxidation described above. Extensive data and modeling by Clayton and Fischer (1985) support the cyclical nature of the oxidation process.

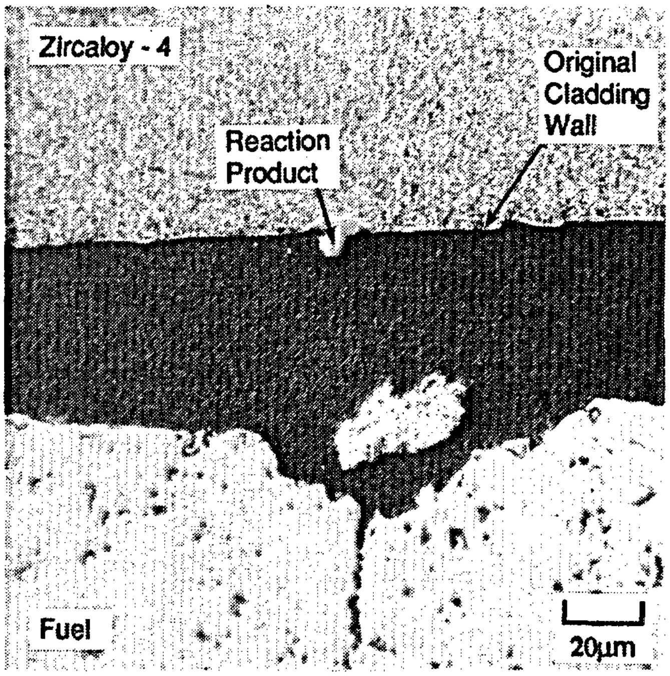
Exterior Oxide

The oxide thicknesses were initially measured for three longitudinal and one transverse samples taken from Rod MKP109. Photomicrographs of both the exterior and interior surfaces of the cladding from Samples 104-MKP109-JJ from a low-power region and 104-MKP109-N from the high-power region are shown in Figures 6.4 and 6.5, respectively. Oxide thicknesses were later measured for Samples 104-MKP109-C, 104-MKP109-H, and 104-MKP109-O in coordination with other analyses. Photomicrographs of these three additional samples were taken at four equidistant locations around the cladding circumference, instead of the normal single location, to define any variation in the oxide/deposit thicknesses in the circumferential direction. Results of the measurements of the exterior and interior oxides/deposits are listed in Table 6.5. A discussion is provided below on 1) the thicknesses of the oxide layers on the exterior surface of the cladding, 2) the change in the structure of the oxide layers from the bottom to the top of the rod, and 3) the relationship between oxide thicknesses and the amount of hydrogen in the cladding.

Oxide Thickness. The oxide layer on the cladding exterior surface of Rod MKP109 is consistent with the relative cladding operating temperatures. As shown in Table 6.5, the thickness of the oxides on the cladding exterior surface increases from about 2 to 4 μm near the bottom of the rod (minimum

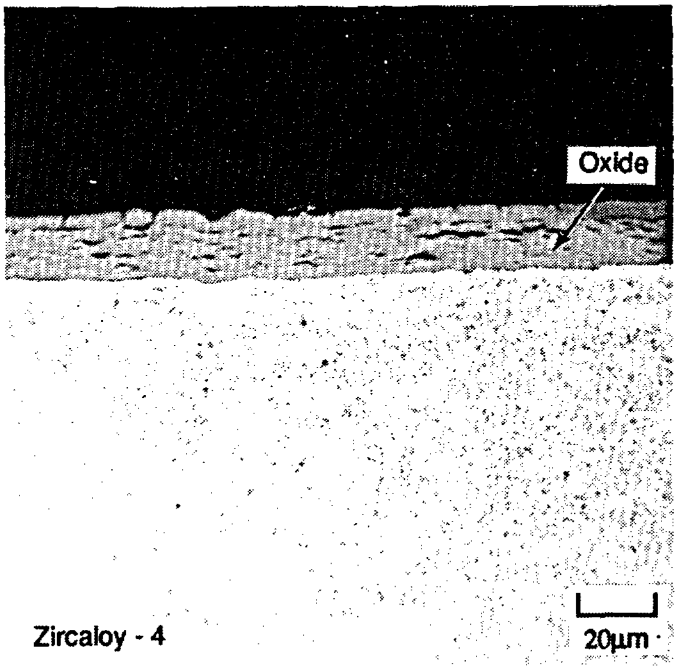


a) Exterior Surface (Neg. No. P-2790)

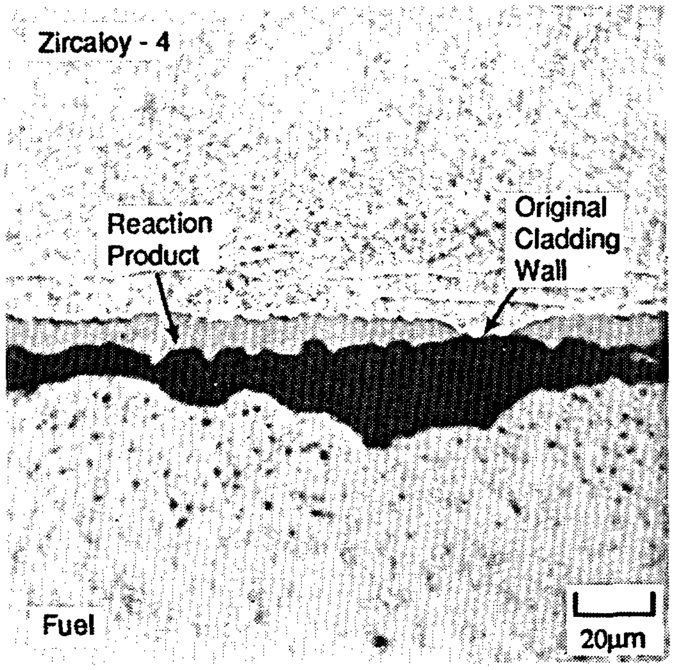


b) Interior Surface (Neg. No. P-2791)

FIGURE 6.4. Cladding Exterior and Interior Surfaces of Polished Sample 104-MKP109-JJ from a Region at Approximately 72% of the Peak Power



a) Exterior Surface (Neg. No. P-2687)



b) Interior Surface (Neg. No. P-2688)

FIGURE 6.5. Cladding Exterior and Interior Surfaces of Polished Sample 104-MKP109-N from the Peak-Power Region

TABLE 6.5. Thickness of Oxide/Deposit on Cladding from ATM-104 Samples

Sample	Axial Location, cm (in.) From Top of Fuel Rod	Orientation, Degrees (b)	Oxide/Deposit Thickness[a], µm (mil) — Exterior Layer: Average Measured Thickness	Exterior Layer: Standard Deviation	Exterior Layer: Observations	Interior Layer: Average Measured Thickness	Interior Layer: Standard Deviation	Interior Layer: Observations
104-MKP109-C	44.0 (17.3)	0	21.0 (0.83)	±1.2 (0.05)	Uniform layer	---	---	None observed
		90	17.8 (0.70)	±0.9 (0.03)	"	---	---	"
		180	21.4 (0.84)	±1.9 (0.08)	"	---	---	"
		270	18.3 (0.72)	±0.8 (0.03)	"	---	---	"
		average	19.6 (0.77)	±1.8 (0.07)				
104-MKP109-H	122.6 (48.3)	0	23.3 (0.92)	±0.7 (0.03)	Uniform layer	8.5 (0.34)	±1.1 (0.04)	Localized, solid
		90	(c)		Fragmented (c)	6.8 (0.27)	±1.2 (0.05)	Uniform, solid
		180	19.8 (0.78)	±2.2 (0.08)	Uniform layer	6.3 (0.25)	±1.1 (0.04)	Localized, solid
		270	21.2 (0.83)	±0.9 (0.03)	"	(d)	(d)	Very localized, comparable to thickness in other samples
		average	21.4 (0.84)	±1.7 (0.07)		7.2 (0.28)	±1.2 (0.05)	
104-MKP109-N	206.3 (81.2)		17.1 (0.67)	±0.8 (0.03)	Uniform layer,	8.3 (0.33)	±1.5 (0.06)	Localized, solid
104-MKP109-O	208.0 (81.9)	0	(c)		Fragmented (c)	6.1 (0.24)	±0.7 (0.03)	Uniform, solid
		90	15.2 (0.60)	±1.7 (0.07)	Uniform, layered ?	7.4 (0.29)	±1.5 (0.06)	"
		180	13.1 (0.52)	±1.1 (0.04)	Uniform, layered ?	5.6 (0.22)	±1.1 (0.04)	"
		270	15.1 (0.59)	±0.8 (0.03)	Uniform, layered	4.5 (0.18)	±0.6 (0.02)	"
		average	14.5 (0.57)	±1.2 (0.05)		5.9 (0.23)	±1.2 (0.05)	
104-MKP109-AA	343.0 (135.0)		1.9 (0.07)	±0.4 (0.01)	Uniform layer	8.2 (0.32)	±1.6 (0.06)	Localized, solid
104-MKP109-BB	344.6 (135.7)		3.6 (0.14)	±0.4 (0.01)	Uniform layer	---	---	No examination
104-MKP109-JJ	357.7 (140.8)		4.1 (0.16)	±0.7 (0.03)	Uniform layer	---	---	None observed

(a) Oxide thickness determined from Figures 6.4, 6.5, and other figures in Appendix E. Reported range is one standard deviation.
(b) Samples with multiple photographs were taken with the 0° picture at the reference notch, then clockwise around the sample every 90°.
(c) Too fragmented to determine thickness.
(d) Only short regions of oxide/deposits observed.

cladding temperature) to a maximum of about 21 μm at Sample 104-MKP109-H taken from the middle of span 3 (~ maximum cladding temperature) (see Figures 3.1 and 4.3). The oxide thickness then decreases slightly in Sample 104-MKP109-C taken near the upper end of the rod (intermediate cladding temperature). Examination of the photomicrographs taken around the cladding circumference indicates that the exterior oxide layers are fairly consistent at a given axial location in the rod, varying by about 10% or less in the samples examined (Table 6.5).

The decrease in oxide thickness near the top end of the rod is not unexpected because the cladding temperature is dictated by both the coolant and fuel operating temperatures (Pyecha et al. 1985). The coolant temperature in CC-1 increased about 30°C from the bottom to the top of the rod, but the operating power near the end of the rod results in lower cladding temperatures than in the peak-power region.

Comparison of oxide thickness data for ATM-104 with similar data for ATMs-101, -103, and -106 in Figure 6.6 indicates that all the rods examined by the MCC had oxide thicknesses that increased from the bottom to the top of the rods. The relative amounts of oxide on the cladding exterior surfaces of the ATM-104 rods are reasonably consistent with exposure times for the various ATMs. The ATM-103 fuel rods were in the reactor for 546 days less than the ATM-104 rods, resulting in considerably thinner oxide layers. ATM-104 was in the reactor for 1852 days compared with 2203 days for ATM-106, which had slightly thinner oxides than in ATM-104 at peak power. The average reactor power was higher during the life of the ATM-104 rods, which may explain why the ATM-104 rods had somewhat thicker oxide layers than the ATM-106 rods. The ATM-101 cladding had oxide thicknesses comparable to those on the ATM-104 cladding, even though the exposure time was 690 days less for the ATM-104 rods. However, the ATM-101 rods were irradiated in a different reactor where coolant chemistry may have been different.

The maximum thicknesses of the oxide on the exterior surface of cladding from the MCC ATMs were estimated from the data shown in Figure 6.6 and are reasonably consistent with data collected for other C-E rods (Anderson and Lobre 1985) as indicated by the comparison in Figure 6.7. However, the MCC

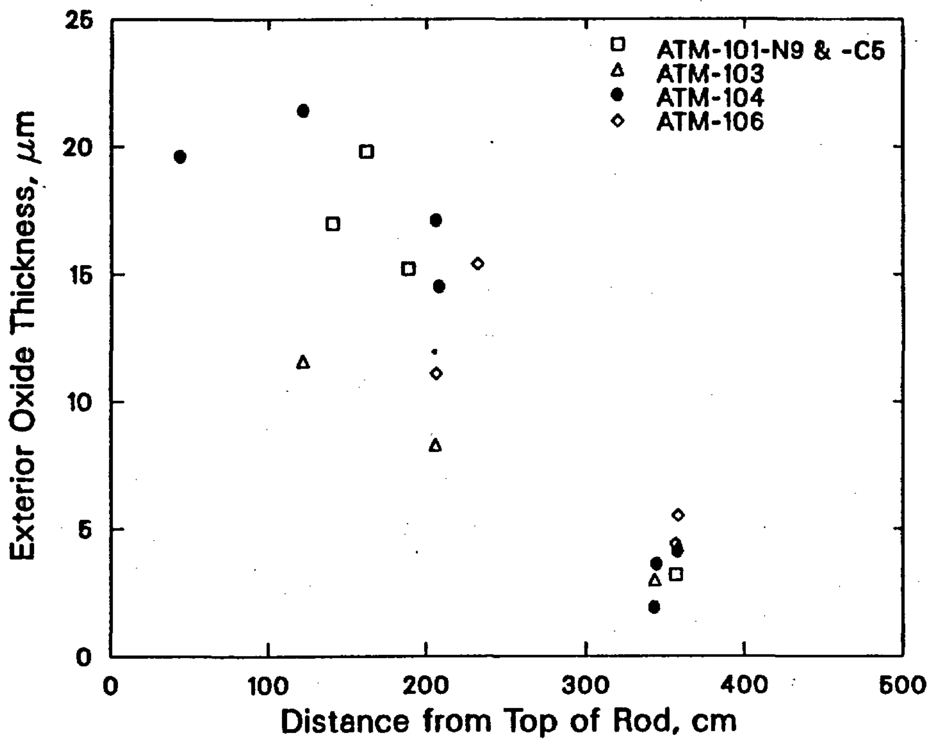


FIGURE 6.6. Variation of Exterior Oxide Thickness Along ATM-101, ATM-103, ATM-104, and ATM-106 Rods

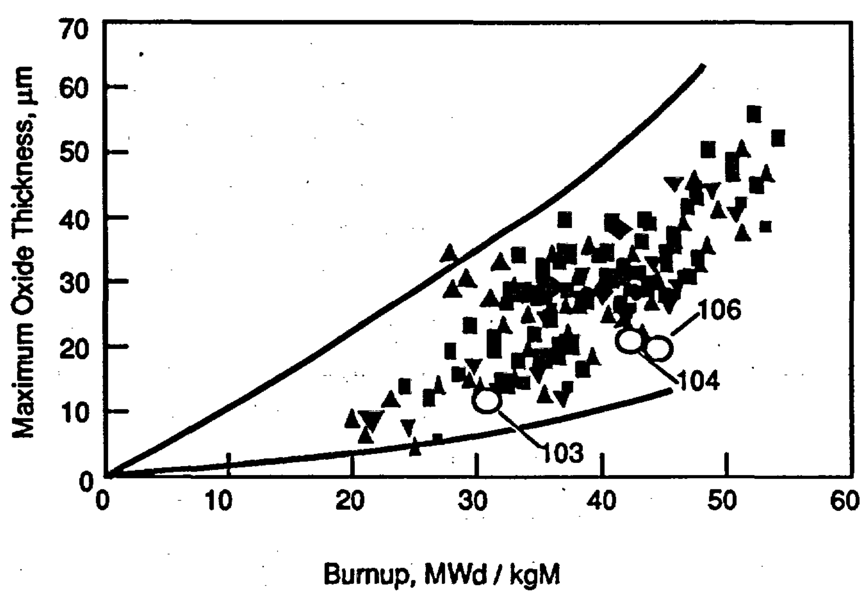


FIGURE 6.7. Estimated Maximum Oxide Thickness in ATMs-103, 104, and 106 (C-E data from Andrews and Lobre 1988)

results are near the lower bound of the C-E data, possibly partially due to differences in measurement techniques (the C-E data were obtained by eddy current measurements).

Oxide Structure. The structure of the oxide layers on the cladding exterior surface also changes along the length of the fuel rod. Sample 104-MKP109-N (see Figure 6.5), from the peak-power region near the center of the fuel rod, has a multilayered exterior oxide about 17 μm thick. The outermost 3- to 4-μm layer of oxide is probably loosely held to the inner layers (Figure 6.5a). The exterior oxide of Sample 104-MKP109-JJ (Figure 6.4a) from the low-power region near the bottom of the rod is a single solid layer approximately one fourth the thickness of the oxide in the peak-power region. The formation of multiple layers on the cladding is consistent with the cyclical oxidation process and described by Bryner (1979) and Clayton and Fischer (1985) and the results of examinations of other C-E fuel rods by Andrews and Lobre (1988). Based on the photomicrographs taken at four locations on the circumference of the cladding (see Table 6.5), the oxides are fairly uniform around the cladding at a given axial location. However, the thicker oxides occasionally are partially removed either during the examination process or during handling.

The Oxide/Hydrogen Relationship. The oxide thickness on the exterior surface of the cladding and the hydrogen content in the cladding both increase from the bottom to the top of the rod (see Figures 6.3 and 6.6). The relationship between hydrogen content in the cladding and the oxide thickness on the exterior surface of the cladding is indicated by the plot in Figure 6.8. The oxide thickness for Sample 104-MKP109-OO was estimated to be 2.5 μm based on its location and the data in Figure 6.6; there were no adjacent metallographic examinations in this region. The hydrogen content for Rod MKP109 increased approximately linearly with oxide thickness. Up to 11% of the hydrogen evolved during the corrosion of the Zircaloy to ZrO_2 was absorbed into the cladding samples based on the hydrogen and oxide data for Sample 104-MKP109-I and an assumed oxide density of 5.6 g/cm^3; but the average amount of hydrogen absorption in the cladding was considerably less than the peak absorption of 11%. Extrapolating the linear fit of the data in Figure 6.8 to

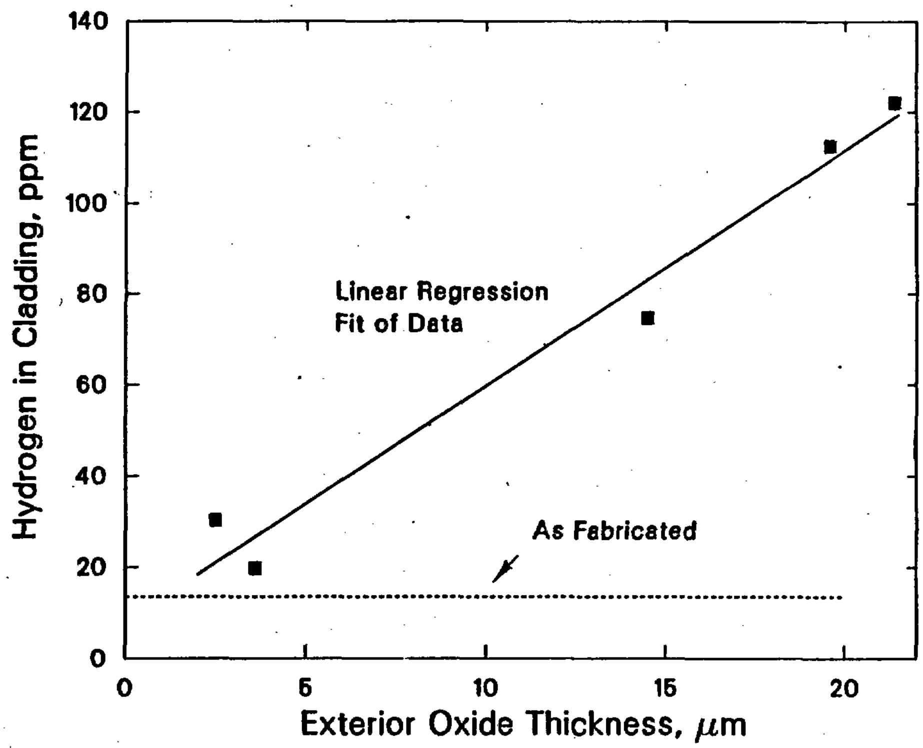


FIGURE 6.8. Comparison of Hydrogen in the Cladding to Exterior Cladding Oxide Thickness in Rod 104-MKP109

zero oxide thickness, the initial hydrogen content was 7.9 ppm, which is in fair agreement with the average as-fabricated value of 13.5 ppm reported by C-E. However, some cladding for fuel rods of earlier designs had thin prefilms prior to irradiation. If the as-fabricated hydrogen content was 13.5 ppm as indicated by C-E, then there may have been an oxide prefilm of about 1 μm prior to irradiation based on the trend in Figure 6.8. These results are fairly typical of PWR fuel rods (Pyecha et al. 1985; Johnson, Gilbert, and Guenther 1983).

Interior Deposits

Deposits on the cladding interior surface may result from oxidation of the cladding wall or reaction with the UO_2 and/or fission products released during irradiation. The amount of these deposits can provide supporting evidence for grain growth and fission gas release observed in fuel rods.

Work by Cubicciotti et al. (1976) provides relevant information on what might be expected on the interior surface of the cladding. They observed minimal deposits on cladding samples from H. B. Robinson fuel rods with slightly lower peak burnups than ATM-101 rods, which were also irradiated in the H. B. Robinson reactor. They also examined cladding from Maine Yankee fuel rods that had high fission gas release (10 to 13%) while achieving a burnup of only 13 MWd/kgM. Analyses of the cladding from Maine Yankee revealed significant deposits of fission products on the cladding near the locations where cracks formed in the fuel pellets during irradiation. The deposits contained cesium, iodine, tellurium and other volatile fission products along with uranium, zirconium, and oxygen. Particles of nearly pure CsI and particles with high tellurium concentrations were observed along side the deposits formed near the cracks. Fuel particles were occasionally stuck to the cladding wall by a material composed of U-Cs-O. A similar material apparently bonded fuel particles to the cladding wall of the H. B. Robinson sample examined.

The deposits on the interior surface of the cladding from Rod MKP109 were consistent with the range in fuel burnups and probable fission gas release. Negligible oxide/deposits were observed on the interior surface of samples from the upper and lower ends of the rods where the burnup and local fission gas release were low; see, for example, the interior surface of Sample 104-MKP109-JJ (Figure 6.4b). The cladding interior surface of Sample 104-MKP109-N from the peak-power region appeared to have localized oxide "islands" that rapidly thinned at their ends (Figure 6.5b). However, examination of four photomicrographs of Sample 104-MKP109-O (see Appendix E) indicated that the interior deposit was relatively uniform, which suggests that the deposits on the interior surface of Sample 104-MKP109-N may have been more uniform than apparent from the single photomicrograph.

The range in features on the cladding interior surface of the ATM-104 rod is consistent with previous results from MCC examinations and work by Cubicciotti et al. (1976). Peak-power samples examined from ATM-101 and ATM-103 rods with low rod-average fission gas releases also had localized regions where deposits were observed on the cladding. The Zircaloy cladding was partially removed underneath some of the deposits in ATM-104 cladding (see Figure 6.5a, in which the original cladding wall is marked). Samples from the peak-power and lower-power regions of an ATM-106 rod with 11% rod-average fission gas release had relatively uniform oxide/reaction product deposits on the cladding interior surface, which is consistent with the higher fission gas release and apparent higher operating temperatures in the ATM-106 rods. In general, the thickness and extent of the deposits on the interior surface of the cladding have increased with increasing local burnup and apparent fuel temperatures.

6.2.2 Cladding Hydride Examinations

The cladding was metallographically examined to determine the general level of hydrides as well as the orientation of hydrides throughout the cladding. Hydride orientations are important to the failure sensitivity of the cladding because hydrides oriented in the radial direction with repect to the cladding surfaces are detrimental to the cladding strength. Circumferentially oriented hydrides do not decrease the cladding ductility. Based on the Fn numbers[(a)] reported in Table 3.2, most of the hydrides observed in the as-fabricated cladding were circumferentially oriented.

The Zircaloy-4 cladding was etched with 45% HNO_3, 45% glycerin, 10% HF to reveal the cladding grain structure. This step was followed by etching with a 45% HNO_3, 45% H_2O_2, 10% HF solution to reveal the hydrides. A comparison is made in Figure 6.9 of hydriding in transverse samples taken from the near the top, middle, and bottom regions of Rod MKP109. The hydride concentrations are greatest near the top of the rod, as observed in Sample 104-MKP109-C, and decrease to almost negligible amounts at the bottom of the rod, as observed in Sample 104-MKP109-KK. Sample 104-MKP109-0, taken from near the middle of the rod, has an intermediate amount of hydriding. Using the mean oxide thickness for Samples 104-MKP109-C and -0 and an estimated oxide thickness of 4.1 μm for Sample 104-MKP109-JJ, the relationship between hydrogen and oxide thickness yields 112, 75, and 25 ppm of hydrogen in these samples, respectively. Thus, the increased number of hydrides from the

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(a) The Fn number is a measure of the number of hydride platelets oriented within ±45° of the radial direction. A low Fn number indicates most of the hydrides are tangentially oriented with respect to the cladding radius, i.e., circumferentially oriented.

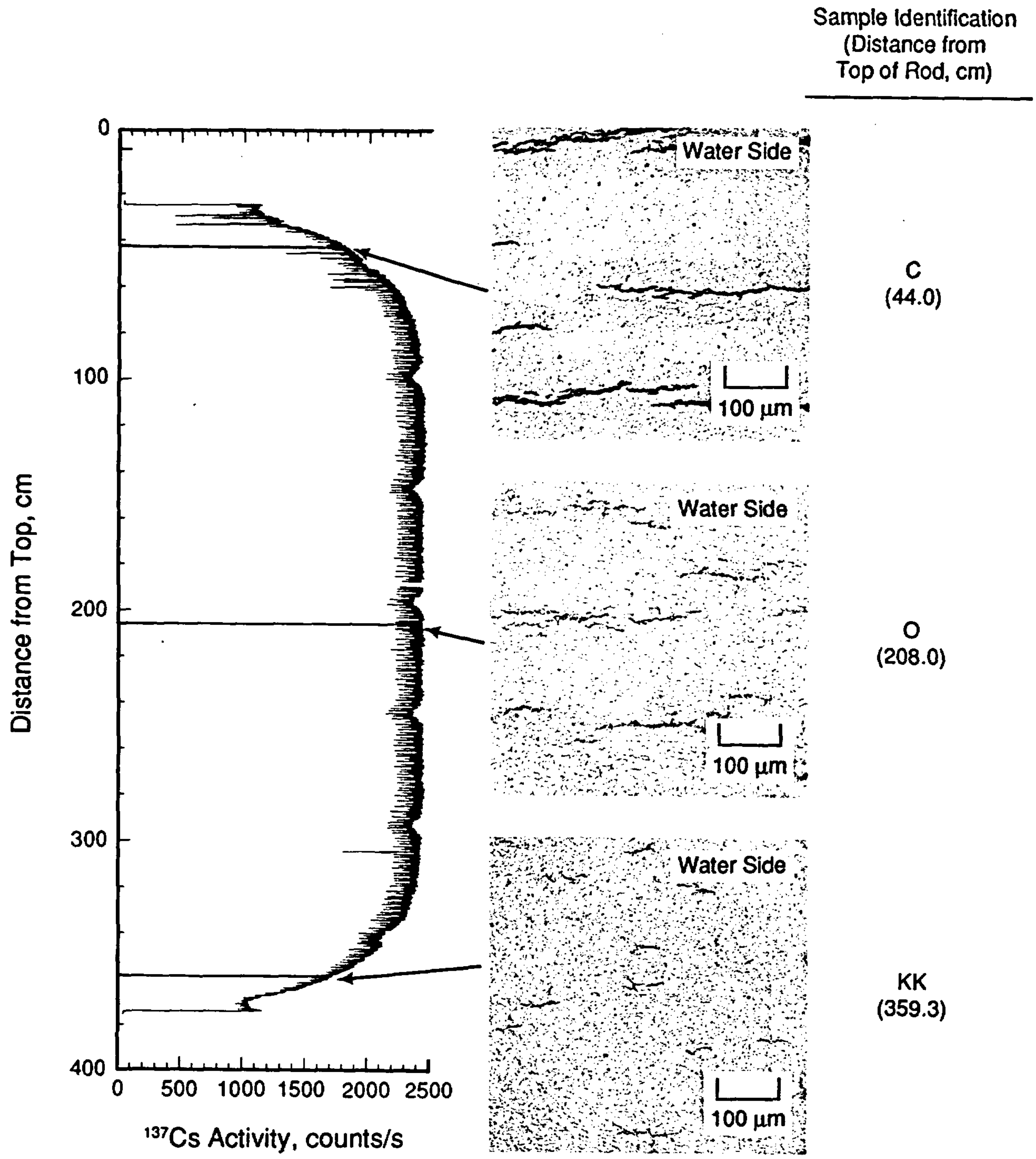


FIGURE 6.9. Comparison of Hydriding in Etched Cladding from Rod 104-MKP109

bottom to the top of the rod compares well with the levels of hydrogen in the cladding. As illustrated in Figure 6.9, hydrides precipitate at room temperature at hydrogen levels as low as about 25 ppm.

For each sample examined from Rod MKP109, the hydrides are oriented primarily in the circumferential/longitudinal planes. These results are similar to those obtained for samples examined from ATM-103 and ATM-106 rods, all of which were made by C-E and irradiated in the same reactor.

7.0 FUEL RADIONUCLIDE INVENTORY

It is important to define the inventory and distribution of radionuclides in spent fuel so that modelers can assess the performance of the proposed repository and scientists can evaluate their results from tests of spent fuel. As mentioned previously, the NRC and EPA limit the amount of radionuclide release that will be allowed from the proposed nuclear waste repository, thus requiring an understanding of the radionuclide inventory (EPA 1985; NRC 1983). The quantities of radionuclides within the fuel are also important to evaluations of spent fuel for transportation and handling operations prior to receipt at the repository site.

This section provides the results from radiochemical analyses, autoradiography, and EPMA that were conducted to define the inventory and distribution of the actinides, fission products, and ^{14}C in fuel samples from Rod MKP109 of ATM-104. The radiochemical analyses were conducted primarily to confirm the expected fuel burnup and determine how well the measured concentrations of selected isotopes compared with those predicted by the ORIGEN2 code. Secondary reasons for the radiochemical analyses were to 1) characterize radionuclide migration (which ORIGEN2 cannot do) as discussed in Section 8.0 and 2) characterize inventories of radionuclides for which input information is unknown or uncertain, such as ^{14}C or various other activation products. Autoradiography and EPMA were used to evaluate the radial distribution of the actinides and fission products. Autoradiography provides a qualitative estimate of the distribution of isotopes that emit either alpha particles (alpha autoradiography) or beta particles and/or gamma rays (beta/gamma autoradiography). EPMA has been used to define the concentration of elements across the fuel radius and to provide a means of determining the radial burnup profile. Results of these examinations are provided in discussions of the fuel burnup (Section 7.1), comparisons of the measured and predicted amounts of selected radionuclides (Section 7.2), and the distribution of actinides and fission products across the fuel radius (Section 7.3).

7.1 FUEL BURNUP MEASUREMENTS

Burnup is the term used to define the amount of energy obtained from the fuel during the course of irradiation and is expressed as the amount of energy produced per unit of fuel weight, such as MWd/kgM, or as the percentage of initial fissile atoms consumed during irradiation, atom% (at%). Because fuel burnup is related to the number of fission events, each of which produces about 200 MeV of energy, the inventory of radionuclides and other fuel characteristics are often expressed as a function of fuel burnup. This section presents 1) the results of burnup measurements for three samples from Rod MKP109 and the development of a correlation between fuel burnup and the ^{137}Cs activity measured during gamma scanning of the entire fuel rod, and 2) comparison of measured and predicted rod-average burnups.

Analytical samples are taken at locations representative of various burnups and fuel and cladding operating temperatures as shown previously in Figure 4.4. The samples used for burnup analyses were obtained from the lower half of Rod MKP109 in conjunction with analyses for the isotopes of uranium and plutonium and other specific nuclides. Additional details on these fuel sections, as they relate to other specimens cut from Rod MKP109, are provided in Appendix C. The procedures used in performing the radiochemical analyses are described in Table 7.1.

7.1.1 Burnup Results and Correlation with Gamma Scan

Burnup analyses were completed on the fuel from Samples 104-MKP109-P, 104-MKP109-CC, and 104-MKP109-LL from the lower half of Rod MKP109 (see Figure 4.4). Based on the ^{137}Cs activity obtained from gamma scanning the entire length of Rod MKP109, these samples were expected to represent burnups from about 60% to 100% of the peak burnup in this rod. The measured burnup values for these samples have been correlated with the ^{137}Cs gamma scan results to estimate the burnup and radionuclide content of any particular sample from ATM-104 that might be provided to a repository experimenter.

The results of the burnup analyses are listed in Table 7.2. Values are presented for burnups determined from the amounts of ^{148}Nd measured in the samples from Rod MKP109. The ^{137}Cs activities measured at the locations of

TABLE 7.1. Description of Radiochemical Analysis Procedures for Fuel Samples

Analysis	Description
Burnup Sample Preparation	Weighed sample is dissolved in heated 12N HNO_3 (+trace HF). Solution is separated from cladding and made up to 100 mL. Aliquots are taken for subsequent analyses. Uncertainty: ±1.0%.[a]
Burnup (including U and Pu isotopes)	Fission product neodymium is chemically separated from irradiated fuel and determined by isotopic dilution mass spectrometry. Enriched ^{150}Nd is used as the neodymium isotope diluent, and mass 142 is used to determine natural neodymium contamination. Uranium and plutonium are also determined by mass spectrometry. The method uses a calibrated triple spike of ^{150}Nd, ^{233}U, and ^{242}Pu per ANSI/ASTM Standard Test Method E321-79. Uncertainty: Atom % burnup, ±2.5%; Pu, ±1.6%; U, ±1.6%.
^{14}C	The carbon in a specially-crushed sample of the fuel is evolved by combustion in pure oxygen. The CO_2 is collected and ^{14}C is measured by liquid scintillation counting. Uncertainty: ±5.6%.
^{79}Se	Selenium-79 is separated from other radioactive species by passing the chemically-adjusted solution through a cation plus anion exchange resin column. The selenium in the column effluent is distilled from hydrobromic acid and precipitated as metal by reducing it with hydroxylamine hydrochloride. The reduced metal is dissolved in nitric acid, and the ^{79}Se is measured using liquid scintillation counting. Uncertainty: ±4.9%.
^{90}Sr	The ^{90}Sr is separated from other radioactive species by selective elution from a cation exchange resin using 2-methyllactic acid. Following separation, the growth of ^{90}Y is measured by beta counting. The ^{90}Sr is then calculated based on the growth of the ^{90}Y daughter over a specific time. Uncertainty: ±5.7%.

(a) Uncertainties are one relative standard deviation that is based on experience in the PNL laboratory.

TABLE 7.1. (contd)

Analysis	Description
^{99}Tc	Technetium is separated from other radioactive species by a process that absorbs most other species on to a cation exchange resin. The technetium is extracted from the effluent into hexone as tetraphenylarsonium pertechnetate. The technetium activity is then measured by beta counting. Uncertainty: ±3.5%.
^{129}I	Iodine is separated by distillation and precipitation as AgI. Iodine-129 is determined in a GeLi well detector. Uncertainty: ±2.2%.
^{126}Sn	Tin is separated by a combination of cation and anion exchange resins. Tin is finally eluted with dilute nitric acid and measured using a GeLi gamma spectrometer. Uncertainty: ±10.2%.
^{135}Cs	Cesium is separated from other elements by chromatographic elution from a cation exchange column. Isotopic abundance of the cesium isotope is determined by mass spectrometry. Uncertainty: ±14%.
^{137}Cs	The cesium is determined by gamma ray spectrometry on an aliquot of the aqueous solution. Uncertainty: ±3.5%.
^{237}Np	Neptunium-237 is separated from other radionuclides species by extraction into a mixture of tri-iso-octylamine (TiOA) in xylene, stripped from the TiOA phase with HCl and re-extraction into a mixture of thenoyltrifluoracetone (TTA) in xylene for additional separation. Neptunium-237 is measured by alpha counting. A ^{239}Np tracer is added to the sample and gamma-counted to determine a recovery factor. Uncertainty: ±1.9%.
^{241}Am, ^{243}Cm plus ^{244}Cm	Americium and curium are separated using cation and anion exchange and determined by alpha spectrometry. Uncertainty: ^{241}Am, ±4.9%; ^{243}Cm plus ^{244}Cm, ±4.1%.

TABLE 7.2. Burnup Results for ATM-104 Fuel Samples[(a)]

Sample No.	Measured Burnup[(b)] Atom%	Measured Burnup[(b)] MWd/kgM	Measured ^{137}Cs Activity Counts/s[(c)]	Sample Location
104-MKP109-P	4.642	44.34	2308	Typical peak burnup in center portion of Rod MKP109.
104-MKP109-CC	3.889	37.12	1962	Representative of ~84% of peak ^{137}Cs activity in bottom portion of Rod MKP109.
104-MKP109-LL	2.869	27.35	1535	Representative of ~63% of peak ^{137}Cs activity in bottom portion of Rod MKP109.

(a) See sectioning diagrams in Appendix C for sample locations with respect to gamma activity.
(b) Burnup analyses were conducted in May 1987, 5.08 years after discharge. The calculation procedure used was ASTM Standard E-219, "Standard Test Method for Atom Percent Fission in Uranium Fuel (Radiochemical Method)."
(c) Cesium-137 activities are corrected as explained in Appendix B.

these fuel samples during the full-length gamma scan of Rod MKP109 are also presented in Table 7.2; these ^{137}Cs activities were adjusted based on burnup analyses and gamma scans for Rod MKP070 and other ATM-104 rods that are not yet available for publication (see Appendix B). The ^{137}Cs activities obtained for the burnup samples during gamma scanning of Rod MKP109 are plotted in Figure 7.1 against measured burnup values, in units of MWd/kgM for ease of interpolating between the values in the tables of Appendix D.

Because the ^{137}Cs activity and the measured burnup form a reasonably linear relationship in the burnup range measured, an equation can be derived for estimating the burnup in other fuel samples from Rod MKP109. Using the ^{137}Cs activity and burnup values shown in Table 7.2 and similar results for

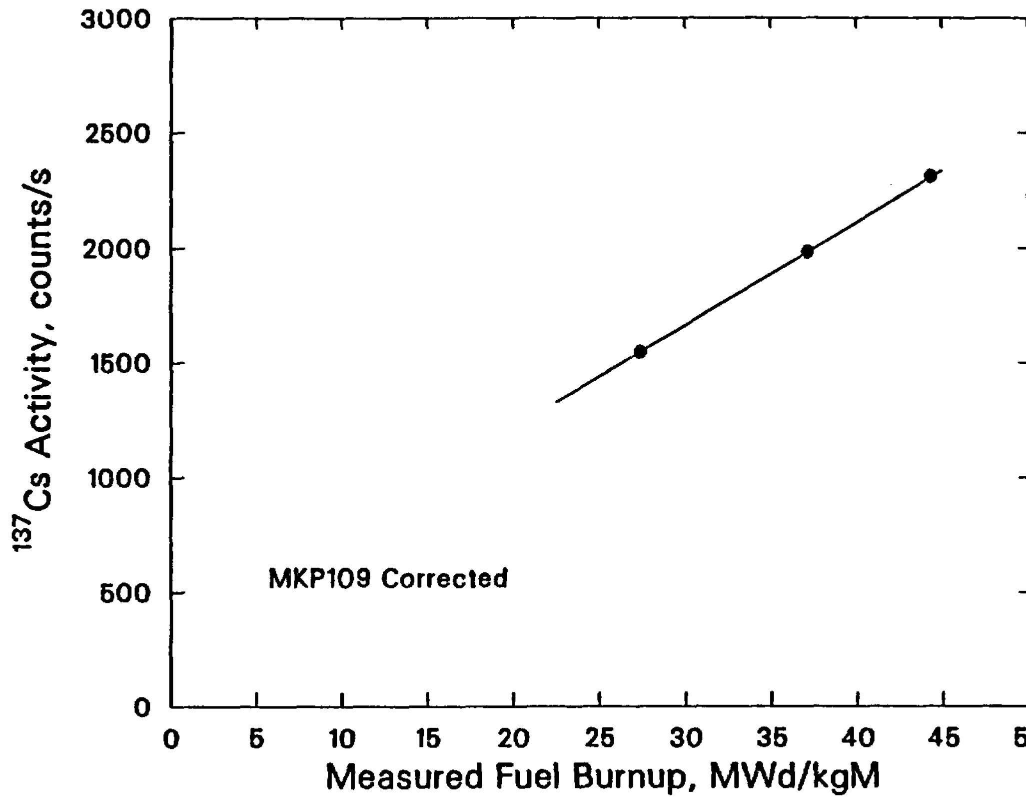


FIGURE 7.1. Correlation Between ^{137}Cs Gamma Activity and ^{148}Nd Burnup Analyses

two samples from Rod MKP070, the relationship between burnup and ^{137}Cs activity in a sample from an ATM-104 rod is determined to be as follows:

$$BU = 0.0222\ A - 6.8 \qquad [1]$$

where BU = the burnup of the fuel sample in question, MWd/kgM

A = the activity measured over the length of the fuel samples in question as of March 28, 1987 (see the sectioning diagram in Appendix C)

Equation [1] is valid for determining the burnup in ATM-104 fuel samples as long as the appropriate ^{137}Cs activities are used; the equation is based on ^{137}Cs measurements of fuel with a 4.92-year discharge time, such as given for Rod MKP109 in Appendix C. The correlation between ^{137}Cs activity and burnup values can be used in conjunction with the radionuclide inventory calculations in Appendix D and the gamma scans in Appendix C to estimate the radioisotopic inventory for a particular ATM-104 sample that might be used by an experimenter.

When ATM-104 fuel rods are gamma scanned in the future, a correction for the 30.17-year half life of ^{137}Cs will be incorporated in comparisons of gamma scan data, as was done in comparing data for Rod MKP070 with data for Rod MKP109. The expected rate of decrease in ^{137}Cs activity is indicated by the plot of calculated ^{137}Cs activity shown in Figure 7.2. If there is no change in the sensitivity of the gamma scanning system with time, then the gamma scanning data need be corrected only for the decay indicated in Figure 7.2. However, the sensitivity of the gamma scanning system is determined by detector efficiencies, geometric effects, background activity, and ^{137}Cs decay, and may require a slightly different correction factor than for just the decay of ^{137}Cs alone. The overall decrease in sensitivity of the gamma scanning system for the ATM-104 rods has been slightly less than the rate of ^{137}Cs decay (see Appendix B). Because of the small difference between the expected and apparent decrease in ^{137}Cs activity measured with the gamma scanning equipment, only the correction for ^{137}Cs decay was used in determining the equation for fuel burnup. The gamma scan data for other ATM-104 rods can be corrected to March 28, 1987, for comparison with Rod MKP109 by using the scan dates indicated on the respective graphs in Appendix B.

7.1.2 Rod-Average Burnups

While the previous discussion of measured burnups provided a relationship between local fuel burnups and local cesium activity, rod-average burnups are needed for many assessments of fuel performance. One of the reasons that the ATM-104 rods were acquired for characterization was that the average burnup of a rod from this ATM was expected to be about 42 MWd/kgM. This burnup level is considered to be moderately high compared with previously discharged rods that have typically had about 33 MWd/kgM burnup, although future PWR spent fuel may have average burnups of 50 to 55 MWd/kgM (Andrews and Lobre 1988).

C-E calculated the rod-average burnups for each of the rods in Assembly D047 based on reactor core neutronics and thermal hydraulics data. Rods

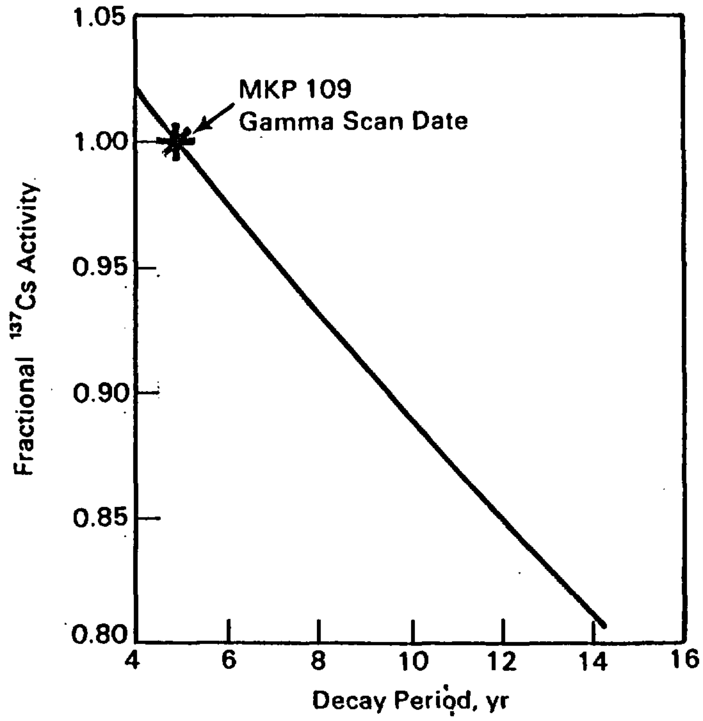


FIGURE 7.2. Fractional ^{137}Cs Activity as a Function of Decay Period

MKP059 and MKP109 were expected to have rod-average burnups of 42.6 MWd/kgM and 40.4 MWd/kgM, respectively. Characterization data obtained from burnup analyses and gamma scanning may be used as described below to determine rod-average burnups that can be compared with rod-average burnups calculated by C-E.

The ^{137}Cs activities measured during gamma scanning of Rods MKP059 and MKP109 and the relationship between ^{137}Cs activity and burnup were used to determine the rod-average burnups for these two rods. Rod-average burnups were determined by numerically integrating under the cesium curves in the respective gamma scan plots (Figures B.3 and B.7) and dividing by the appropriate fuel column length. The fuel column lengths were 351.0 cm for Rod MKP059 and 349.4 cm for Rod MKP109. Average ^{137}Cs activities for Rods MKP059 and MKP109 were 2,139 and 2089 counts/sec, respectively. Using Equation [1], Rod MKP059 had a rod-average burnup of 40.7 MWd/kgM, which is about 4.4% lower than predicted by C-E. Rod MKP109 had a rod-average burnup of 39.6 MWd/kgM, which is 2.0% lower than predicted by C-E. Calculations by C-E indicated that the rod-average burnup in Rod MKP059 would be 5.3% higher than in Rod MKP109; our calculations indicate that Rod MKP059 had 2.8% higher burnup than in Rod MKP109. Considering the 2.5% uncertainty in measuring burnup and small uncertainties in determining average cesium activities, the rod-average burnups determined for Rods MKP059 and MKP109 agree very well with C-E values.

7.2 FUEL RADIOCHEMICAL ANALYSES AND COMPARISONS WITH ORIGEN2 PREDICTIONS

Considering the vast number of elements and isotopes that exist in spent fuel, it is practical to measure only a limited number of radionuclides for comparison with predicted values. Oversby (1987b) has indicated that 17 or fewer chemical elements may be considered important to meeting the NRC and EPA requirements, depending on a number of assumptions. A list of elements and radionuclides important to repository performance was developed through discussions with repository representatives. The elements and radionuclides that have been, or may be, measured by the MCC include the isotopes listed previously in Table 7.1.[a] Tritium (^{3}H) was not included in the original list of isotopes of interest to the repository experimenters, but will be included in future analyses. The procedures used in performing the radiochemical analyses and an estimate of the uncertainty, expressed as the relative standard deviation, are provided for each analysis described in Table 7.1. Results of the radiochemical analyses are provided in Section 7.2.1. Comparisons of the analyses of ^{14}C and ^{129}I in the fuel are made against results from other ATMs in Section 7.2.2.

7.2.1 Results of Fuel Radiochemistry

A total of 11 fuel samples from Rod MKP109 were submitted for radiochemical analyses as indicated in Figure 4.4 and Appendix C. The burnup levels were estimated for the eight fuel samples being analyzed for ^{14}C or ^{129}I by using the gamma scan sectioning diagram in Appendix C and Equation [1] relating fuel burnup and ^{137}Cs activity in Section 7.1.1. Actual burnup

(a) Note: The MCC has also been requested to analyze ^{93}Zr, ^{226}Ra, ^{243}Am, and ^{245}Cm in the ATM fuels. These analyses have not been performed on ATM-104 because procedures were not in place in the analytical laboratory and funding limitations prevented developing the procedures.

values were measured for the remaining three samples. The results of the radiochemical analyses and comparisons with the ORIGEN2 predictions are provided in Table 7.3.

Nearly all of the radiochemical results agreed with ORIGEN2 predictions within ±10%. Exceptions to this generally good agreement between measured and predicted values for the fuel radiochemistry occurred for ^{79}Se, ^{126}Sn, and ^{14}C. The greatest exceptions are for ^{79}Se and ^{126}Sn, for which the measured values were about 15% and 22% of their respective values predicted by ORIGEN2. Previous results for fuel from ATM-101, ATM-103, ATM-105, and ATM-106 analyses also indicated similar differences between the measured and predicted values for ^{79}Se and ^{126}Sn (Guenther et al. 1989). The amount of ^{237}Np measured in the fuel samples was about 15% less than predicted. These data are being provided to Oak Ridge National Laboratory for their validation work on the ORIGEN2 code (Roddy and Mailen 1987).

The variation in the analytical-to-predicted ratios for all of the samples from the ATM-104 rod are compared graphically in Figure 7.3. The triangles represent the mean values of the ratios and the bars represent one standard deviation. All of the measured quantities of uranium and plutonium isotopes, except for ^{241}Pu, were within 5% of the predicted concentrations. While the measured amounts of ^{79}Se and ^{126}Sn were considerably less than predicted, as explained above, the measured amounts were consistently lower regardless of the sample burnup. The ^{14}C concentrations averaged 36% higher than predicted; possibly because the amount of nitrogen in the fuel was actually higher than the assumed amount of 25 ppm. Fabrication data from C-E indicates that there could have been 14 to 34 ppm initial nitrogen in the fuel (see Table 3.1).

7.2.2 Comparison with Other ATMS

The variations in ^{14}C and ^{129}I contents in the fuel at different burnups have been compared with results from other relevant ATMs. The ^{14}C content in the fuel is of interest because very little data exists in the literature for this radionuclide. The amount of ^{129}I in the fuel is necessary for evaluating the release of iodine to the fuel/cladding surfaces.

TABLE 7.3. Fuel Radiochemical Analyses Results and Comparisons with ORIGEN2 Radionuclide Inventory

Sample ID and Radionuclide	Burnup,[a] MWd/kgM	Analytical Value	ORIGEN2 Value(b)	Ratio, Analytical to ORIGEN2
104-MKP109-E				
C-14	33.4	9.00×10^{-7} Ci/g fuel[c]	5.734×10^{-7} Ci/g fuel	1.57
104-MKP109-J				
C-14	44.3	9.31×10^{-7} Ci/g fuel[c]	8.105×10^{-7} Ci/g fuel	1.15
104-MKP109-P				
U-234	44.34	1.2×10^{-4} g/g fuel	1.200×10^{-4} g/g fuel	1.00
U-235		3.54×10^{-3} "	3.420×10^{-3} "	1.04
U-236		3.69×10^{-3} "	3.599×10^{-3} "	1.03
U-238		8.249×10^{-1} "	8.239×10^{-1} "	1.00
Pu-238		2.688×10^{-4} "	2.688×10^{-4} "	1.00
Pu-239		4.357×10^{-3} "	4.501×10^{-3} "	0.97
Pu-240		2.543×10^{-3} "	2.437×10^{-3} "	1.04
Pu-241		1.020×10^{-3} "	1.099×10^{-3} "	0.93
Pu-242		8.401×10^{-4} "	7.696×10^{-4} "	1.09
Np-237		3.31×10^{-7} Ci/g fuel	3.913×10^{-7} Ci/g fuel	0.85
Am-241		1.31×10^{-3} "	1.245×10^{-3} "	1.05
Cm-243 & 244		6.40×10^{-3} "	6.038×10^{-3} "	1.06
Se-79		6.49×10^{-8} "	4.695×10^{-7} "	0.14
Sr-90		6.58×10^{-2} "	6.667×10^{-2} "	0.99
Tc-99		1.35×10^{-5} "	1.457×10^{-5} "	0.93
Sn-126		2.2×10^{-7} "	9.916×10^{-7} "	0.22
Cs-135		4.95×10^{-7} "	4.884×10^{-7} "	1.01
Cs-137		1.09×10^{-1} "	1.059×10^{-1} "	1.03
104-MKP109-T				
I-129	44.4	3.75×10^{-8} Ci/g fuel	3.816×10^{-8} Ci/g fuel	0.98
104-MKP109-U				
C-14	44.4	1.63×10^{-6} Ci/g fuel[c]	8.068×10^{-7} Ci/g fuel	2.02
104-MKP109-CC[c]				
U-234	37.12	1.4×10^{-4} g/g fuel	1.317×10^{-4} g/g fuel	1.06
U-235		5.17×10^{-3} "	5.111×10^{-3} "	1.01
U-236		3.53×10^{-3} "	3.479×10^{-3} "	1.01
U-238		8.327×10^{-1} "	8.297×10^{-1} "	1.00
Pu-238		1.893×10^{-4} "	1.891×10^{-4} "	1.00
Pu-239		4.357×10^{-3} "	4.475×10^{-3} "	0.97
Pu-240		2.239×10^{-3} "	2.242×10^{-3} "	1.00
Pu-241		9.028×10^{-4} "	9.493×10^{-4} "	0.95
Pu-242		5.761×10^{-4} "	5.419×10^{-4} "	1.06
Np-237		2.51×10^{-7} Ci/g fuel	3.193×10^{-7} Ci/g fuel	0.79
Am-241		1.18×10^{-3} "	1.104×10^{-3} "	1.07
Cm-243 & 244		2.93×10^{-3} "	2.738×10^{-3} "	1.07
Se-79		6.036×10^{-8} "	3.997×10^{-7} "	0.15
Sr-90		5.90×10^{-2} "	5.877×10^{-2} "	1.00
Tc-99		1.23×10^{-5} "	1.262×10^{-5} "	0.97
Sn-126		1.82×10^{-7} "	8.030×10^{-7} "	0.23
Cs-135		4.59×10^{-7} "	4.556×10^{-7} "	1.01
Cs-137		9.01×10^{-2} "	8.867×10^{-2} "	1.02

TABLE 7.3. Fuel Radiochemical Analyses Results and Comparisons with ORIGEN2 Radionuclide Inventory (contd)

Sample ID and Radionuclide	Burnup,(a) MWd/kgM	Analytical Value	ORIGEN2 Value(b)	Ratio, Analytical to ORIGEN2
104-MKP109-FF				
I-129	34.9	3.39×10^{-8} Ci/g fuel	2.975×10^{-8} Ci/g fuel	1.14
104-MKP109-GG				
C-14	33.8	9.26×10^{-7} Ci/g fuel(c)	5.977×10^{-7} Ci/g fuel	1.55
104-MKP109-LL				
U-234	27.35	1.6×10^{-4} g/g fuel	1.502×10^{-4} g/g fuel	1.07
U-235		8.47×10^{-3} "	8.467×10^{-3} "	1.00
U-236		3.14×10^{-3} "	3.084×10^{-3} "	1.02
U-238		8.425×10^{-1} "	8.371×10^{-1} "	1.01
Pu-238		1.012×10^{-4} "	9.713×10^{-5} "	1.04
Pu-239		4.264×10^{-3} "	4.318×10^{-3} "	0.99
Pu-240		1.719×10^{-3} "	1.770×10^{-3} "	0.97
Pu-241		6.812×10^{-4} "	6.947×10^{-4} "	0.98
Pu-242		2.886×10^{-4} "	2.771×10^{-4} "	1.04
Np-237		1.89×10^{-7} Ci/g fuel	2.137×10^{-7} Ci/g fuel	0.88
Am-241		8.56×10^{-4} "	8.423×10^{-4} "	1.02
Cm-243 & 244		7.34×10^{-4} "	6.539×10^{-4} "	1.12
Se-79		4.55×10^{-8} "	3.014×10^{-7} "	0.15
Sr-90		4.59×10^{-2} "	4.657×10^{-2} "	0.99
Tc-99		9.59×10^{-6} "	9.713×10^{-6} "	0.99
Sn-126		1.25×10^{-7} "	5.602×10^{-7} "	0.22
Cs-135		4.16×10^{-7} "	4.094×10^{-7} "	1.02
Cs-137		6.71×10^{-2} "	6.526×10^{-2} "	1.03
104-MKP109-OO				
I-129	22.7	2.10×10^{-8} Ci/g fuel	1.885×10^{-8} Ci/g fuel	1.11
104-MKP109-PP				
C-14	20.4	6.45×10^{-7} Ci/g fuel(c)	3.223×10^{-7} Ci/g fuel	2.00

(a) Burnup values were measured for Samples 104-MKP109-P, 104-MKP109-CC, and 104-MKP109-LL. All other burnups are estimated using the equation [1] in Section 7.1.1 and ^{137}Cs activity in Appendix C for specific samples. Estimated burnups are probably accurate to about ±0.5 MWd/kgM.

(b) ORIGEN2 values obtained from Appendix D using burnup derived with equation [1] in Section 7.1.1 and ^{137}Cs activity in Appendix C, except for Samples 104-MKP109-P, 104-MKP109-CC, and 104-MKP109-LL, for which these values were directly calculated using ORIGEN2 and the measured sample burnup. Values in Appendix D were converted from g/gU to g/g UO_2. 1 g of unirradiated UO_2 is equivalent to 1 g of as-irradiated fuel with all fission products.

(c) Average of two measurements that varied within less than 10%, except 104-MKP109-J, which varied ±25%.

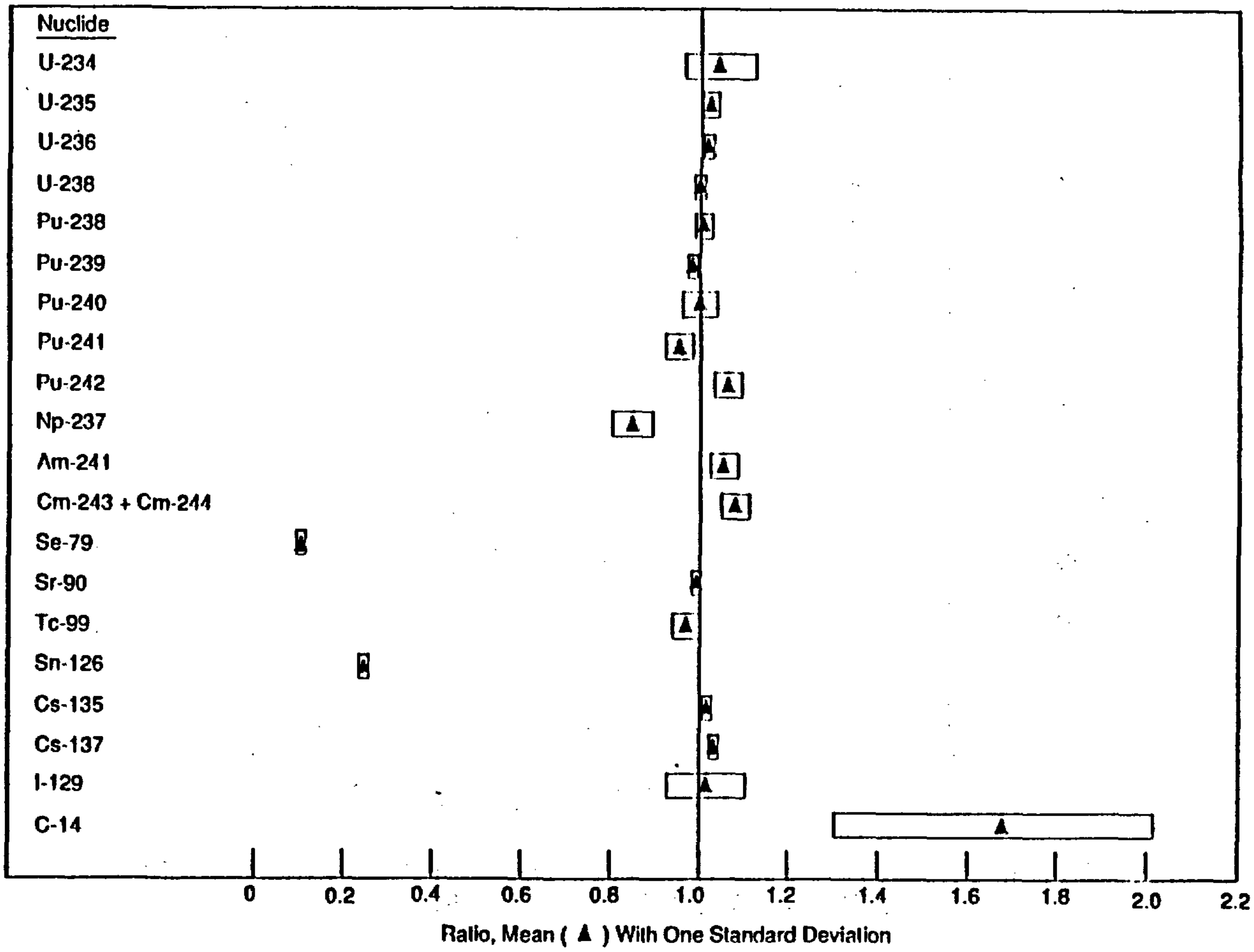


FIGURE 7.3. Ratios of Measured-to-Predicted Values for Nuclides in ATM-104 Fuel

The ^{14}C values measured in fuel from ATM-101, ATM-103, ATM-105, and ATM-106 are compared with the results for the ATM-104 fuel in Figure 7.4. There is a distinct increase in ^{14}C content with increasing burnup in all the fuels, even considering the range in ^{14}C values for a given burnup in an ATM. The initial nitrogen content in the ATM-106 fuel was about 80% higher than in either ATM-103 or ATM-104 fuel. The ATM-101 and ATM-105 rods are presumed to have had initial nitrogen contents similar to those in the ATM-103 and ATM-104 rods based on the radiochemical analyses. The effect of the higher initial nitrogen content in the ATM-106 rods is apparent by the higher ^{14}C contents at almost all burnups for the ATM-106 rod. About 75% of the ^{14}C inventory in an

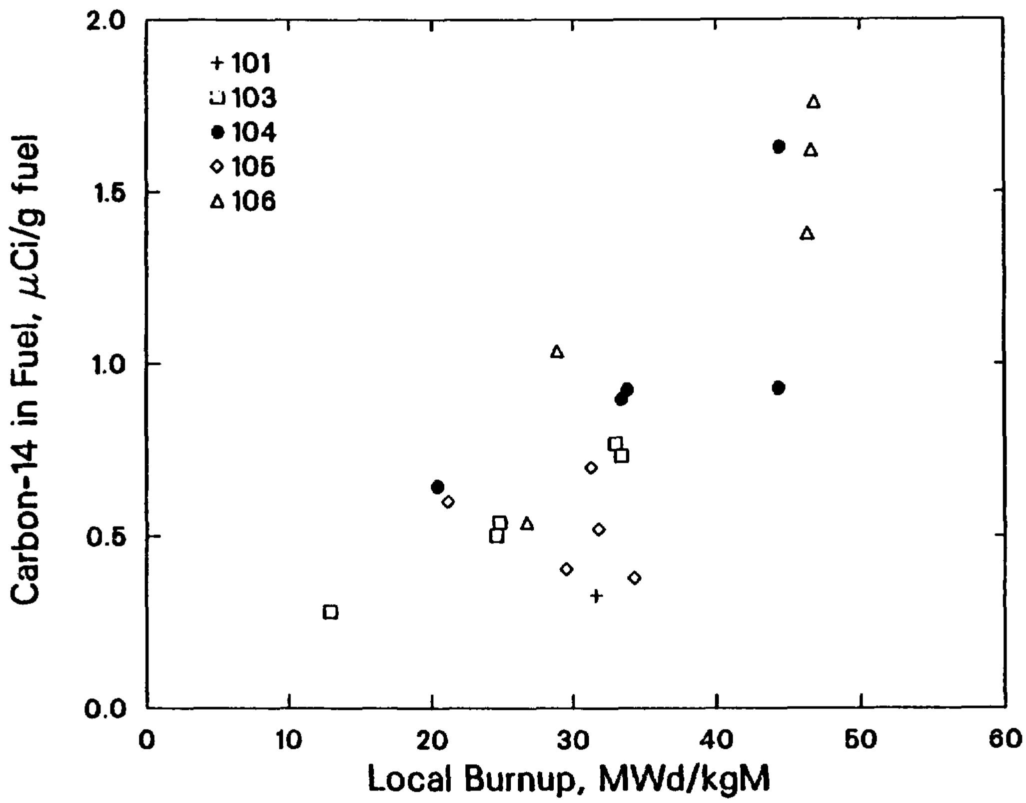


FIGURE 7.4. Comparison of ^{14}C in the fuel from ATM-101, ATM-103, ATM-104, ATM-105 and ATM-106.

ATM-104 rod is contained within the fuel based on the fuel weight, initial nitrogen content, and radiochemical analyses of the gas, fuel and cladding from ATM-104.

The amounts of ^{129}I in fuel from ATM-104 and ATM-103 are compared in Figure 7.5. This comparison is made between these two ATMs because they both consist of PWR fuel with low fission gas release; fuel with high fission gas release, such as ATM-106, may have a measurable amount of iodine migration from the fuel to the cladding interior surfaces. The amount of ^{129}I in the fuel in both the ATM-103 and ATM-104 rods indicates a fairly linear relationship with burnup, as is expected. The results plotted in Figure 7.5 are from three samples from Rod MLA098 of ATM-103 and three samples from Rod MKP109 of ATM-104, all of which were taken from the lower half of their respective rod.

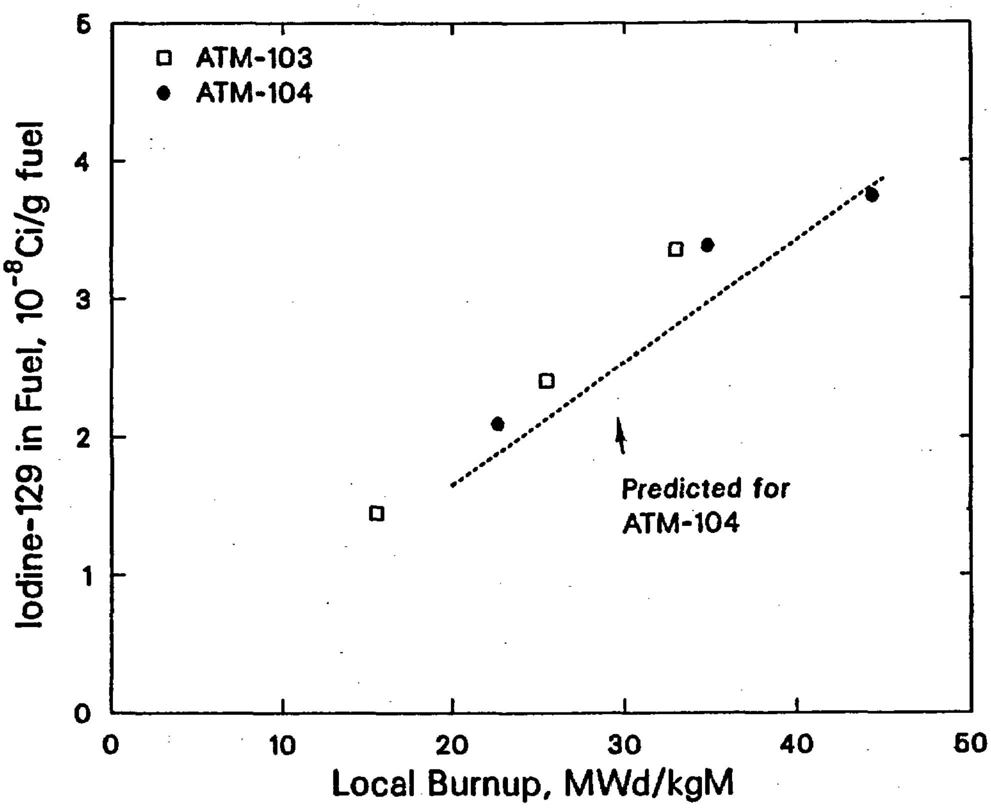


FIGURE 7.5. Trend in ^{129}I in the Fuel Versus Burnup in Rods MLA098 of ATM-103 and MKP109 of ATM-104

The data fit a straight line reasonably well, considering the potential errors in measuring the burnup, the ^{137}Cs content of the fuel, the fuel location, and the ^{129}I content. The amount of iodine increases with increasing burnup and is close to the expected amount as indicated by comparison with the predicted amount of iodine in the ATM-104 fuel. As additional data are received, similar comparisons will be made of other radiochemical analyses to determine trends in the content and location of fission products and other nuclides of interest in the fuel rods.

7.3 RADIAL DISTRIBUTION OF FISSION PRODUCTS AND ACTINIDES

The distribution of fission products and actinides across the fuel radius in the ATM-104 fuel was evaluated by autoradiography and EPMA.

Radiochemical analyses of the fuel provides values for the bulk inventory of radionuclides, but there is a distinct variation in the amount of fission products and actinides across the fuel radius, even in fuel samples with only moderate peak operating temperatures. This variation results from the thermal neutron flux peaking near the fuel edge and decreasing rapidly within a short distance. The thermal flux remains relatively constant the remaining distance towards the fuel center. As a result, more fissions and neutron absorptions occur near the fuel edge, accompanied by an increase in fission products (such as xenon and cesium) and actinides (such as plutonium and americium) (see Figures 7.10 and 7.11 as examples).

The radial distributions of fission products and actinides are of interest for several reasons. First, during radiochemical analyses, small portions of the fuel may be selected for analyses; the analytical results can be biased from the bulk average by selecting a fuel sample from either the fuel edge or the fuel center. Secondly, selection of small samples of fuel for testing can be guided by the known variation in fission product concentrations across the fuel radius. And thirdly, knowledge of the radial distribution of important nuclides is useful in evaluating the migration of fission products in fuel rods with a range of local fission gas release; this information can be used to evaluate the gap and grain boundary inventory in spent fuels. Results from autoradiography and EPMA of ATM-104 fuel samples are provided in Section 7.3.1 and 7.3.2, respectively.

7.3.1 Autoradiography

Autoradiography provides a qualitative indication of the radial distribution of actinides and fission products in the fuel. There are two types of autoradiography: 1) alpha autoradiography, where the relative quantity of alpha particles emitted from the fuel is registered, and 2) beta/gamma autoradiography, where the relative quantity of beta and gamma radiation is captured on film. Actinides generally decay by alpha particle emission. Fission products are typically beta particle and/or gamma emitters. Kodak Type LR115 (Type II) film and Kodak Type SO-343 film were used for the alpha and beta/gamma radiographs, respectively. The radiographs were obtained by direct contact exposure on film.

Alpha and beta/gamma radiographs of peak-power fuel samples from Rod MKP109 are given in Figures 7.6 through 7.9. The samples were radiographed after ion etching. The dark regions of the radiographs indicate higher relative activity (greater exposure).

The alpha radiographs for longitudinal Sample 104-MKP109-N and transverse Sample 104-MKP109-0 are shown in Figures 7.6 and 7.8, respectively. The dark rim at the pellet outer edge in the alpha radiographs indicates the preferential generation of alpha-emitting isotopes, such as plutonium, americium, and curium. The alpha-rich outer region appears thinner in Samples 104-MKP109-JJ and -KK (see Appendix E), which is consistent with the 30% lower burnup in these samples than in the peak-power ATM-104 samples.

Comparison of peak-power ATM-104 samples with peak-power ATM-103 samples (103-MLA098-N and -0) suggests that the outer alpha-enriched layer is thicker in the ATM-104 samples. The ATM-103 samples had about 35% lower burnup than the comparably located ATM-104 samples. EPMA of peak-power ATM-104 and ATM-103 samples discussed below indicates that the peak level of plutonium at the edge is higher in the ATM-104 fuel than in the ATM-103 fuel, and the region of above average plutonium concentration extends about 100 μm farther towards the fuel center in ATM-104.

Beta/gamma autoradiography of the ATM-104 fuel samples from the peak-power region of Rod MKP109 (Figures 7.7 and 7.9) did not show any significant radial variations in activity. Similar results were obtained for peak-power ATM-101 and ATM-103 samples (Barner 1985; Guenther et al. 1988a). Slightly higher production of the fission products does occur near the fuel edge, as is the case for the actinides, but the higher production of fission products at the edge is not noticeable in beta/gamma radiographs because of the range and geometric effects of gamma radiation in the fuel. Because beta/gamma radiation shines down the cracks, most fuel cracks appear dark in the beta/gamma radiographs; this does not necessarily indicate substantial fission product movement, especially if the intensity is uniform along all the cracks. Because the inventory of fission products is relatively uniform across the fuel radius, except close to the fuel edge, there should be a relatively uniform intensity from the beta and gamma rays. An exception would be in fuel

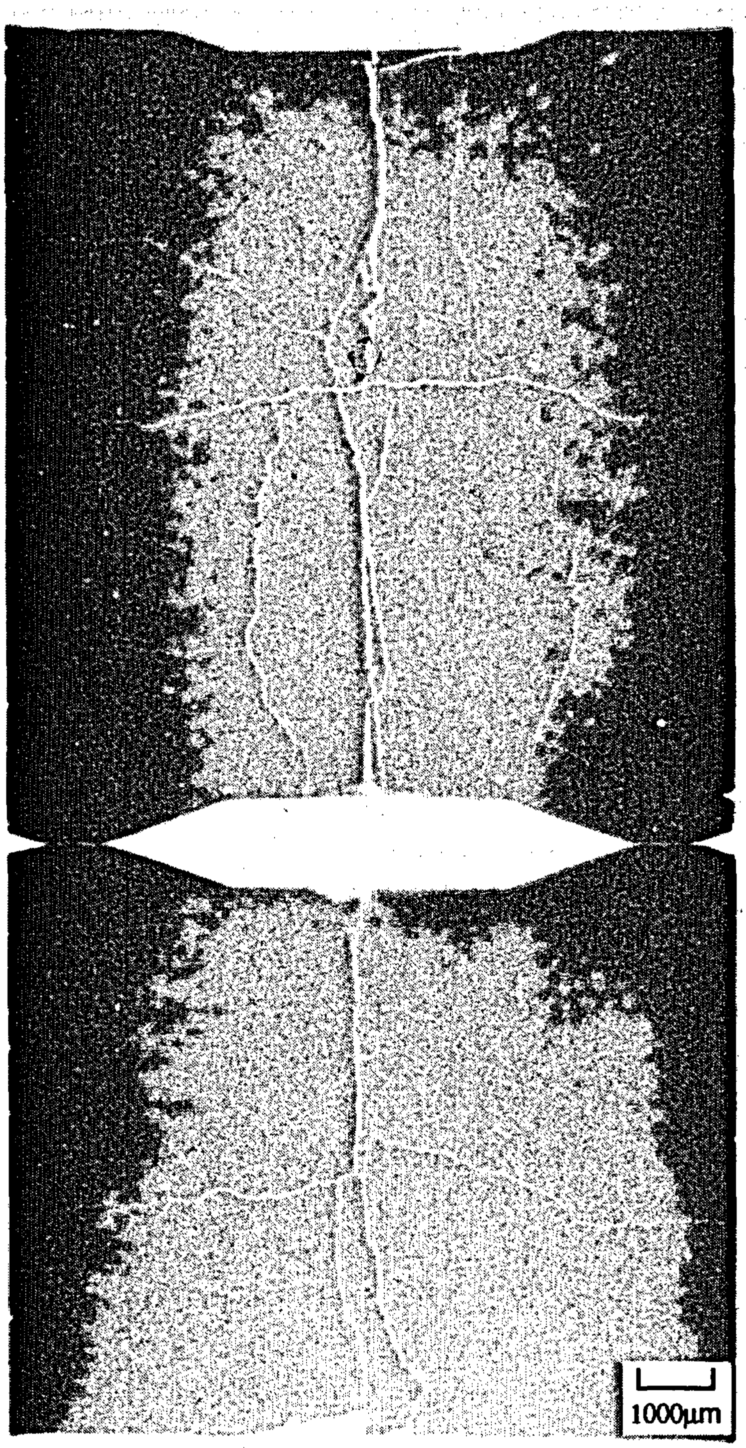


FIGURE 7.6. Alpha Autoradiograph of Longitudinal Sample 104-MKP109-N from Peak-Power Region (Neg. No. 5422)

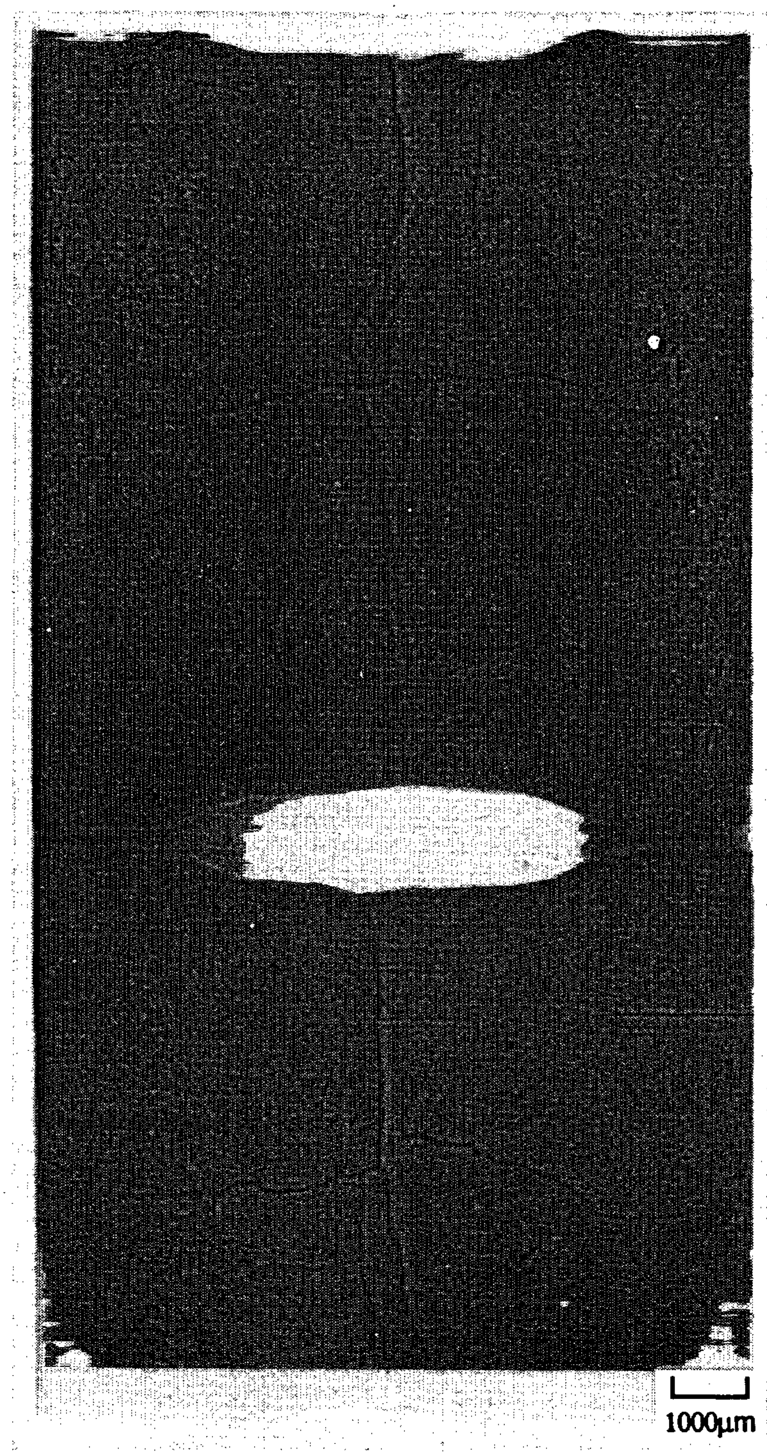


FIGURE 7.7. Beta/Gamma Autoradiograph of Longitudinal Sample 104-MKP109-N from Peak-Power Region (Neg. No. 5415)

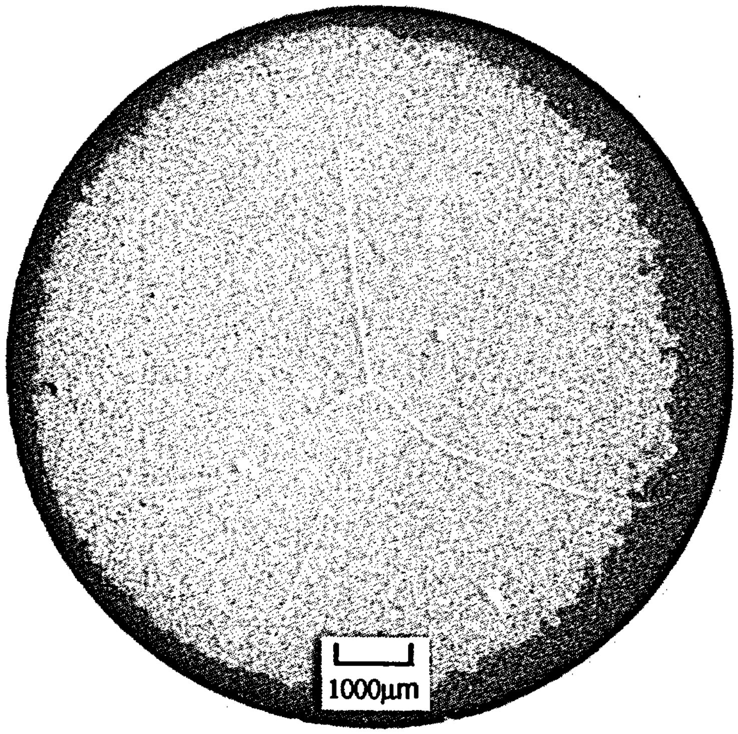


FIGURE 7.8. Alpha Autoradiograph of Transverse Sample 104-MKP109-0 (Neg. No. 5416)

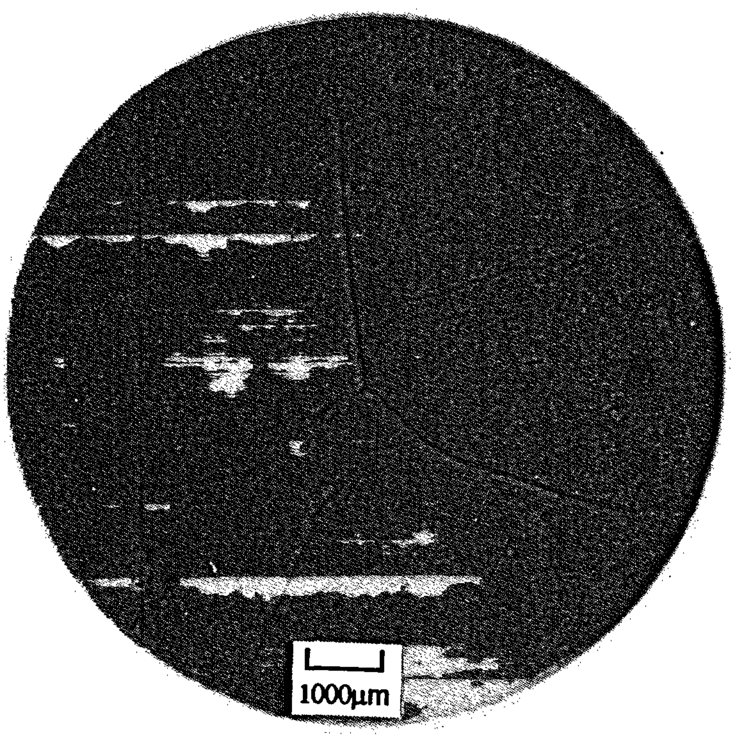


FIGURE 7.9. Beta/Gamma Autoradiograph of Transverse Sample 104-MKP109-0 (Neg. No. 5417)

that operated at temperatures high enough to allow fission gas release and migration of volatile fission products, such as cesium. The apparent lack of localized fission product concentrations in the beta/gamma radiographs is consistent with the 1.4% fission gas release determined for this rod, the minimal grain growth in the fuel, and minimal deposits of cesium on the cladding interior surfaces (see Section 8).

The evaluation of alpha and beta/gamma radiographs for Rod MKP109 indicated the expected peak in alpha-emitting material near the fuel edge and no unusual concentrations of fission products in the ATM-104 fuel. Because the ATM-104 rod had low fission gas release, significant fission product migration was not expected. In comparison, the ATM-106 fuel with 11% fission gas release had significant movement of some fission products as indicated by the beta/gamma autoradiography; there were local accumulations of beta/gamma emitters along fuel cracks and a depletion of beta/gamma emitters in the central region of the fuel column (Guenther et al. 1988b).

7.3.2 Electron Probe Microanalyses

Electron probe microprobe was conducted on Sample 104-MKP109-H that was sectioned from the peak-power region in the upper half of Rod MKP109 (see Figure 4.3). This type of analysis was conducted to obtain more quantitative information on the distribution of selected fission products and actinides across the fuel radius. An understanding of the radial distribution of fission products can be important to interpreting spent fuel test results. The radial profile for neodymium may also be used to determine the variation in burnup across the fuel pellet. Indications of fission gas release from the EPMA data may also be compared with the observed fuel structural changes.

Several authors have published data on the concentration of xenon, other fission products, and the actinides across the fuel radius. Xenon concentrations across the fuel radius have been presented by Kleykamp (1979); Pearce (1984); Mogensen, Knudsen, and Walker (1987); and Pati, Garde, and Clink (1988). Pearce (1984) has also reported radial profiles for cesium, iodine, molybdenum, and zirconium. Forsyth, Mattsson and Schrire (1988) reported on the distribution of strontium, xenon, cesium, and neodymium across fuel grains at several locations across the fuel radius. Manzel, Sontheimer and Würtz

(1984) reported the radial concentrations of xenon, ^{137}Cs, ^{134}Cs, ^{144}Ce, and ^{106}Ru, although their work involved micro-gamma scanning and micro sampling the fuel. Thus, there are data against which this work may be compared.

The shielded microprobe used for this work is described in Appendix F. Briefly, an electron beam is used to generate characteristic x-rays from the specially prepared sample. The x-rays are examined by wavelength dispersive spectrometry. Standards are also measured during the examinations to obtain quantitative results. Standards used were elemental metals or oxides as supplied by the microprobe manufacturer, except for UO_2 and PuO_2 which were added locally. The standards used, the detection limits for each element, a detailed list of measured data, and plots of the results for each element are provided in Appendix F.

Sample 104-MKP109-H was examined to determine the concentration of nine elements: cesium, uranium, xenon, technetium, plutonium, neodymium, ruthenium, and iodine. Iodine could not be detected above background levels. Each element of interest was obtained during a radial scan that examined fuel material from the the outer edge to the pellet center. The first five data points are separated by about 75 μm; with the remaining approximately 25 data points separated by about 180 μm.

The intensities of X-rays emitted from the sample and an appropriate standard are measured during EPMA. The sample intensity divided by the standard's beam intensity provides the K ratio, which is related to the element's concentration in weight percent (wt%). The computer code MAGIC IV was used to correct the K ratios for atomic number, absorption, and flourescence (Colby 1971). The measured concentrations for some of the elements have also been adjusted for slight differences between the bulk inventory based on the pellet-average burnup and the bulk inventory indicated by EPMA (see Appendix F). Results of the EPMA of ATM-104 are provided below, followed by a discussion of the xenon release observed at the fuel edge, and estimation of the radial burnup profile in the fuel.

General Results from EPMA

Results of the EPMA are consistent with data reported by other experimenters. The radial concentrations of all of the measurable elements were relatively constant from the fuel center to within a few hundred micrometers of the fuel edge. This was expected because the ATM-104 rod had only 1.4% fission gas release and fuel grain growth was only minimal even at the fuel center. The radial profiles for plutonium, neodymium, cesium, and xenon are shown in Figures 7.10 through 7.13. The profiles for additional elements are shown in Appendix F.

The concentrations of neodymium, plutonium, cesium, and ruthenium all increased within a few hundred micrometers of the fuel edge as would be expected based on the known trend in neutron flux, fission events, and neutron absorptions. The ruthenium values appear to be about three times higher than would be expected from the bulk average burnup for this sample (see Figure F.8). However, even if the values were a third of those measured, the edge concentration of ruthenium would be proportionally higher than for other elements, such as neodymium. Manzel, Sontheimer and Würtz (1984) found what they believed to be radial movement of ^{106}Ru from the fuel center to the edge in a fuel with high burnup. However, there does not appear to be any loss of ruthenium from the ATM-104 fuel center, as the curve is relatively smooth. The americium concentration (see Figure F.6) appears to increase near the fuel edge, but most of the measured concentrations for this element are near the detection limit. Pearce (1984) has also shown that the zirconium, molybdenum, and iodine peak near the fuel edge, although iodine was only observed in fuel with high burnup (~50 MWd/kgM).

The profiles for uranium (see Figure F.5) and xenon (Figure 7.12) indicate a loss of these elements near the fuel edge. The decrease in uranium concentration is consistent with the consumption of uranium as more fissions occur at higher burnups. Because the fission events and neutron absorptions peak at the fuel edge, the uranium concentration should decrease slightly near the fuel edge. There also appears to be a slight loss of technetium near the fuel edge, but the measured concentrations vary considerably (see Figure F.7). The xenon release at the fuel edge is discussed below.

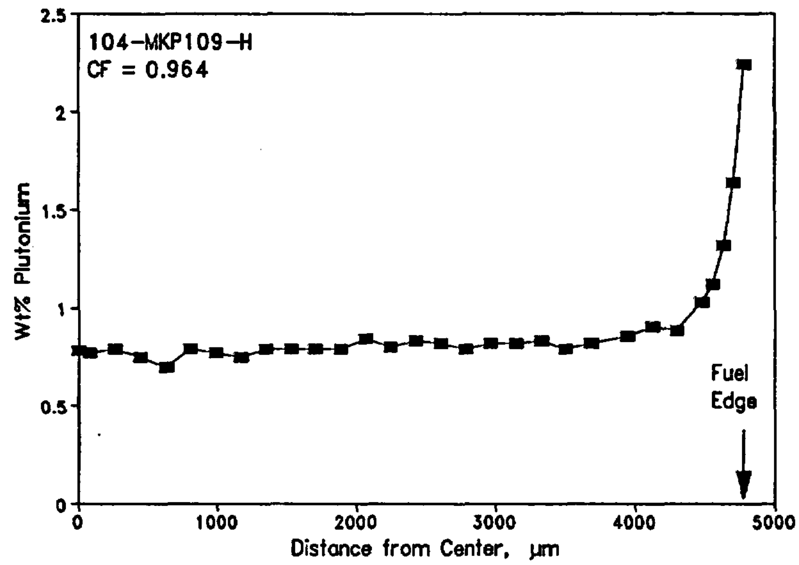


FIGURE 7.10. Plutonium Concentration Across Radius of Sample 104-MKP109-H

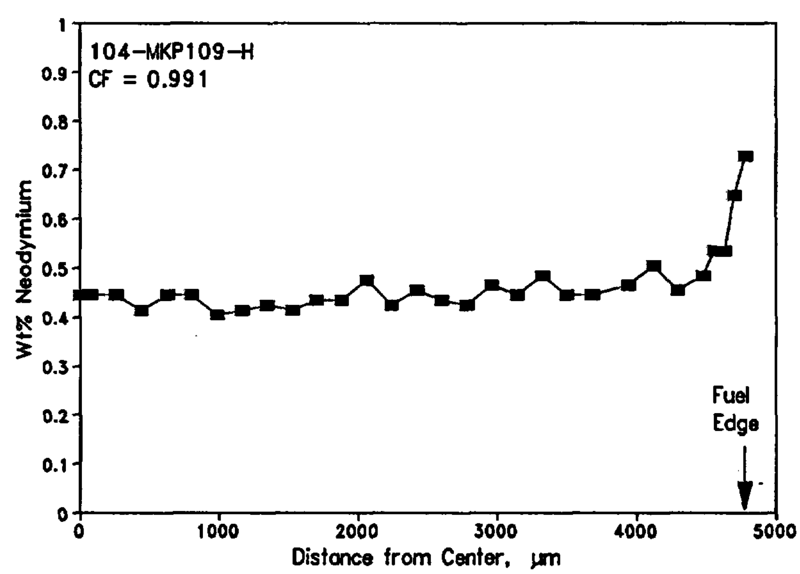


FIGURE 7.11. Neodymium Concentration Across Radius of Sample 104-MKP109-H

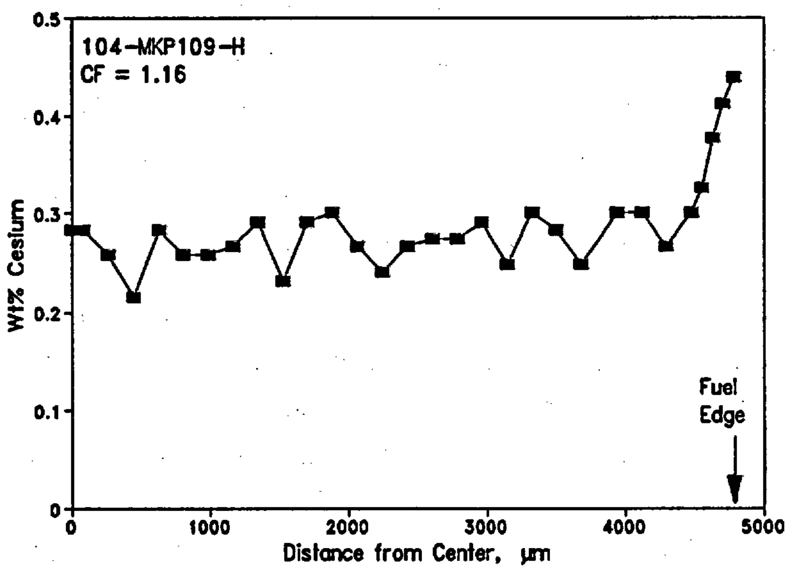


FIGURE 7.12. Cesium Concentration Across Radius of Sample 104-MKP109-H

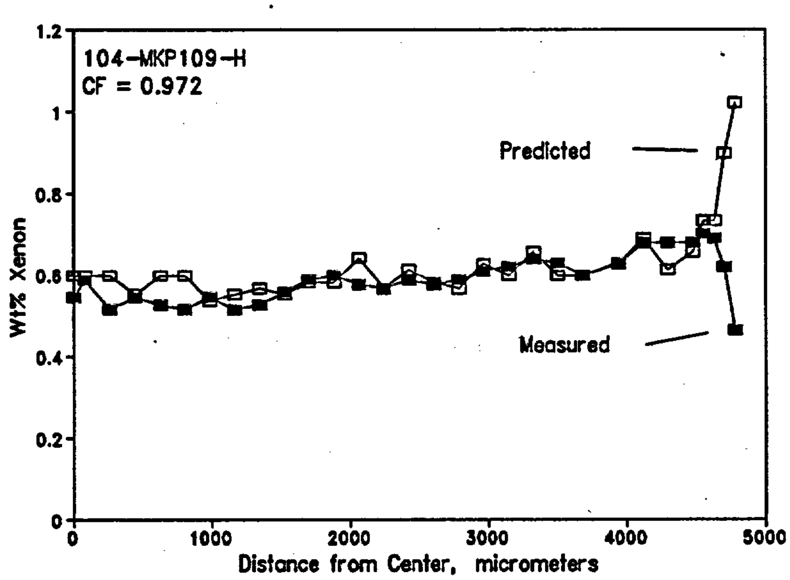


FIGURE 7.13. Xenon Concentration Across Radius of Sample 104-MKP109-H

Xenon Release from the Fuel Edge

In EPMA examinations of moderate burnup fuel, the xenon concentrations increased near the fuel edge in a manner comparable to the other fission products (Mogensen, Knudsen, and Walker 1987; Pearce 1984). Figure 7.14 is a plot of the radial profile of xenon in Sample 103-MLA098-H from the ATM-103 fuel with a local burnup of 33 MWd/kgM and very low fission gas release; the xenon concentration of this sample follows the expected trend.

In contrast to ATM-103, there is a distinct decrease in the indicated xenon concentration within about 200 μm from the fuel edge in the ATM-104 sample. The relative amount of apparent xenon loss from the fuel edge in Sample 104-MKP109-H is indicated by comparing the measured and predicted curves shown in Figure 7.13. These two profiles can be used to estimate the fission gas release from this location in the fuel rod. It is estimated about 4% local fission gas release occurred in Sample 104-MKP109-H and that half to three fourths of the release occurred from the fuel rim, if the apparent release there is real.

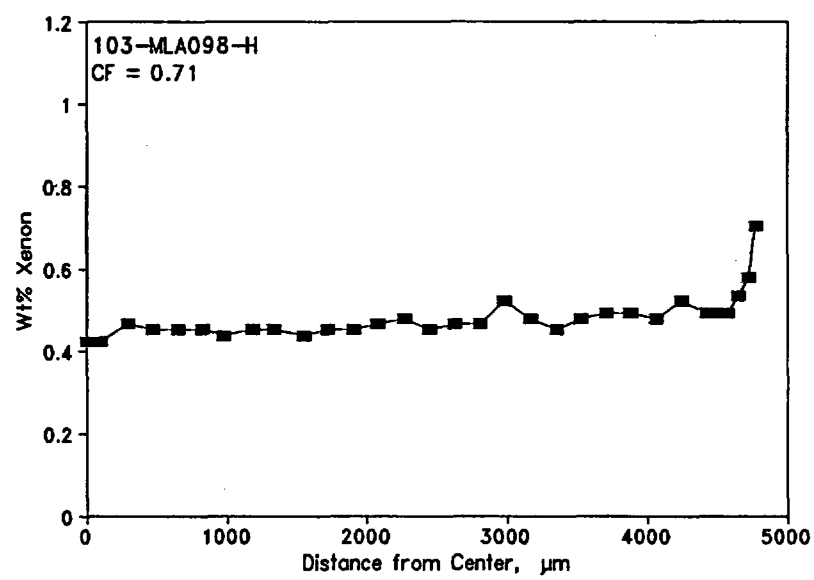


FIGURE 7.14. Xenon Concentration Across Radius of Sample 103-MLA098-H with 33 MWd/kgM Burnup

The decrease in xenon near the edge of the ATM-104 fuel sample has been attributed to athermal fission gas release in the porous rim of the fuel pellet (Pati, Garde, and Clink 1988). They have examined fission gas release data for a large number of fuel rods with rod-average burnups up to 56 MWd/kgM and postulated that the xenon release was related to the porous rim that forms near the fuel edge of rods with burnups averaging over 40 MWd/kgM.

The ATM-104 fuel does fit the criteria suggested by Pati, Garde, and Clink (1988). Rod MKP109 had low fission gas release of 1.4% (see Section 8.1), and the porous fuel structure at the fuel edge was observed in two peak-burnup samples, particularly in Sample 104-MKP109-H used for EPMA (see Section 8.2.1 and Appendix E). The porous rim shown in Appendix E for the EPMA sample (104-MKP109-H) extends about 70 μm inwards from the fuel edge, or about half of the radial distance over which the xenon appears to have been lost in Figure 7.13. Because the electron beam is intentionally placed within a grain to avoid porosity, it is possible that xenon in large pores or at the grain boundaries was not measured by EPMA, depending on how much xenon is in pores and how the xenon was dispersed in the fuel matrix. Mogensen, Knudsen, and Walker (1987) showed that there are grain boundary inventories of xenon that are not observed by EPMA that can be determined by using both EPMA and x-ray flourescence analyses. However, their work did not show a decrease in xenon near the pellet rim, probably because the fuel they examined did not have the 40 MWd/kgM burnup that Pati, Garde and Clink (1988) sugggest is necessary before enhanced fission gas release occurs. Apparent xenon depletion near the fuel edge and similar porous fuel structures have also been observed in ATM-106 samples with burnups comparable to ATM-104 (Campbell, Guenther, and Jenson 1990; Guenther et al. 1989).

Because of the decreasing yield of krypton as more fissions occur from plutonium, a disproportionate release of gas from the fuel edge would tend to increase the measured xenon/krypton ratio in gas samples from the entire rod. The xenon/krypton ratios in ATM-104 rods were generally higher than in previous fuel rods examined, averaging 11.4 for the six ATM-104 rods examined (see Section 8.1.1). The expected xenon/krypton ratio was about 10 for a peak burnup of 44 MWd/kgM. Ratios for ATM-106 averaged about 9, probably because of the greater contribution of fission gas release from the fuel center where the average burnup is lower than fuel at the rim (Guenther et al. 1988b). Thus, the fission gas analyses tend to support the case for fission gas release from the fuel edge of the ATM-104 rods, although the amount of xenon release at the fuel edge is probably overpredicted by EPMA. However, the porous structure near the fuel edge does exist, and may be important to leach rates of fuels with burnups greater than 40 MWd/kgM.

Radial Burnup Profile

The radial burnup profile can be useful in predicting the concentration of radionuclides for which analyses have not been, or cannot be, conducted. The measurement of neodymium across the fuel radius was used to obtain the radial burnup profile. Neodymium-148 is used to obtain the bulk average burnups measured by radiochemical methods. Forsyth, Mattsson, and Schrire (1988) have shown that neodymium is essentially unaffected by fuel operating temperatures and remains relatively constant at a given radial position, even across fuel grains.

The burnup profile was determined by integrating the neodymium curve in Figure 7.11 and comparing the resulting pellet average concentration of neodymium with the known burnup from radiochemical methods (see Equation [1] in Section 7.1.1). The resulting burnup profile for Sample 104-MKP109-H is shown in Figure 7.15. The burnup ranges from about 42 MWd/kgM at the fuel center to 44 MWd/kgM within about 1 mm of the fuel edge. The burnup continues to increase dramatically to the fuel edge where it is about 70 MWd/kgM, or 58% higher than the pellet average burnup.

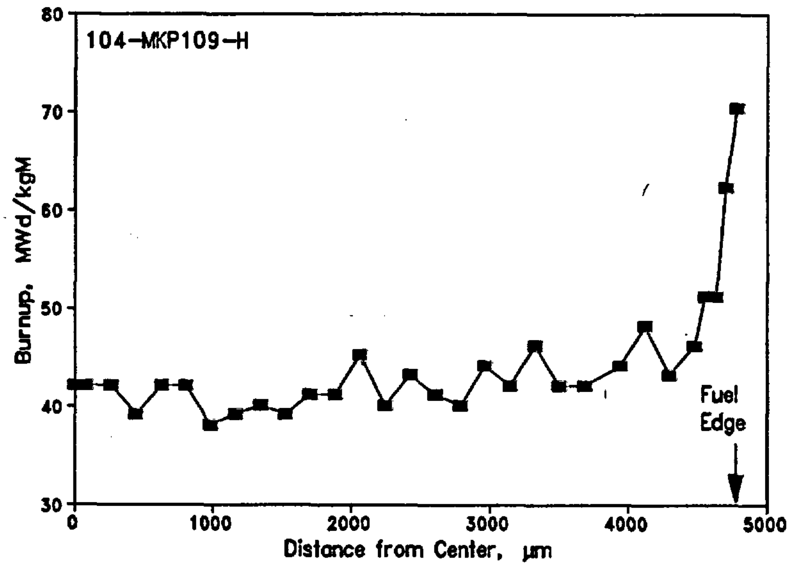


FIGURE 7.15. Radial Burnup Profile in Sample 104-MKP109-H with Pellet-Average Burnup of 44.3 MWd/kgM

8.0 REDISTRIBUTION OF FISSION PRODUCTS

As discussed in Section 7.0, the fission process and neutron absorptions define the locations where the various fission products and actinides are produced within the fuel. Xenon, krypton, and other volatile fission products can redistribute during reactor operation as a result of fuel operating temperatures and conditions. Movement of fission products to grain boundaries, fuel surfaces, the cladding interior surface, or the fuel rod plenum (void space) could be important to the performance assessment of a nuclear waste repository. Higher initial release rates to the repository environment might occur from a breached fuel rod with significant fission product redistribution than from a fuel rod in which essentially all of the fission products are contained within the fuel matrix (Garisto, Johnson, and Hocking 1989; Wilson and Gray 1990).

At moderate burnups and typical in-reactor fuel operating temperatures below about 1300°C, less than about 2% of the xenon and krypton gases are released from the fuel to the rod void space (Manzel, Sontheimer, and Stehle 1985). As the fuel burnup and/or operating temperatures increase, additional quantities of fission gas are released from the fuel to the rod void space. If temperatures are high enough, then cesium and other volatile fission products can be released from the hotter regions of the fuel and migrate to cooler locations within the fuel rod.

This section provides the results of several examinations made to evaluate the amount of fission product redistribution within the ATM-104 fuel rods. Results are provided for the 1) elemental and isotopic analyses of the fission gases and ^{14}C released from the fuel during reactor operation (Section 8.1); 2) ceramographic examinations of the fuel to determine fuel structure, including any grain growth that may have resulted from fuel operating temperatures (Section 8.2); 3) evaluation of cesium and iodine deposits on the interior surface of the cladding for comparison with fission gas release and apparent fuel operating conditions (Section 8.3); and 4) AEM of selected samples of fuel from across the fuel radius to evaluate microscopic changes in the fuel structure and fission product distributions.

8.1 GASES RELEASED FROM THE FUEL

Fission gas release and the subsequent composition of the gas in the fuel rod void space can appreciably affect the operating temperatures in the fuel. Xenon has a much lower thermal conductivity than the helium used to pressurize the fuel rod prior to irradition. Operating temperatures, in turn, can affect the final characteristics of the spent fuel by increasing grain size, promoting additional fission gas release, and changing the distribution of fission products within the fuel. The extent of this effect depends on the final burnup, gas composition and pressure, power history, and initial fuel characteristics.

The procedures for gas sampling, void volume measurement, and determination of the gas volume are described in Appendix G. Results of the elemental and isotopic gas analyses (Section 8.1.1) and the calculated fission gas releases (Section 8.1.2) are discussed below.

8.1.1 Elemental and Isotopic Gas Analyses

Analyses were conducted on gas samples from six ATM-104 rods to determine the components of the gas in the rods, the amount of the krypton and xenon isotopes, and the amount of ^{14}C in the gas. Measurement of the levels of xenon and krypton allow the calculation of fission gas releases, an indication of the fuel operating temperatures during reactor operation. Measurements of the ^{14}C content in the gas were desired for comparison with the ^{14}C inventory in the fuel and the cladding. Carbon-14 is of interest to the repository because of its potential for migration in the repository environment (Van Konynenburg et al. 1987).

Elemental Gas Analyses

Only small amounts of xenon and krypton gases were expected to be found in the ATM-104 gas samples because these rods were anticipated to have low fission gas releases. The results of the elemental gas analyses for the rods are listed in Table 8.1. These data were obtained using a mass spectrometer. The primary components of the gas sample were helium, the gas used to pressurize the fuel rod during fabrication, and small amounts of xenon and krypton. As indicated in Table 8.1, a small amount of air was detected in two samples (simultaneously taken) from Rod MKP028. This rod was used first to test the sampling system because Rod MKP028 would not receive extensive characterization. The gas sample from Rod MKP028 contained about 1% air due to a leak in the gas sampling system; the air is not believed to have been in the fuel rod during reactor operation or subsequent storage. Because the amount of air contamination was small, no corrections were made in subsequent calculations. None of the other gas samples indicated any leakage of air into the sample bottles.

The xenon/krypton ratios ranged from 10.5 to 12.2, averaging 11.4 ± 0.6 (1σ) for the six ATM-104 rods examined. Assuming an average burnup of 42 MWd/kgM and a discharge time of 5.1 years, ORIGEN2 calculations described in Section 5 result in a xenon/krypton ratio of 9.9 (based on vol%). The measured xenon/krypton ratios may be higher than predicted because of enhanced fission gas release from the porous rim of the fuel. As previously discussed, EPMA of Sample 104-MKP109-H indicated depletion of xenon within a few hundred micrometers of the fuel edge, and there is evidence of a highly porous rim in ATM-104 and ATM-106 samples, as discussed later. It is not certain how much xenon depletion there really is near the fuel edge; as Mogensen, Knudsen, and Walker (1987) explained, EPMA cannot measure xenon located in large low-pressure bubbles along the grain boundaries or porosity in the fuel grains with diameters greater than ~0.1 μm. However, Pati, Garde, and Clink (1988) attributed the enhanced fission gas release in rods with fission gas releases of less than 2% and burnups above about 40 MWd/kgM to the depletion of xenon from the porous rim of the fuel.

TABLE 8.1. Gas Composition for ATM-104 Fuel Rods

	Volume Percentage										Xe/Kr
Rod No.	He	Xe	Kr	Ar	H_2	CO_2	CO	N_2	O_2	Organics	Ratio
MKP028	97.7	1.09	0.09	0.02	<0.01	<0.01	<0.01	0.94	0.18	<0.01	12.1
MKP028	97.8	1.21	0.115	0.02	<0.01	0.01	<0.01	0.69	0.17	<0.01	10.5
MKP059	97.8	2.02	0.18	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	11.2
MKP063	98.5	1.40	0.13	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	10.8
MKP070	98.6	1.34	0.11	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	12.2
MKP106	98.5	1.35	0.12	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	11.3
MKP109	96.4	3.30	0.28	<0.01	<0.01	<0.01	<0.03	0.03	<0.01	<0.01	11.8

Enhanced fission gas release from near the fuel edge could have resulted in the xenon/krypton ratios being higher than predicted by ORIGEN2 using the rod-average fuel burnup. As explained previously, the concentration of plutonium increases considerably near the fuel edge, roughly doubling within about 300 μm of the fuel edge. As burnup increases, more and more of the fissions result from ^{239}Pu and ^{241}Pu, particularly near the fuel edge. Because the yield of krypton from a plutonium fission is about half of that from uranium while the xenon yield remains relatively constant for both uranium and plutonium fissile material, higher xenon/krypton ratios result for plutonium fissions than for uranium fissions. If fission gas release occurred from the porous rim near the fuel edge of the ATM-104 rod with generally low fission gas release, then the xenon/krypton ratio could be higher than expected based on the rod-average burnup.

The xenon/krypton ratios measured for the ATM-104 rods were also higher than in either the ATM-103 and ATM-106 rods. Because of the higher rod-average burnup in the ATM-104 rods, the xenon/krypton ratio should be higher than in the ATM-103 rod that had a rod-average burnup of only 30 MWd/kgM burnup and a xenon/krypton ratio of 9.2 (Guenther et al. 1988a). The xenon/krypton ratio averaged 9.2 for three ATM-106 rods, although one would expect values similar to those for the ATM-104 rods because of comparable burnups (Guenther et al. 1988b). However, higher operating temperatures in the ATM-106 rods caused over 100% grain growth and significant fission gas release from portions of those fuel rods. The high fission gas release from the fuel center of ATM-106 samples, where the xenon/krypton ratio should be ~10, probably masked any contribution of fission gas release from the fuel edge because most of the fissions involve uranium at the fuel center.

<u>Xenon and Krypton Isotopes in the Gas</u>

The amounts of xenon and krypton gas recovered from each rod were evaluated in two ways. First, the volume percentages of the total rod gas were determined for xenon isotopes and krypton isotopes; the total rod gas includes the original fill gases plus any gases released to the rod void space as shown in Table 8.1. Second, the relative amounts of the various isotopes that make up the total xenon or krypton gas were determined and compared with the calculated values.

The isotopic gas analyses for xenon and krypton as a percentage of the total rod gas are given in Tables 8.2 and 8.3, respectively. The general amounts of xenon and krypton gas in the total gas are consistent with rods with low fission gas release, such as the ATM-103 rods.

TABLE 8.2. Percentages of Xenon Isotopes in Total Rod Gas

	Volume Percentage					
Rod No.	^{128}Xe	^{130}Xe	^{131}Xe	^{132}Xe	^{134}Xe	^{136}Xe
MKP028	<0.01	<0.01	0.07	0.24	0.31	0.47
MKP028	<0.01	<0.01	0.09	0.26	0.34	0.52
MKP059	<0.01	<0.01	0.14	0.40	0.57	0.91
MKP063	<0.01	<0.01	0.10	0.31	0.40	0.59
MKP070	<0.01	<0.01	0.10	0.29	0.38	0.57
MKP106	<0.01	<0.01	0.10	0.30	0.38	0.57
MKP109	<0.01	<0.01	0.24	0.74	0.93	1.39

TABLE 8.3. Percentages of Krypton Isotopes in Total Rod Gas

	Volume Percentage				
Rod No.	^{82}Kr	^{83}Kr	^{84}Kr	^{85}Kr	^{86}Kr
MKP028	<0.01	0.01	0.03	<0.01	0.05
MKP028	<0.01	0.01	0.04	0.005	0.06
MKP059	<0.01	0.01	0.07	<0.01	0.10
MKP063	<0.01	0.02	0.04	<0.01	0.07
MKP070	<0.01	0.01	0.04	<0.01	0.06
MKP106	<0.01	0.02	0.04	<0.01	0.06
MKP109	<0.01	0.03	0.09	0.02	0.14

The relative amounts of the isotopes of xenon or krypton measured in the rod gas are given in Tables 8.4 and 8.5, respectively. The relative amounts of the different xenon and krypton isotopes estimated by using the ORIGEN2 code (see Section 5 and Appendix D), assuming a discharge time of 5.1 years and 42 MWd/kgM burnup, are also listed in Tables 8.4 and 8.5. In general, the relative amounts of xenon and krypton isotopes measured in the gas agree very well with the relative amounts predicted by ORIGEN2.

Carbon-14 in the Gas

The ^{14}C contents in the gas removed from the six ATM-104 fuel rods were determined by converting all forms of carbon in the gas to CO_2, trapping the CO_2 in a caustic solution, and measuring the ^{14}C concentration by beta-scintillation analysis. The amounts of ^{14}C in the six ATM-104 fuel rods at standard temperature (0°C) and pressure (0.1 MPa, 1 Atm) (STP) are listed in Table 8.6.

The gas samples from Rods MKP059, MKP070, and MKP109 were the only samples having ^{14}C concentrations greater than detection levels; the detection level varies from rod to rod depending primarily on the volume of the gas sample and the measurement system background level. If 0.016 nCi/cm^3 from Rod MKP028 is assumed to be the highest ^{14}C level for ATM-104, then the ^{14}C level of ATM-104 is still comparable to the value measured for an ATM-103 rod (Guenther et al. 1988a) and is only about 1% of the average measurements for the nine ATM-101 fuel rods (Barner 1985). The fill gas in the ATM-101 fuel rods is believed to have contained a small amount of residual nitrogen that was activated to ^{14}C, resulting in greater amounts of ^{14}C in the ATM-101 rods than in ATM-104.

The amounts of ^{14}C in the gas recovered from the fuel rods are insignificant compared with the ^{14}C inventory in the fuel. Assuming there are 0.016 nCi/cm^3 of ^{14}C in a gas volume of 830 cm^3, then the ^{14}C inventory in the open void space of the rod is 13 nCi. This amount of ^{14}C is extremely small compared with the typical inventory of 2,000,000 nCi in a fuel rod with moderate burnup and typical initial nitrogen contents. Whether the ^{14}C inventory in the gas will remain insignificant will depend on how the storage temperatures and the condition of the fuel affect ^{14}C release.

TABLE 8.4. Relative Amounts of Xenon Isotopes in Xenon Gas

Rod No.	Relative Volume Percentage					
	^{128}Xe	^{130}Xe	^{131}Xe	^{132}Xe	^{134}Xe	^{136}Xe
MKP028	(a)	(a)	6.4	22.0	28.4	43.1
MKP028	(a)	(a)	7.4	21.5	28.1	43.0
MKP059	(a)	(a)	6.9	19.8	28.2	45.0
MKP063	(a)	(a)	7.1	22.1	28.6	42.1
MKP070	(a)	(a)	7.5	21.6	28.4	42.5
MKP106	(a)	(a)	7.4	22.2	28.1	42.2
MKP109	(a)	(a)	7.3	22.4	28.2	42.1
Predicted(b)	0.1	0.3	7.4	22.0	27.6	42.6

(a) Assumed to be essentially zero for calculating relative percentages of xenon (See Table 8.2).
(b) Relative amounts of xenon isotopes predicted by ORIGEN2 (See Appendix D) assuming a burnup of 42 MWd/kgM and 5.1 years discharge.

TABLE 8.5. Relative Amounts of Krypton Isotopes in Krypton Gas

Rod No.	Relative Volume Percentage				
	^{82}Kr	^{83}Kr	^{84}Kr	^{85}Kr	^{86}Kr
MKP028	(a)	11.1	33.3	(a)	55.5
MKP028	(a)	8.7	34.8	4.3	52.2
MKP059	(a)	5.5	38.9	(a)	55.5
MKP063	(a)	15.4	30.8	(a)	53.8
MKP070	(a)	9.1	36.4	(a)	54.5
MKP106	(a)	16.7	33.3	(a)	50.0
MKP109	(a)	10.7	32.1	7.1	50.0
Predicted(b)	0.4	10.6	33.2	4.3	51.5

(a) Assumed to be essentially zero for calculating relative percentages of xenon (See Table 8.3).
(b) Relative amounts of xenon isotopes predicted by ORIGEN2 (See Appendix D) assuming a burnup of 42 MWd/kgM and 5.1 years discharge.

TABLE 8.6. Concentration of ^{14}C in Gas Samples from ATM-104 Rods

Rod No.	^{14}C, nCi/cm^3 at STP [(a)]
MKP028	<0.016
MKP028	<0.014
MKP059	0.0012
MKP063	<0.00006
MKP070	0.0010
MKP106	0.0019
MKP109	0.0003

(a) Detection level varies from sample to sample depending primarily on the volume of the gas sample and the measurement system background.

8.1.2 Fission Gas Release

Results from the gas analyses of three of the six ATM-104 rods have been used to calculate fission gas releases. All of the ATM-104 rods were expected to have about 1% or less gas release based on data provide by C-E. Based on the gas sampling, fission gas releases in the ATM-104 rods were estimated to range from 0.38% to 1.06% (see Table 8.7). These values were obtained assuming 1) 31.0 cm^3 of fission gas at STP was generated for each MWd of energy produced (SSA 1982); 2) data in Table 8.7; and 3) the rod-average burnups provided by C-E for each ATM-104 rod. Additional data used to estimate the fission gas release from the ATM-104 fuel rods are provided in Table 8.7.

The rod void volumes were determined by the sampling described in Appendix G and varied from 18.0 to 19.4 cm^3. The initial void volume was estimated to be 35 cm^3 based on fabricated dimensions. Fuel swelling and cladding creepdown during irradiation cause a decrease in the free void space. Any uncertainty in void volumes determined by gas sampling contributes little to the error in estimating fission gas release because the fuel rod void volume is a small fraction of the total gas volume collected at STP.

TABLE 8.7. Fission Gas Release Information for ATM-104 Fuel Rods[a]

Rod Number	Total Recovered Gas at STP, cm^3	Xe + Kr, %	Volume of Xe + Kr at STP, cm^3	Rod-Average Burnup, MWd/kgM	Estimated Fission Gas Produced, cm^3	Fission Gas Released, %
MKP028	829	1.25[b]	10.4	40.26	2763	0.38
MKP059	829	2.20	18.2	42.56	2921	0.62
MKP109	852	3.58	30.5	40.40	2773	1.10

(a) Fuel weight in each rod was 2.214 kgM (nominal).
(b) Average of two samples.

The fission gas releases determined from the gas sampling indicated the expected levels of release from the ATM-104 rods. The ATM-104 rods had fission gas releases slightly higher than those for either the ATM-101 or ATM-103 rods with moderate burnup, but the release values for the ATM-104 rods are still considered to be low. The fission gas releases in the ATM-104 rods were significantly lower than in most of the ATM-106 rods, some of which had releases greater than 10%. Again, these results were anticipated based on the power history and other information provided by C-E.

As mentioned in this section, the amount of xenon and krypton produced during irradiation is assumed to be 31 cm^3/MWd at STP. This is a standard value used to calculate fission gas production without detailed calculations and can be compared with the value that ORIGEN2 predicts for an ATM-104 fuel rod with its specific power history. Using the data for xenon and krypton isotopes in Appendix D, one can calculate the expected amount of xenon and krypton produced. From the values in Appendix D, there are 5.04×10^{-6} moles of krypton and 5.02×10^{-5} moles of xenon in an ATM-104 rod with 2.214 kgM of fuel irradiated to an average burnup of 42 MWd/kgM. Using these predicted quantities of xenon and krypton in the ideal gas equation results in 251 cm^3 of krypton and 2487 cm^3 of xenon gas at STP. Combining these two values yields a total fission gas produced of 2738 cm^3 compared with 2773 cm^3 using the assumed yield of 31 cm^3/MWd. Thus, the assumed yield for the fission gases and the yield predicted by ORIGEN2 agree within about 1%.

8.2 CERAMOGRAPHIC EXAMINATIONS

The fuel samples obtained from Rod MKP109 were used to characterize porosity and microstructural variations as a function of radial position and axial location. Such information is helpful in evaluating the variation in fission products and actinides in the fuel after irradiation. Evaluations of the fuel were made after sample preparation in one of two conditions, polished or etched.

In the polished transverse and longitudinal samples, the general cracking pattern, porosity in the fuel, wedging of small fuel particles between fuel fragments between the fuel and cladding, and as-irradiated gap width are of interest and can be observed. The cracking pattern and gap width affect in-reactor temperatures. The number of fuel fragments and their sizes can be used to estimate the surface area of the fuel, a useful parameter for studies of fuel leaching.

The etched fuel sample can be used to examine fission gas bubble size and distribution, metallic ingots, and grain size variations, which are also of interest. The number and size of fission gas bubbles is best observed with the fuel sample in the polished condition; however, etching is useful in determining the location of fission gas bubbles relative to grain boundaries. Etching is required to examine the grains and determine the grain sizes. The formation of fission gas bubbles and grain growth generally correlate with higher fuel temperatures and migration of fission products. Metallic ingots (also called five-metal or ϵ-ruthenium particles) are typically seen only near the fuel center using optical microscopy, if at all, in fuel with moderate to high operating temperatures. Details are given below for the photomacrography and photomicrography of the fuel in the polished and etched conditions.

8.2.1 Polished Fuel Condition

The transverse and longitudinal fuel samples for Rod MKP109 (see Figure 4.3) were prepared for examination by placing them in prelabeled mounts followed by vacuum impregnation with polyester resin. Each mount included a reference notch so that photographs of the polished and etched samples could be taken along approximately the same radial line. After the mounted fuel samples were ground with up to a 600 grit in a water-base lubricant, they were polished with a 1-μm diamond paste using kerosene. A final polish was then made in a 0.3-μm Al_2O_3 aqueous suspension.

Several features of interest were investigated using the polished fuel samples: 1) crack patterns, 2) fuel-cladding gap and dish closure, 3) variations in porosity of the fuel, and 4) metallic ingot formation. These features are discussed below. Estimates of the fuel particle sizes have not yet been made.

Crack Patterns

The polished transverse and longitudinal samples of fuel sectioned from the peak-power region of Rod MKP109 are shown in Figures 8.1 and 8.2, respectively. Transverse Sample 104-MKP109-O has six major cracks that originate at the approximate center of the fuel and extend to the outer pellet edge. At the outer edge of the fuel, these cracks are approximately normal to the fuel surface. Several short fine-gapped cracks intersect the major cracks and outer edge of the fuel at random angles.

Longitudinal Sample 104-MKP109-N, which was also taken at the peak-power region adjacent to the previously described transverse section, has a crack observable along the full length of the center axis of the polished sample. Four to six fine-gapped transverse cracks can be seen intersecting normal to both the center axis crack and the outer edge of the fuel. A few additional cracks are approximately parallel to the central crack and are about one-half of a pellet length. A larger number of cracks are observed in the peak-power Samples 104-MKP109-N and -O than in the lower-power Samples 104-MKP109-KK and -JJ (Figures 8.3 and 8.4). The increase in the number of cracks with increasing operating power/temperature was also evident in previous examinations of fuel from ATM-103 (Guenther et al. 1988a) and ATM-106 (Guenther et al. 1988b). The increase in operating temperature causes greater thermal stresses in fuel samples located in the peak-power locations. Negligible numbers of fuel particles relocated into the dish region.

The centerline cracks observed in the ATM-104 fuel pellets are more distinct than in the ATM-106 fuel pellets with similar burnups. Centerline cracks similar to those in ATM-104 were observed in the ATM-103 pellets, but the centerline cracks in the ATM-106 fuel appear more broken and random than in the ATM-104 or ATM-103 fuel pellets. Less cracking in the ATM-104 and ATM-103 fuel pellets probably resulted from the lower ratio between the pellet length (L) and the pellet diameter (D) than in the ATM-106 pellets. The L/D was lowered from 1.7 in the ATM-106 fuel to 1.2 in the ATM-104 and ATM-103 fuels; this common practice by fuel vendors was part of the fuel redesign to mitigate fuel-cladding-interaction (Bailey et al. 1977).

The net effects of the cracking pattern are fewer fuel fragments in the ATM-104 fuel than in the ATM-106 fuel. While the surface area of the ATM-104 fuel was not determined, the lower number of major cracks indicates larger fuel fragments and a lower surface area, even though the ATM-104 and ATM-106 fuel had comparable burnups. Possible surface area differences between the various ATMs may be a consideration in evaluating leach test results.

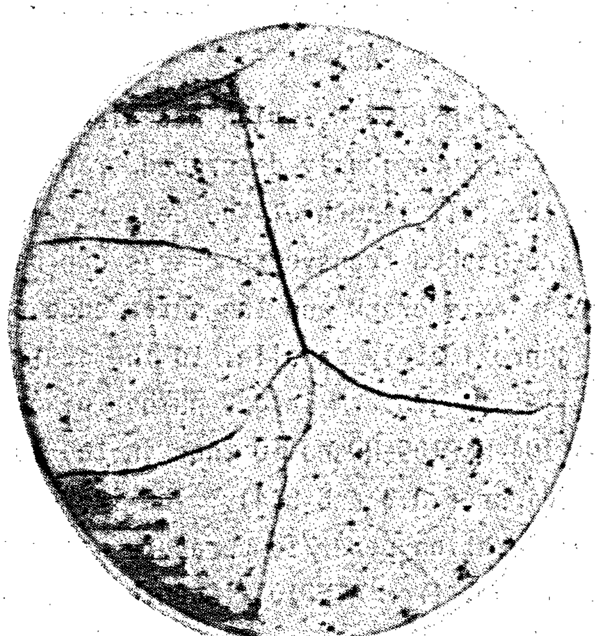


FIGURE 8.1. Photomacrograph of Polished Transverse Sample 104-MKP109-0 from the Peak-Power Region (~8x) (Neg. No. 8704675-13) (Note: Photo taken at an oblique angle to fuel surface.)

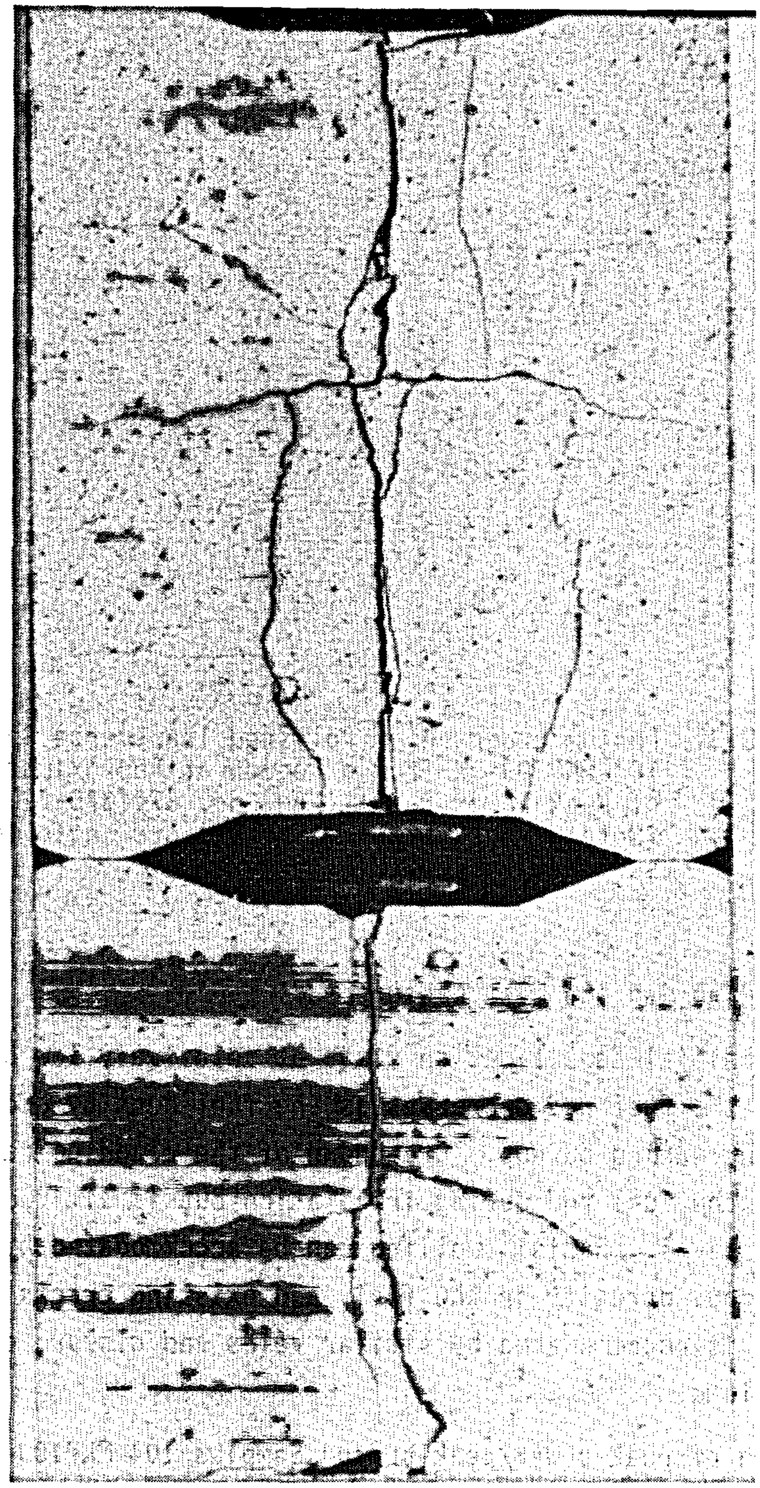


FIGURE 8.2. Photomacrograph of Polished Longitudinal Sample 104-MKP109-N from the Peak-Power Region (~10x) (Neg. No. 8704675-3) (Note: Photo taken at an oblique angle to fuel surface.)

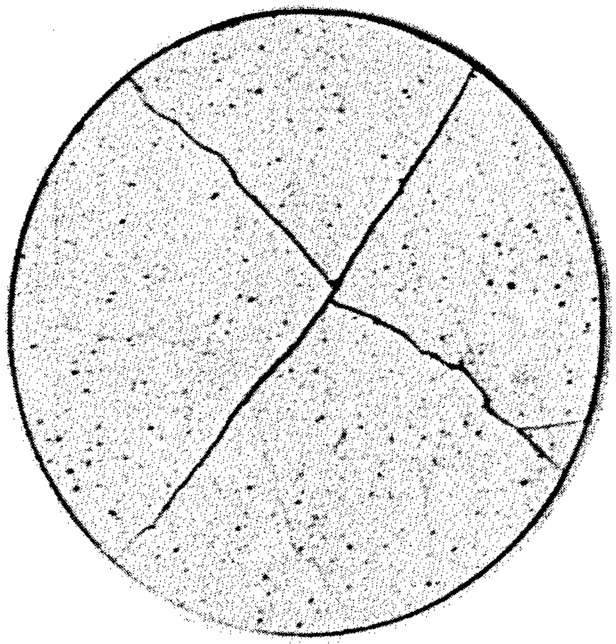


FIGURE 8.3. Photomacrograph of Polished Transverse Sample 104-MKP109-KK from a Region at Approximately 68% of Peak Power (~8x) (Neg. No. 8704675-22) (Note: Photo taken at an oblique angle to fuel surface.)

Fuel-Cladding Gap and Dish Closure

After an initial densification stage at relatively low burnup levels, void volume in the fuel rod decreases as the fuel density decreases (the fuel swells) with increasing burnup. Creepdown of the cladding can also eliminate void volume in the fuel rod during irradiation but is limited by the fuel rod pressurization level. Radial swelling can be accommodated by closure of the fuel-cladding gap, porosity in the fuel, and existing cracks in the fuel; axial swelling is accommodated by similar voids and closure of the pellet-to-pellet dish volume.

Comparison of peak-power/peak-burnup Samples 104-MKP109-N and -O to those of ATM-103 Samples 103-MLA98-N and -O (Guenther et al. 1988a) shows the latter samples had relatively open cracks with visible pellet-to-cladding gaps, whereas the ATM-104 peak-power samples have relatively fine-gapped cracks and a narrow fuel-cladding gap. The fabricated dimensions of the

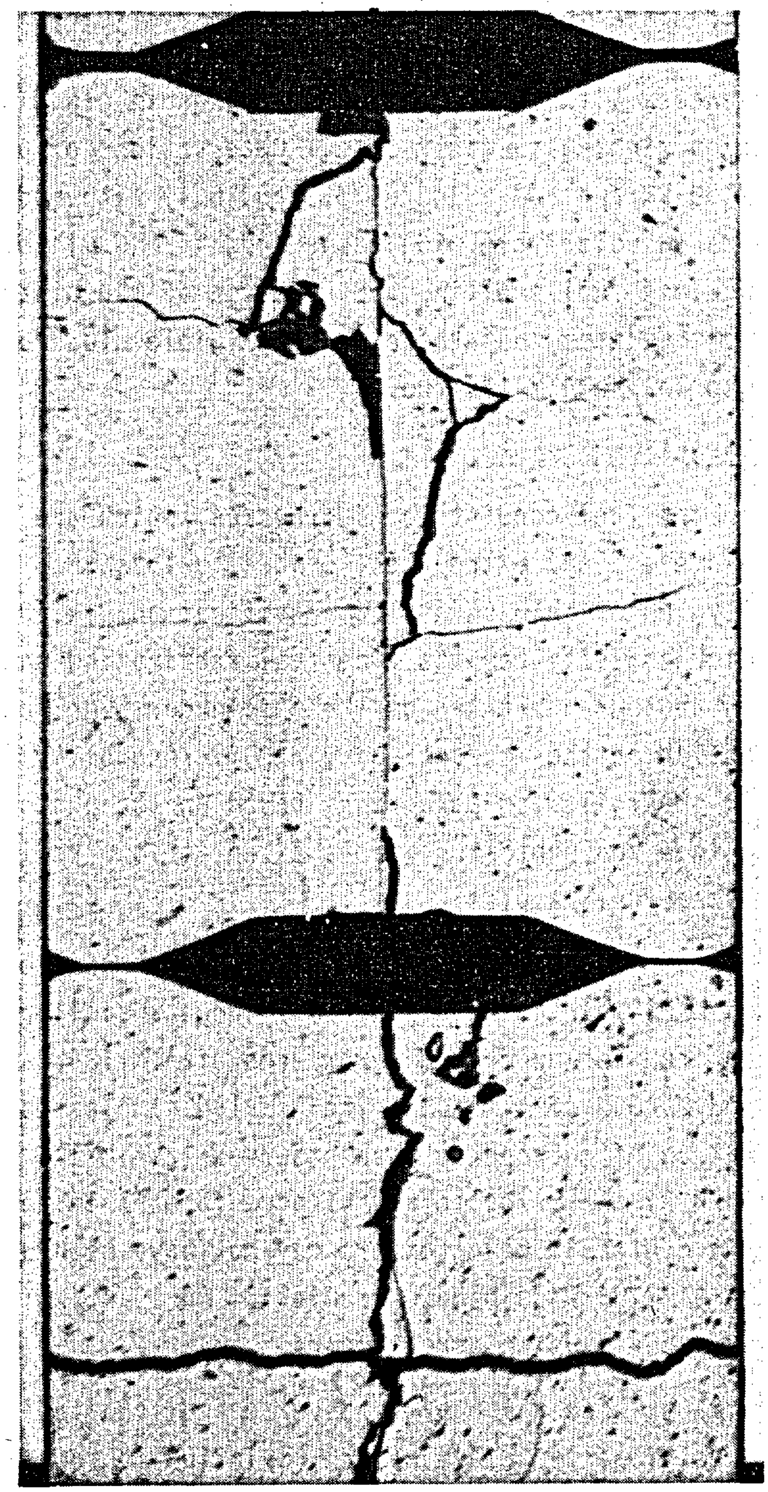


FIGURE 8.4. Photomacrograph of Polished Longitudinal Sample 104-MKP109-JJ from a Region at Approximately 72% of Peak Power (~10x) (Neg. No. 8704675-18) (Note: Photo taken at an oblique angle to fuel surface.)

ATM-103 and ATM-104 fuel pellets and cladding were identical. A greater amount of radial swelling of the higher burnup ATM-104 fuel may explain the observed differences, although potential increases in cladding creepdown with longer irradiation might also contribute. Observations of photomacrographs of Samples 104-MKP109-KK and -JJ (Figures 8.3 and 8.4) with moderate-power/moderate-burnup show relatively wide-gapped cracks and visible fuel-cladding gaps, suggesting less fuel swelling. Evaluation of the distance between two adjacent pellets indicates that there was negligible closure of the fabricated pellet-pellet gap in the ATM-104 fuel.

Porosity Variation

Porosity in the fuel consists of macropores, which are generally greater than 30 μm in diameter, and micropores, generally less than 5 μm in diameter. The macroporosity, observable under low magnification, is formed during fuel fabrication. Microporosity results from fuel fabrication and irradiation and is observable in photographs taken of the fuel under high magnification. Detailed information on the macroporosity and microporosity for the ATM-104 fuel is given in the following paragraphs based on the photomacrographs taken of the fuel sections and photomicrographs taken at four radial locations across the polished fuel samples.

The macroporosity concentration and size distribution of the peak-power samples from Rod MKP109 (Figures 8.1 and 8.2) appear similar to those of other samples examined from the upper and lower ends of ATM-104, as well as samples examined from Rod MLA098 of ATM-103. The ATM-104 samples have a significantly higher concentration of macropores than observed in ATM-106 Rod NBD107; this might be explained by the probable use of pore formers in the ATM-103 and ATM-104 fuel. In contrast, pore formers may not have been used in the ATM-106 fuel because the ATM-106 rods began irradiation in 1974, which is about the time manufacturers began using pore formers.

Photomicrographs were taken of transverse and longitudinal fuel samples at four radial positions to determine the variation in porosity from center to edge at a given axial location and as a function of axial position. Comparison of these photomicrographs provides a means of detecting changes in fission gas bubble size, porosity concentration and distribution, and the agglomeration of fission products. These features are affected by operating fuel temperatures that increase from the edge towards the center of the fuel pellet.

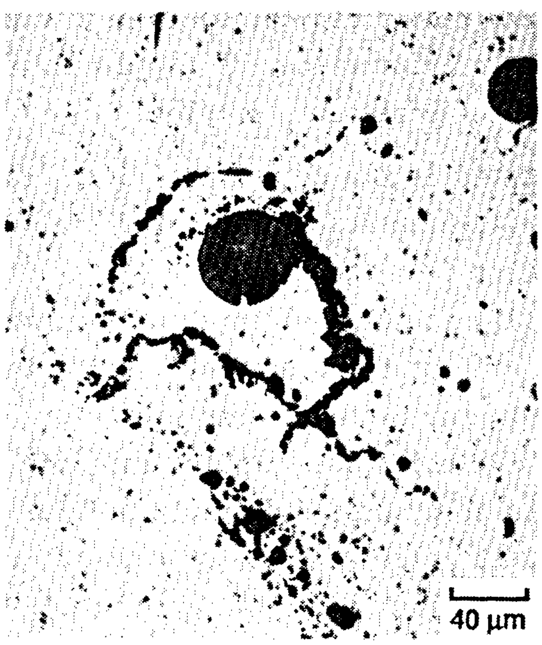
Comparisons were made between the polished samples from regions of the rod operated at approximately 68% of the peak power (Figure 8.5), approximately 72% of the peak power (Figure 8.6), and peak-power (Figures 8.7 and 8.8). Sample 104-MKP109-KK from the low-power region has a relatively low concentration of small rounded pores (up to about 4 μm in diameter) from the fuel center to approximately 2/3 radius (Figure 8.5). A few macropores (up to about 50 μm in diameter) are observed in Sample 104-MKP109-KK and are probably the result of the addition of a pore former during fuel fabrication. The porosity concentration and size distribution are similar in adjacent longitudinal sample 104-MKP109-JJ (Figure 8.6).

Micrographs of peak-power Samples 104-MKP109-O and 104-MKP109-N in Figures 8.7 and 8.8, respectively, reveal a much higher concentration of small rounded pores (~2 to 4 μm) from center to 1/3 radius. Angular pores, primarily concentrated at the pellet edge to the 2/3 radius region, are apparent and are probably due to grain pullout during sample preparation. A large amount of grain pullout appears to have occurred in the peak-power samples.

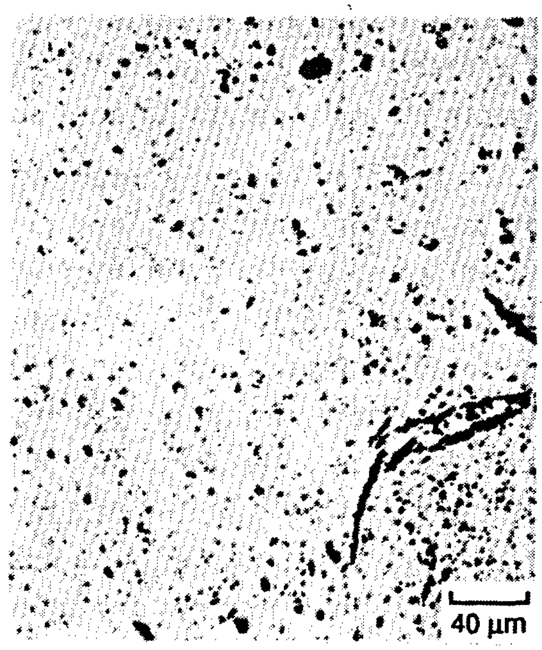
In addition to the rounded porosity located in the center to 1/3 radius regions of these samples, there is a relatively high concentration of small (1 to 2 μm) pores within a few hundred micrometers from the fuel edge (Figures 8.7d and 8.8d). This increase in porosity at the fuel edge, or rim, has been noted by Pati, Garde, and Clink (1988) as a possible explanation for the enhanced release of fission gas from fuel with rod average burnups greater than 40 MWd/kgM. The formation of a porous rim coincides with the significantly higher fission rate near the fuel edge as discussed in Section 7.3.2. For the peak-power samples from Rod MKP109 with pellet-average burnups of ~44 MWd/kgM, the outer rim has a burnup of 60 MWd/kgM or higher based on EPMA measurements of neodymium (see Figure 7.15). EPMA of the ATM-104 fuel also indicated depletion of xenon in the porous rim region similar to that observed by Pati, Garde, and Clink (1988). The existence of this thin, porous outer rim may be important to radionuclide releases from high-burnup fuel under repository conditions.

a) Center (Neg. No. P-2773)

b) 1/3 Radius (Neg. No. P-2772)

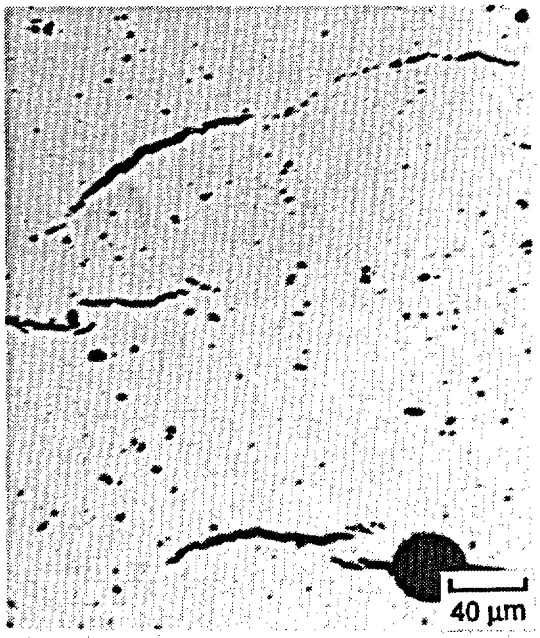


c) 2/3 Radius (Neg. No. P-2771)



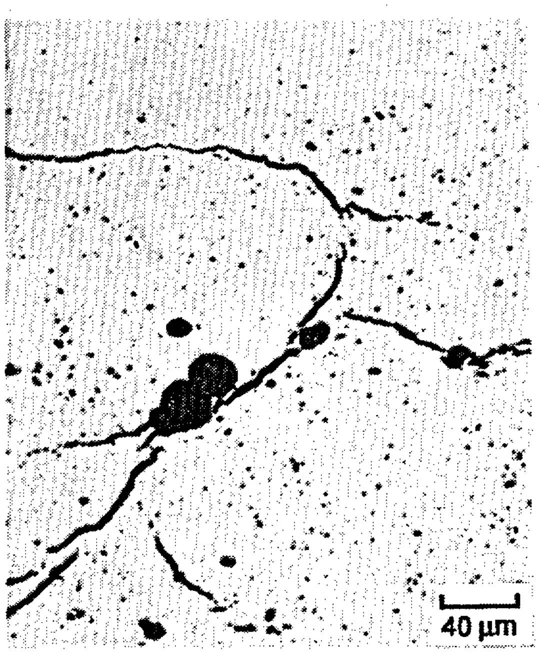
d) Edge (Neg. No. P-2770)

FIGURE 8.5. Photomicrographs of Polished Transverse Sample 104-MKP109-KK from a Region at Approximately 68% of Peak Power

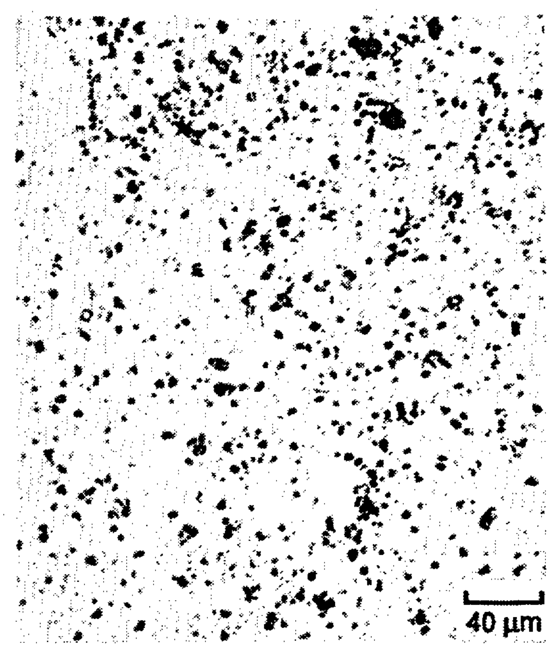


a) Center (Neg. No. P-2789)

b) 1/3 Radius (Neg. No. P-2788)

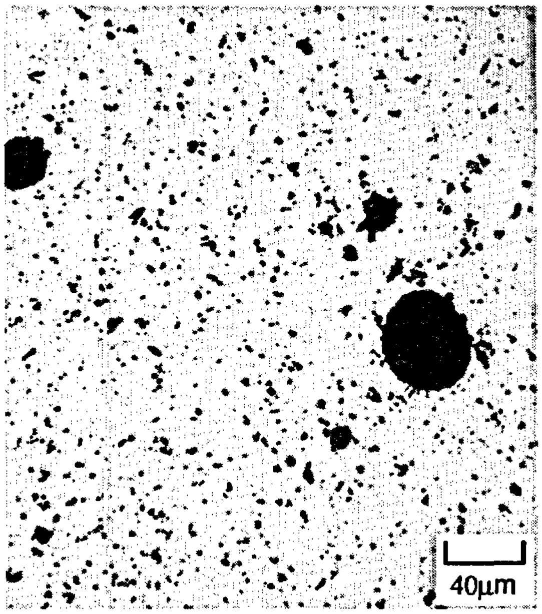


c) 2/3 Radius (Neg. No. P-2787)



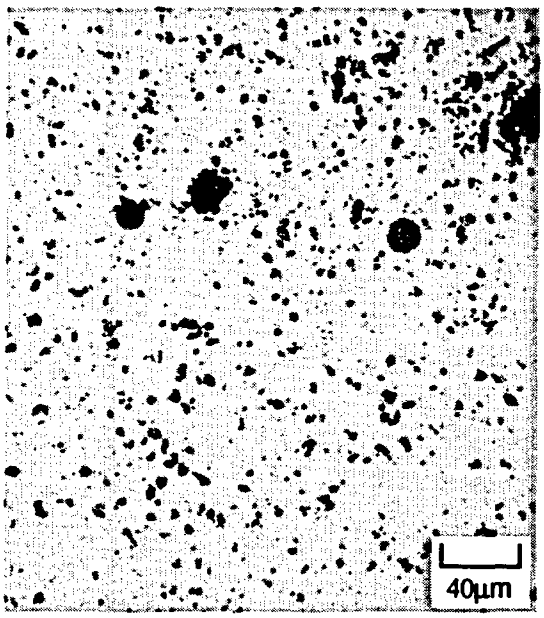
d) Edge (Neg. No. P-2786)

FIGURE 8.6. Photomicrographs of Polished Longitudinal Sample 104-MKP109 JJ from a Region at Approximately 72% of Peak Power

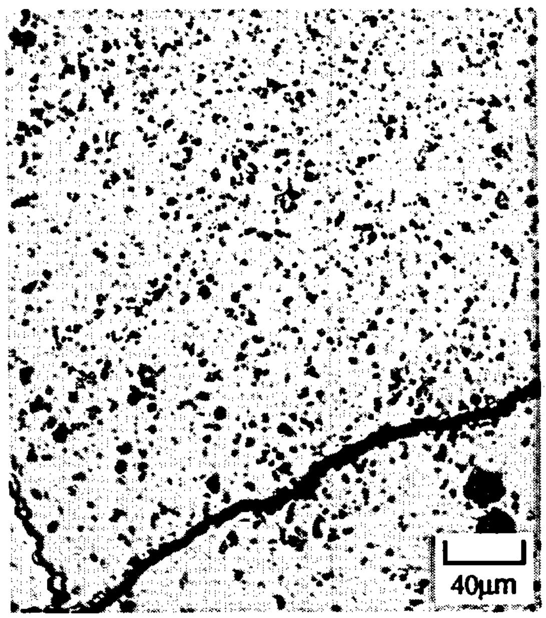


a) Centerline (Neg. No. P-2681)

b) 1/3 Radius (Neg. No. P-2680)

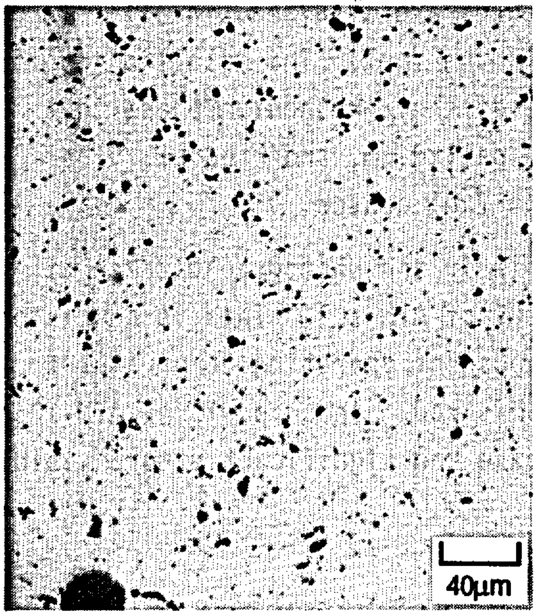


c) 2/3 Radius (Neg. No. P-2679)



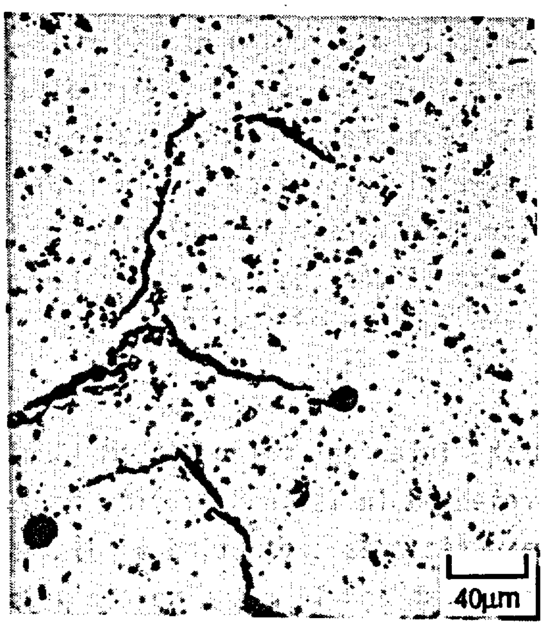
d) Edge (Neg. No. P-2678)

FIGURE 8.7. Photomicrographs of Polished Transverse Sample 104-MKP109-0 from the Peak-Power Region

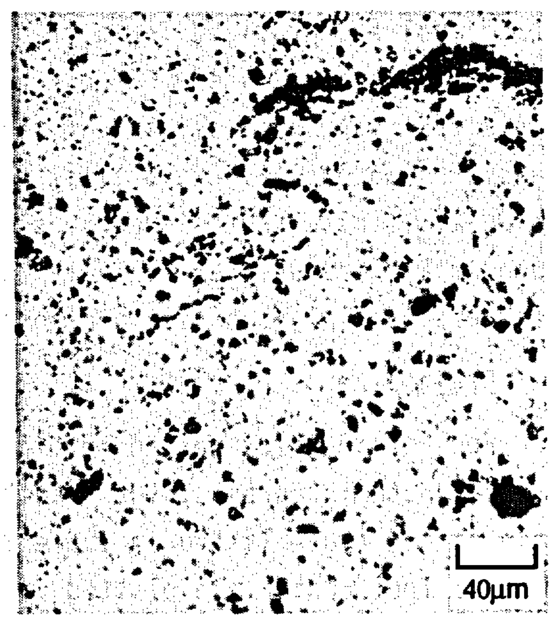


a) Centerline (Neg. No. P-2686)

b) 1/3 Radius (Neg. No. P-2685)



c) 2/3 Radius (Neg. No. P-2684)



d) Edge (Neg. No. P-2683)

FIGURE 8.8. Photomicrographs of Polished Longitudinal Sample 104-MKP109-N from the Peak-Power Region

Metallic Ingot Formation

If sufficient burnup and fuel temperatures are attained, metallic ingots observable by optical microscopy can form in the fuel. The metallic ingots (also called five-metal particles) are made of the ϵ-ruthenium phase that contains molybdenum, ruthenium, technetium, palladium, and rhodium. The ingots appear as bright white spots near the fuel center.

There were very few metal ingots visible in the photographs taken at 500x magnification of samples from Rod MKP109 of ATM-104. This is consistent with the low fission gas release and low, apparent operating temperatures indicated by minimal fuel grain growth in this rod. In comparison, ATM-106 rods with ten times higher fission gas release had significantly more visible metallic ingots (Guenther et al. 1988b).

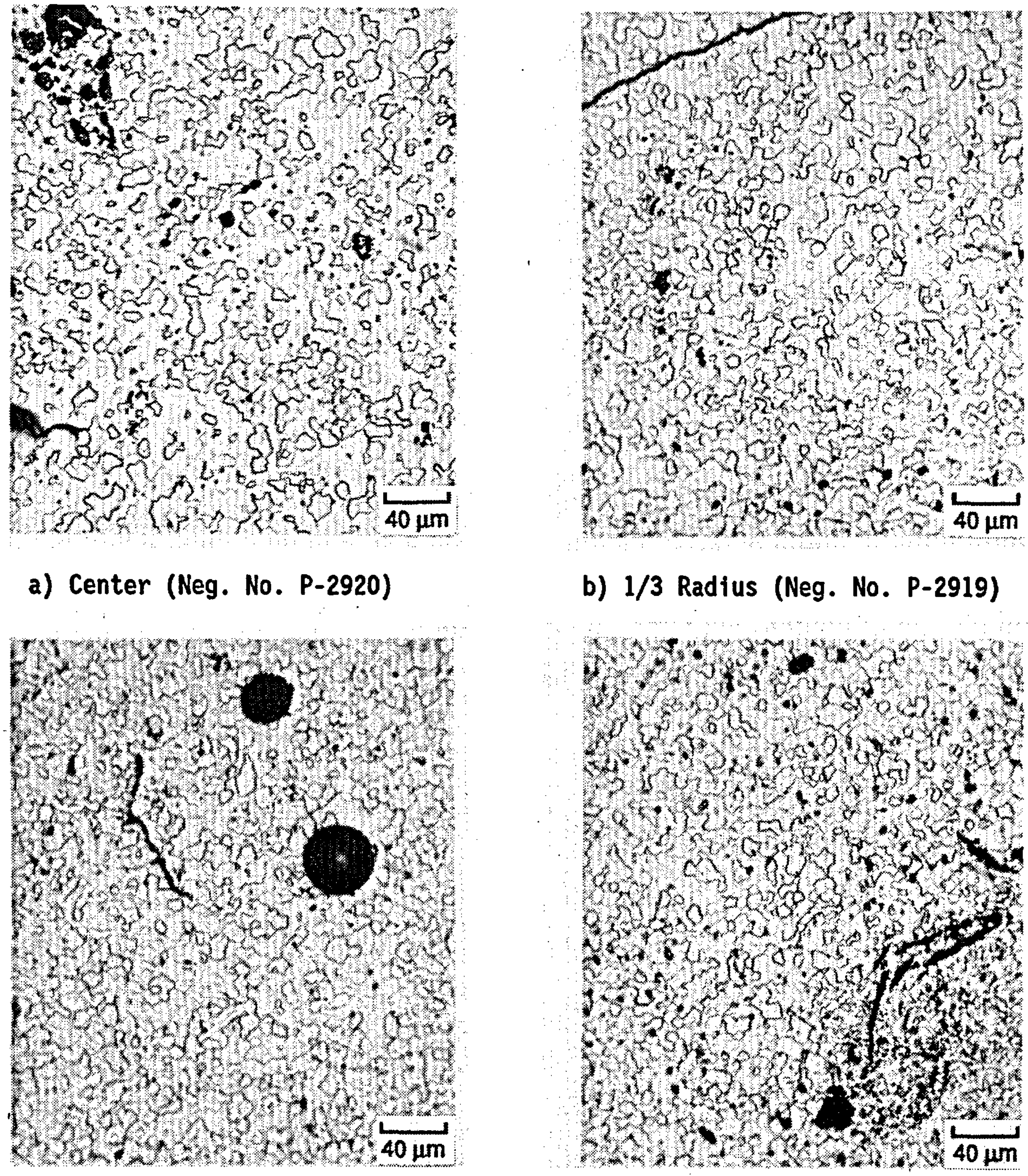
8.2.2 Etched Fuel Condition

Fuel samples from Rod MKP109 were etched using argon ions in a cathode vacuum etcher to determine any variation in grain size with radial position and to determine if porosity was preferentially located at selected sites, such as at grain boundaries or within the grain interiors. Examples of the etched fuel are provided for a transverse sample from a region of the rod operated at approximately 68% of the peak power (Figure 8.9), a longitudinal sample from approximately 72% of the peak power (Figure 8.10), a peak-power transverse sample (Figure 8.11), and a peak-power longitudinal sample (Figure 8.12). These photomicrographs and similar ones for other fuel samples (in Appendix E) were used to evaluate the grain size of the fuel as fabricated and the variation in grain size and porosity of the fuel in Rod MKP109.

Grain Size

Fuel grain sizes were determined using the intercept method (ASTM 1980) on 250x photomicrographs; the results are presented in Table 8.8. The true grain sizes[a] are listed in Table 8.8. Grain sizes as a function of distance from the fuel center are plotted for the transverse and longitudinal samples in Figures 8.13 and 8.14, respectively.

(a) True grain sizes equal the intercept grain size multiplied by 1.57. This corrects the measured grain size for grains cut above or below the middle of the grain during ceramography.



a) Center (Neg. No. P-2920)

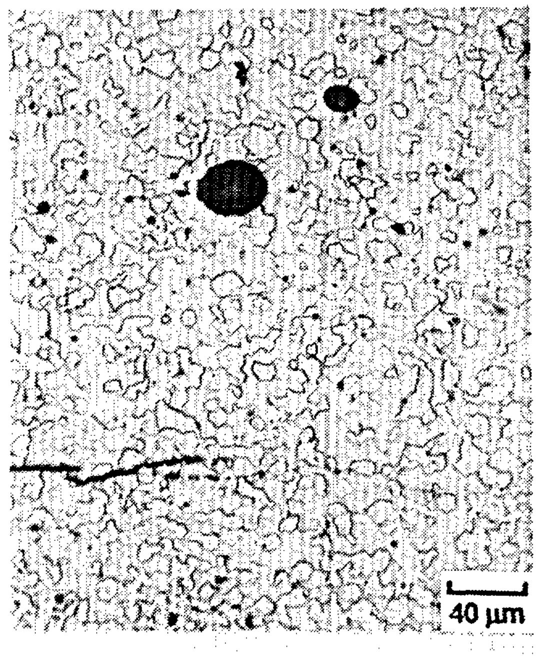
b) 1/3 Radius (Neg. No. P-2919)

c) 2/3 Radius (Neg. No. P-2918)

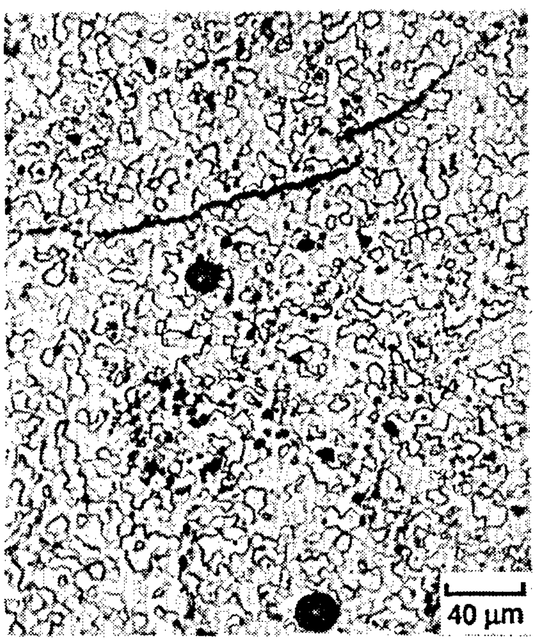
d) Edge (Neg. No. P-2917)

FIGURE 8.9. Photomicrographs of Argon Ion-Etched Transverse Sample 104-MKP109-KK from a Region at Approximately 68% of Peak Power

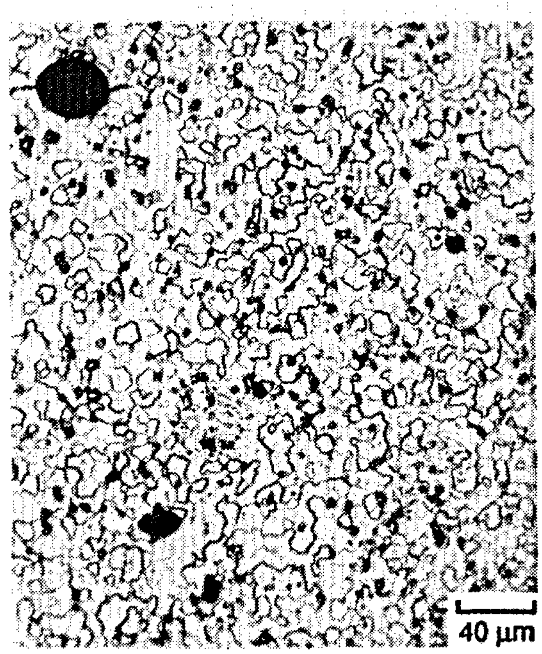
a) Center (Neg. No. P-2916)



b) 1/3 Radius (Neg. No. P-2915)

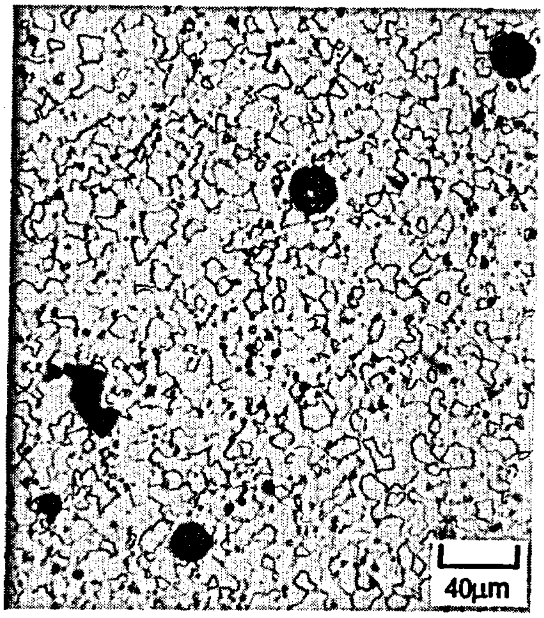


c) 2/3 Radius (Neg. No. P-2914)

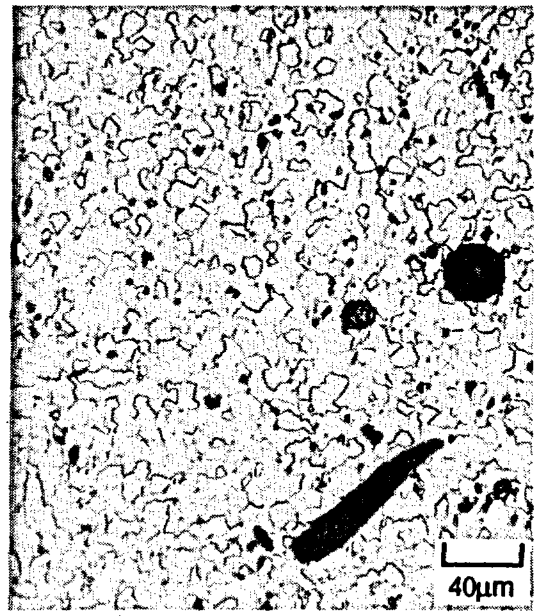


d) Edge (Neg. No. P-2913)

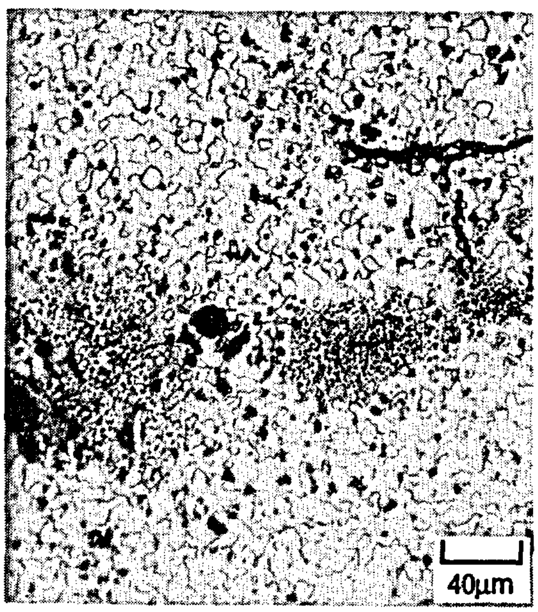
FIGURE 8.10. Photomicrographs of Argon Ion-Etched Longitudinal Sample 104-MKP109-JJ from a Region at Approximately 72% of Peak Power



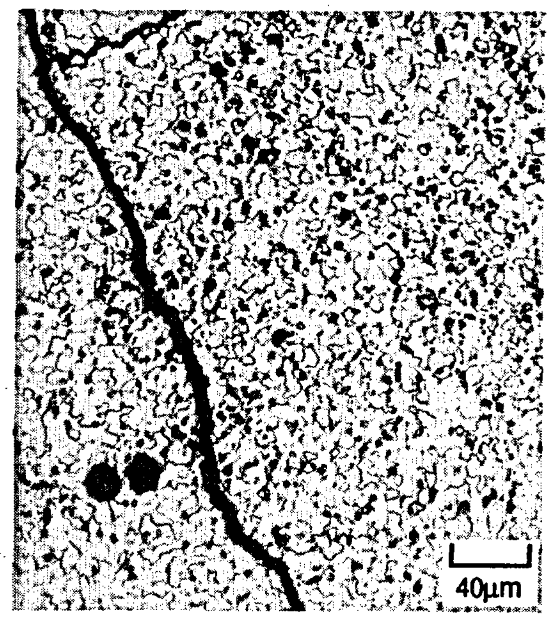
a) Centerline (Neg. No. P-2928)



b) 1/3 Radius (Neg. No. P-2927)

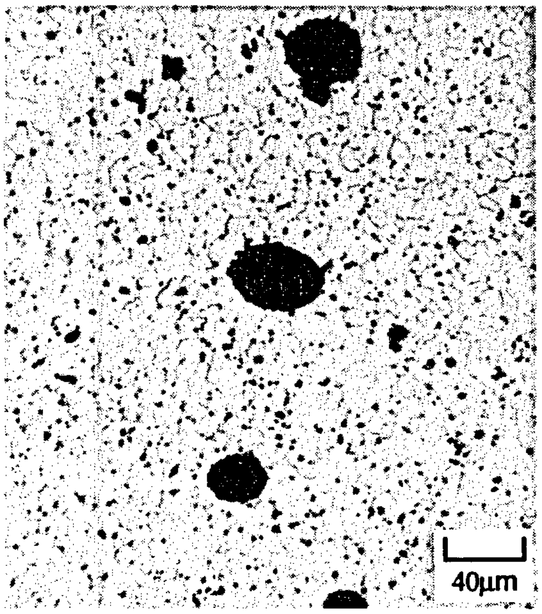


c) 2/3 Radius (Neg. No. P-2926)

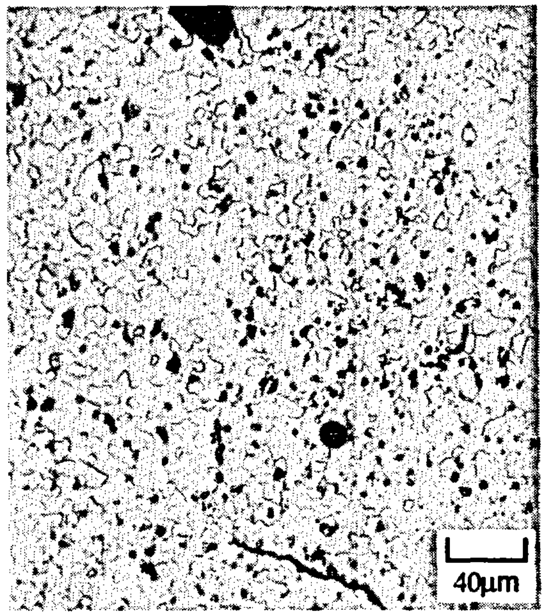


d) Edge (Neg. No. P-2925)

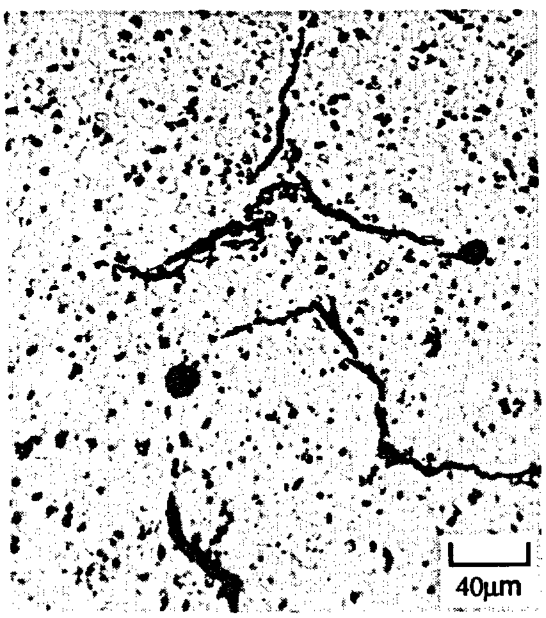
FIGURE 8.11. Photomicrographs of Argon Ion-Etched Transverse Sample 104-MKP109-0 from the Peak-Power Region



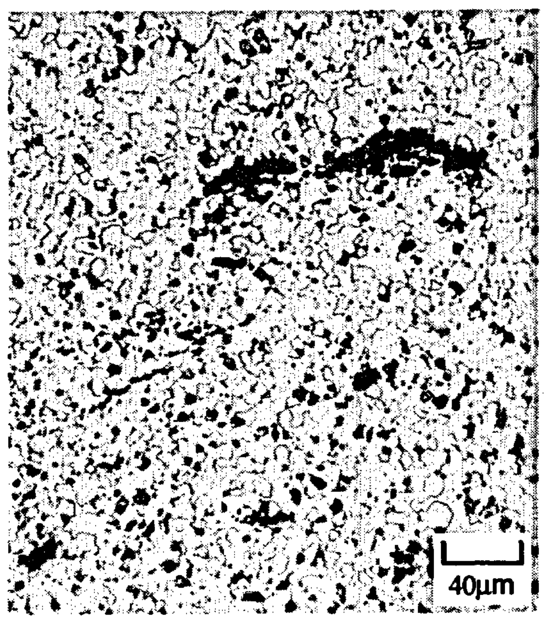
a) Centerline (Neg. No. P-2912)



b) 1/3 Radius (Neg. No. P-2911)



c) 2/3 Radius (Neg. No. P-2910)



d) Edge (Neg. No. P-2909)

FIGURE 8.12. Photomicrographs of Argon Ion-Etched Longitudinal Sample 104-MKP109-N from the Peak-Power Region

TABLE 8.8. Results of ATM-104 Fuel Grain Size Measurements

	Grain Size, μm							
	Centerline		1/3 Radius		2/3 Radius		Edge	
Sample No.	Intercept	True[a]	Intercept	True[a]	Intercept	True[a]	Intercept	True[a]
104-MKP109-C	7.0±0.6	11.0±0.9	7.0±0.6	11.0±0.9	7.4±0.2	11.6±0.3	7.2±0.3	11.3±0.5
104-MKP109-H	6.9±0.6	10.8±0.9	6.6±0.5	10.4±0.8	6.3±0.6	9.9±0.9	6.9±0.5	10.8±0.8
104-MKP109-N	8.7±1.0	13.7±1.6	7.3±0.6	11.5±0.9	7.0±1.1	11.0±1.7	6.6±0.9	10.4±1.4
104-MKP109-O	8.0±0.7	12.6±1.1	7.5±0.9	11.8±1.4	6.6±0.4	10.4±0.6	6.1±0.7	9.6±1.1
104-MKP109-AA	6.5±0.3	10.2±0.5	7.0±0.1	11.0±0.2	6.7±0.5	10.5±0.8	6.3±0.2	9.9±0.3
104-MKP109-BB	7.2±0.3	11.3±0.5	6.6±0.6	10.4±0.9	7.2±1.2	11.3±1.9	6.7±0.4	10.5±0.6
104-MKP109-JJ	7.5±0.8	11.8±1.3	7.0±0.9	11.0±1.4	6.0±0.5	9.4±0.8	6.9±0.5	10.8±0.8
104-MKP109-KK	7.6±0.3	11.9±0.5	6.5±0.4	10.2±0.6	6.6±0.4	10.4±0.6	6.6±0.3	10.4±0.5
Average ± 1σ	7.4±0.7	11.6±1.1	6.9±0.4	10.8±0.6	6.7±0.5	10.5±0.8	6.7±0.4	10.5±0.6

(a) The true grain size equals the intercept grain size multiplied by 1.57. Standard deviation for each sample is estimated from range in grain sizes determined from three or more intercept lines used to calculate the grain size for each sample.

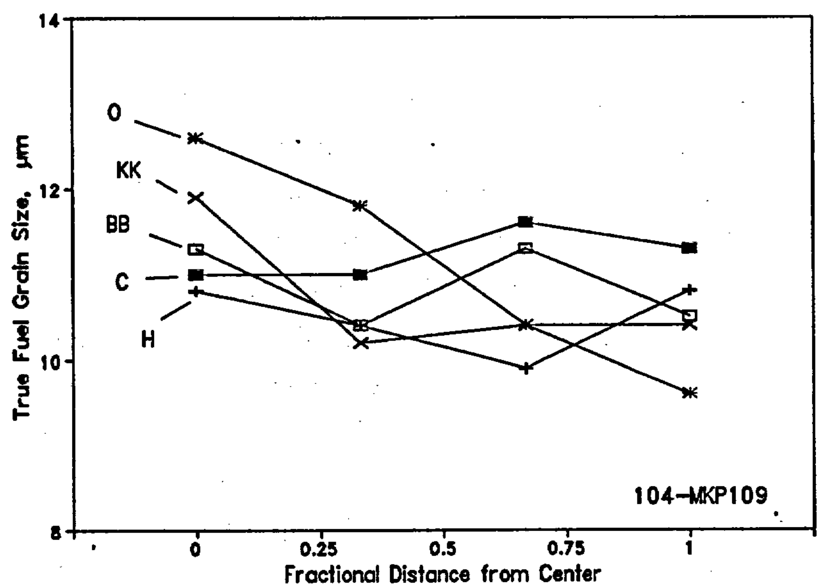


FIGURE 8.13. Variation in True Grain Size Across the Radius of Transverse Fuel Samples from Rod MKP109

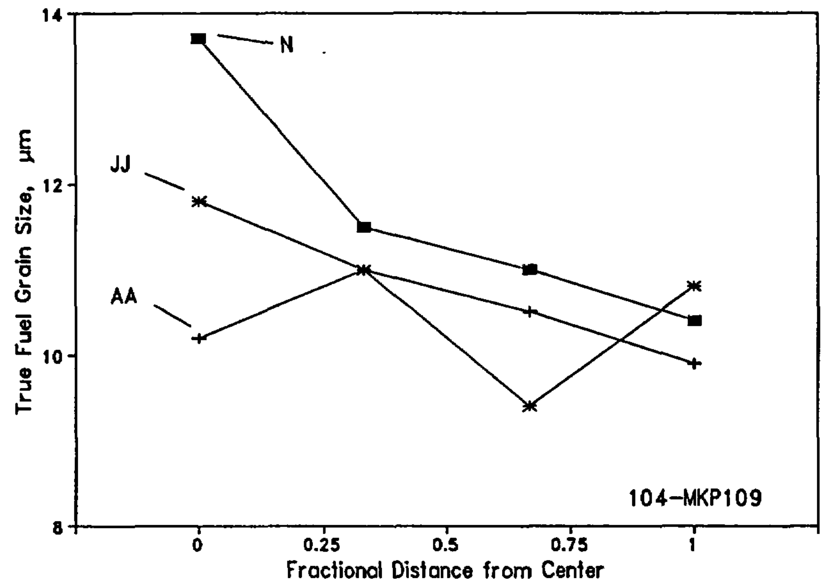


FIGURE 8.14. Variation in True Grain Size Across the Radius of Longitudinal Fuel Samples from Rod MKP109

Based on these examinations, the fabricated grain size was ~10 µm; the design specified grains ≥5 µm. Negligible grain growth occurred in the top third of the fuel rod in Samples 104-MKP109-C and -H. The grains in Samples 104-MKP109-O and 104-MKP109-N from the peak-power region in the middle of the rod were approximately 30% larger at the center than near the pellet edge, indicating that the fuel temperatures were high enough to cause detectable grain growth near the center of the pellets (see Figures 8.11 and 8.12). Examination of the microstructure for Samples 104-MKP109-JJ and 104-MKP109-KK from the lower-power region at the bottom of the rod indicated that the fuel grains at the pellet center may have grown by up to ~15%; there is some variability in the as-fabricated grain size as suggested by the data in Figures 8.13 and 8.14. The overall results are consistent with the expected axial temperature profile of the fuel rod during in-reactor operation, when the extreme ends of the rods operate at lower power and achieve lower burnups.

Porosity

As indicated previously in the discussion of porosity in polished fuel samples, ~2 to 4 μm diameter pores were observed from the center to 1/3 radius of peak-power Samples 104-MKP109-O and 104-MKP109-N. Based on photomicrographs of the etched samples, these pores are primarily located at grain boundaries and grain boundary intersections (Figures 8.11 and 8.12). The grain growth and grain boundary bubbles are clearly evident in Figure 8.12 for Sample 104-MKP109-N. The accumulation of porosity at the grain boundaries is indicative of fission gas redistribution from the grains to the grain boundaries. Lower-power Samples 104-MKP109-KK and -JJ have significantly lower concentrations of similar sized pores at the grain boundaries (see Figures 8.9 and 8.10).

These variations in fission gas bubbles along the grain boundaries of samples from ATM-104 are consistent with the differences in grain growth indicated in Table 8.8, as well as the measured fission gas releases and grain growths for other ATMs. In the peak-power region of Rod MLA098 of ATM-103, which had a burnup approximately 30% lower than in a comparable peak-power location in Rod MKP109, most of the smaller porosity is located within the grains and not at the grain boundaries. There was essentially no grain growth in the ATM-103 samples, and the fission gas release from Rod MLA098 was about one fourth of that for Rod MKP109 from ATM-104. Considering the limited grain growth throughout the ATM-104 fuel rod, the 30% higher burnup in the ATM-104 rod than in the ATM-103 rod, the high rim porosity, and apparent depletion of xenon near the fuel edge in peak-power region, a significant portion of the fission gas release in the ATM-104 may have resulted from athermal release of xenon and krypton from the fuel rim in Rod MKP109.

Peak-power samples from Rod NBD107 of ATM-106, with burnups comparable to the ATM-104 samples, had significantly more and larger fission bubbles, which can be attributed to higher operating temperatures indicated by 11% fission gas release and grain growths in excess of 100% (Guenther et al. 1988b). While xenon depletion has also been indicated in the rim of the peak-power fuel samples from ATM-106 (Campbell, Guenther, and Jenson 1990), most of the fission gas release and grain growth are related to higher fuel operating temperatures. Thus, the porosity and grain growth of the ATM-104 fuel rod is consistent with moderately high burnup and low fission gas release.

8.3 CESIUM AND IODINE PLATEOUT ON INNER CLADDING SURFACES

The rate at which radionuclides will be released from spent fuel in the event of contact with water in a geologic repository is a function of the radionuclide distribution in the spent fuel. If the radionuclides are bound within the matrix of the UO_2 grains, then their release may be expected to be congruent with the UO_2 matrix. However, in laboratory leach tests it is found that the release rate of some radionuclides, such as cesium, strontium, technetium and iodine, greatly exceeds the UO_2 release rate, at least in the initial stages of the leach tests (Katayama 1976; Johnson et al. 1983; Johnson, Garisto, and Stroes-Gascoyne 1985; and Wilson and Gray 1990). The rapid release is attributed to release of a portion of those radionuclides that redistributed to grain boundaries, fuel surfaces and cracks, and the pellet-cladding gap during reactor operation. This redistribution makes them more accessible for leaching than if they remained within the UO_2 matrix.

The inventory of radionuclides available for rapid release in leach tests may come from grain boundaries, fuel surfaces, and/or the interior surface of the cladding. A total of five cladding samples were taken from Rod MKP109 and analyzed for the amount of ^{129}I, ^{135}Cs, and ^{137}Cs on the interior surface of the cladding samples to evaluate the gap inventory in ATM-104. The analyses of these isotopes on the interior cladding surface can provide useful information on the relationship between fission product release, possible migration, and fuel operating conditions. The radionuclides on the interior cladding surface may represent only part of the total gap inventory, depending on the relative amount of the gap inventory on the fuel surfaces and the grain boundaries. Results of the measured amounts of cesium and iodine on the cladding interior surfaces are provided in Section 8.3.1. These results are compared in Section 8.3.2 with the deposits observed on the cladding surfaces during metallography, fuel grain growth, and fission gas release.

8.3.1 Results of Cesium and Iodine Measurements

Radiochemical analyses for cesium and iodine on the cladding interior surfaces were obtained from 2.5-cm (1.0-in.) cladding sections taken from locations along the length of the rod as indicated in Figure 4.4. The same samples were used to measure the deposits of the cesium isotopes on the exterior surface of the cladding (see Section 6.1.1). After removing the fuel from the cladding, the interior cladding surface was wiped four to five times with fresh, dry cotton to remove loose particles. The open ends of the cladding sample were sealed with stoppers and the cladding was immersed in 8N HNO_3 to remove ^{137}Cs and ^{135}Cs from the exterior surface. Then the stoppers were removed before another 8N HNO_3 treatment was made to remove cesium and iodine from the interior surface for measurement.

The results of the cladding radiochemical analyses for cesium and iodine are provided in Table 8.9. The ^{137}Cs concentration on the interior cladding surface ranged from 8.2 $\mu Ci/cm^2$ to 114 $\mu Ci/cm^2$. The level of ^{135}Cs on the cladding interior surface followed the trend in ^{137}Cs but at a much lower level that was roughly equal to the expected $^{135}Cs/^{137}Cs$ ratio of about 10^{-5}. The amounts of these isotopes are somewhat similar in terms of grams, but the shorter half life for ^{137}Cs results in a much greater activity. As indicated by the data in Table 8.9, the general trend of cesium activity along the interior cladding surface correlates more with the power/burnup of the adjacent fuel, which is highest in the middle of the rod and low at both ends, than with the interior cladding temperature, which increases by about 30°C from the bottom to the top of the fuel rod during irradiation.

The values for ^{129}I on the interior cladding surface indicated a trend that also approximates the variation of the power/burnup in the fuel. Because the chemical form of iodine is expected to be the very stable CsI (Cubicciotti et al. 1976), the similar patterns of deposition for iodine and cesium were expected.

Measured amounts of both cesium and iodine were generally lower in the ATM-104 fuel than in ATM-106 fuel, which had higher apparent operating tempertures (Guenther et al. 1988b). ATM-104 and ATM-103 (Guenther et al. 1988a) had similar amounts and trends in the deposits of cesium and iodine on the interior cladding surfaces in these fuels with low fission gas release.

TABLE 8.9. Radiochemical Analyses of Cesium and Iodine on Cladding Interior Surfaces

	Activity, $\mu Ci/cm^2$		
Sample No.	^{137}Cs	^{135}Cs	^{129}I
104-MKP109-D	15.1	8.56×10^{-5}	1.32×10^{-5}
104-MKP109-I	47.3	21.5×10^{-5}	4.68×10^{-5}
104-MKP109-T	114	51.4×10^{-5}	5.27×10^{-5}
104-MKP109-FF	27.3	14.5×10^{-5}	1.38×10^{-5}
104-MKP109-00	8.20	5.45×10^{-5}	0.486×10^{-5}

8.3.2 Comparison of Cesium and Iodine Deposits with Other Fuel Features

The cesium and iodine deposits on the interior surfaces of the cladding can be compared with 1) the deposits observed on the cladding interior surface during metallography, 2) measured fuel grain growth, and 3) rod-average fission gas release. Each of these comparisons are made below.

As discussed in Section 6.1.1, negligible oxide/deposits were observed on the interior surface of samples from the upper and lower ends of the rods, where the burnup and probably the fission gas release were low (Figure 6.4b). Localized "islands" that rapidly thinned at their ends were observed in the peak-power region (Figure 6.5b). Cubicciotti et al. (1976) observed similar differences in two LWR fuels and found that the deposits contained cesium, iodine, tellurium and other volatile fission products along with uranium, zirconium, and oxygen. The radiochemical analyses of cesium and iodine on the interior surfaces of ATM-104 cladding also indicated increasing amounts of cesium and iodine with increasing burnup of the adjacent fuel (see Table 8.9). Data for ATM-106 (Guenther et al. 1988b) and ATM-105 (Guenther et al. 1990) indicate similar comparisons between the radiochemical and metallographic analyses of fuel rods.

The driving force for depositing cesium and iodine on the cladding interior surface is the fuel temperature during reactor operation. Because there is no direct measurement of fuel operating temperatures, the maximum fuel grain growth has been used as a relative measure of local operating fuel temperatures. It is possible to have fission gas release without grain growth; however, analyses of these ATMs have indicated a reasonable correlation between the amount of cesium and iodine deposited on the cladding and the maximum grain growth measured from ceramographic samples (Campbell, Guenther, and Jenson 1990).

The activities from ^{137}Cs and ^{129}I deposited on the interior surfaces of cladding sections from three PWR rods (ATM-103, ATM-104, and ATM-106) are shown in Figures 8.15 and 8.16, respectively. Grain growths used in these figures were from the nearest sample for which grain growth data are available (-C, -H, -O, -BB, and -KK in the ATM-104 rod). The maximum grain growths used in these figures were obtained assuming that the fuel grain size measured at the edge of a given sample was the fabricated grain size; there is obviously some uncertainty in making such an assumption. The grain growths measured in ATM-104 fuel samples were generally low, but the measured amounts of cesium and iodine on the cladding fall within a pattern consistent with the data shown in Figures 8.15 and 8.16. The data for ATM-106 are for a rod with 11% fission gas release and a significant range in grain growth. As indicated in Figures 8.15 and 8.16, there are increasingly greater amounts of cesium and iodine activity on the cladding adjacent to fuel with higher maximum grain growth.

Another way of showing the relationship between cladding deposits and fuel operating conditions is to determine the percentage of the inventory produced in the fuel that has been released to the cladding; some of the material released is expected to remain on the fuel surface and/or grain boundaries. Using the fuel burnups in Appendix B, the activity/cm^2 deposited along the cladding was converted to a percentage of the inventory of ^{137}Cs or ^{129}I that was produced in the fuel over the same axial length. It is assumed that all the isotopes of the same element are deposited at the same percentage of total inventory. The percentage of the local inventory of cesium and iodine that deposits on the cladding interior surface is plotted against the maximum grain growth in Figures 8.17 and 8.18, respectively. Data from two ATM-105 BWR rods are also included in these figures (Guenther et al. 1990).

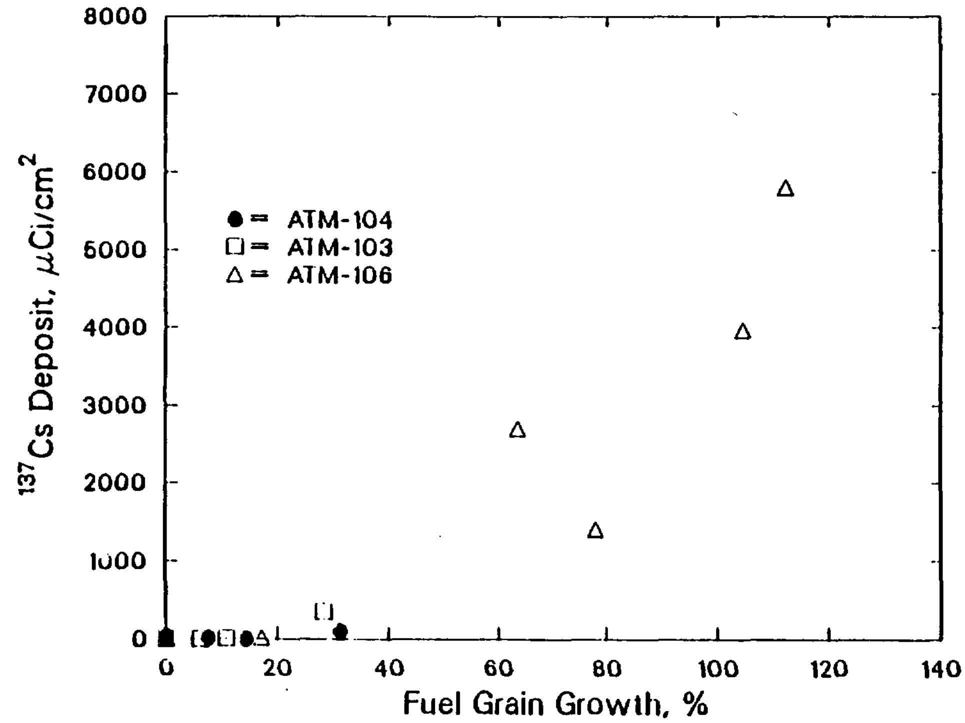


FIGURE 8.15. Trend in ^{137}Cs Deposits on Interior Cladding Surfaces of ATM-103, ATM-104, and ATM-106

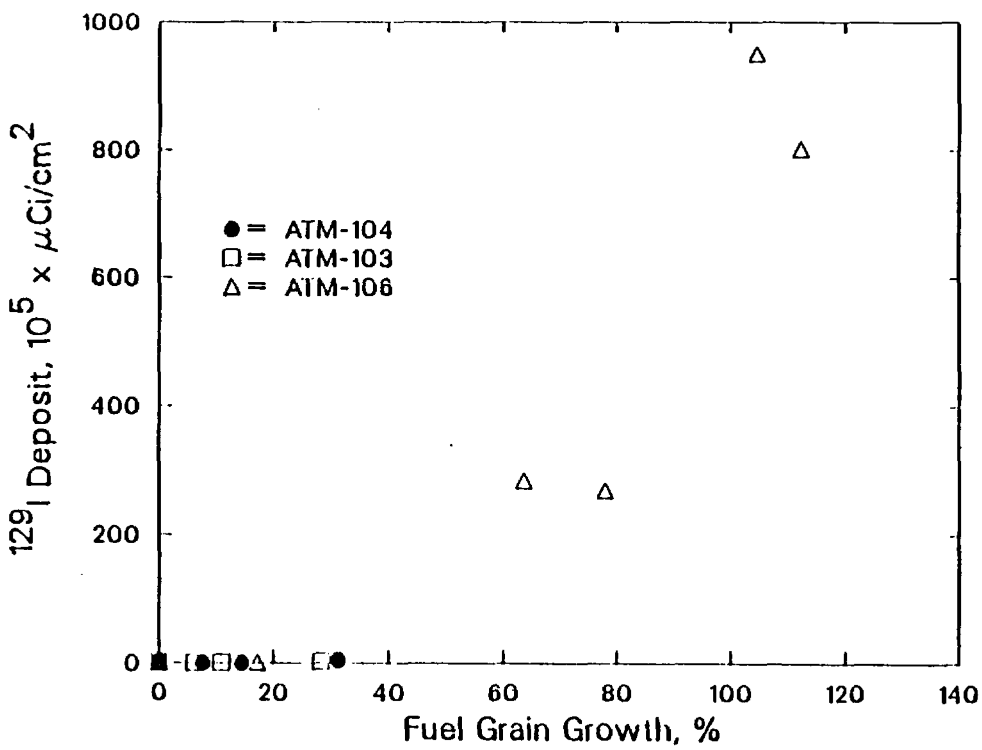


FIGURE 8.16. Trend in ^{129}I Deposits on Interior Cladding Surfaces of ATM-103, ATM-104, and ATM-106

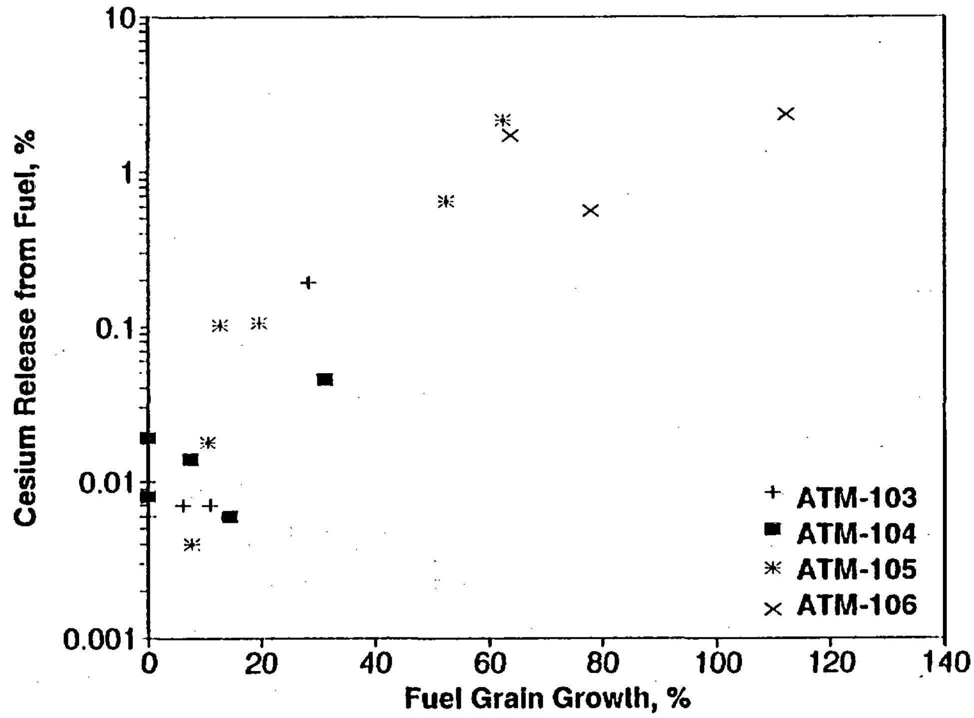


FIGURE 8.17. Local Inventory of Cesium Deposited on Interior Cladding Surfaces of ATM-103, ATM-104, ATM-105, and ATM-106

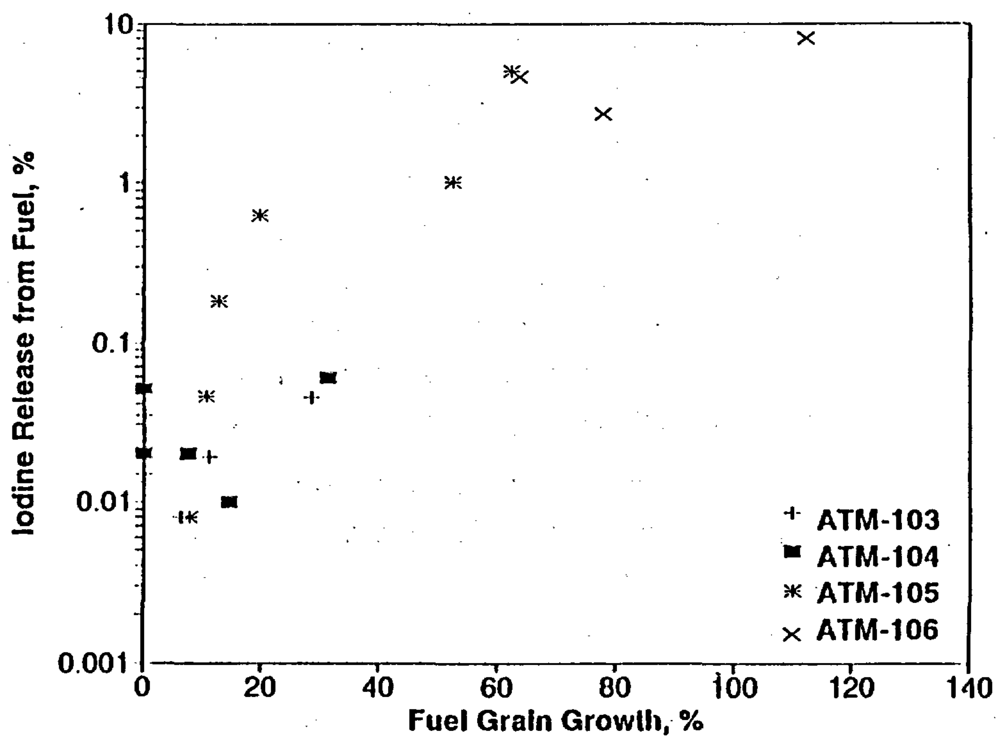


FIGURE 8.18. Local Inventory of Iodine Deposited on Interior Cladding Surfaces of ATM-103, ATM-104, ATM-105 and ATM-106

A semilogarithmic plot has been used to provide details of the trends at very low release levels. The amount of the iodine released from the fuel to the cladding ranged from 0.01 to 0.06% of the inventory produced in ATM-104 fuel samples. Cesium deposits on the cladding were consistently lower, ranging from 0.006 to 0.046% of the cesium inventory produced in the ATM-104 fuel.

While the data for just ATM-104 would not be sufficient in themselves, the combined data shown in Figures 8.17 and 8.18 follow a reasonable trend of increasing deposition with increasing fuel grain growth and, presumably, fuel temperatures. In general, the percentage of the local inventory of iodine that reaches the cladding interior surface is higher than the percentage of cesium, particularly at higher grain growths; this has been observed in all of the ATMs examined. Both cesium and iodine may approach a saturation level based on the trends in Figures 8.17 and 8.18; data from Mogensen, Knudsen, and Walker (1987) and from Manzel, Sontheimer, and Stehle (1985) indicate that fission gas release saturates at about 90% release.

While it is important to correlate the inventory of fission products against local conditions for experimenters using samples from the ATMs, repository performance assessments are often based on average values for larger quantities of fuel material. Uncertainties are usually assigned to these average values. The rod-average fission gas release is a parameter often used to define fuel characteristics because the average amount of fission gas release from a rod can be calculated reasonably well with computer codes. Johnson et al. (1983) showed that there is a relationship between the gap inventory of cesium (and possibly iodine) and the fission gas release from a rod during leach testing; cesium release occurred in nearly a 1:1 relationship with xenon release, particularly at higher release levels.

The local inventory of cesium and iodine released to the cladding surfaces are plotted against rod-average fission gas releases in Figures 8.19 and 8.20, respectively. For a given rod-average fission gas release, there is a distinct range of cesium or iodine inventory that is deposited on the cladding interior surface. As indicated above, this results because local conditions vary along the fuel rod. The information in Figures 8.19 and 8.20 could be used to predict the average amount of cesium and iodine deposited on the cladding surface within a defined uncertainty. It may be necessary to limit

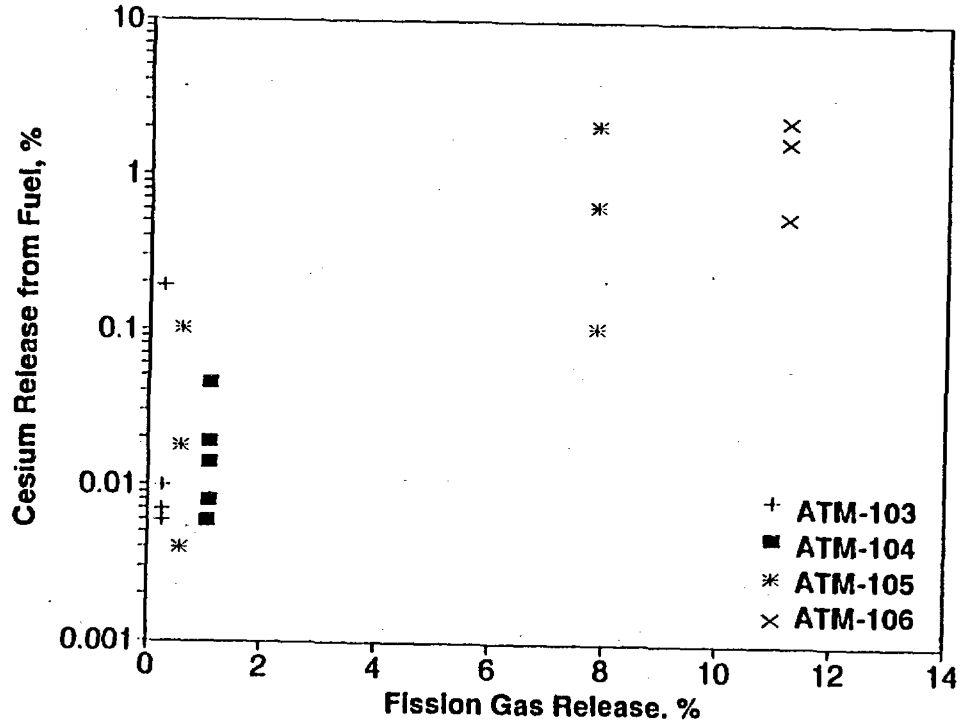


FIGURE 8.19. Local Inventory of Cesium Deposits on Interior Cladding of Fuel Rods with Different Rod-Average Fission Gas Releases

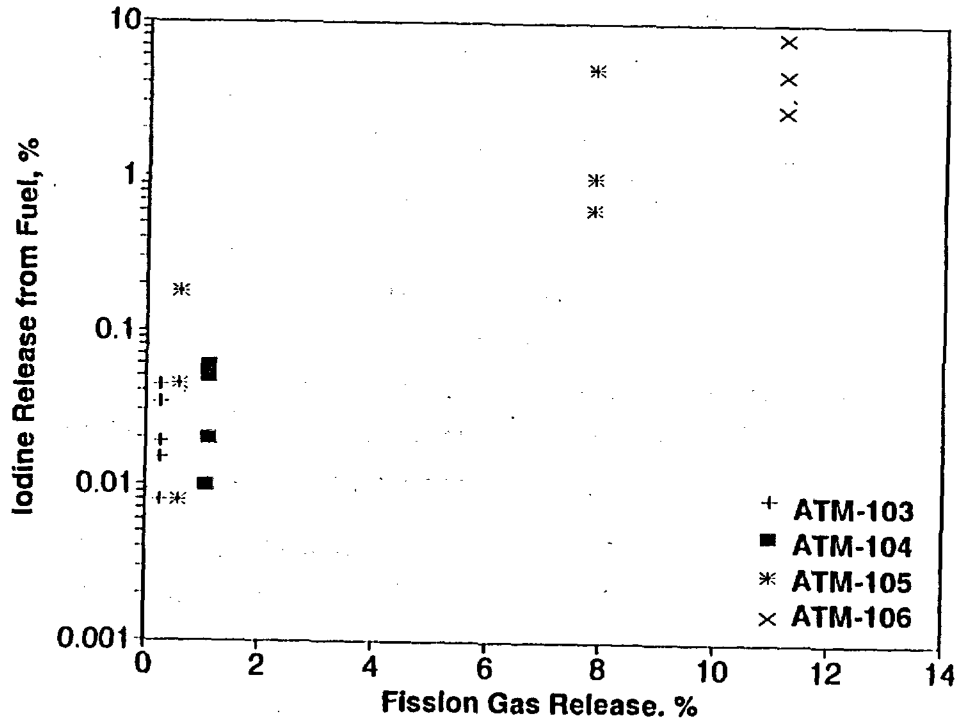


FIGURE 8.20. Local Inventory of Iodine Deposits on Interior Cladding of Fuel Rods with Different Rod-Average Fission Gas Releases

such a prediction with these data to rod-average fission gas releases below about 15%, because higher fission gas releases may result in volatile fission products moving from their point of origin to cooler locations near the rod ends. These data may become even more useful once a relationship has been determined between the amount of deposition on the cladding interior surface and the total gap inventory that is released during leach testing.

8.4 ANALYTICAL ELECTRON MICROSCOPY EXAMINATIONS

Analytical transmission electron microscopy has been conducted on MCC spent fuels to enhance characterization of microstructural features that could affect the rate of release of radionuclides from spent fuel in a geologic repository. Direct observation and analysis of fission product aggregates (gas bubbles and solid particles) too small for most other methods of analysis can be made by using AEM for microstructural, compositional, and crystallographic evaluations. Although most fission product aggregates (gas bubbles and solid particles) in LWR spent fuel are too small to be observed by optical microscopy, they are present in the fuel in high densities at grain boundaries and within UO_2 grains (Thomas, McCarthy, and Gilbert 1986; Thomas and Guenther 1989; Matzke 1989). Metallic ingots were not observed by optical microscopy of the ATM-104 fuel, but they were visible by optical microscopy of the center region of ATM-105 (Guenther et al. 1990) and ATM-106 rods (Guenther et al. 1988b). However, the optically visible particles represent only the extreme upper size fraction of particles actually present in the fuel. AEM allows the observation of fuel microstructures at resolutions approaching the atomic level and provides compositional analyses and phase identification of particles as small as about 20 nm in diameter. Such analyses may afford a means of understanding differences between various fuel samples that might otherwise seem similar based on radiochemical or ceramographic evidence alone.

The remainder of this section contains discussions on 1) the preparation techniques, equipment, and analytical techniques used to perform these analyses (Section 8.4.1); and 2) results for AEM conducted on samples taken from locations along the radius of Section 104-MKP109-S[a] (Section 8.4.2).

8.4.1 Experimental Details of AEM

Section 104-MKP109-S was taken from the peak-power region of Rod MKP109 (see Appendix C) to provide samples for characterization by AEM. The AEM samples were fuel fragments 200 to 400 μm in diameter that were selected from three radial locations on the as-cut fuel surface of Section 104-MKP109-S (the outer edge, mid-radius, and fuel pellet center). Samples were prepared by potting a single particle of fuel into a 3-mm-dia. molybdenum or copper washer with epoxy resin, grinding the embedded particle to about 10 μm thickness, and ion micromilling until a hole with thin edges suitable for examination appeared within the 50- to 150-nm thick particle. Details on the preparation method are given by McCarthy and Thomas (1985). No water was used in preparing the samples; however, acetone, ethanol, and Freon TF® solvents were used for necessary sample cleaning. Finished samples contained only about 10 μg of fuel held in epoxy, and consequently could be handled and analyzed without special shielding.

Microstructural, compositional, and crystallographic analyses were performed in a 200 kV transmission/scanning transmission electron microscope (TEM/STEM) equipped with a Si(Li) detector for energy-dispersive x-ray spectrometry (EDS). Analytical methods included brightfield TEM microstructural imaging, selected-area and microbeam electron diffraction for phase identification, and EDS for qualitative and semi-quantitative elemental analyses of sample micro-areas. The x-ray (EDS) detector used in this work was sensitive to all elements heavier than neon ($Z = 10$), and gave minimum detection limits of 0.3 to 0.5 wt%. The accuracy of semi-quantitative elemental analyses performed with the commercial analysis program SMTF in the Tracor Northern TN-5500 multichannel analyzer was not verified.

(a) For this discussion on AEM only, Sample 104-MKP109-S is being referred to as Section 104-MKP109-S to prevent confusion with the fuel samples taken from along the fuel radius.

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8.4.2 Results of AEM

AEM examinations and analyses were conducted on fuel samples from the outer edge, mid-radius, and center of Section 104-MKP109-S. Despite the relatively higher burnup in ATM-104 fuel than in ATM-103, AEM of these fuels revealed microstructures that are not greatly different from those previously reported (Guenther et al. 1988a; Thomas and Guenther 1989). Details on the AEM of ATM-104 fuel are provided below.

AEM of Material from Fuel Edge

As shown in the overview micrograph of Figure 8.21, the microstructure near the edge of the fuel pellet consisted of UO_2 grains containing high densities of uniformly dispersed particles with 2 to 8 nm diameters and numerous dislocations lines. Many of the dislocations are in sub-boundaries. Scattered dislocations are observed in the UO_2 grains, but they are mostly line segments that comprise loose networks and irregular sub-boundaries. The appearance of the dislocation substructure and the absence of well-formed loops indicate that the dislocations formed during fabrication rather than irradiation. The high-angle grain boundaries appear to be open, locally cracked structures. Enlarged particles about 20 nm in size, but occasionally up to 50 nm, are associated with the grain boundaries. Not all of the enlarged particles are on grain boundaries, but most of them are found within about 150 nm from the boundaries. A grain boundary is shown in Figure 8.22 with most of the dislocations out of contrast (i.e., invisible) so that small bubbles and particles can be seen. The UO_2 grain is denuded of 2- to 8-nm bubbles and particles over distances of about 250 nm and 80 nm, respectively. Denuded zones appeared on both sides of this boundary but are difficult to observe on one side due to the image contrast in the micrograph. Bubbles outside the denuded zones are associated with particles of similar sizes. Grain boundary fine-structures are too small to resolve in Figure 8.22, but a closely spaced bubble array having bubble sizes smaller than 1 nm appeared to exist along the boundary upon examination at higher magnification.

EDS analyses of the particles with 20 to 50 nm diameters found along the grain boundaries indicate that the particles are composed of molybdenum, ruthenium, technetium, palladium, and rhodium. A typical spectrum from one of these particles (Figure 8.23) contains a large contribution from the UO_2

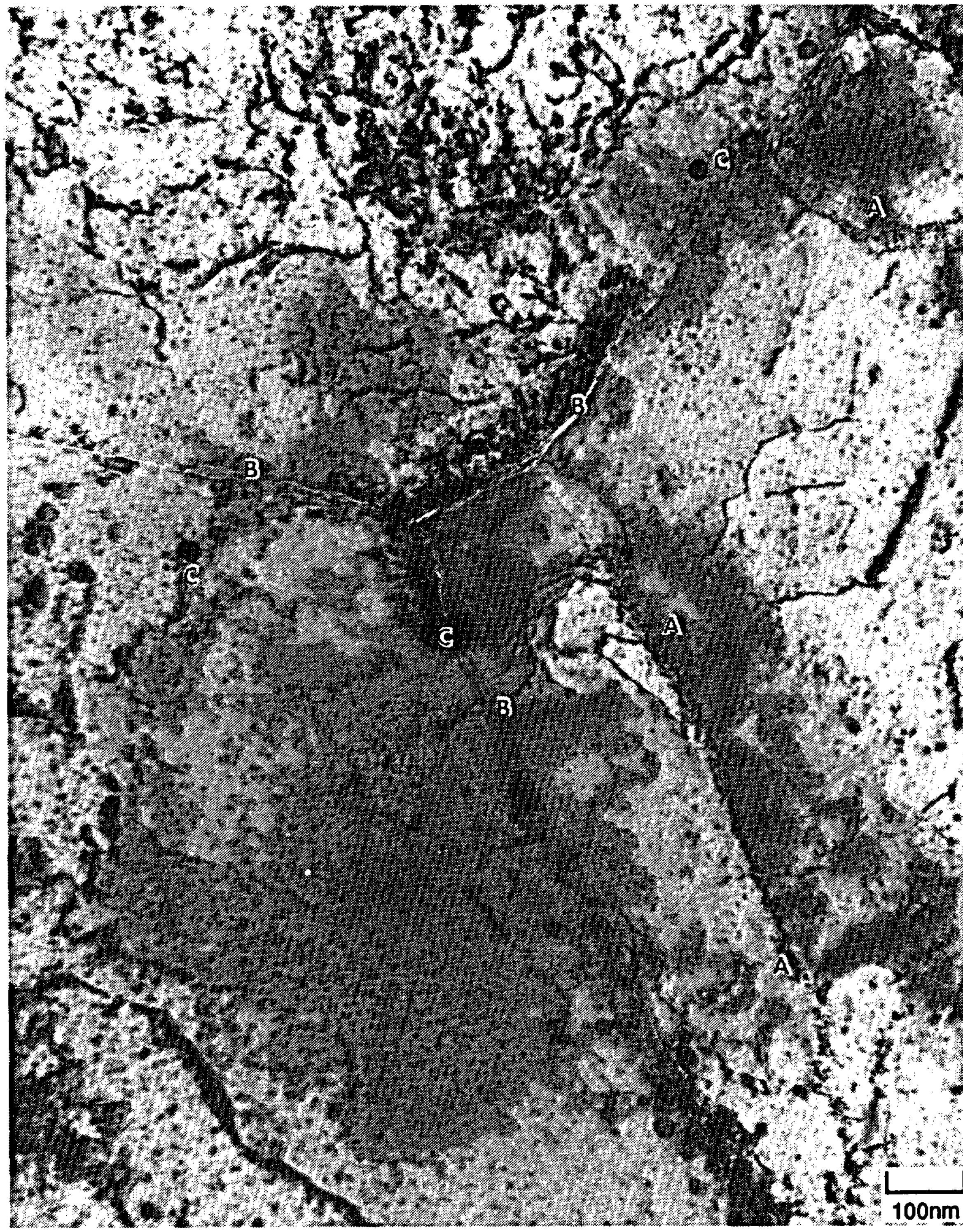


FIGURE 8.21. Microstructure of ATM-104 Fuel Near Edge. (Brightfield micrograph showing (A) dislocation sub-boundaries, (B) grain boundaries, and (C) ϵ-phase particles.) (Neg. LT 1540)

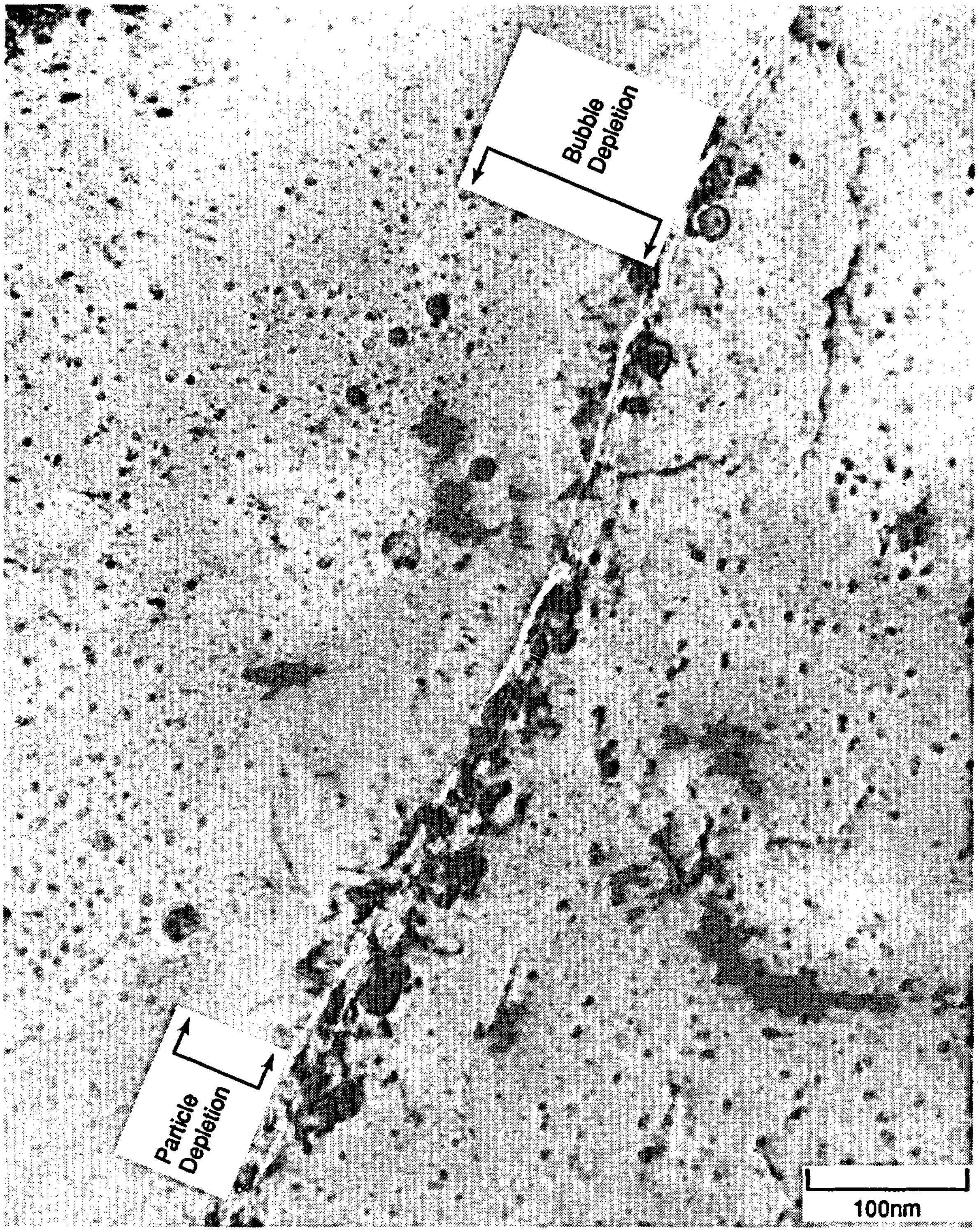


FIGURE 8.22. Grain Boundary Region Near Fuel Edge of Section 104-MKP109-S. (Enlarged particles on and near grain boundary are ϵ-phase; Note particle and bubble denuding near boundary) (Neg. LT 1533)

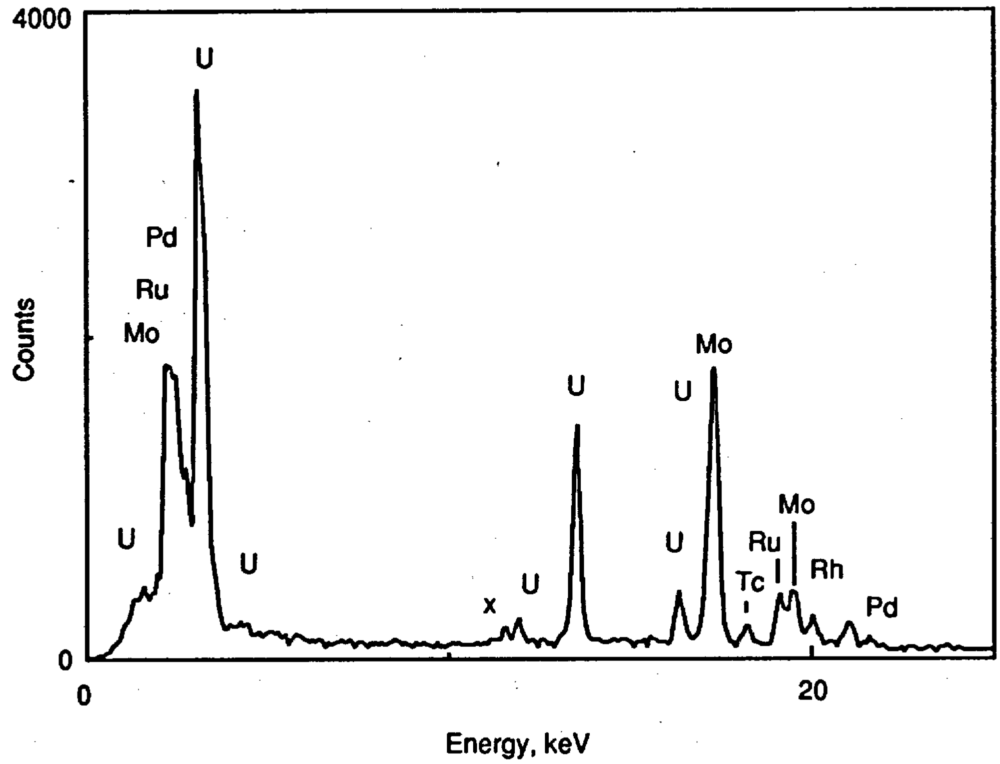


FIGURE 8.23. EDS Spectrum from ε-Phase Particle in UO_2 Near Grain Boundary at Fuel Edge of Section 104-MKP109-S (Small peak marked x is a detector artifact.) (File 606/32)

matrix around the particle and a smaller molybdenum contribution caused by secondary electron excitation of molybdenum washers used in sample preparation. Semi-quantitative analyses of the particle composition was accomplished after stripping the spectrum in Figure 8.23 of the spectra determined for uranium and molybdenum in the adjacent particle-free matrix. The particle composition was about 40 wt% molybdenum, 30 wt% ruthenium, 15 wt% palladium, 10 wt% technetium, and 5 wt% rhodium. This composition is characteristic of the ε-ruthenium alloy phase common in irradiated fuel; similar compositions were observed in ATM-103 and ATM-105 (Thomas and Guenther 1989).

No other fission products were detected in bubbles or at grain boundaries. Although neodymium and cerium were marginally detected in UO_2 grain interiors near the edge of the fuel, the x-ray peaks from these fission products were too small for positive identification. Detection limits for cerium and neodymium in the fuel matrix could be as high as 1 wt% due to interferences and multiplicities of the L-shell peaks used for EDS analyses.

Results from EPMA of an ATM-104 fuel sample in a peak-power location similar to that examined by AEM indicated the neodymium concentration is only 0.7 wt% at the fuel edge (see Appendix F).

Many grains in the fuel edge sample from ATM-104 contained microcracks about 1000 nm in length as shown in Figure 8.24. The material is highly strained around these defects as indicated by the visible dislocations surrounding the defect. There are also particle-bubble denuded regions extending out about 150 nm from the defects. No second-phase inclusion appeared within these defects. Similar intragranular microcracks have been observed in the ATM-105 fuel, but their cause is unknown.

AEM of Material From Fuel Mid-Radius

The microstructure of the fuel in the mid-radius region of Section 104-MKP109-S appeared coarser than in regions near the fuel edge. Dislocation lines and particles 80 to 150 nm in diameter were associated with cavities in the grain interior as shown in Figure 8.25. The larger particles were surrounded by dislocation tangles, indicating internal pressures sufficient to plastically deform the UO_2 matrix. EDS analyses have identified similar particles as aggregates of the ϵ-phase and a high-density xenon-krypton phase (Thomas and Guenther 1989). However, most of the particles in the grains at the mid-radius were smaller than 10 nm and showed no strains in the surrounding matrix or detectable xenon. Some of the larger particles have cavities associated with them; these cavities were observed in ATM-103 and ATM-105 samples and are believed to form when the surface of a particle associated with high-density gas is intersected during the thinning preparation. The release of the gas would then cause the formation of the cavity next to the remaining ϵ-phase particle.

Grain boundaries at the mid-radius region of Section 104-MKP109-S were decorated with scattered particles of ϵ-phase up to about 150 nm in size and bubbles 2 nm or smaller as shown in Figure 8.26. The small bubbles along the grain boundaries in Figure 8.26 appear dark due to a focusing effect in the electron microscope.

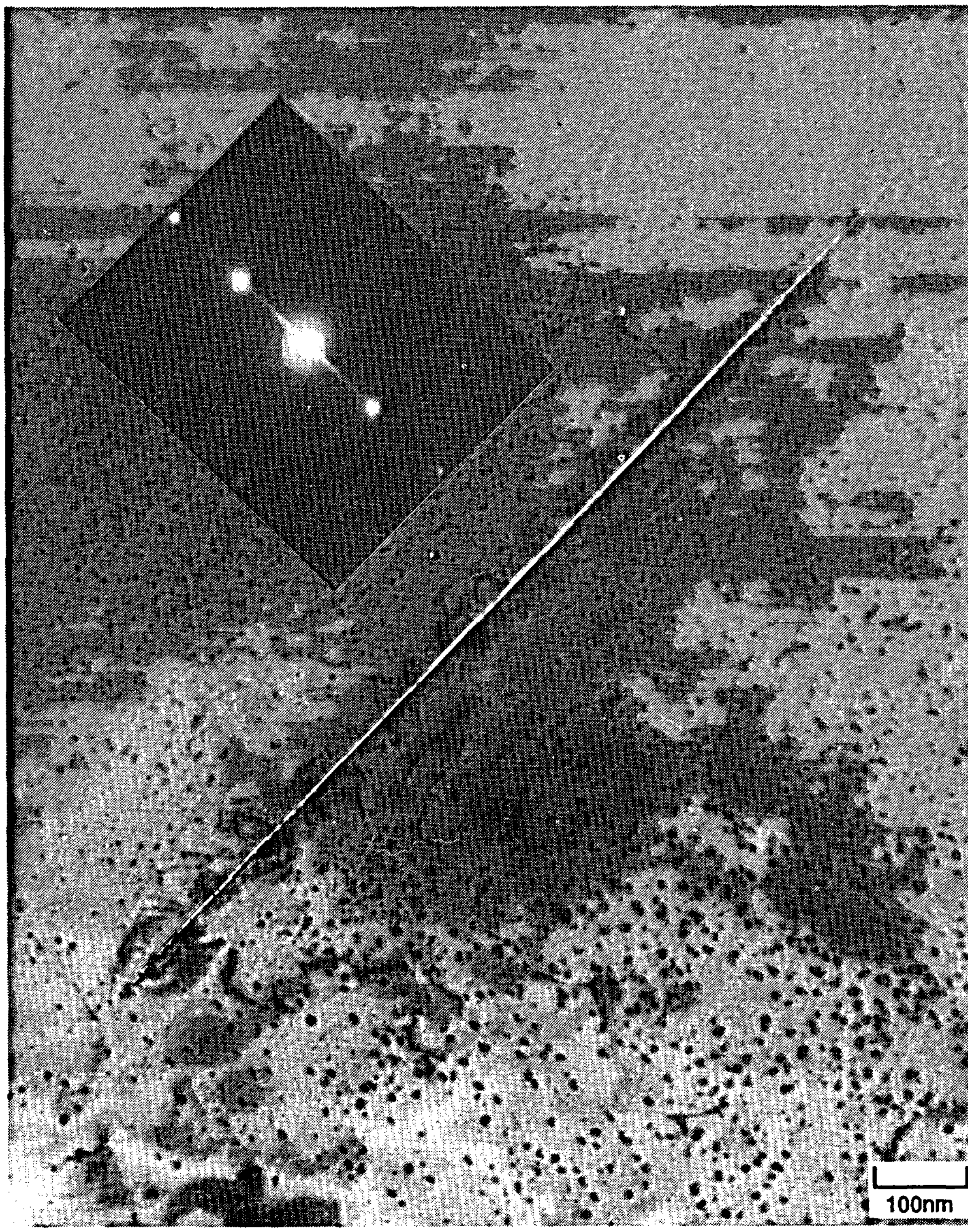


FIGURE 8.24. Microcrack in Grain Interior of Fuel from Edge of Section 104-MKP109-S (Streak along <111> in inset pattern arises from electron diffraction from crack surfaces.) (Neg. LT 1538)

edge

FIGURE 8.25. Microstructure of Grain Interior Near the Mid-Radius of Section 104-MKP109-S. (Particle (A) surrounded by dislocation tangles.) (Neg. LT 1157)

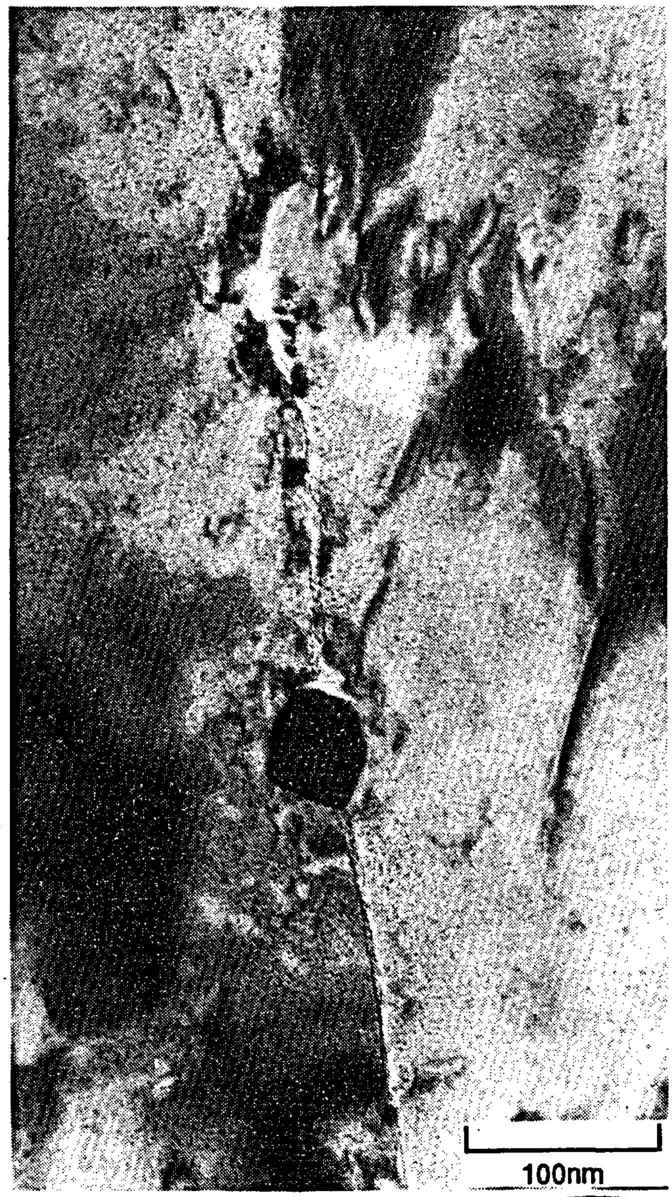


FIGURE 8.26. Grain Boundary in Fuel from Mid-Radius Region of Section 104-MKP109-S. (Neg. LT 1169)

AEM of Material From Fuel Center

Grain boundaries near the fuel center of Section 104-MKP109-S contained no visible bubbles but were decorated with scattered 150-nm ϵ-phase particles and larger pores (Figure 8.27). The UO_2 near the boundaries of a thicker portion of the sample (Figure 8.28) contains 100- to 150-nm particles surrounded by dislocation tangles. Many of the particles within the grains were associated with surface pits believed to be formed during thinning of the sample when contained xenon was released. Particles enclosed within the samples were not asssociated with visible bubbles, but contained high concentrations of xenon (and smaller amounts of krypton). The xenon/krypton concentrations and the dislocations surrounding the particles are indicative of high gas pressures within the particles. The grain interiors also contained high densities of particles with sizes around 5 nm.

The inset photo in Figure 8.28 is of particles that were enclosed within the thin foil sample, i.e., not cut by a surface. The particles are aggregates of discrete ϵ-phase and Xe-Kr phase regions. The fission gas region of one of the particles in the inset micrograph shows contrast fringes that might be interpreted as an indication that the Xe-Kr phase is crystalline. Without further electron diffraction evidence, however, the question of whether the phase is crystalline or amorphous remains unresolved.

EDS spectra shown in Figure 8.29 demonstrate the association of fission-gas concentrations with particles enclosed by the thin-foil samples. The particle associated with the surface pit is lacking xenon and krypton while the enclosed particle has a distinct level of xenon with smaller amounts of krypton. These results are consistent with previous analyses of ATM-101, ATM-103, and ATM-105 (Thomas and Guenther 1989).

Comparisons with Previous Work

Observations on the distribution of fission gas bubbles and the existence of a solid xenon phase may improve the understanding of differences in oxidation or leach testing of different fuels. In general, the ATM-104 and ATM-103 fuels were similar even though the burnup was about 30% higher in ATM-104. There are high densities of small (less than 10 nm) particles and

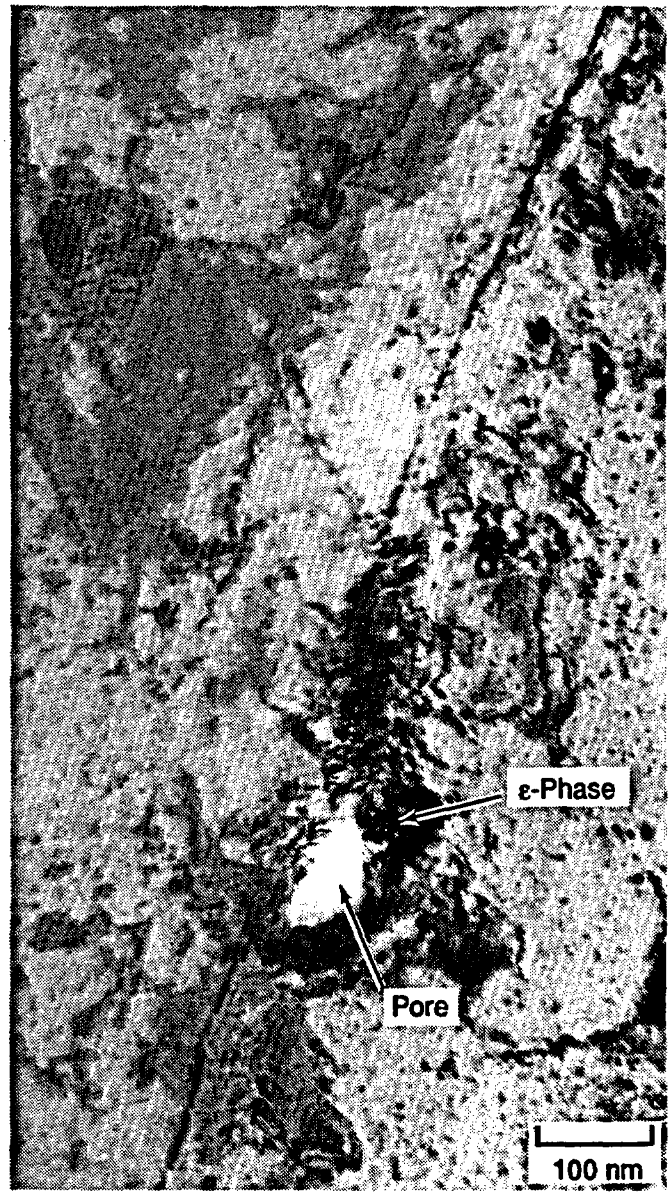


FIGURE 8.27. Grain Boundary Near Fuel Center of Section 104-MKP109-S (Neg. LT 1427)

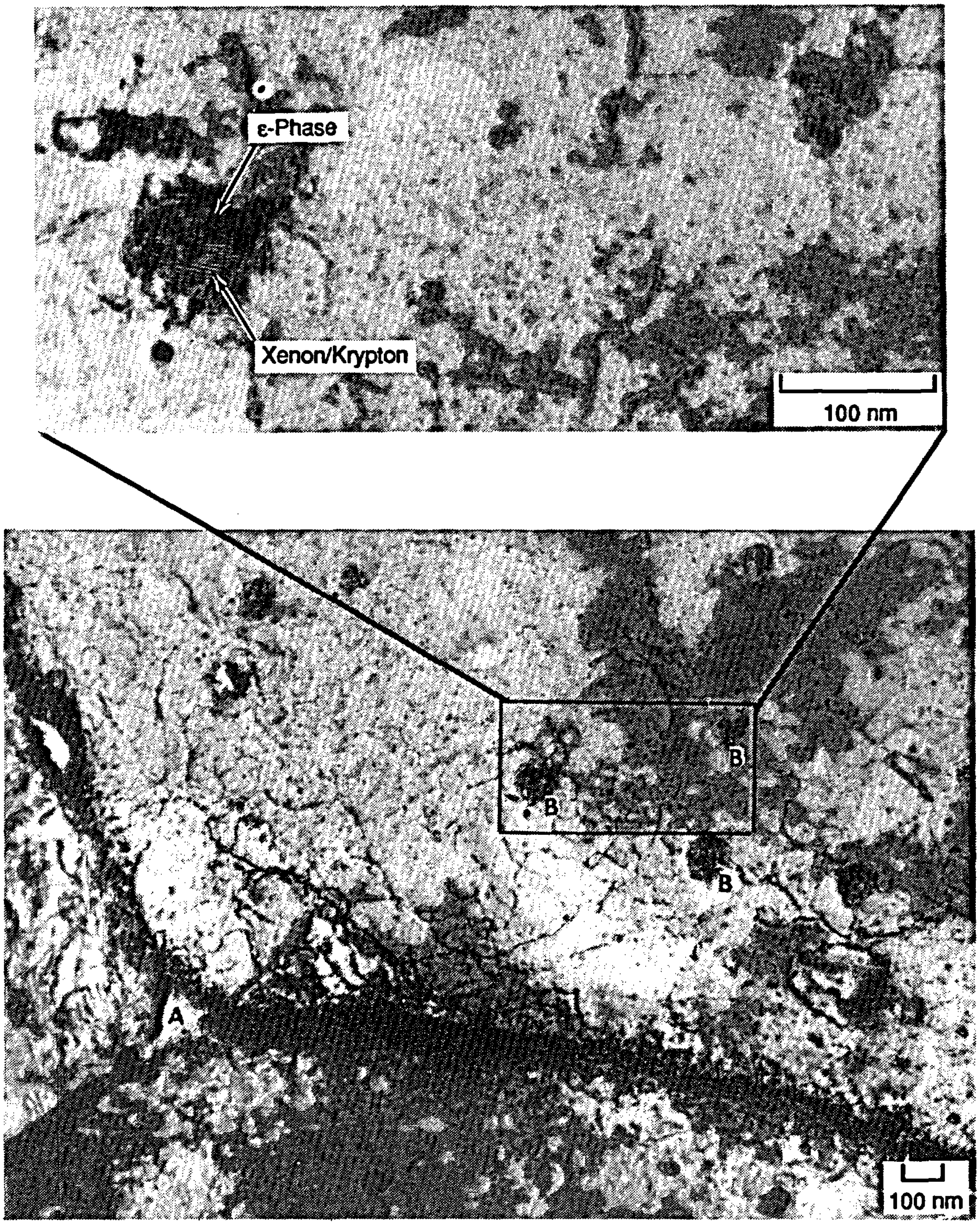
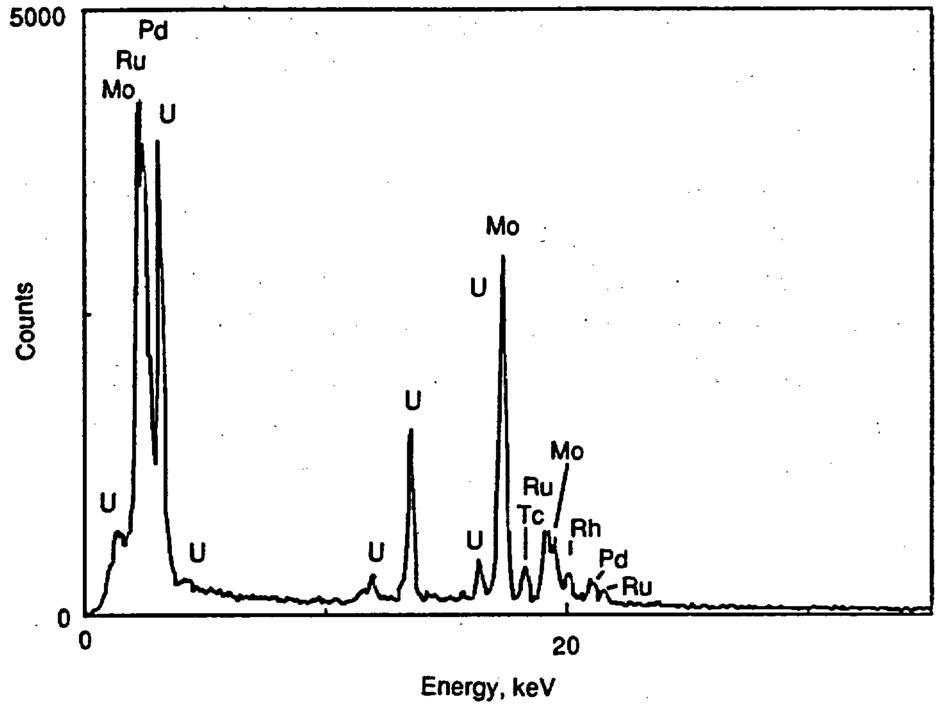
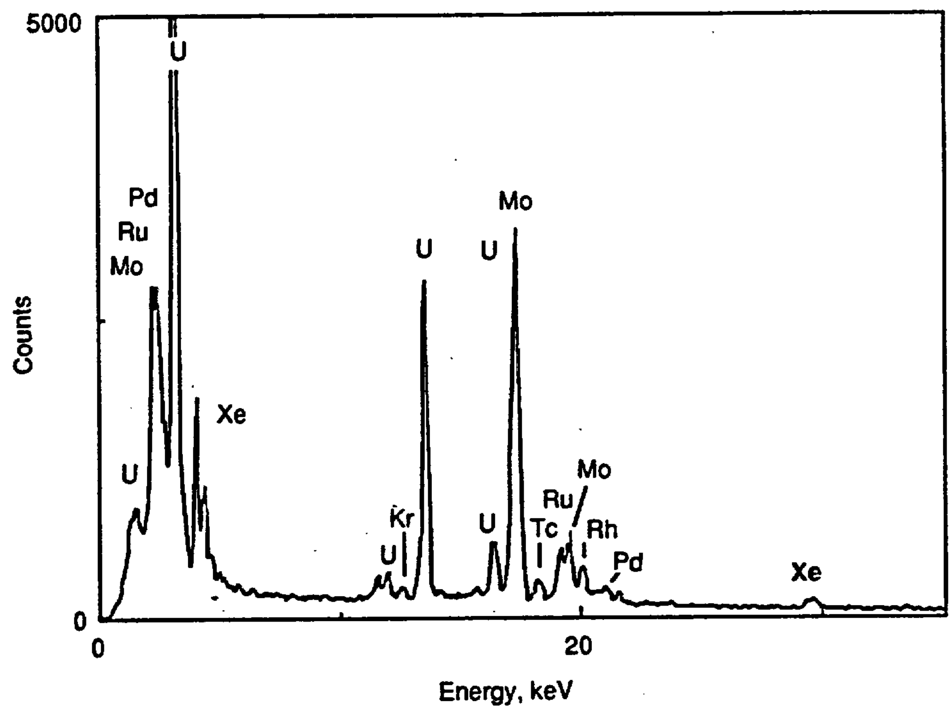


FIGURE 8.28. Grain Boundary in Thicker Region of Fuel Center Showing Xenon Containing Particle. Pore along grain boundary (A), intragranular ϵ-phase particles (B). (Neg. LT 1417)



a) Surface-intersected particle of ϵ-phase. (File 606/37)



b) Enclosed Particle with xenon and krypton plus ϵ-phase (File 606/38)

FIGURE 8.29. EDS Spectra from Intragranular Particles Near Center of Fuel from Section 104-MKP109-S

bubbles thought to contain fission products, but these particles and bubbles were too small to allow identification of the fission products by EDS microbeam analysis.

Features that the ATM-104 and ATM-103 fuels have in common are the small gas bubbles concentrated along grain boundaries near the fuel edge, and the larger particles containing high-density xenon-krypton from the fuel center to about mid-radius. Another characteristic of these low-gas-release fuels is the absence of detectable fission products other than the alloy ϵ-phase or the xenon/krypton. Except for the five metals in the ϵ-phase, xenon, and krypton, the fission products remain finely dispersed in the UO_2 matrix.

9.0 REFERENCES

Andrews, M. G., and J. A. Lobre. 1988. "Examining Fuel Behavior in Longer Operating Cycles." Nucl. Eng. Int. pp. 42-43.

Andrews, M. G., G. P. Smith, and M. A. Shubert. 1988. "Experience and Developments with Combustion Engineering Fuel." In Proceedings of the International Topical Meeting on LWR Fuel Performance, pp. 90 to 95. April 17-28, 1988, Williamsburg, Virginia. American Nuclear Society, La Grange Park, Illinois.

ASTM. 1980. "Standard Method for Estimating the Average Grain Size of Metals." ASTM E 112 in Annual Book of ASTM Standards, Part II, pp. 186-220, Philadelphia, Pennsylvania.

Bailey, W. J., and A. B. Johnson, Jr. 1983. Wet Storage Integrity Update. PNL-4726, Pacific Northwest Laboratory, Richland, Washington.

Bailey, W. J., C. L. Wilson, L. J. MacGowan, and P. J. Pankaskie. 1977. State-of-the-Technology Review of Fuel-Cladding Interaction. COO-4066-2, PNL-2488, Pacific Northwest Laboratory, Richland, Washington.

Barner, J. O. 1984. LWR Spent Fuel Approved Testing Materials for Radionuclide Release Studies. PNL-4686, Pacific Northwest Laboratory, Richland, Washington.

Barner, J. O. 1985. Characterization of LWR Spent Fuel MCC-Approved Testing Material - ATM-101. PNL-5109, Rev.1, Pacific Northwest Laboratory, Richland, Washington.

Bryner, J. S. 1979. "The Cyclical Nature of Corrosion of Zircaloy-4 in 633K Water." J. Nucl. Mater. 82:84-101.

Campbell, T. K., R. J. Guenther, and E. D. Jenson. 1990. "Volatile Fission Product Distribution in LWR Spent Fuels." In American Ceramic Society Symposium, April 23-27, 1989, Indianapolis, Indiana.

Colby, J. W. 1971. MAGIC IV - A Computer Program for Quantitative Electron Microprobe Analysis. Bell Telephone Laboratories, Inc., Allentown, Pennsylvania.

Clayton, J. C., and R. L. Fisher. 1985. "Corrosion and Hydriding of Zircaloy Fuel Rod Cladding in 633K Water and Reactor Environments." In Proceedings of Topical Meeting on Light Water Reactor Fuel Performance, Vol. 1, pp. 3-1 to 3-16. April 21-24, 1985, Orlando, Florida. American Nuclear Society, La Grange Park, Illinois. TK 9360. A447 1985

Croff, A. G. 1978. Revised Uranium-Plutonium Cycle PWR and BWR Models for the ORIGEN Computer Code. ORNL/TM-6051, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Croff, A. G., R. L. Haese, and N. B. Gove. 1979. Updated Decay and Photon Libraries for the ORIGEN Code. ORNL/TM-6055, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Croff, A. G. 1980a. ORIGEN2 - A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code. ORNL-5621, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Croff, A. G. 1980b. A User's Manual for the ORIGEN2 Computer Code. ORNL/TM-7175, Oak Ridge National Laboratory, Oak Ridge, TN.

Cubicciooti, D., J. E. Sanecki, R. V. Strain, S. Greenberg, L. A. Neimark, and C. E. Johnson. 1976. The Nature of Fission-Product Deposits Inside Light-Water-Reactor Fuel Rods. No. RP 455-1, Electric Power Research Institute, Stanford Research Institute, Meno Park, California.

Environmental Protection Agency (EPA). 1985. EPA Final Rule, Federal Regulation 40CFR191, Federal Register 50(182):38066.

Forsyth, R. S., O. Mattsson, and D. Schrire. 1988. Fission Product Concentration Profiles (Sr, Xe, Cs and Nd) at the Individual Grain Level in Power-Ramped LWR Fuel. Technical Report 88-24, Studsvik Nuclear, Swedish Nuclear Fuel and Waste Management Co., Stockholm, Sweden.

Garber, D. E. 1984. Extended Burnup Demonstration Reactor Fuel Program, Results of Fission Gas Release Measurements at Big Rock Point- September 1982. XN-NF-84-10, DOE/ET-34006-12, Exxon Nuclear Co., Inc., Richland, Washington.

Garisto, N. C., L. H. Johnson, and W. H. Hocking. 1989. "An Instant-Release Source Term for the Assessment of Used Nuclear Fuel Disposal." In Proceedings of the Second International Conference on CANDU Fuel. October 1-5, 1989, Chalk River, Canada.

Glasstone, S., and A. Sesonske. 1967. Nuclear Reactor Engineering, p. 5. D. Van Nostran Co., Inc., New Jersey.

Guenther, R. J., D. E. Blahnik, T. K. Campbell, U. P. Jenquin, J. E. Mendel, L. E. Thomas, and C. K. Thornhill. 1988a. Characterization of Spent Fuel Approved Testing Material--ATM-103. PNL-5109-103, Pacific Northwest Laboratory, Richland, Washington.

Guenther, R. J., D. E. Blahnik, T. K. Campbell, U. P. Jenquin, J. E. Mendel, and C. K. Thornhill. 1988b. Characterization of Spent Fuel Approved Testing Material--ATM-106. PNL-5109-106, Pacific Northwest Laboratory, Richland, Washington.

Guenther, R. J., D. E. Blahnik, T. K. Campbell, U. P. Jenquin, J. E. Mendel, L. E. Thomas, and C. K. Thornhill. 1989. "Detailed Characterization of LWR Fuel Rods for the U.S. Civilian Radioactive Waste Management Program." In Proceedings of Materials Research Society Symposium 127:325-336.

Guenther, R. J., D. E. Blahnik, T. K. Campbell, U. P. Jenquin, J. E. Mendel, L. E. Thomas, and C. K. Thornhill. 1990. Characterization of Spent Fuel Approved Testing Material--ATM-105. PNL-5109-105, Pacific Northwest Laboratory, Richland, Washington.

Hillner, E. 1977. "Corrosion of Zirconium-Base Alloys - An Overview." In Zirconium in the Nuclear Industry, ASTM STP 633, eds. A. L. Lowe, and G. W. Parry, pp. 211-235. American Society for Testing and Materials, Philadelphia, Pennsylvania.

Johnson, A. B., Jr., E. R. Gilbert, and R. J. Guenther. 1983. Behavior of Spent Nuclear Fuel and Storage System Components in Dry Interim Storage. PNL-4189, Rev. 1, Pacific Northwest Laboratory, Richland, Washington.

Johnson, A. B., Jr., and D. D. Lanning. 1985. Assessment of N-Reactor Zircaloy-2 Pressure Tube Corrosion and Hydriding Trends. UNI-3146, Rev. 1, UNC Nuclear Industries, Richland, Washington.

Johnson, L. H., K. I. Burns, H. H. Joling, and C. J. Moore. 1983. "Leaching of ^{137}Cs, ^{134}Cs, and ^{129}I from Irradiated UO_2 Fuel." Nucl. Tech. 63:470-475.

Johnson, L. H., N. C. Garisto, and S. Stroes-Gascoyne. 1985. "Used-Fuel Dissolution Studies in Canada." In Waste Management 1985, eds. R. G. Post and M. E Wacks, Vol. 1, pp. 479-482. University of Arizona, Tucson, Arizona.

Katayama, Y. B. 1976. Leaching of Irradiated LWR Fuel Pellets in Deionized and Typical Ground Water. BNWL-2057, Pacific Northwest Laboratory, Richland, Washington.

Kleykamp, H. 1979. "Radial Distribution of Bonded Fission Gas in Mixed Carbide Fuel Pins." J. Nucl. Mater. 80(1979):13-17.

Lanning, D. D., M. E. Cunningham, R. E. Williford, and A. B. Johnson, Jr. 1984. Interim Assessment of N-Reactor Zircaloy-2 Pressure Tube Corrosion and Hydriding. PNL-5311, Pacific Northwest Laboratory, Richland, Washington.

Luksic, A. T., R. W. McKee, P. M. Daling, G. J. Konzek, J. D. Ludwick, and L. Purcell. 1986. Spent Fuel Disassembly Hardware and Other Non-Fuel Bearing Components: Characterization, Disposal Cost Estimates, and Proposed Repository Acceptance Requirements. PNL-6046, Pacific Northwest Laboratory, Richland, Washington.

Manzel, R., F. Sontheimer, and H. Stehle. 1985. "Fission Gas Release of PWR Fuel Under Steady and Transient Conditions Up to High Burnup." In Proceedings of the Topical Meeting on Light Water Reactor Fuel Performance, pp. 4-33 to 4-49. Orlando, Florida. American Nuclear Society, LaGrange Park, Illinois.

Manzel, R., F. Sontheimer, and R. Würtz. 1984. "The Radial Distribution of Fission Gases and Other Fission Products in Irradiated PWR Fuels." J. Nucl. Mater. 126:132-143.

Matzke, Hj. 1989. "Fission Gases in Nuclear Fuels." Ann. Chim Fr. 14:133-147.

McCarthy, J. M., and L. E. Thomas. 1985. "Preparation of TEM Specimens from Highly Radioactive Materials." In Proceedings EMSA 1985, ed. G. W. Bailey, pp. 184-185. San Francisco Press, San Francisco, California.

Mogensen, M., P. Knudsen, and C. T. Walker. 1987. "Fission Gas Release Mechanisms Operating in Water Reactor Fuel in Power Transients." In Improvements in Water Reactor Fuel Technology and Utilization, pp. 291-303, IAEA-SM-288/12. International Atomic Energy Agency, Vienna, Austria.

Nuclear Regulatory Commission (NRC). 1983. NRC Final Rule, Federal Regulation 10CFR60, Federal Register 48(120):28194.

Oversby, V. M. 1987a. "Spent Fuel as a Waste Form - Data Needs to Allow Long Term Performance Assessment Under Repository Disposal Conditions." In Proceedings of Materials Research Society Symposium 84:87-101.

Oversby, V. M. 1987b. "Important Radionuclides in High Level Nuclear Waste Disposal: Determination Using a Comparison of the U.S. EPA and NRC Regulations." Nucl. Chem. Waste Manage. 7:149-161.

Oversby, V. M., and C. N. Wilson. 1985. "Derivation of a Waste Package Source Term for NNWSI from the Results of Laboratory Experiments." In Proceedings of Materials Research Society 50:337-347.

Pati, S. R., A. M. Garde, and L. J. Clink. 1988. "Contribution of Pellet Rim Porosity to Low-Temperature Fission Gas Release at Extended Burnups." In Proceedings of the International Topical Meeting on LWR Fuel Performance, pp. 204-215. April 17-20, 1988, Williamsburg, Virginia. American Nuclear Society, La Grange Park, Illinois.

Pearce, J. H. 1984. "The Use of Electron-Probe Microanalyzer to Determine the Radial Distribution of Fission Products in Irradiated Thermal Reactor Fuel." J. de Physique., Colloque C2, supplément au n°2, Tome 45, pp. C2-829 to C2-832.

Pyecha, T. D., G. M. Bain, W. A. McInteer, and C. H. Pham. 1985. "Water-side Corrosion of PWR Fuel Rods Through Burnups of 50,000 MWd/MTU." In Proceedings of Topical Meeting on Light Water Reactor Fuel Performance, Vol. 1, pp. 3-17 to 3-35. April 21-24, 1985, Orlando, Florida. American Nuclear Society, La Grange Park, Illinois.

Roddy, J. W., and J. C. Mailen. 1987. Radiological Characteristics of Light Water Reactor Spent Fuel: A Literature Survey of Experimental Data, ORNL/TM-10105, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Ross, B. 1988. "Gas-Phase Transport of Carbon-14 Released from Nuclear Waste into the Unsaturated Zone," In Proceedings of Materials Research Society Symposium 112:273-284.

SSA (Southern Science Applications, Inc.). 1982. Background and Derivation of ANS 5.4 Standard Fission Product Release Model. NUREG/CR-2507, U.S. Nuclear Regulatory Commission, Washington, D.C.

Soo, P. 1985. Review of DOE Waste Package Program, Subtask 1.1 - National Waste Package Program. NUREG/CR-2482, U.S. Nuclear Regulatory Commission, Washington, D.C.

Stehle, H., et al. 1975. "External Corrosion of Cladding in PWRs." Nucl. Eng. & Design 33:155-169.

Thomas, L. E., J. M. McCarthy, and E. R. Gilbert. 1986. "Transmission Electron Microscopy of Oxidized UO_2 Spent Fuel." In Proceedings EMSA 1986, ed. G. W. Bailey, pp. 478-479. San Francisco Press, San Francisco, California.

Thomas, L. E., and R. J. Guenther. 1989. "Characterization of LWR Fuels by Transmission Electron Microscopy." In Proceedings of Materials Research Society Symposium 127:293-300.

Van Konynenburg, R. A., C. F. Smith, H. W. Culham, and H. D. Smith. 1987. "Carbon-14 In Waste Packages for Spent Fuel In A Tuff Repository." In Proceedings of Materials Research Society Symposium 84:185-196.

Van Luik, A. E., R. J. Guenther, M. J. Apted, R. J. Serne, W. J. Bailey, E. R. Gilbert, J. H. Haberman, R. Peters, J. S. Shade, and R. E. Williford. 1987. Spent Nuclear Fuel as a Waste Form for Geologic Disposal: Assessment and Recommendations on Data and Modeling Needs. PNL-6329, Pacific Northwest Laboratory, Richland, Washington.

Wilson, C. N., and V. M. Oversby. 1985. "Radionuclide Release from PWR Fuels in a Reference Tuff Repository Groundwater." In Waste Management 85 1:497-504.

Wilson, C. N., and H. F. Shaw. 1987. "Experimental Study of the Dissolution of Spent Fuel at 85°C in Natural Ground Water." In Proceedings of Materials Research Society Symposium 84:123-130.

Wilson, C. N., and W. J. Gray. 1990. "Measurement of Soluble Nuclide Dissolution Rates from Spent Fuel." In Proceedings of Materials Research Society Symposium, Scientific Basis for Nuclear Waste Management XIII.

APPENDIX A

POWER HISTORY FOR ASSEMBLY D047

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POWER HISTORY FOR ASSEMBLY D047

Fuel Assembly D047 contained 176 fuel rods during irradiation in the Calvert Cliffs No. 1 reactor during Cycles 2, 3, 4, and 5. Cycle 2 started on March 22, 1977, and Cycle 5 ended on April 17, 1982. During Cycle 3 the reactor was down for approximately 25 days, starting on December 28, 1978. The detailed power history for Rod MKP104 (Figure 3.6 and Table A.1) was used as the basis for generating the irradiation times and power densities for the ORIGEN2 code because this rod had a burnup comparable to the assembly average and was centrally located in the fuel assembly. The average burnup for Rod MKP104 was calculated to be 41.9 MWd/kgM as compared with 41.8 MWd/kgM for the assembly-average burnup; Rod MKP109 was expected to have a slightly lower burnup of 40.4 MWd/kgM. Calculated power histories were provided by Combustion Engineering (C-E) for all of the ATM-104 fuel rods in Assembly D047 and were based on reactor physics, in-core flux monitors, and thermal hydraulic data.

The irradiation history was extracted from data reported by C-E. The detailed data given in Table A.1 have been averaged over periods when the power did not change by more than 30%. The results are given in Table A.2. The power densities given in Table A.2 were then normalized to give burnups of 20, 25, 30, 35, 40, 45, and 50 MWd/kgM at discharge. Normalization is required because some portions of the fuel (such as at the ends of the rod) do not achieve the peak or rod-average burnups. Additionally, the power densities given in Table A.2 were normalized to give burnups of 27.35, 37.12, and 44.34 MWd/KgM at discharge to predict radionuclide inventories in samples from Rod MKP109 that had measured burnups equivalent to these burnup values. Results from these calculations are given in Table 7.3. Results of the ORIGEN2 calculations are provided in Appendix D.

TABLE A.1. Detailed Power History for Rod MKP104

Cycle 2		Cycle 3[(a)]		Cycle 4		Cycle 5	
Time Interval, Days	LHGR, kW/m (kW/ft)	Time Interval, Days	LHGR, kW/m (kW/ft)	Time Interval, Days	LHGR, kW/m (kW/ft)	Time Interval, Days	LHGR, kW/m (kW/ft)
7.1	19.5 (5.94)	7.8	22.2 (6.77)	46.1	19.4 (5.90)	29.7	12.9 (3.93)
30.8	24.0 (7.33)	14.1	21.7 (6.60)	24.0	19.2 (5.85)	5.9	13.7 (4.18)
16.4	24.1 (7.35)	19.4	15.2 (4.63)	22.6	19.2 (5.85)	7.1	13.8 (4.22)
11.4	24.1 (7.36)	16.9	23.6 (7.20)	25.6	19.2 (5.86)	48.2	14.0 (4.26)
12.5	24.1 (7.35)	16.4	23.8 (7.25)	30.5	9.4 (2.87)	16.8	14.0 (4.27)
23.4	24.1 (7.34)	15.4	25.1 (7.65)	41.1	9.6 (2.92)	29.4	14.2 (4.34)
22.8	24.0 (7.31)	39.4	23.3 (7.11)	50.2	9.4 (2.88)	24.7	14.3 (4.37)
23.2	23.9 (7.27)	31.4	23.3 (7.10)	11.1	16.3 (4.98)	30.0	11.3 (3.45)
8.1	23.8 (7.26)	31.9	23.0 (7.01)	10.8	19.4 (5.90)	55.3	13.5 (4.12)
31.4	24.0 (7.32)	32.0	22.6 (6.88)	45.4	19.4 (5.92)	27.1	14.8 (4.52)
34.3	23.8 (7.26)	44.3	22.5 (6.85)	29.4	19.1 (5.82)	45.7	15.1 (4.59)
16.5	24.2 (7.39)	59.1	22.4 (6.84)	28.1	19.5 (5.95)	23.5	15.2 (4.62)
19.2	23.8 (7.26)	28.9	23.3 (7.11)	65.4	19.4 (5.91)	30.2	13.8 (4.21)
12.8	24.0 (7.31)			35.7	19.5 (5.93)	20.8	15.2 (4.62)
34.3	22.7 (6.93)					66.6	15.5 (4.73)
1.8	22.8 (6.94)						

(a) Reactor was shut down for 25 days starting with day 270 of Cycle 3.

TABLE A.2. ATM-104 Power History Based on Rod MKP104

Cycle No.	Time Interval, days	Power Density, W/g
2	306.0	32.87
down	71.0	0
3	21.9	30.76
3	19.4	20.41
3	227.7	38.14
3	25.0	0
3	88.0	31.14
down	81.0	0
4	118.3	27.27
4	121.8	13.43
4	225.9	27.25
down	85.0	0
5	461.0	21.43

APPENDIX B

GAMMA SCANNING FOR ATM-104

APPENDIX B

GAMMA SCANNING FOR ATM-104

The Materials Characterization Center (MCC) gamma scanning system consists of three major components: 1) the Data Acquisition (DA) System, 2) the in-cell hardware, and 3) an IBM host computer that supervises and controls the gamma scan process and logs all pertinent data. The DA system and IBM host system are illustrated in Figure B.1. The in-cell hardware is shown in Figure B.2. The fuel rod is drawn by a motor-driven chuck past the germanium-lithium gamma ray detector, which is located at a wall plug in the front face of the hot cell. The wall plug contains a collimator and normally a 0.254-cm (0.1-in.) slit, although a 0.0254-cm (0.01-in.) slit may be installed. A stepping motor controls the position of the fuel rod relative to the detector and controls the rate at which the fuel rod is stepped past the detector.

The available hot cell space is insufficient for gamma scanning full-length PWR and BWR fuel rods from top to bottom. Thus, this system is designed to scan from the center of the fuel rod to one end. The rod is then rotated 180° (end-over-end), and the process is repeated to scan the other half. The stepping motors determine the center of the fuel rod from an overall fuel rod length measurement made before scanning is started.

The software used to complete gamma scanning operations was written to use a variable counting time at each position. The counting time is set to maintain a fixed statistical uncertainty (set at 1%) until the counting time reaches a maximum preset value. Typically, the counting time is 40 to 60 s in the center of the fuel rod (area of maximum activity) and gradually increases to 5 min (preset maximum value) as the activity decreases near the end of the fuel rod. With this approach, gamma scan results have been obtained for the following isotopes: ^{134}Cs (0.6 MeV), ^{137}Cs, and ^{134}Cs (0.8 MeV). A ^{60}Co signal was also detected during gamma scanning, because a sample of this material is placed in the detection system to identify whether the

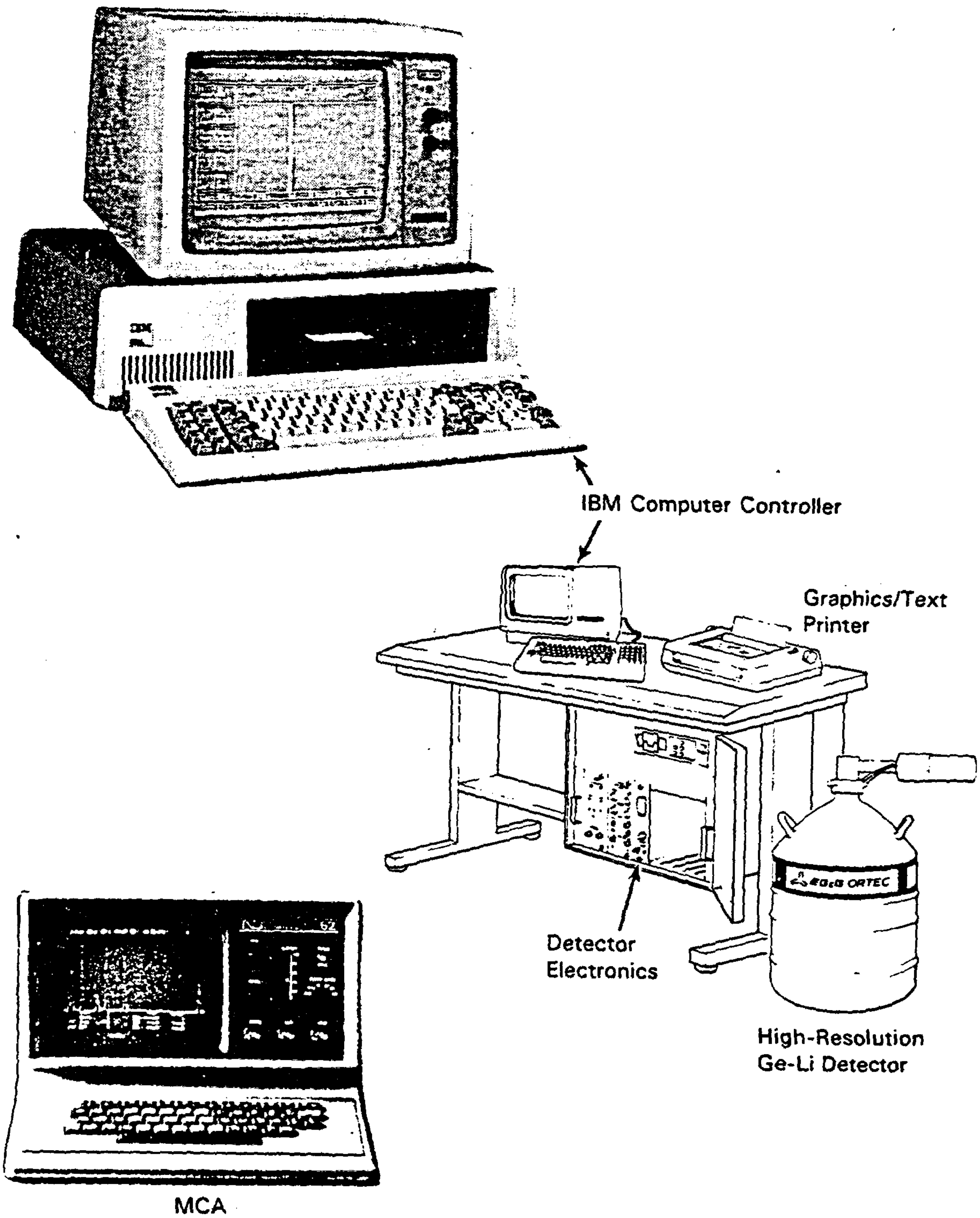

FIGURE B.1. Data Acquisition System and IBM Host System for Gamma Scanning Spent Fuel Rods

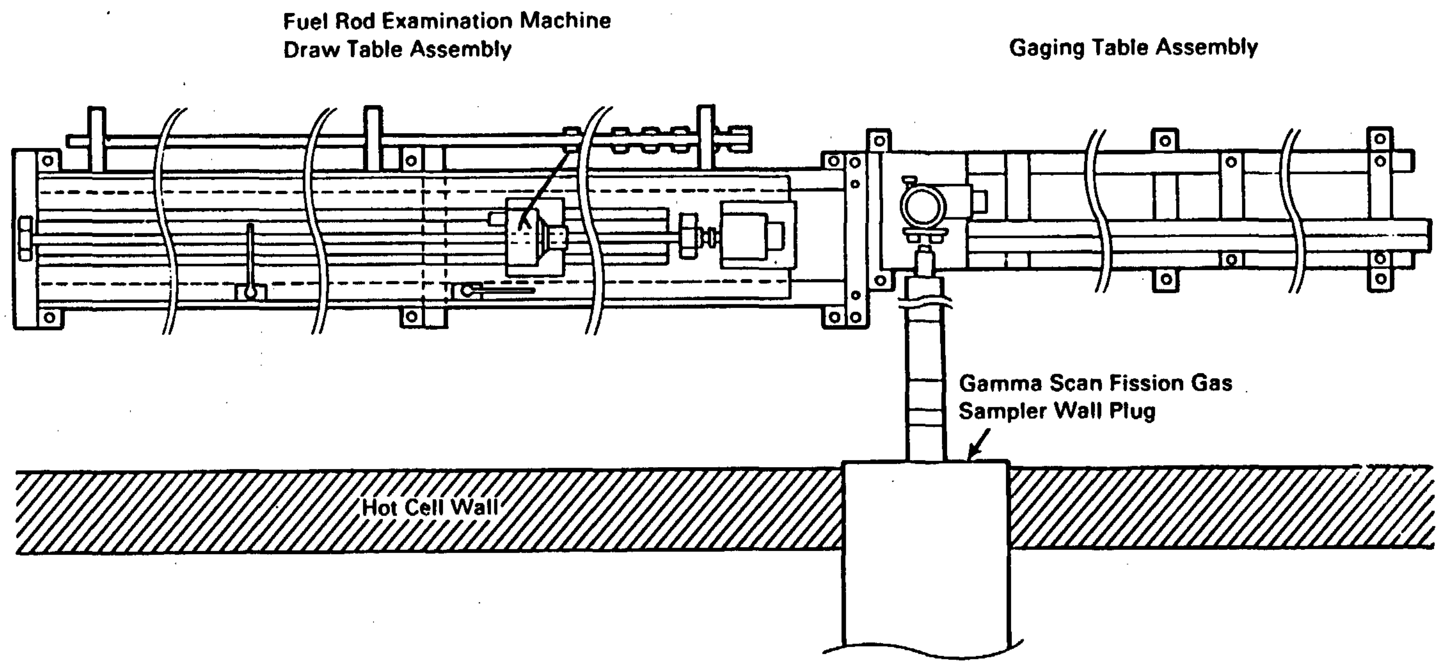

Figure B.2. Plan View of In-Cell Hardware for Gamma Scanning of MCC Spent Fuel Rods multichannel analyzer (MCA) is functioning correctly. These are the only isotopes present that meet the predetermined statistical requirements. Other isotopes can be selected and counted, but the error associated with them would force the use of maximum counting times.

The following procedure is used for each ATM. One reference rod is designated for each ATM (MKP059 for ATM-104). A full-length gamma scan of the reference rod is completed by measuring the activity along the rod in 0.25-cm (0.1 in.) steps, which requires about a week of setup and scanning for the full-length rod. The data is plotted and the scan accepted or rejected on the basis of "reasonableness" of the data plot. For example, there should be no sudden shifts in activity, and the activity is normally highest near the middle, decreasing rapidly toward the ends. Subsequent scans of standard fuel rods are accepted or rejected on the basis of a 5-cm (2-in.) scan of the reference rod taken at a preselected location before and after the full-length gamma scan. The variability in the average activity for those 5-cm (2-in.) scans must be less than 5% for ^{137}Cs for the rod being scanned to be accepted.

Gamma scan results for the ^{137}Cs isotope are presented in this appendix for Rods MKP059, MKP063, MKP070, MKP106, and MKP109 (Figures B.3 through B.7). All of the gamma activities in Figure B.3 through B.7 are for the date indicated on the plot. Rod MKP028 was not gamma scanned; it has only been used to obtain a fission gas sample for checking the operation of the gas sampling system. Only the ^{137}Cs gamma scans are presented because the ^{134}Cs isotope has a short half-life and the activity is significantly lower than for ^{137}Cs. The ^{134}Cs gamma scans are used during gamma scanning to double check the results.

Corrections were made to the gamma scan activities measured for Rods MKP109, MKP063, and MKP106. These corrections were required because of drifts in the detector during the scanning of Rod MKP109 and the lower sensitivity of a temporary detector used during the gamma scans of Rods MKP063 and MKP106.

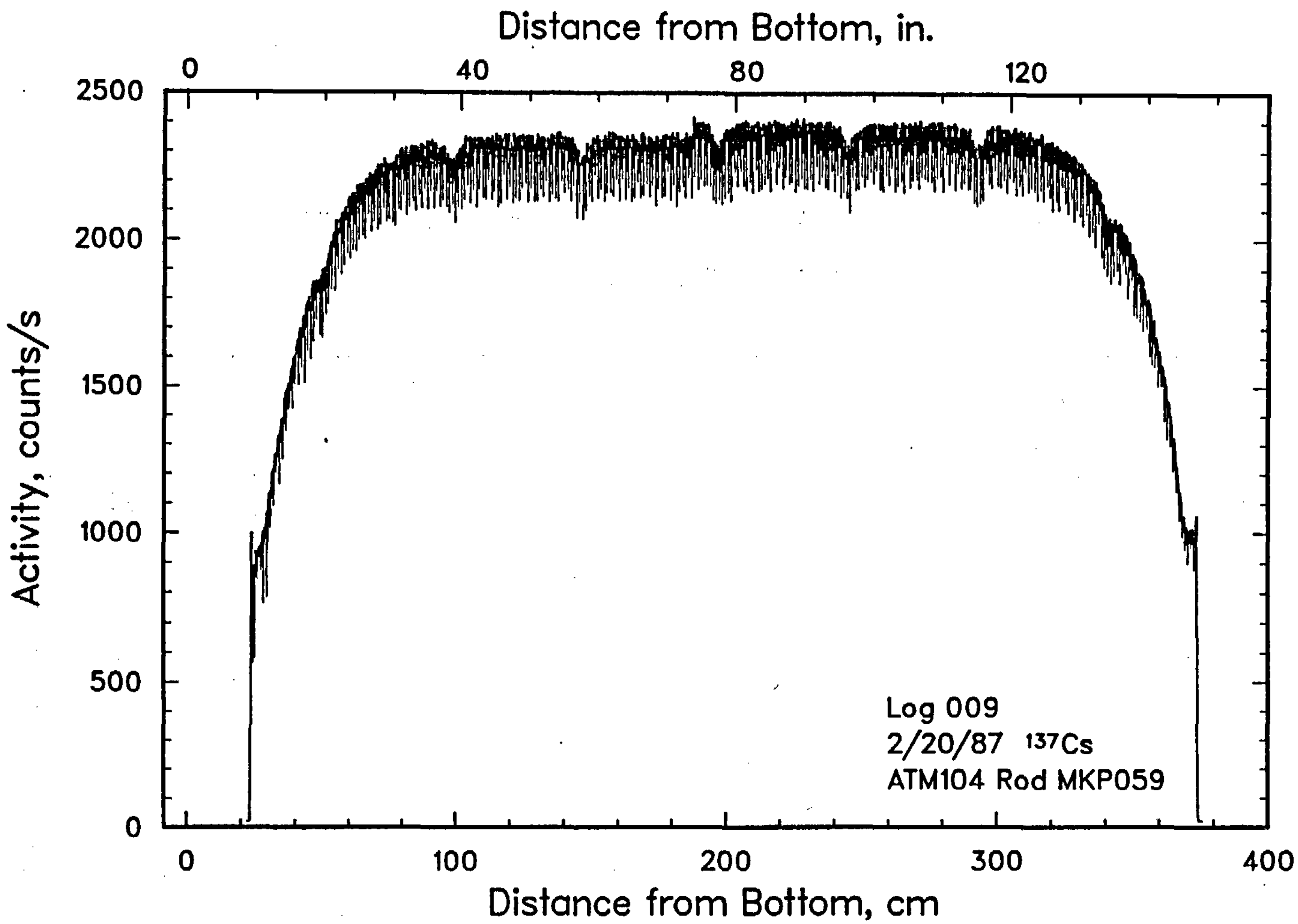

FIGURE B.3. Spectral Gamma Scan for ^{137}Cs - Rod MKP059

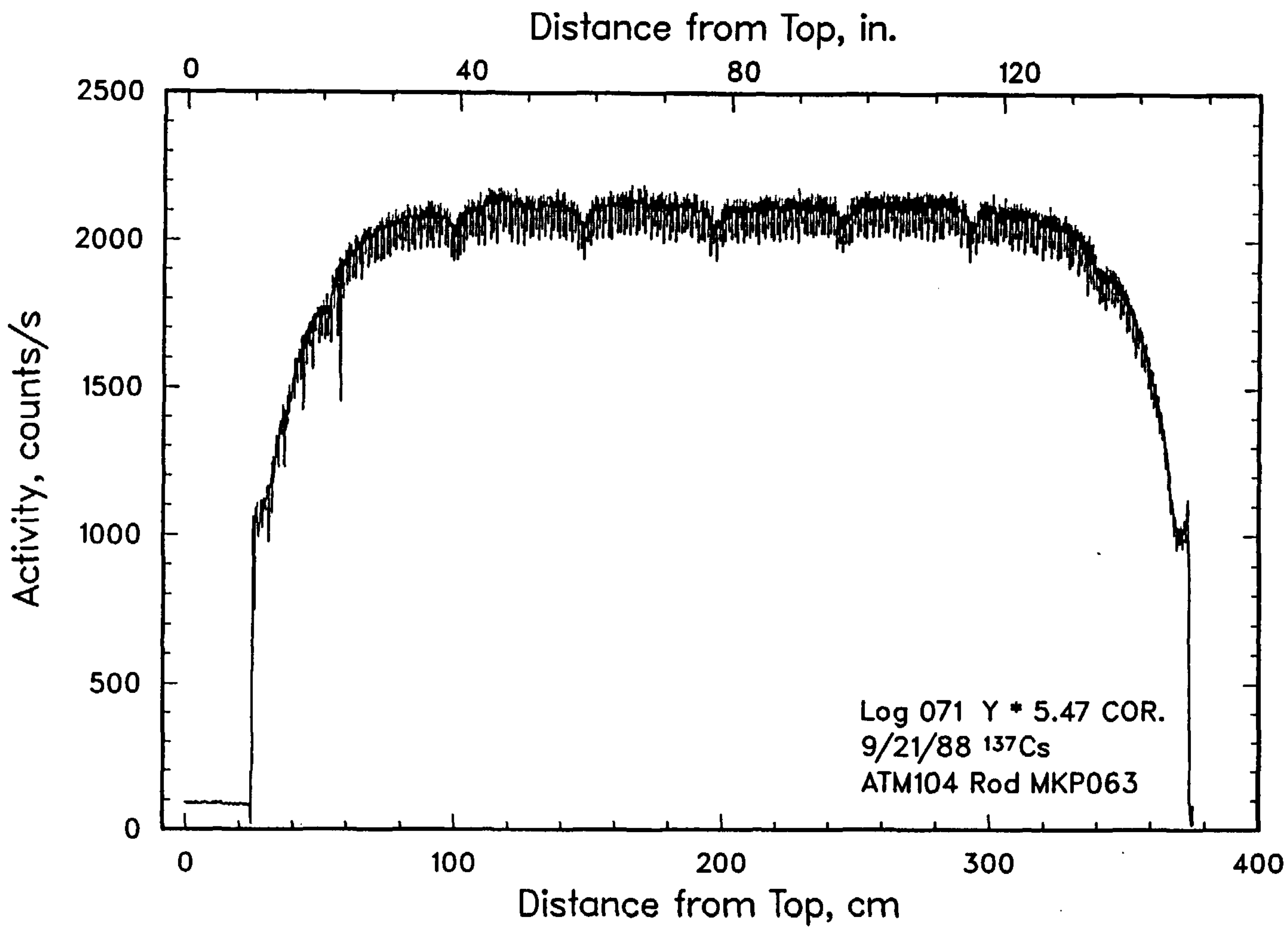

FIGURE B.4. Spectral Gamma Scan for ^{137}Cs - Rod MKP063

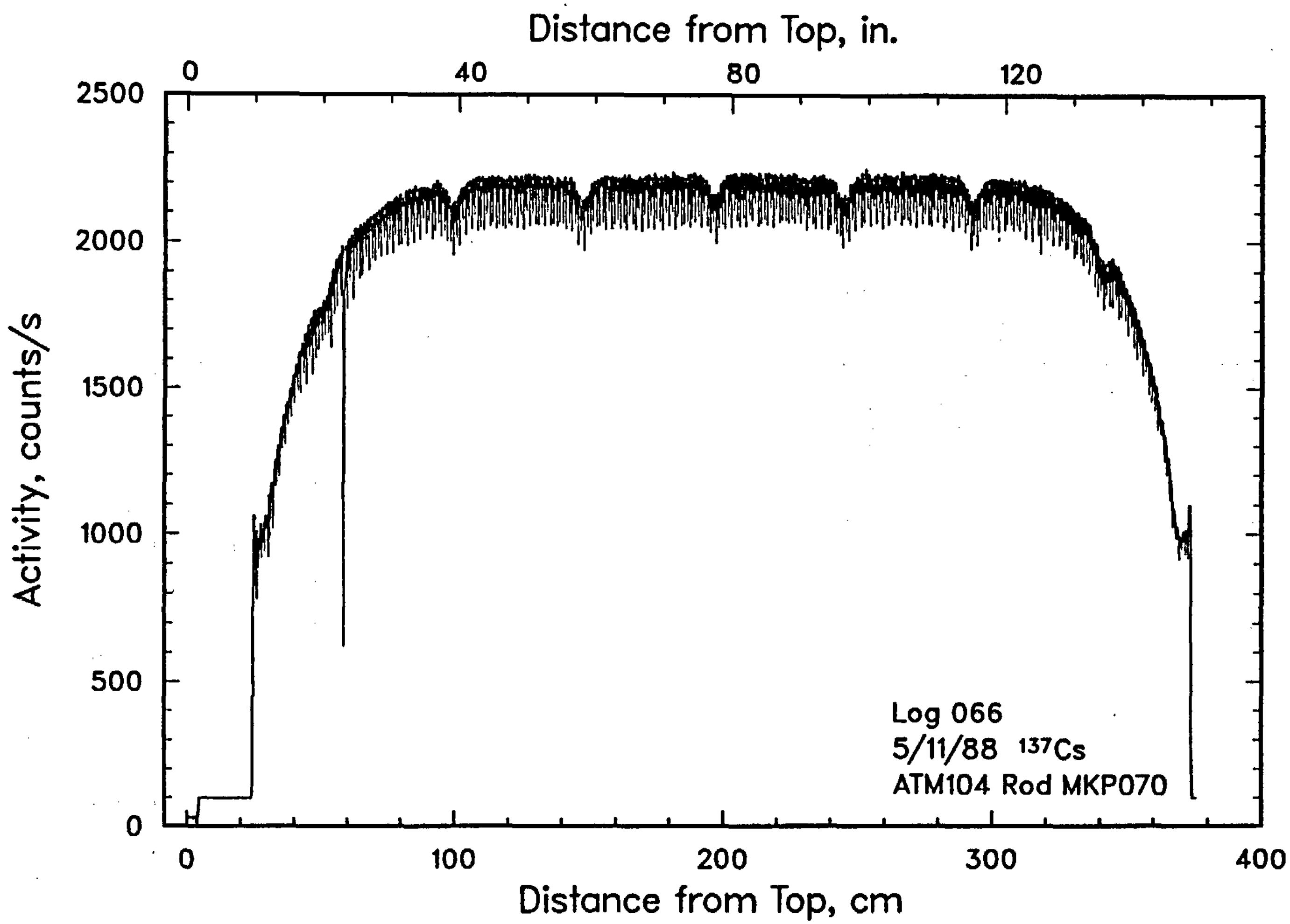

FIGURE B.5. Spectral Gamma Scan for ^{137}Cs - Rod MKP070

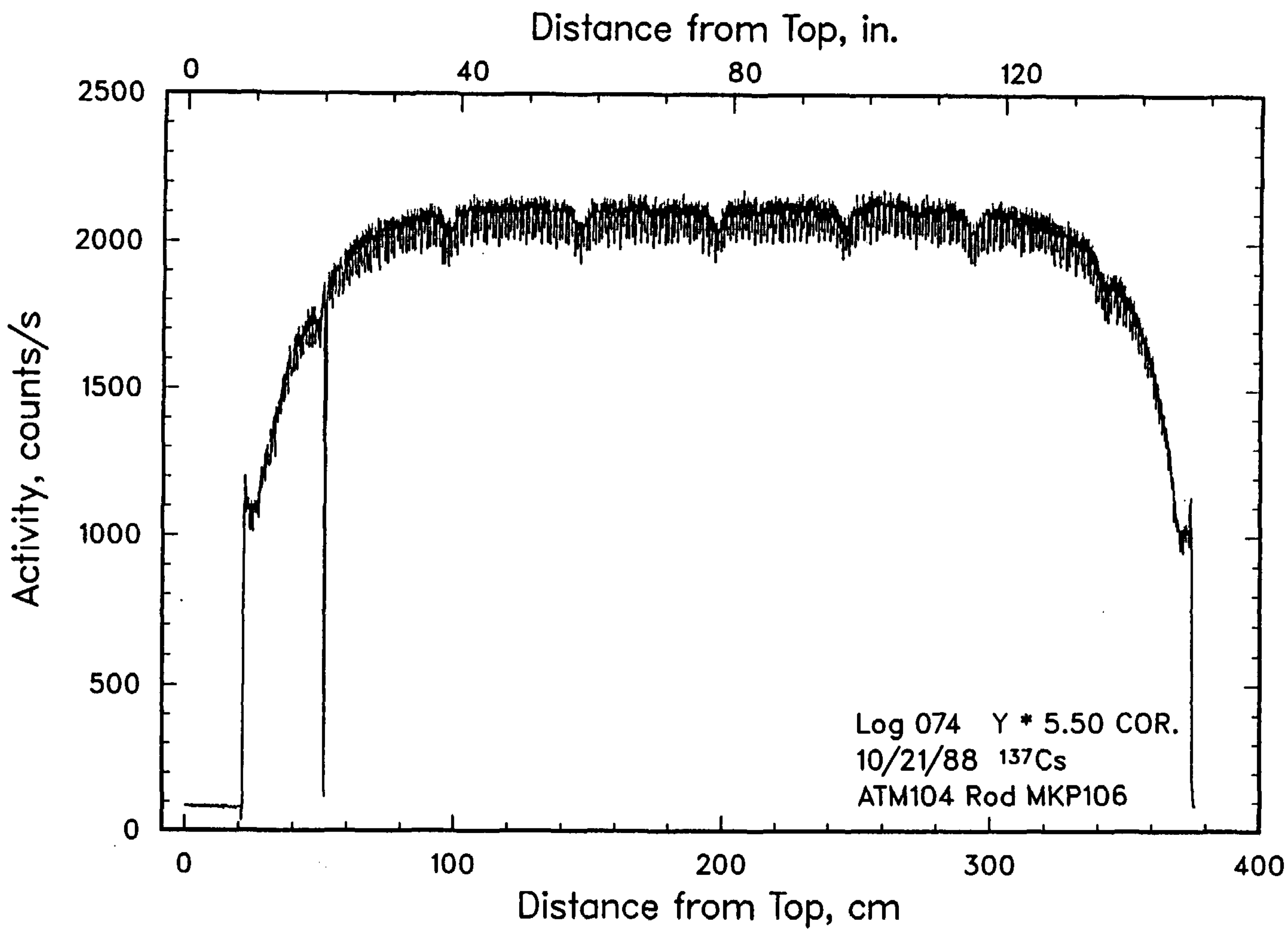

FIGURE B.6. Spectral Gamma Scan for ^{137}Cs - Rod MKP106

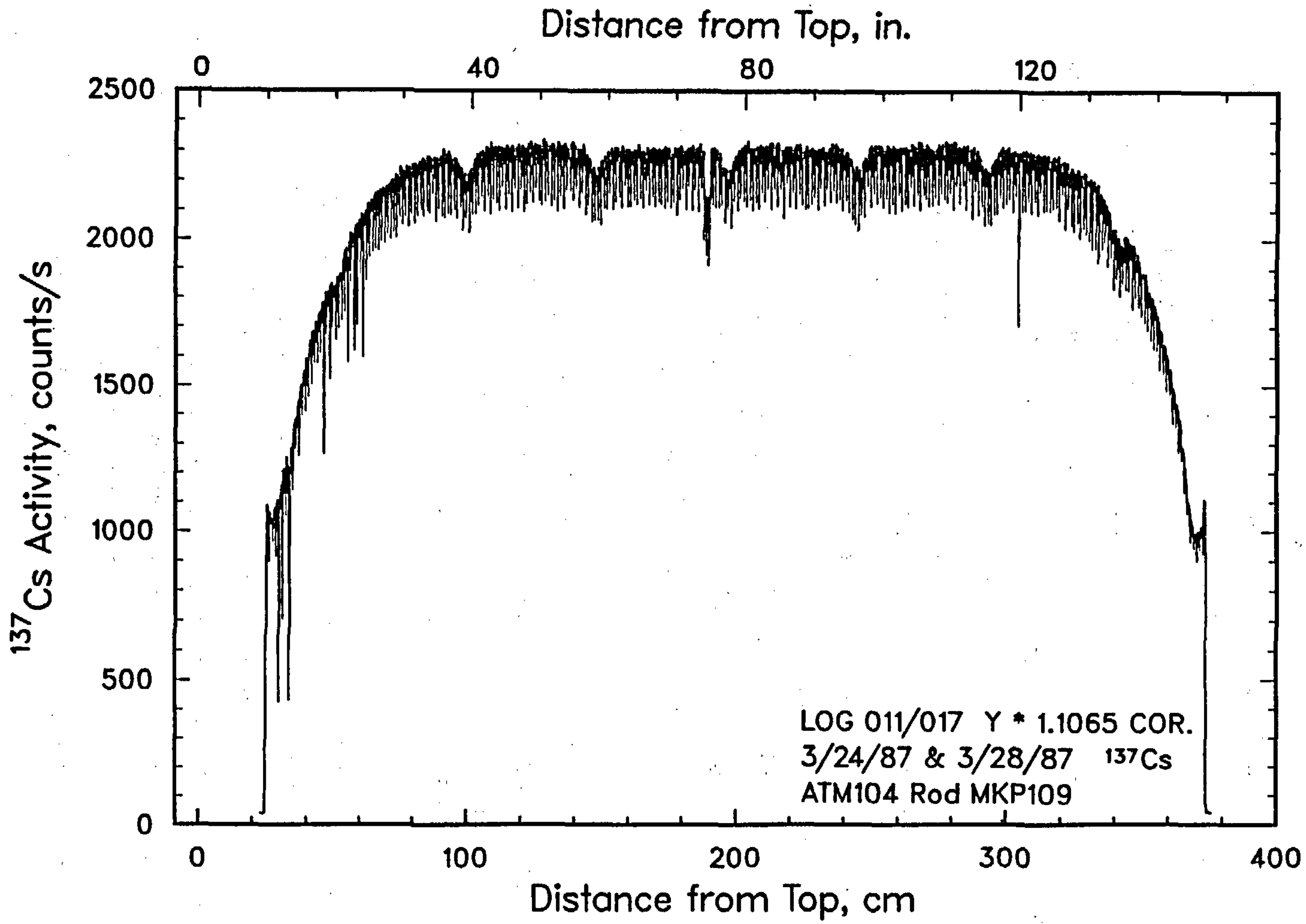

FIGURE B.7. Spectral Gamma Scan for ^{137}Cs - Rod MKP109

The original ^{137}Cs activities measured for Rod MKP109 were lower than expected based on results for the gamma scanning of Rod MKP070 that had a similar measured burnup for a comparable peak-power location; characterization data for Rod MKP070 is not generally available for reporting at this time. Based on the analysis described below, the cesium activities measured for Rod MKP109 were multiplied by 1.1065 and are plotted in Figure B.7. This adjustment is based on gamma scan results for the entire reference rod (MKP059) and/or the central 5-cm (2-in.) region made thirteen times over a 451-day period during which the average ^{137}Cs activity in the reference rod decreased 1.7%, which is close to the 2.8% decrease expected for the 30.17-year half-life of ^{137}Cs (see Figure B.8). Furthermore, the measured burnup of 44.34 MWd/kgM for Rod MKP109 was only 1.35% higher than for a similar sample from Rod MKP070. Correcting for the difference in burnups, the measured activities, and the date of the gamma scans, the ^{137}Cs gamma activities at a given burnup should have been the same for both rods. Using this logic, a correction factor (1.1065) was applied to the original data for Log 011/017 to generate Figure B.7. The measured ^{137}Cs activities, corrected ^{137}Cs activities, and burnup values for all of the samples from Rod MKP109 are listed in Table B.1.

A portion of the gamma scan data for Rod MKP109 was also affected by an electronic shift over a very short length of the fuel rod. For this reason, the gamma activity data over the fuel rod length 1.879 to 1.899 m (73.962 to 74.762 in.) from the top of Rod MKP109 are omitted in Figure B.7.

The original gamma scan detector malfunctioned prior to completion of the scans for Rods MKP063 and MKP106. The temporary detector used during the scans of these two rods was similar to the original detector, but the activities measured with the temporary detector were about 20% of those using the original detector. Both the original and temporary detectors were used to scan some of the ATM-104 rods. Based on the ratio of activities measured for the reference and standard rods with the original and temporary detectors, the data obtained with the temporary detector were converted to values that would have been obtained using the original detector. Activities obtained for Rods MKP063 and MKP106 using the temporary detector were multiplied by 5.47 and

5.50, respectively. These corrections have been included in preparing Figures B.4 and B.6 for Rods MKP063 and MKP106, respectively. All of the gamma activities in Figures B.3 through B.7 are for the date indicated on the plot.

TABLE B.1. ^{137}Cs Activities and Estimated Burnups for Rod MKP109

Section Identification	Section Assignment	Original Activity, Counts/s	Corrected Activity Counts/s	Burnup, MWd/kgM
104-MKP109-A	MCC Spare Material			
104-MKP109-B	ONWI(b) Material	1500.0	1659.8	30.0
104-MKP109-C	MCC Transverse Met./Ceram.	1548.1	1713.0	31.2
104-MKP109-D	MCC ^{129}I on Cladding ID, MCC ^{135}Cs and ^{137}Cs on Cladding ID and OD	1605.8	1776.8	32.6
104-MKP109-E	MCC ^{14}C in Fuel and Cladding	1634.6	1808.7	33.4
104-MKP109-F	MCC Spare Material	1658.7	1835.4	33.9
104-MKP109-G	MCC Spare Material	2081.0	2302.6	44.3
104-MKP109-H	MCC Transverse Met./Ceram.	2081.0	2302.6	44.3
104-MKP109-I	MCC ^{129}I on Cladding ID, MCC ^{135}Cs and ^{137}Cs on Cladding ID and OD	2081.0	2302.6	44.3
104-MKP109-J	MCC ^{14}C in Fuel and Cladding	2081.0	2302.6	44.3
104-MKP109-K	ONWI Material	2081.0	2302.6	44.3
104-MKP109-L	NNWSI(c) Material	2081.0	2302.6	44.3
104-MKP109-M	NNWSI Material	2083.3	2305.2	44.4
104-MKP109-N	MCC Longitudinal Metallography-Ceramography	2085.7	2307.8	44.4
104-MKP109-O	MCC Transverse Met./Ceram.	2085.7	2307.8	44.4

TABLE B.1. (contd)

Section Identification	Section Assignment	Original Activity, Counts/s	Corrected Activity Counts/s	Burnup, MWd/kgM
104-MKP109-P	MCC Burnup, Isotopes, and Radionuclides	2085.7	2307.8	44.34[a]
104-MKP109-Q	ORNL Spark Source	2085.7	2307.8	44.4
104-MKP109-R	ORNL Spark Source	2085.7	2307.8	44.4
104-MKP109-S	MCC Transmission Electron Microscopy	2085.7	2307.8	44.4
104-MKP109-T	MCC ^{129}I in Fuel and on Cladding ID; MCC ^{135}Cs and ^{137}Cs on Cladding ID and OD	2085.7	2307.8	44.4
104-MKP109-U	MCC ^{14}C in Fuel and Cladding	2085.7	2307.8	44.4
104-MKP109-V	MCC Spare Material	2085.7	2307.8	44.4
104-MKP109-W	ONWI Material	2085.7	2307.8	44.4
104-MKP109-X	MCC Spare and Archive Material			
104-MKP109-Y	MCC Spare Material			
104-MKP109-Z	MCC Spare Material			
104-MKP109-AA	MCC Longitudinal Metallography-Ceramography	1792.5	1983.4	37.2
104-MKP109-BB	MCC Transverse Met./Ceram.	1792.5	1983.4	37.2
104-MKP109-CC	MCC Burnup, Isotopes, and Radionuclides	1773.6	1962.5	37.12[a]
104-MKP109-DD	ORNL Spark Source	1745.3	1931.2	36.2

(a) Measured burnup.
(b) Former Office of Nuclear Waste Isolation.
(c) Former Nevada Nuclear Waste Storage Investigation, now Yucca Mountain Project.

TABLE B.1. (contd)

Section Identification	Section Assignment	Original Activity, Counts/s	Corrected Activity Counts/s	Burnup, MWd/kgM
104-MKP109-EE	ORNL Spark Source	1745.3	1931.2	36.2
104-MKP109-FF	MCC ^{129}I in Fuel and on Cladding ID; MCC ^{135}Cs and ^{137}Cs on Cladding ID and OD	1698.1	1878.9	34.9
104-MKP109-GG	MCC ^{14}C in Fuel and Cladding	1650.9	1826.7	33.8
104-MKP109-HH	MCC Spare Material	1617.9	1790.2	32.9
104-MKP109-II	ONWI Material	1566.0	1732.8	31.7
104-MKP109-JJ	MCC Longitudinal Metallography-Ceramography	1481.1	1638.8	29.6
104-MKP109-KK	MCC Transverse Met./Ceram.	1429.2	1581.4	28.3
104-MKP109-LL	MCC Burnup, Isotopes, and Radionuclides	1386.8	1534.5	27.35[(a)]
104-MKP109-MM	ORNL Spark Source	1339.6	1482.3	26.1
104-MKP109-NN	ORNL Spark Source	1283.0	1419.6	24.7
104-MKP109-OO	MCC 129I in Fuel and on Cladding ID; MCC ^{137}Cs and ^{137}Cs on Cladding ID and OD	1202.8	1330.9	22.7
104-MKP109-PP	MCC 14C in Fuel and Cladding	1108.5	1226.6	20.4
104-MKP109-QQ	MCC Spare Material	1000.0	1106.5	17.8
104-MKP109-RR	MCC Spare Material			

(a) Measured burnup.

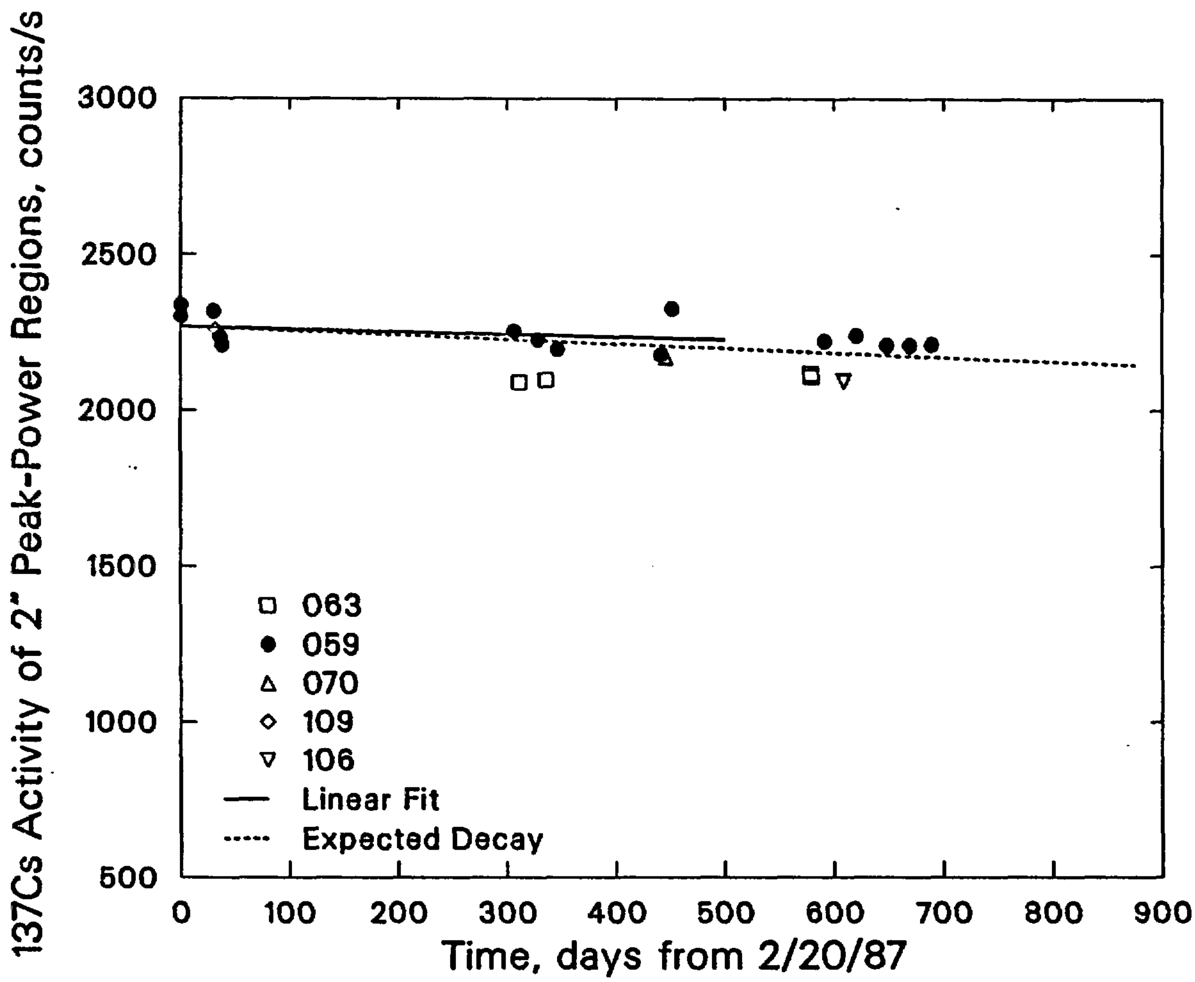

FIGURE B.8. Comparison of Actual and Predicted Temporal Change in ^{137}Cs Activity in Reference Rod MKP059 (Activity for scans at similar locations in other ATM-104 rods are also shown.)

APPENDIX C

SECTIONING DIAGRAM

APPENDIX C

SECTIONING DIAGRAM

The sectioning diagram for Rod MKP109 is shown in a graph of the ^{137}Cs gamma scan (Figure C.1). Each letter along the top of the graph identifies a specific section of the rod and is keyed to the detailed section assignment and location description (Table C.1) that follows the graph. The graphs are referenced to the top end of the rod. Dashed lines represent cuts that have not been made at the time of preparing this report.

Sections were cut from the rod using a circular saw with an aluminum oxide blade; the saw is operated without coolant. Each cut required less than 1 min. After cutting, the small fuel samples were placed in glass vials for transfer to the analytical facilities. The remaining longer segments (for repository testing or MCC spare material) were marked at the top end for orientation purposes and were placed in individual stainless steel storage tubes that were filled with argon before being capped with a Swagelok® fitting. Two operators were used during sectioning operations to verify that the sections were cut correctly and placed in the proper prelabeled transfer or storage containers. As the sections longer than 2.5 cm (1.0 in.) were cut, the measurements were made. These measurements were used to prepare the sectioning diagram shown in this appendix.

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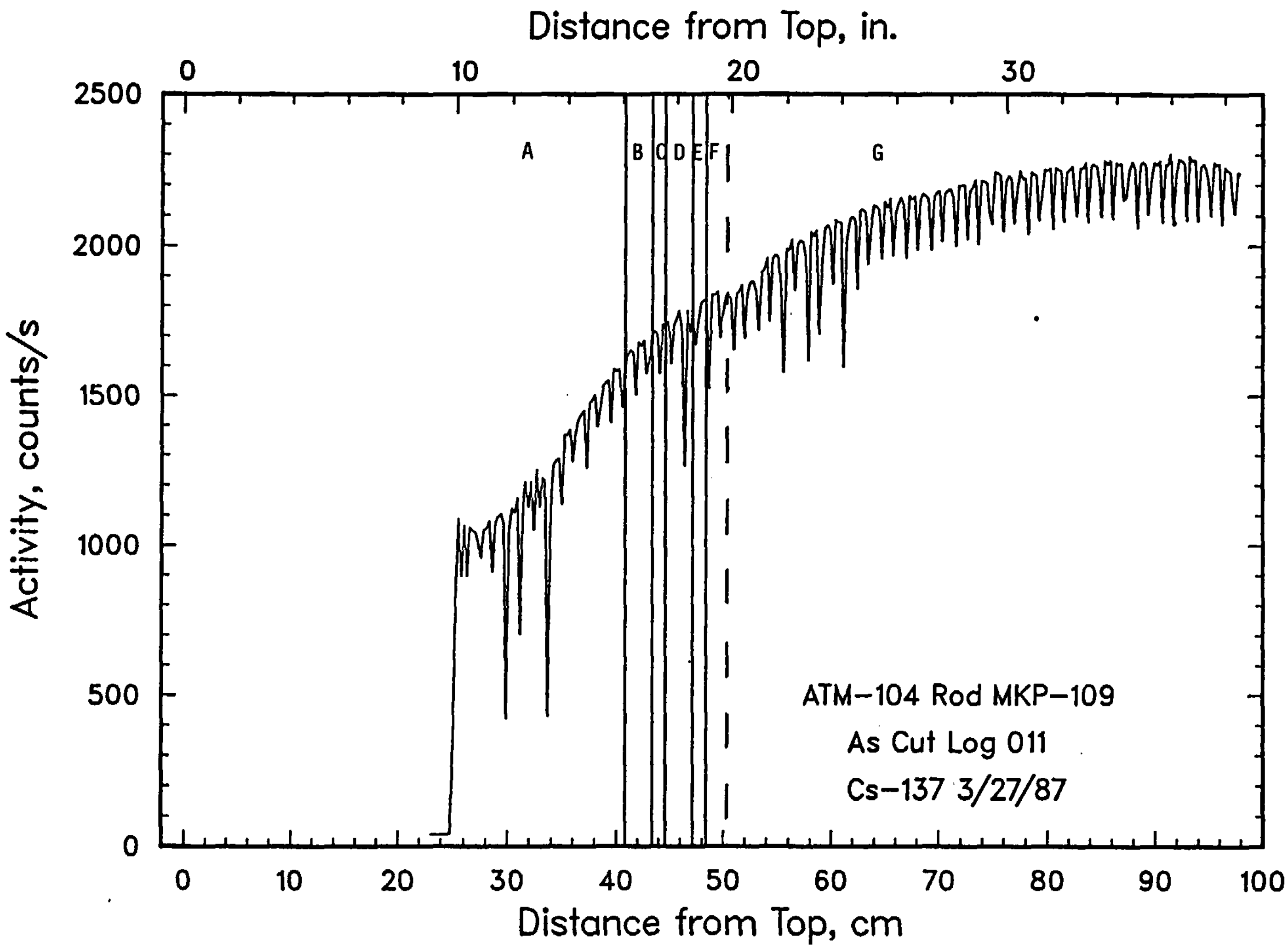


FIGURE C.1. Sectioning Diagram for Rod MKP109

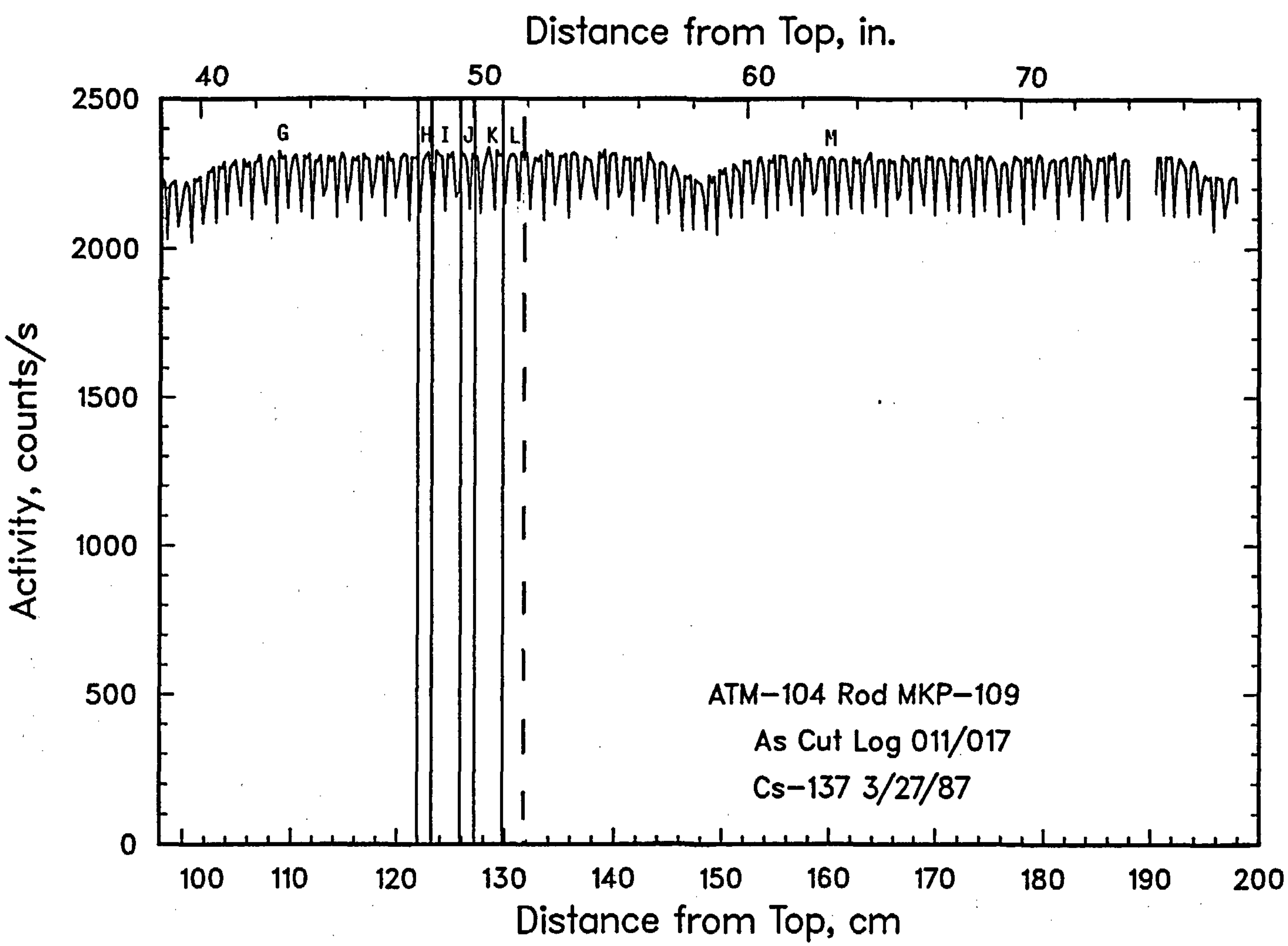


FIGURE C.1. (contd)

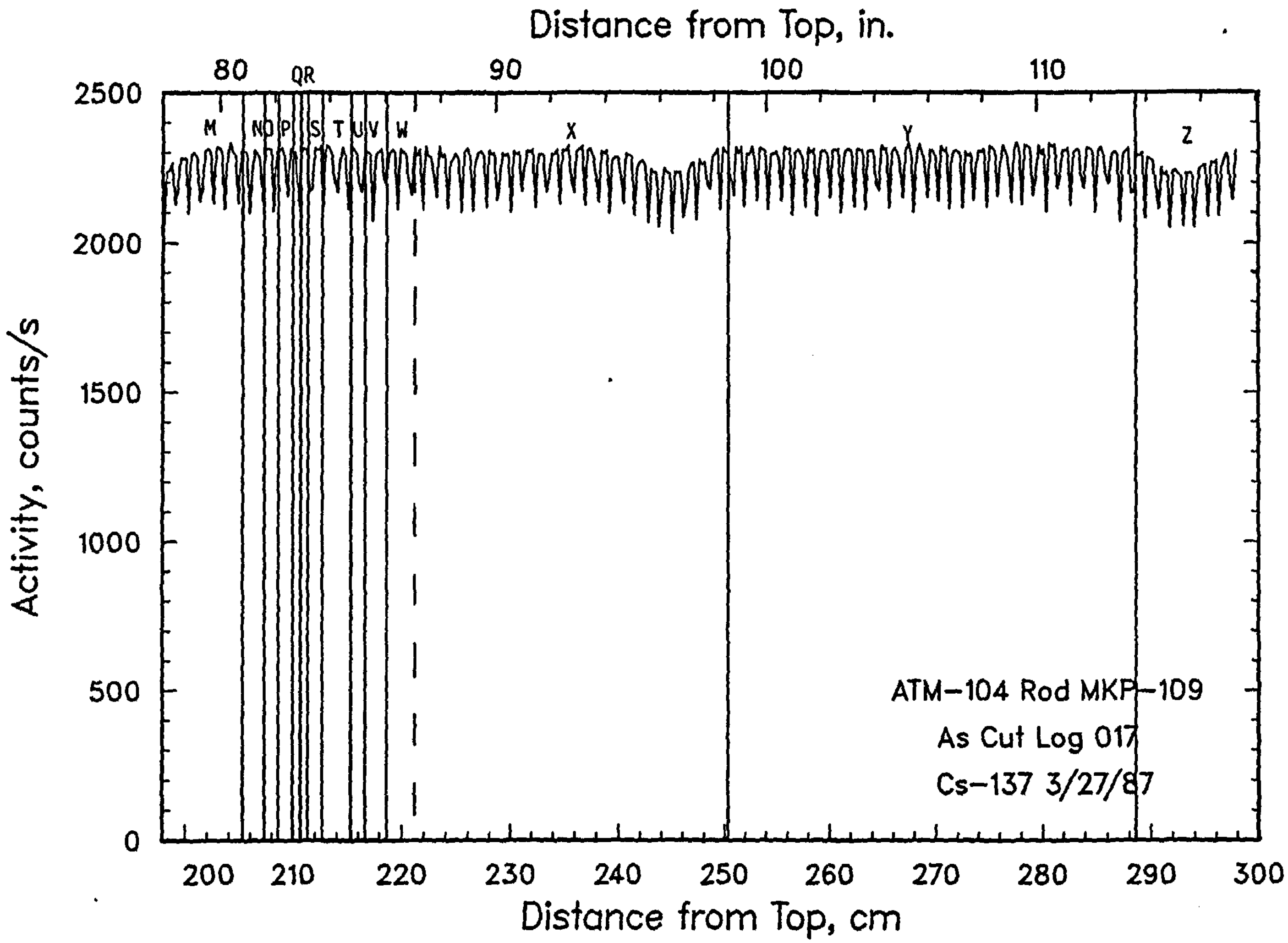


FIGURE C.1. (contd)

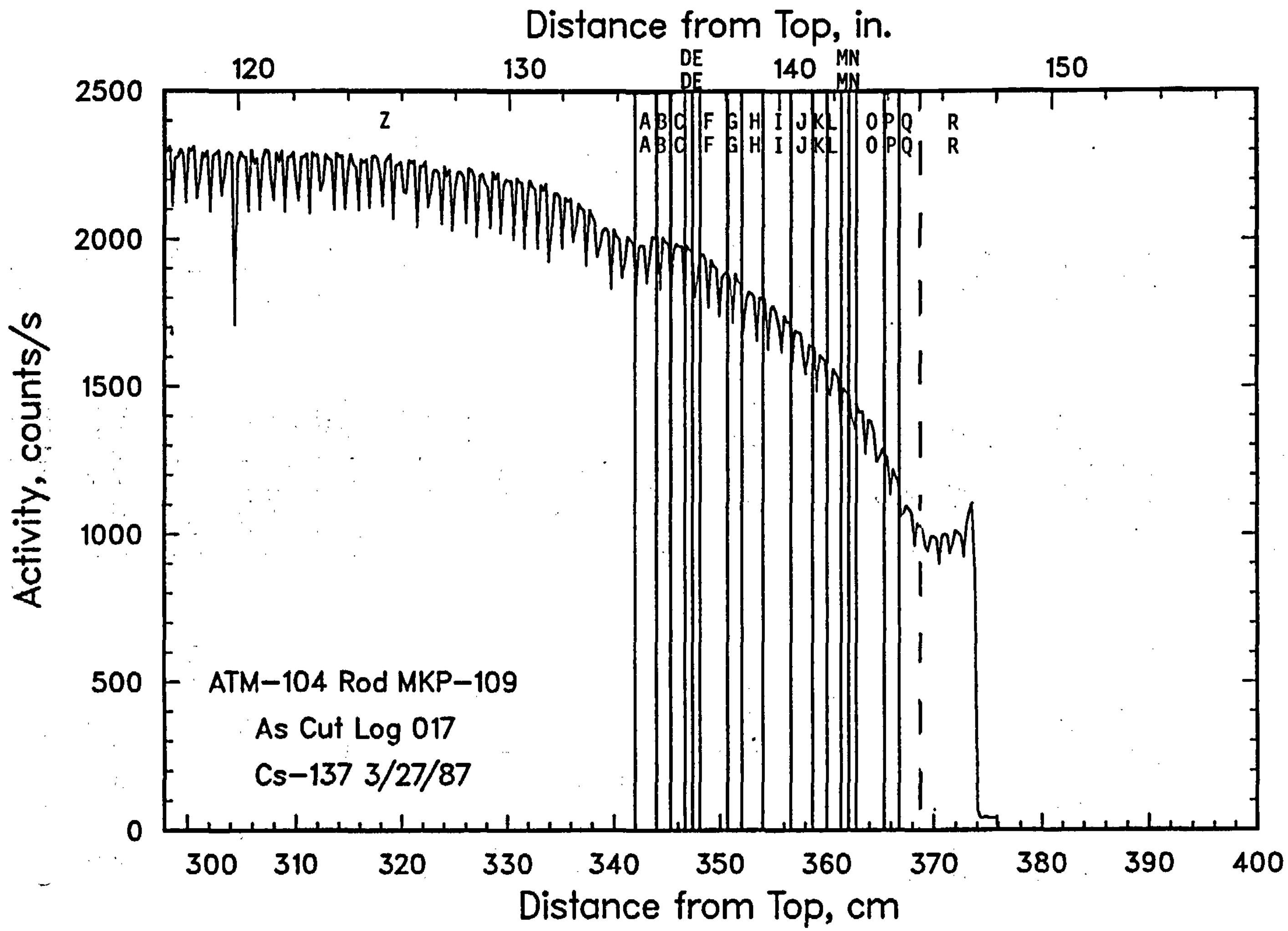


FIGURE C.1. (contd)

TABLE C.1. Description of Sections Cut from of ATM-104, Rod MKP-109 (Keyed to Figure D.1)

Section Identification	Section Assignment	Distance From Top,[a] cm (in.)	Length,[b] cm (in.)	Notes
A.	MCC Spare Material	0-40.810 (0-16.067)	40.81 (16.07)	c,d
B.	ONWI Material	40.874-43.330 (16.092-17.059)	2.46 (0.97)	d
C.	MCC Transverse Metallog-aphy-Ceramography	43.393-44.580 (17.084-17.551)	1.19 (0.47)	d
D.	MCC ^{129}I on Cladding ID, MCC ^{135}Cs and ^{137}Cs on Cladding ID and OD	44.643-47.099 (17.576-18.543)	2.46 (0.97)	d
E.	MCC ^{14}C in Fuel and Cladding	47.163-48.349 (18.568-19.035)	1.19 (0.47)	d
F.	MCC Spare Material	48.412-50.317* (19.060-19.810*)	1.91 (0.75)	c,e
G.	MCC Spare Material	50.381*-121.851 (19.835*-47.973)	71.47 (28.14)	c,e
H.	MCC Transverse Metallog-raphy-Ceramography	121.915-123.185 (47.998-48.498)	1.27 (0.50)	
I.	MCC ^{129}I on Cladding ID, MCC ^{135}Cs and ^{137}Cs on Cladding ID and OD	123.248-125.788 (48.523-49.523)	2.54 (1.00)	
J.	MCC ^{14}C in Fuel and Cladding	125.852-127.122 (49.548-50.048)	1.27 (0.50)	
K.	ONWI Material	127.185-129.725 (50.073-51.073)	2.54 (1.00)	
L.	NNWSI Material	129.789-131.694* (51.098-51.848*)	1.91 (0.75)	c,e
M.	NNWSI Material	131.757*-205.290 (51.873*-80.823)	73.53 (28.95)	c,e
N.	MCC Longitudinal Metallog-raphy-Ceramography	205.354-207.259 (80.848-81.598)	1.91 (0.75)	
O.	MCC Transverse Metallog-raphy-Ceramography	207.322-208.592 (81.623-82.123)	1.27 (0.50)	
P.	MCC Burnup, Isotopes, and Radionuclides	208.656-209.926 (82.148-82.648)	1.27 (0.50)	
Q.	ORNL Spark Source	209.989-210.624 (82.673-82.923)	0.64 (0.25)	

TABLE C.1. (contd)

Section Identification	Section Assignment	Distance From Top,[a] cm (in.)	Length,[b] cm (in.)	Notes
R.	ORNL Spark Source	210.688-211.323 (82.948-83.198)	0.64 (0.25)	
S.	MCC Transmission Electron Microscopy	211.386-212.656 (83.223-83.723)	1.27 (0.50)	
T.	MCC ^{129}I in Fuel and on Cladding ID; MCC ^{135}Cs and ^{137}Cs on Cladding ID and OD	212.720-215.260 (83.748-84.748)	2.54 (1.00)	
U.	MCC ^{14}C in Fuel and Cladding	215.323-216.593 (84.773-85.273)	1.27 (0.50)	
V.	MCC Spare Material	216.657-218.562 (85.298-86.048)	1.91 (0.75)	f
W.	ONWI Material	218.625-221.165* (86.073-87.073*)	2.54 (1.00)	c,e,f
X.	MCC Spare and Archive Material	221.229*-250.312 (87.098*-98.548)	29.08 (11.45)	c,e
Y.	MCC Spare Material	250.375-288.572 (98.573-113.611)	38.20 (15.04)	c
Z.	MCC Spare Material	288.635-341.930 (113.636-134.618)	53.29 (20.98)	c,g
AA.	MCC Longitudinal Metallography-Ceramography	341.993-343.916 (134.643-135.400)	1.92 (0.76)	g
BB.	MCC Transverse Metallography-Ceramography	343.980-345.267 (135.425-135.932)	1.29 (0.51)	g
CC.	MCC Burnup, Isotopes, and Radionuclides	345.331-346.619 (135.957-136.464)	1.29 (0.51)	g
DD.	ORNL Spark Source	346.682-347.335 (136.489-136.746)	0.65 (0.26)	g
EE.	ORNL Spark Source	347.398-348.051 (136.771-137.028)	0.65 (0.26)	g
FF.	MCC ^{129}I in Fuel and on Cladding ID; MCC ^{135}Cs and ^{137}Cs on Cladding ID and OD	348.115-350.672 (137.053-138.060)	2.56 (1.01)	g
GG.	MCC ^{14}C in Fuel and Cladding	350.736-352.024 (138.085-138.592)	1.29 (0.51)	g
HH.	MCC Spare Material	352.087-354.010 (138.617-139.374)	1.92 (0.76)	g

TABLE C.1. (contd)

Section Identification	Section Assignment	Distance From Top,[a] cm (in.)	Length,[b] cm (in.)	Notes
II.	ONWI Material	354.074-356.631 (139.399-140.406)	2.56 (1.01)	g
JJ.	MCC Longitudinal Metallography-Ceramography	356.695-358.618 (140.431-141.188)	1.92 (0.76)	g
KK.	MCC Transverse Metallography-Ceramography	358.681-359.969 (141.213-141.720)	1.29 (0.51)	g
LL.	MCC Burnup, Isotopes, and Radionuclides	360.032-361.320 (141.745-142.252)	1.29 (0.51)	g
MM.	ORNL Spark Source	361.384-362.036 (142.277-142.534)	0.65 (0.26)	g
NN.	ORNL Spark Source	362.100-362.753 (142.559-142.816)	0.65 (0.26)	g
OO.	MCC ^{129}I in Fuel and on Cladding ID; MCC ^{135}Cs and ^{137}Cs on Cladding ID and OD	362.816-365.374 (142.841-143.848)	2.56 (1.01)	g
PP.	MCC ^{14}C in Fuel and Cladding	365.437-366.725 (143.873-144.380)	1.29 (0.51)	g
QQ.	MCC Spare Material	366.789-368.694* (144.405-145.155*)	1.91 (0.75)	e
RR.	MCC Spare Material	368.757*-375.793 (145.180*-147.95)	7.04 (2.77)	e

(a) Distance from top reported to three decimal places to keep account of saw loss between sections only. Section lengths reported to two decimal places.
(b) Length does not include 0.064 cm (0.025 in.) saw loss. (This is accounted for between sections.) Measured lengths are within ±0.16 cm (1/16 in.).
(c) Within ±0.16 cm (1/16 in.) of measured length.
(d) Subtracted 0.084 cm (0.033 in.) from each of the five sections (A-E) to compensate for 0.419 cm (0.165 in.) difference between as-cut length measurements and "theoretical" summation of sections B through E after accounting for saw loss.
(e) Sections are one section of fuel. Asterisk (*) indicates a theoretical distance from top of the rod that gives a length specified in the pre-cut plan.
(f) Lengths of V and W exchanged due to an error in cutting. Section V, originally specified as ONWI material, is designated as MCC spare material. Section W, originally specified as MCC spare material, is designated as ONWI material.
(g) Length increased by 0.018 cm (0.007 in.) for each of 17 sections (Z-PP) to compensate for 0.318 cm (0.125 in.) difference between as-cut length measurements and "theoretical" summation of sections AA through PP after accounting for saw loss.

APPENDIX D

RESULTS OF ORIGEN2 RADIONUCLIDE INVENTORY CALCULATIONS

APPENDIX D

RESULTS OF ORIGEN2 RADIONUCLIDE INVENTORY CALCULATIONS

Appendix D contains input and output from the ORIGEN2 calculations for ATM-104 spent fuel based on data described in Section 5.1 and Appendix A. An example of the ORIGEN2 input for fuel irradiation/decay is shown in Figure D.1. An example of the ORIGEN2 input for cladding irradiation/decay is shown in Figure D.2. The power densities given in Appendix A were normalized to give radionuclide inventories at burnups of 20, 25, 30, 35, 40, 45, and 50 MWd/kgM. Eight tables of output at each of these burnups are given in Appendix D. Their contents are as follows:

Table D.1.a - D.1.g	Fission Product Radioactivity by Isotope, Ci/gU
Table D.2.a - D.2.g	Actinide Radioactivity by Isotope, Ci/gU
Table D.3.a - D.3.g	Fission Product Inventory by Isotope, g/gU
Table D.4.a - D.4.g	Actinide Inventory by Isotope, g/gU
Table D.5.a - D.5.g	Fission Product Inventory by Element, g/gU
Table D.6.a - D.6.g	Actinide Inventory by Element, g/gU
Table D.7.a - D.7.g	Fuel Activation Product Inventory by Isotope, g/gU
Table D.8.a - D.8.g	Cladding Activation Product Inventory by Isotope, g/gZr

Each table contains values for out-of-reactor decay times of 4, 6, 8, 10, 15, 20, and 1000 years.

ORIGEN2 output includes a variety of additional tables, a few of which were used in preparing the comparisons of measured and predicted activities in Tables 6.3 and Table 7.3.

```
-1
-1
-1
TIT     ATM-104 FUEL PWR E=3.038 20.0 GWD/MTU
BAS     GRAM
LIB     0 1 2 3 204 205 206 9 3 0 1 1
PHO     101 102 103 10
LIP     0 0 0
INP     1 1 -1 -1 1 1
RDA     BURNUP TO 20,000 MWD/MTU
BUP
IRP     100.      15.7064-6  1 2 4 2
IRP     200.      15.7064-6  2 3 4 0
IRP     306.      15.7064-6  3 4 4 0
DEC     377.                 4 5 4 0
IRP     398.9     14.6982-6  5 6 4 0
IRP     418.3      9.7526-6  6 7 4 0
IRP     528.3     14.8798-6  7 8 4 0
IRP     646       14.8798-6  8 9 4 0
DEC     671                  9 1 4 0
IRP     759       14.8798-6  1 2 4 0
DEC     840                  2 3 4 0
IRP     958.3      3.0305-6  3 4 4 0
IRP     1080.1     6.4173-6  4 5 4 0
IRP     1190.1    13.0210-6  5 6 4 0
IRP     1306      13.0210-6  6 7 4 0
DEC     1391                 7 8 4 0
IRP     1506      10.2400-6  8 9 4 0
IRP     1621      10.2400-6  9 1 4 0
IRP     1736      10.2400-6  1 2 4 0
IRP     1852      10.2400-6  2 3 4 0
DEC     1.       3  4  5 2
DEC     4.        4  1  5 0
DEC     6.        1  2  5 0
DEC     8.        2  3  5 0
DEC     10.       3  4  5 0
DEC     15.       4  5  5 0
DEC     20.       5  6  5 0
DEC     50.       6  7  5 0
DEC     100.      7  8  5 0
DEC     200.      8  9  5 0
DEC     500.      9 10  5 0
DEC     1000.    10  7  5 0
BUP
HED     1 ' 4 YEARS
HED     2 ' 6 YEARS
HED     3 ' 8 YEARS
```

FIGURE D.1. Sample ORIGEN2 Input for ATM-104 Fuel

```
HED     4  10 YEARS
HED     5  15 YEARS
HED     6  20 YEARS
HED     7  1000 YEARS
OPTA    8 8 8 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTL    8 8 8 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTF    8 8 8 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
CUT     5 1.0-15 7 1.0-15 -1
OUT     7 1 0 1
STP     4
2   922340 .000246  922350 .03038  922380 .96937 0 0.0
4   80000 .13452  60000 20.4-6  70000 26.1-6  90000 5.7-6
4   170000 5.7-6  260000 51.1-6  470000 1.1-6  200000 36.3-6
4   130000 36.3-6  140000 36.3-6  280000 28.4-6  0 0.0
0
END
```

FIGURE D.1. Sample ORIGEN2 Input for ATM-104 Fuel (contd)

```
-1
-1
-1
TIT    ATM-104 CLAD PWR E=3.038 20.0 GWD/MTU
BAS    GRAM
LIB    0 1 2 3 204 205 206 9 3 0 1 1
PHO    101 102 103 10
LIP    0 0 0
INP    1 1 -1 -1 1 1
RDA    BURNUP TO 20,000 MWD/MTU
BUP
IRP    100.      70.8983-6  1 2 4 2
IRP    200.      70.8983-6  2 3 4 0
IRP    306.      70.8983-6  3 4 4 0
DEC    377.                 4 5 4 0
IRP    398.9     66.3472-6  5 6 4 0
IRP    418.3     44.0229-6  6 7 4 0
IRP    528.3     67.1668-6  7 8 4 0
IRP    646       67.1668-6  8 9 4 0
DEC    671                  9 1 4 0
IRP    759       67.1668-6  1 2 4 0
DEC    840                  2 3 4 0
IRP    958.3     58.8195-6  3 4 4 0
IRP    1080.1    28.9676-6  4 5 4 0
IRP    1190.1    58.7763-6  5 6 4 0
IRP    1306      58.7763-6  6 7 4 0
DEC    1391                 7 8 4 0
IRP    1506      46.2230-6  8 9 4 0
IRP    1621      46.2230-6  9 1 4 0
IRP    1736      46.2230-6  1 2 4 0
IRP    1852      46.2230-6  2 3 4 0
DEC    1.      3  4  5 2
DEC    4.      4  1  5 0
DEC    6.      1  2  5 0
DEC    8.      2  3  5 0
DEC    10.     3  4  5 0
DEC    15.     4  5  5 0
DEC    20.     5  6  5 0
DEC    50.     6  7  5 0
DEC    100.    7  8  5 0
DEC    200.    8  9  5 0
DEC    500.    9 10  5 0
DEC    1000.  10  7  5 0
BUP
HED    1 ' 4 YEARS
HED    2 ' 6 YEARS
HED    3 ' 8 YEARS
```

FIGURE D.2. Sample ORIGEN Input for ATM-104 Cladding

```
HED    4 10 YEARS
HED    5 15 YEARS
HED    6 20 YEARS
HED    7 1000 YEARS
OPTA   8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTL   8 8 8 8 7 8 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
OPTF   8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8
CUT    5 1.0-15  7 1.0-15  -1
OUT    7 1  0  1
STP    4
2  922340 .001110  922350 .13713  922380 4.3757  0 0.0
4  400000 .9805  500000 0.015  260000 0.002  240000 0.001
4  130000 40.0-6  720000 55.0-6  140000 80.0-6  80000 1165.0-6
4  60000 115.0-6  70000 25.0-6  10000 14.0-6  0 0.0
0
END
```

FIGURE D.2. Sample ORIGEN Input for ATM-104 Cladding (contd)

TABLE D.1.a. Fission Product Radioactivity by Isotope at 20 MWd/kgM, Ci/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-3	2.376E-04	2.124E-04	1.898E-04	1.696E-04	1.281E-04	9.678E-05	0.00
Be-10	1.765E-12	1.765E-12	1.765E-12	1.765E-12	1.765E-12	1.765E-12	1.764E-12
C-14	7.114E-11	7.112E-11	7.110E-11	7.109E-11	7.104E-11	7.100E-11	6.306E-11
Se-79	2.545E-07	2.544E-07	2.544E-07	2.544E-07	2.544E-07	2.544E-07	2.518E-07
Kr-81	1.865E-13	1.865E-13	1.865E-13	1.865E-13	1.865E-13	1.865E-13	1.859E-13
Kr-85	4.274E-03	3.755E-03	3.300E-03	2.900E-03	2.099E-03	1.519E-03	0.00
Rb-87	1.393E-11	1.393E-11	1.393E-11	1.393E-11	1.393E-11	1.393E-11	1.393E-11
Sr-89	5.378E-10	2.377E-14	1.050E-18	4.640E-23	0.00	0.00	0.00
Sr-90	4.198E-02	4.002E-02	3.816E-02	3.639E-02	3.231E-02	2.868E-02	2.124E-12
Y-90	4.199E-02	4.003E-02	3.817E-02	3.640E-02	3.231E-02	2.869E-02	2.125E-12
Y-91	1.078E-08	1.880E-12	3.278E-16	5.715E-20	0.00	0.00	0.00
Zr-93	1.153E-06	1.153E-06	1.153E-06	1.153E-06	1.153E-06	1.153E-06	1.153E-06
Nb-93m	3.213E-07	3.963E-07	4.641E-07	5.253E-07	6.535E-07	7.530E-07	1.095E-06
Nb-94	7.226E-11	7.226E-11	7.225E-11	7.225E-11	7.223E-11	7.222E-11	6.985E-11
Zr-95	6.292E-08	2.300E-11	8.411E-15	3.075E-18	0.00	0.00	0.00
Nb-95	1.397E-07	5.107E-11	1.867E-14	6.827E-18	0.00	0.00	0.00
Nb-95m	4.667E-10	1.707E-13	6.239E-17	2.281E-20	0.00	0.00	0.00
Tc-98	1.951E-12	1.951E-12	1.951E-12	1.951E-12	1.951E-12	1.951E-12	1.951E-12
Tc-99	8.301E-06	8.301E-06	8.300E-06	8.300E-06	8.300E-06	8.300E-06	8.274E-06
Rh-102	1.503E-07	9.318E-08	5.777E-08	3.582E-08	1.084E-08	3.282E-09	0.00
Ru-103	2.648E-12	6.682E-18	1.686E-23	0.00	0.00	0.00	0.00
Rh-103m	2.387E-12	6.024E-18	1.520E-23	0.00	0.00	0.00	0.00
Ru-106	1.043E-02	2.635E-03	6.661E-04	1.684E-04	5.408E-06	1.737E-07	0.00
Rh-106	1.043E-02	2.635E-03	6.661E-04	1.684E-04	5.408E-06	1.737E-07	0.00
Pd-107	5.365E-08	5.365E-08	5.365E-08	5.365E-08	5.365E-08	5.365E-08	5.364E-08
Ag-108	1.224E-12	1.211E-12	1.198E-12	1.185E-12	1.153E-12	1.122E-12	5.335E-15
Ag-108m	1.376E-11	1.361E-11	1.346E-11	1.331E-11	1.295E-11	1.261E-11	5.995E-14
Ag-109m	1.947E-11	6.539E-12	2.196E-12	7.374E-13	4.818E-14	3.148E-15	0.00
Cd-109	1.947E-11	6.539E-12	2.196E-12	7.374E-13	4.818E-14	3.148E-15	0.00
Ag-110	1.848E-07	2.436E-08	3.211E-09	4.232E-10	2.670E-12	1.685E-14	0.00
Ag-110m	1.389E-05	1.831E-06	2.414E-07	3.182E-08	2.008E-10	1.267E-12	0.00
Cd-113m	2.146E-05	1.951E-05	1.774E-05	1.613E-05	1.272E-05	1.003E-05	6.031E-26
In-114	1.082E-15	3.917E-20	1.418E-24	0.00	0.00	0.00	0.00
In-114m	1.130E-15	4.093E-20	1.482E-24	0.00	0.00	0.00	0.00
Cd-115m	6.553E-14	7.679E-19	9.000E-24	0.00	0.00	0.00	0.00
Sn-119m	1.052E-06	1.332E-07	1.686E-08	2.135E-09	1.218E-11	6.953E-14	0.00
Sn-121m	1.033E-07	1.005E-07	9.771E-08	9.504E-08	8.867E-08	8.273E-08	1.033E-13
Sn-123	4.031E-07	7.998E-09	1.587E-10	3.148E-12	1.745E-16	9.676E-21	0.00
Te-123m	3.451E-10	5.017E-12	7.294E-14	1.060E-15	2.702E-20	6.887E-25	0.00
Sb-124	1.145E-11	2.546E-15	5.661E-19	1.258E-22	0.00	0.00	0.00
Sb-125	2.293E-03	1.390E-03	8.427E-04	5.109E-04	1.462E-04	4.183E-05	0.00
Te-125m	5.594E-04	3.392E-04	2.057E-04	1.247E-04	3.567E-05	1.021E-05	0.00
Sn-126	4.425E-07	4.425E-07	4.425E-07	4.425E-07	4.425E-07	4.424E-07	4.395E-07
Sb-126	6.195E-08	6.195E-08	6.195E-08	6.195E-08	6.195E-08	6.194E-08	6.152E-08
Sb-126m	4.425E-07	4.425E-07	4.425E-07	4.425E-07	4.425E-07	4.424E-07	4.395E-07

TABLE D.1.a. Fission Product Radioactivity by Isotope at 20 MWd/kgM, Ci/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Te-127	3.640E-07	3.498E-09	3.361E-11	3.229E-13	2.922E-18	2.644E-23	0.00
Te-127m	3.716E-07	3.571E-09	3.431E-11	3.297E-13	2.983E-18	2.699E-23	0.00
Te-129	6.879E-16	1.962E-22	0.00	0.00	0.00	0.00	0.00
Te-129m	1.057E-15	3.014E-22	0.00	0.00	0.00	0.00	0.00
I-129	1.868E-08	1.868E-08	1.868E-08	1.868E-08	1.868E-08	1.868E-08	1.868E-08
Cs-134	1.200E-02	6.124E-03	3.126E-03	1.596E-03	2.972E-04	5.535E-05	0.00
Cs-135	4.102E-07	4.102E-07	4.102E-07	4.102E-07	4.102E-07	4.102E-07	4.100E-07
Cs-137	5.545E-02	5.294E-02	5.055E-02	4.827E-02	4.300E-02	3.831E-02	5.615E-12
Ba-137m	5.245E-02	5.008E-02	4.782E-02	4.566E-02	4.068E-02	3.624E-02	5.312E-12
Ce-141	1.388E-14	2.391E-21	0.00	0.00	0.00	0.00	0.00
Ce-142	1.664E-11	1.664E-11	1.664E-11	1.664E-11	1.664E-11	1.664E-11	1.664E-11
Ce-144	1.074E-02	1.810E-03	3.048E-04	5.133E-05	5.976E-07	6.957E-09	0.00
Pr-144	1.075E-02	1.810E-03	3.048E-04	5.134E-05	5.976E-07	6.957E-09	0.00
Pr-144m	1.289E-04	2.172E-05	3.658E-06	6.160E-07	7.172E-09	8.349E-11	0.00
Nd-144	8.804E-16	8.837E-16	8.843E-16	8.844E-16	8.844E-16	8.844E-16	8.844E-16
Pm-146	6.412E-07	4.984E-07	3.873E-07	3.010E-07	1.603E-07	8.537E-08	0.00
Sm-146	1.461E-13	1.503E-13	1.535E-13	1.560E-13	1.601E-13	1.623E-13	1.648E-13
Pm-147	3.075E-02	1.813E-02	1.069E-02	6.301E-03	1.681E-03	4.487E-04	0.00
Sm-147	3.381E-12	3.691E-12	3.873E-12	3.981E-12	4.094E-12	4.124E-12	4.135E-12
Pm-148	1.631E-14	7.718E-20	3.652E-25	0.00	0.00	0.00	0.00
Pm-148m	2.896E-13	1.370E-18	6.483E-24	0.00	0.00	0.00	0.00
Eu-150	1.875E-11	1.804E-11	1.736E-11	1.670E-11	1.517E-11	1.378E-11	8.807E-20
Sm-151	2.552E-04	2.513E-04	2.475E-04	2.437E-04	2.345E-04	2.256E-04	1.189E-07
Eu-152	1.160E-05	1.047E-05	9.457E-06	8.541E-06	6.620E-06	5.131E-06	0.00
Gd-153	5.788E-07	7.143E-08	8.816E-09	1.088E-09	5.823E-12	3.115E-14	0.00
Eu-154	2.724E-03	2.319E-03	1.973E-03	1.680E-03	1.122E-03	7.502E-04	0.00
Eu-155	1.430E-03	1.081E-03	8.176E-04	6.182E-04	3.073E-04	1.528E-04	0.00
Tb-160	1.226E-10	1.115E-13	1.014E-16	9.214E-20	0.00	0.00	0.00
Ho-166m	5.621E-10	5.615E-10	5.608E-10	5.602E-10	5.585E-10	5.569E-10	3.162E-10
Tm-170	1.674E-12	3.263E-14	6.361E-16	1.232E-17	6.534E-22	0.00	0.00
Tm-171	8.612E-12	4.183E-12	2.032E-12	9.871E-13	1.623E-13	2.670E-14	0.00
Total	2.889E-01	2.256E-01	1.981E-01	1.813E-01	1.544E-01	1.353E-01	1.232E-05

TABLE D.1.b. Fission Product Radioactivity by Isotope at 25 MWd/kgM, Ci/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-3	3.031E-04	2.709E-04	2.422E-04	2.165E-04	1.635E-04	1.235E-04	0.00
Be-10	2.202E-12	2.202E-12	2.202E-12	2.202E-12	2.202E-12	2.202E-12	2.201E-12
C-14	8.875E-11	8.872E-11	8.870E-11	8.868E-11	8.863E-11	8.857E-11	7.867E-11
Se-79	3.142E-07	3.142E-07	3.142E-07	3.142E-07	3.142E-07	3.142E-07	3.109E-07
Kr-81	2.855E-13	2.855E-13	2.855E-13	2.855E-13	2.855E-13	2.855E-13	2.845E-13
Kr-85	5.168E-03	4.541E-03	3.990E-03	3.506E-03	2.537E-03	1.837E-03	0.00
Rb-87	1.678E-11	1.678E-11	1.678E-11	1.678E-11	1.678E-11	1.678E-11	1.678E-11
Sr-89	6.251E-10	2.762E-14	1.220E-18	5.393E-23	0.00	0.00	0.00
Sr-90	5.044E-02	4.809E-02	4.586E-02	4.372E-02	3.882E-02	3.446E-02	2.553E-12
Y-90	5.045E-02	4.810E-02	4.587E-02	4.374E-02	3.883E-02	3.447E-02	2.553E-12
Y-91	1.266E-08	2.208E-12	3.849E-16	6.711E-20	0.00	0.00	0.00
Zr-93	1.405E-06	1.405E-06	1.405E-06	1.405E-06	1.405E-06	1.405E-06	1.404E-06
Nb-93m	3.926E-07	4.839E-07	5.663E-07	6.408E-07	7.969E-07	9.178E-07	1.334E-06
Nb-94	9.918E-11	9.917E-11	9.916E-11	9.916E-11	9.914E-11	9.912E-11	9.586E-11
Zr-95	7.661E-08	2.801E-11	1.024E-14	3.744E-18	0.00	0.00	0.00
Nb-95	1.701E-07	6.219E-11	2.274E-14	8.313E-18	0.00	0.00	0.00
Nb-95m	5.683E-10	2.078E-13	7.597E-17	2.778E-20	0.00	0.00	0.00
Tc-98	3.110E-12	3.110E-12	3.110E-12	3.110E-12	3.110E-12	3.110E-12	3.109E-12
Tc-99	1.017E-05	1.017E-05	1.017E-05	1.017E-05	1.017E-05	1.017E-05	1.014E-05
Rh-102	2.387E-07	1.480E-07	9.177E-08	5.690E-08	1.722E-08	5.213E-09	0.00
Ru-103	3.444E-12	8.690E-18	2.193E-23	0.00	0.00	0.00	0.00
Rh-103m	3.104E-12	7.834E-18	1.977E-23	0.00	0.00	0.00	0.00
Ru-106	1.466E-02	3.707E-03	9.369E-04	2.368E-04	7.607E-06	2.443E-07	0.00
Rh-106	1.466E-02	3.707E-03	9.369E-04	2.368E-04	7.607E-06	2.443E-07	0.00
Pd-107	7.580E-08	7.580E-08	7.580E-08	7.580E-08	7.580E-08	7.580E-08	7.579E-08
Ag-108	1.777E-12	1.758E-12	1.739E-12	1.720E-12	1.674E-12	1.629E-12	7.746E-15
Ag-108m	1.997E-11	1.975E-11	1.954E-11	1.933E-11	1.881E-11	1.830E-11	8.703E-14
Ag-109m	4.360E-11	1.464E-11	4.917E-12	1.651E-12	1.079E-13	7.049E-15	0.00
Cd-109	4.360E-11	1.464E-11	4.917E-12	1.651E-12	1.079E-13	7.049E-15	0.00
Ag-110	3.285E-07	4.330E-08	5.707E-09	7.523E-10	4.748E-12	2.996E-14	0.00
Ag-110m	2.470E-05	3.255E-06	4.291E-07	5.657E-08	3.570E-10	2.253E-12	0.00
Cd-113m	2.965E-05	2.697E-05	2.452E-05	2.230E-05	1.758E-05	1.387E-05	8.334E-26
In-114	1.853E-15	6.707E-20	2.428E-24	0.00	0.00	0.00	0.00
In-114m	1.936E-15	7.008E-20	2.537E-24	0.00	0.00	0.00	0.00
Cd-115m	8.663E-14	1.015E-18	1.190E-23	0.00	0.00	0.00	0.00
Sn-119m	1.417E-06	1.795E-07	2.273E-08	2.878E-09	1.642E-11	9.368E-14	0.00
Sn-121m	1.376E-07	1.339E-07	1.302E-07	1.267E-07	1.182E-07	1.103E-07	1.377E-13
Sn-123	5.193E-07	1.030E-08	2.044E-10	4.055E-12	2.248E-16	1.246E-20	0.00
Te-123m	7.249E-10	1.054E-11	1.532E-13	2.227E-15	5.677E-20	1.447E-24	0.00
Sb-124	1.886E-11	4.193E-15	9.320E-19	2.072E-22	0.00	0.00	0.00
Sb-125	2.986E-03	1.810E-03	1.097E-03	6.653E-04	1.904E-04	5.447E-05	0.00
Te-125m	7.285E-04	4.418E-04	2.678E-04	1.624E-04	4.645E-05	1.329E-05	0.00
Sn-126	5.726E-07	5.726E-07	5.726E-07	5.725E-07	5.725E-07	5.725E-07	5.686E-07
Sb-126	8.016E-08	8.016E-08	8.016E-08	8.016E-08	8.015E-08	8.015E-08	7.961E-08
Sb-126m	5.726E-07	5.726E-07	5.726E-07	5.725E-07	5.725E-07	5.725E-07	5.686E-07

TABLE D.1.b. Fission Product Radioactivity by Isotope at 25 MWd/kgM, Ci/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Te-127	4.777E-07	4.590E-09	4.410E-11	4.237E-13	3.834E-18	3.469E-23	0.00
Te-127m	4.877E-07	4.686E-09	4.502E-11	4.325E-13	3.914E-18	3.541E-23	0.00
Te-129	8.841E-16	2.522E-22	0.00	0.00	0.00	0.00	0.00
Te-129m	1.358E-15	3.874E-22	0.00	0.00	0.00	0.00	0.00
I-129	2.372E-08	2.372E-08	2.372E-08	2.372E-08	2.372E-08	2.372E-08	2.372E-08
Cs-134	1.866E-02	9.525E-03	4.863E-03	2.483E-03	4.623E-04	8.610E-05	0.00
Cs-135	4.492E-07	4.492E-07	4.492E-07	4.492E-07	4.492E-07	4.492E-07	4.491E-07
Cs-137	6.936E-02	6.623E-02	6.324E-02	6.038E-02	5.380E-02	4.793E-02	7.025E-12
Ba-137m	6.562E-02	6.265E-02	5.983E-02	5.712E-02	5.089E-02	4.534E-02	6.646E-12
Ce-141	1.712E-14	2.949E-21	0.00	0.00	0.00	0.00	0.00
Ce-142	2.060E-11	2.060E-11	2.060E-11	2.060E-11	2.060E-11	2.060E-11	2.060E-11
Ce-144	1.313E-02	2.211E-03	3.723E-04	6.271E-05	7.300E-07	8.499E-09	0.00
Pr-144	1.313E-02	2.211E-03	3.723E-04	6.271E-05	7.300E-07	8.500E-09	0.00
Pr-144m	1.575E-04	2.653E-05	4.468E-06	7.525E-07	8.760E-09	1.020E-10	0.00
Nd-144	1.129E-15	1.133E-15	1.134E-15	1.134E-15	1.134E-15	1.134E-15	1.134E-15
Pm-146	9.471E-07	7.361E-07	5.721E-07	4.446E-07	2.368E-07	1.261E-07	0.00
Sm-146	2.159E-13	2.220E-13	2.268E-13	2.305E-13	2.365E-13	2.398E-13	2.434E-13
Pm-147	3.406E-02	2.008E-02	1.184E-02	6.979E-03	1.862E-03	4.969E-04	0.00
Sm-147	3.738E-12	4.081E-12	4.283E-12	4.402E-12	4.528E-12	4.561E-12	4.573E-12
Pm-148	1.983E-14	9.384E-20	4.440E-25	0.00	0.00	0.00	0.00
Pm-148m	3.521E-13	1.666E-18	7.883E-24	0.00	0.00	0.00	0.00
Eu-150	2.063E-11	1.985E-11	1.910E-11	1.838E-11	1.669E-11	1.516E-11	9.681E-20
Sm-151	2.765E-04	2.723E-04	2.681E-04	2.640E-04	2.541E-04	2.445E-04	1.289E-07
Eu-152	1.042E-05	9.411E-06	8.499E-06	7.676E-06	5.949E-06	4.611E-06	0.00
Gd-153	7.051E-07	8.702E-08	1.074E-08	1.325E-09	7.092E-12	3.796E-14	0.00
Eu-154	4.327E-03	3.683E-03	3.134E-03	2.668E-03	1.783E-03	1.192E-03	0.00
Eu-155	2.131E-03	1.612E-03	1.219E-03	9.214E-04	4.581E-04	2.277E-04	0.00
Tb-160	2.225E-10	2.023E-13	1.839E-16	1.672E-19	0.00	0.00	0.00
Ho-166m	1.118E-09	1.117E-09	1.116E-09	1.114E-09	1.111E-09	1.108E-09	6.291E-10
Tm-170	4.180E-12	8.148E-14	1.588E-15	3.101E-17	1.645E-21	8.725E-26	0.00
Tm-171	2.800E-11	1.360E-11	6.607E-12	3.210E-12	5.279E-13	8.681E-14	0.00
Total	3.603E-01	2.792E-01	2.444E-01	2.235E-01	1.901E-01	1.665E-01	1.508E-05

TABLE D.1.c. Fission Product Radioactivity by Isotope at 30 MWd/kgM, Ci/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-3	3.705E-04	3.312E-04	2.960E-04	2.646E-04	1.998E-04	1.509E-04	0.00
Be-10	2.637E-12	2.637E-12	2.637E-12	2.637E-12	2.637E-12	2.637E-12	2.636E-12
C-14	1.063E-10	1.063E-10	1.062E-10	1.062E-10	1.062E-10	1.061E-10	9.423E-11
Se-79	3.727E-07	3.727E-07	3.727E-07	3.727E-07	3.726E-07	3.726E-07	3.687E-07
Kr-81	4.085E-13	4.085E-13	4.084E-13	4.084E-13	4.084E-13	4.084E-13	4.071E-13
Kr-85	6.009E-03	5.280E-03	4.640E-03	4.077E-03	2.951E-03	2.136E-03	0.00
Rb-87	1.943E-11	1.943E-11	1.943E-11	1.943E-11	1.943E-11	1.943E-11	1.943E-11
Sr-89	6.963E-10	3.077E-14	1.359E-18	6.007E-23	0.00	0.00	0.00
Sr-90	5.828E-02	5.558E-02	5.299E-02	5.053E-02	4.486E-02	3.983E-02	2.950E-12
Y-90	5.830E-02	5.559E-02	5.300E-02	5.054E-02	4.487E-02	3.984E-02	2.951E-12
Y-91	1.427E-08	2.488E-12	4.338E-16	7.564E-20	0.00	0.00	0.00
Zr-93	1.645E-06	1.645E-06	1.645E-06	1.645E-06	1.645E-06	1.645E-06	1.644E-06
Nb-93m	4.610E-07	5.677E-07	6.642E-07	7.512E-07	9.338E-07	1.075E-06	1.562E-06
Nb-94	1.278E-10	1.278E-10	1.278E-10	1.278E-10	1.278E-10	1.277E-10	1.235E-10
Zr-95	8.969E-08	3.279E-11	1.199E-14	4.383E-18	0.00	0.00	0.00
Nb-95	1.991E-07	7.280E-11	2.662E-14	9.732E-18	0.00	0.00	0.00
Nb-95m	6.653E-10	2.433E-13	8.894E-17	3.252E-20	0.00	0.00	0.00
Tc-98	4.576E-12	4.576E-12	4.576E-12	4.576E-12	4.576E-12	4.576E-12	4.575E-12
Tc-99	1.195E-05	1.195E-05	1.195E-05	1.195E-05	1.195E-05	1.195E-05	1.191E-05
Rh-102	3.490E-07	2.164E-07	1.342E-07	8.318E-08	2.518E-08	7.620E-09	0.00
Ru-103	4.302E-12	1.086E-17	2.739E-23	0.00	0.00	0.00	0.00
Rh-103m	3.878E-12	9.786E-18	2.470E-23	0.00	0.00	0.00	0.00
Ru-106	1.938E-02	4.897E-03	1.238E-03	3.129E-04	1.005E-05	3.228E-07	0.00
Rh-106	1.938E-02	4.897E-03	1.238E-03	3.129E-04	1.005E-05	3.228E-07	0.00
Pd-107	1.006E-07	1.006E-07	1.006E-07	1.006E-07	1.006E-07	1.006E-07	1.005E-07
Ag-108	2.414E-12	2.388E-12	2.362E-12	2.336E-12	2.273E-12	2.212E-12	1.052E-14
Ag-108m	2.712E-11	2.683E-11	2.654E-11	2.625E-11	2.554E-11	2.485E-11	1.182E-13
Ag-109m	8.513E-11	2.859E-11	9.600E-12	3.224E-12	2.106E-13	1.376E-14	0.00
Cd-109	8.513E-11	2.859E-11	9.600E-12	3.224E-12	2.106E-13	1.376E-14	0.00
Ag-110	5.301E-07	6.988E-08	9.211E-09	1.214E-09	7.662E-12	4.834E-14	0.00
Ag-110m	3.986E-05	5.254E-06	6.926E-07	9.130E-08	5.761E-10	3.634E-12	0.00
Cd-113m	3.924E-05	3.568E-05	3.245E-05	2.951E-05	2.327E-05	1.835E-05	1.103E-25
In-114	3.003E-15	1.087E-19	3.937E-24	0.00	0.00	0.00	0.00
In-114m	3.138E-15	1.136E-19	4.114E-24	0.00	0.00	0.00	0.00
Cd-115m	1.113E-13	1.304E-18	1.529E-23	0.00	0.00	0.00	0.00
Sn-119m	1.837E-06	2.327E-07	2.946E-08	3.730E-09	2.129E-11	1.214E-13	0.00
Sn-121m	1.740E-07	1.693E-07	1.646E-07	1.601E-07	1.494E-07	1.394E-07	1.741E-13
Sn-123	6.463E-07	1.282E-08	2.544E-10	5.047E-12	2.798E-16	1.551E-20	0.00
Te-123m	1.385E-09	2.014E-11	2.928E-13	4.257E-15	1.085E-19	2.765E-24	0.00
Sb-124	2.932E-11	6.518E-15	1.449E-18	3.221E-22	0.00	0.00	0.00
Sb-125	3.716E-03	2.253E-03	1.366E-03	8.280E-04	2.369E-04	6.780E-05	0.00
Te-125m	9.067E-04	5.498E-04	3.333E-04	2.021E-04	5.781E-05	1.654E-05	0.00
Sn-126	7.083E-07	7.083E-07	7.083E-07	7.083E-07	7.083E-07	7.083E-07	7.035E-07
Sb-126	9.917E-08	9.917E-08	9.917E-08	9.916E-08	9.916E-08	9.916E-08	9.849E-08
Sb-126m	7.083E-07	7.083E-07	7.083E-07	7.083E-07	7.083E-07	7.083E-07	7.035E-07

TABLE D.1.c. Fission Product Radioactivity by Isotope at 30 MWd/kgM, Ci/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Te-127	6.000E-07	5.765E-09	5.540E-11	5.322E-13	4.816E-18	4.358E-23	0.00
Te-127m	6.126E-07	5.886E-09	5.656E-11	5.434E-13	4.917E-18	4.449E-23	0.00
Te-129	1.093E-15	3.118E-22	0.00	0.00	0.00	0.00	0.00
Te-129m	1.680E-15	4.791E-22	0.00	0.00	0.00	0.00	0.00
I-129	2.879E-08	2.879E-08	2.879E-08	2.879E-08	2.879E-08	2.879E-08	2.879E-08
Cs-134	2.679E-02	1.368E-02	6.982E-03	3.565E-03	6.638E-04	1.236E-04	0.00
Cs-135	4.800E-07	4.800E-07	4.800E-07	4.800E-07	4.800E-07	4.800E-07	4.798E-07
Cs-137	8.329E-02	7.953E-02	7.594E-02	7.251E-02	6.460E-02	5.755E-02	8.435E-12
Ba-137m	7.879E-02	7.523E-02	7.184E-02	6.859E-02	6.111E-02	5.444E-02	7.980E-12
Ce-141	2.029E-14	3.495E-21	0.00	0.00	0.00	0.00	0.00
Ce-142	2.450E-11	2.450E-11	2.450E-11	2.450E-11	2.450E-11	2.450E-11	2.450E-11
Ce-144	1.542E-02	2.597E-03	4.374E-04	7.367E-05	8.576E-07	9.984E-09	0.00
Pr-144	1.542E-02	2.597E-03	4.374E-04	7.367E-05	8.576E-07	9.984E-09	0.00
Pr-144m	1.850E-04	3.116E-05	5.249E-06	8.840E-07	1.029E-08	1.198E-10	0.00
Nd-144	1.390E-15	1.395E-15	1.396E-15	1.396E-15	1.396E-15	1.396E-15	1.396E-15
Pm-146	1.293E-06	1.005E-06	7.812E-07	6.072E-07	3.233E-07	1.722E-07	0.00
Sm-146	2.945E-13	3.029E-13	3.094E-13	3.144E-13	3.227E-13	3.271E-13	3.321E-13
Pm-147	3.620E-02	2.134E-02	1.258E-02	7.417E-03	1.979E-03	5.281E-04	0.00
Sm-147	3.961E-12	4.325E-12	4.540E-12	4.666E-12	4.799E-12	4.835E-12	4.848E-12
Pm-148	2.288E-14	1.082E-19	5.121E-25	0.00	0.00	0.00	0.00
Pm-148m	4.061E-13	1.922E-18	9.092E-24	0.00	0.00	0.00	0.00
Eu-150	2.228E-11	2.144E-11	2.063E-11	1.985E-11	1.803E-11	1.637E-11	1.046E-19
Sm-151	2.933E-04	2.888E-04	2.844E-04	2.800E-04	2.694E-04	2.593E-04	1.367E-07
Eu-152	9.309E-06	8.407E-06	7.592E-06	6.857E-06	5.314E-06	4.119E-06	0.00
Gd-153	8.181E-07	1.010E-07	1.246E-08	1.538E-09	8.226E-12	4.402E-14	0.00
Eu-154	6.212E-03	5.287E-03	4.500E-03	3.830E-03	2.560E-03	1.711E-03	0.00
Eu-155	2.982E-03	2.255E-03	1.705E-03	1.289E-03	6.409E-04	3.186E-04	0.00
Tb-160	3.725E-10	3.386E-13	3.078E-16	2.798E-19	0.00	0.00	0.00
Ho-166m	2.029E-09	2.027E-09	2.025E-09	2.022E-09	2.016E-09	2.011E-09	1.142E-09
Tm-170	9.075E-12	1.769E-13	3.448E-15	6.718E-17	3.564E-21	1.891E-25	0.00
Tm-171	7.500E-11	3.643E-11	1.770E-11	8.597E-12	1.414E-12	2.325E-13	0.00
Total	4.320E-01	3.323E-01	2.899E-01	2.648E-01	2.251E-01	1.970E-01	1.774E-05

TABLE D.1.d. Fission Product Radioactivity by Isotope at 35 MWd/kgM, Ci/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-3	4.398E-04	3.931E-04	3.513E-04	3.140E-04	2.372E-04	1.791E-04	0.00
Be-10	3.071E-12	3.071E-12	3.071E-12	3.071E-12	3.071E-12	3.071E-12	3.070E-12
C-14	1.238E-10	1.238E-10	1.237E-10	1.237E-10	1.236E-10	1.236E-10	1.097E-10
Se-79	4.297E-07	4.297E-07	4.297E-07	4.297E-07	4.297E-07	4.297E-07	4.252E-07
Kr-81	5.584E-13	5.584E-13	5.584E-13	5.584E-13	5.584E-13	5.583E-13	5.565E-13
Kr-85	6.799E-03	5.974E-03	5.249E-03	4.613E-03	3.338E-03	2.416E-03	0.00
Rb-87	2.190E-11	2.190E-11	2.190E-11	2.190E-11	2.190E-11	2.190E-11	2.190E-11
Sr-89	7.525E-10	3.325E-14	1.469E-18	6.492E-23	0.00	0.00	0.00
Sr-90	6.552E-02	6.247E-02	5.957E-02	5.680E-02	5.043E-02	4.477E-02	3.316E-12
Y-90	6.554E-02	6.249E-02	5.959E-02	5.682E-02	5.044E-02	4.478E-02	3.317E-12
Y-91	1.562E-08	2.723E-12	4.748E-16	8.278E-20	0.00	0.00	0.00
Zr-93	1.873E-06	1.873E-06	1.873E-06	1.873E-06	1.873E-06	1.873E-06	1.872E-06
Nb-93m	5.265E-07	6.479E-07	7.576E-07	8.566E-07	1.064E-06	1.225E-06	1.779E-06
Nb-94	1.579E-10	1.579E-10	1.579E-10	1.579E-10	1.578E-10	1.578E-10	1.526E-10
Zr-95	1.021E-07	3.732E-11	1.364E-14	4.988E-18	0.00	0.00	0.00
Nb-95	2.266E-07	8.285E-11	3.029E-14	1.107E-17	0.00	0.00	0.00
Nb-95m	7.571E-10	2.768E-13	1.012E-16	3.701E-20	0.00	0.00	0.00
Tc-98	6.370E-12	6.370E-12	6.370E-12	6.370E-12	6.370E-12	6.370E-12	6.369E-12
Tc-99	1.364E-05	1.364E-05	1.364E-05	1.364E-05	1.364E-05	1.364E-05	1.359E-05
Rh-102	4.806E-07	2.980E-07	1.848E-07	1.146E-07	3.467E-08	1.049E-08	0.00
Ru-103	5.235E-12	1.321E-17	3.334E-23	0.00	0.00	0.00	0.00
Rh-103m	4.719E-12	1.191E-17	3.006E-23	0.00	0.00	0.00	0.00
Ru-106	2.462E-02	6.223E-03	1.573E-03	3.976E-04	1.277E-05	4.102E-07	0.00
Rh-106	2.462E-02	6.223E-03	1.573E-03	3.976E-04	1.277E-05	4.102E-07	0.00
Pd-107	1.279E-07	1.279E-07	1.279E-07	1.279E-07	1.279E-07	1.279E-07	1.279E-07
Ag-108	3.137E-12	3.103E-12	3.070E-12	3.036E-12	2.955E-12	2.875E-12	1.367E-14
Ag-108m	3.525E-11	3.487E-11	3.449E-11	3.412E-11	3.320E-11	3.230E-11	1.536E-13
Ag-109m	1.504E-10	5.052E-11	1.696E-11	5.696E-12	3.722E-13	2.432E-14	0.00
Cd-109	1.504E-10	5.052E-11	1.696E-11	5.696E-12	3.722E-13	2.432E-14	0.00
Ag-110	7.935E-07	1.046E-07	1.379E-08	1.818E-09	1.147E-11	7.235E-14	0.00
Ag-110m	5.966E-05	7.865E-06	1.037E-06	1.367E-07	8.621E-10	5.440E-12	0.00
Cd-113m	5.042E-05	4.585E-05	4.169E-05	3.791E-05	2.990E-05	2.358E-05	1.417E-25
In-114	4.527E-15	1.639E-19	5.934E-24	0.00	0.00	0.00	0.00
In-114m	4.731E-15	1.713E-19	6.201E-24	0.00	0.00	0.00	0.00
Cd-115m	1.377E-13	1.614E-18	1.892E-23	0.00	0.00	0.00	0.00
Sn-119m	2.314E-06	2.930E-07	3.710E-08	4.698E-09	2.681E-11	1.529E-13	0.00
Sn-121m	2.123E-07	2.064E-07	2.008E-07	1.953E-07	1.822E-07	1.700E-07	2.123E-13
Sn-123	7.776E-07	1.543E-08	3.061E-10	6.073E-12	3.367E-16	1.866E-20	0.00
Te-123m	2.401E-09	3.491E-11	5.075E-13	7.379E-15	1.881E-19	4.793E-24	0.00
Sb-124	4.256E-11	9.462E-15	2.103E-18	4.676E-22	0.00	0.00	0.00
Sb-125	4.484E-03	2.718E-03	1.648E-03	9.989E-04	2.858E-04	8.180E-05	0.00
Te-125m	1.094E-03	6.633E-04	4.021E-04	2.438E-04	6.974E-05	1.996E-05	0.00
Sn-126	8.497E-07	8.496E-07	8.496E-07	8.496E-07	8.496E-07	8.496E-07	8.438E-07
Sb-126	1.190E-07	1.189E-07	1.189E-07	1.189E-07	1.189E-07	1.189E-07	1.181E-07
Sb-126m	8.497E-07	8.496E-07	8.496E-07	8.496E-07	8.496E-07	8.496E-07	8.438E-07

TABLE D.1.d. Fission Product Radioactivity by Isotope at 35 MWd/kgM, Ci/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Te-127	7.290E-07	7.005E-09	6.730E-11	6.466E-13	5.851E-18	5.294E-23	0.00
Te-127m	7.442E-07	7.151E-09	6.871E-11	6.601E-13	5.973E-18	5.405E-23	0.00
Te-129	1.307E-15	3.727E-22	0.00	0.00	0.00	0.00	0.00
Te-129m	2.008E-15	5.726E-22	0.00	0.00	0.00	0.00	0.00
I-129	3.387E-08	3.387E-08	3.387E-08	3.387E-08	3.387E-08	3.387E-08	3.387E-08
Cs-134	3.630E-02	1.853E-02	9.460E-03	4.829E-03	8.994E-04	1.675E-04	0.00
Cs-135	5.062E-07	5.062E-07	5.062E-07	5.062E-07	5.062E-07	5.062E-07	5.060E-07
Cs-137	9.722E-02	9.283E-02	8.864E-02	8.464E-02	7.540E-02	6.718E-02	9.846E-12
Ba-137m	9.197E-02	8.782E-02	8.385E-02	8.007E-02	7.133E-02	6.355E-02	9.315E-12
Ce-141	2.339E-14	4.028E-21	0.00	0.00	0.00	0.00	0.00
Ce-142	2.834E-11	2.834E-11	2.834E-11	2.834E-11	2.834E-11	2.834E-11	2.834E-11
Ce-144	1.762E-02	2.967E-03	4.998E-04	8.417E-05	9.799E-07	1.141E-08	0.00
Pr-144	1.762E-02	2.967E-03	4.998E-04	8.417E-05	9.799E-07	1.141E-08	0.00
Pr-144m	2.114E-04	3.561E-05	5.997E-06	1.010E-06	1.176E-08	1.369E-10	0.00
Nd-144	1.662E-15	1.667E-15	1.668E-15	1.669E-15	1.669E-15	1.669E-15	1.669E-15
Pm-146	1.672E-06	1.299E-06	1.010E-06	7.848E-07	4.179E-07	2.226E-07	0.00
Sm-146	3.797E-13	3.905E-13	3.990E-13	4.055E-13	4.162E-13	4.218E-13	4.283E-13
Pm-147	3.743E-02	2.207E-02	1.301E-02	7.670E-03	2.047E-03	5.462E-04	0.00
Sm-147	4.073E-12	4.450E-12	4.672E-12	4.803E-12	4.941E-12	4.977E-12	4.991E-12
Pm-148	2.559E-14	1.211E-19	5.729E-25	0.00	0.00	0.00	0.00
Pm-148m	4.543E-13	2.150E-18	1.017E-23	0.00	0.00	0.00	0.00
Eu-150	2.373E-11	2.283E-11	2.197E-11	2.114E-11	1.920E-11	1.744E-11	1.114E-19
Sm-151	3.107E-04	3.060E-04	3.013E-04	2.967E-04	2.855E-04	2.747E-04	1.448E-07
Eu-152	8.258E-06	7.458E-06	6.735E-06	6.083E-06	4.714E-06	3.654E-06	0.00
Gd-153	9.128E-07	1.127E-07	1.390E-08	1.716E-09	9.180E-12	4.912E-14	0.00
Eu-154	8.285E-03	7.051E-03	6.002E-03	5.108E-03	3.414E-03	2.282E-03	0.00
Eu-155	3.957E-03	2.992E-03	2.263E-03	1.711E-03	8.505E-04	4.229E-04	0.00
Tb-160	5.750E-10	5.227E-13	4.752E-16	4.320E-19	0.00	0.00	0.00
Ho-166m	3.456E-09	3.452E-09	3.448E-09	3.444E-09	3.434E-09	3.424E-09	1.944E-09
Tm-170	1.770E-11	3.450E-13	6.724E-15	1.310E-16	6.951E-21	3.687E-25	0.00
Tm-171	1.764E-10	8.569E-11	4.163E-11	2.022E-11	3.325E-12	5.469E-13	0.00
Total	5.042E-01	3.848E-01	3.346E-01	3.051E-01	2.591E-01	2.267E-01	2.029E-05

TABLE D.1.e. Fission Product Radioactivity by Isotope at 40 MWd/kgM, Ci/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-3	5.107E-04	4.564E-04	4.080E-04	3.646E-04	2.754E-04	2.080E-04	0.00
Be-10	3.504E-12	3.504E-12	3.504E-12	3.504E-12	3.504E-12	3.504E-12	3.503E-12
C-14	1.412E-10	1.412E-10	1.412E-10	1.411E-10	1.410E-10	1.410E-10	1.252E-10
Se-79	4.854E-07	4.854E-07	4.854E-07	4.854E-07	4.854E-07	4.853E-07	4.803E-07
Kr-81	7.369E-13	7.369E-13	7.369E-13	7.369E-13	7.369E-13	7.369E-13	7.345E-13
Kr-85	7.541E-03	6.627E-03	5.823E-03	5.116E-03	3.703E-03	2.680E-03	0.00
Rb-87	2.419E-11	2.419E-11	2.419E-11	2.419E-11	2.419E-11	2.419E-11	2.419E-11
Sr-89	7.987E-10	3.529E-14	1.559E-18	6.891E-23	0.00	0.00	0.00
Sr-90	7.220E-02	6.885E-02	6.565E-02	6.259E-02	5.557E-02	4.934E-02	3.654E-12
Y-90	7.222E-02	6.886E-02	6.566E-02	6.261E-02	5.558E-02	4.935E-02	3.655E-12
Y-91	1.679E-08	2.928E-12	5.105E-16	8.900E-20	0.00	0.00	0.00
Zr-93	2.091E-06	2.091E-06	2.091E-06	2.091E-06	2.091E-06	2.091E-06	2.090E-06
Nb-93m	5.893E-07	7.247E-07	8.469E-07	9.573E-07	1.189E-06	1.368E-06	1.985E-06
Nb-94	1.889E-10	1.889E-10	1.889E-10	1.889E-10	1.889E-10	1.888E-10	1.826E-10
Zr-95	1.140E-07	4.167E-11	1.524E-14	5.570E-18	0.00	0.00	0.00
Nb-95	2.530E-07	9.251E-11	3.382E-14	1.237E-17	0.00	0.00	0.00
Nb-95m	8.455E-10	3.091E-13	1.130E-16	4.132E-20	0.00	0.00	0.00
Tc-98	8.491E-12	8.491E-12	8.491E-12	8.491E-12	8.491E-12	8.491E-12	8.490E-12
Tc-99	1.523E-05	1.523E-05	1.523E-05	1.523E-05	1.523E-05	1.523E-05	1.518E-05
Rh-102	6.313E-07	3.914E-07	2.427E-07	1.505E-07	4.554E-08	1.378E-08	0.00
Ru-103	6.152E-12	1.553E-17	3.918E-23	0.00	0.00	0.00	0.00
Rh-103m	5.546E-12	1.400E-17	3.532E-23	0.00	0.00	0.00	0.00
Ru-106	3.029E-02	7.657E-03	1.935E-03	4.892E-04	1.571E-05	5.047E-07	0.00
Rh-106	3.029E-02	7.657E-03	1.935E-03	4.892E-04	1.571E-05	5.048E-07	0.00
Pd-107	1.575E-07	1.575E-07	1.575E-07	1.575E-07	1.575E-07	1.575E-07	1.575E-07
Ag-108	3.946E-12	3.903E-12	3.861E-12	3.819E-12	3.716E-12	3.616E-12	1.720E-14
Ag-108m	4.434E-11	4.386E-11	4.338E-11	4.291E-11	4.175E-11	4.063E-11	1.932E-13
Ag-109m	2.455E-10	8.244E-11	2.768E-11	9.296E-12	6.074E-13	3.969E-14	0.00
Cd-109	2.455E-10	8.244E-11	2.768E-11	9.296E-12	6.074E-13	3.969E-14	0.00
Ag-110	1.119E-06	1.475E-07	1.945E-08	2.563E-09	1.617E-11	1.020E-13	0.00
Ag-110m	8.414E-05	1.109E-05	1.462E-06	1.927E-07	1.216E-09	7.672E-12	0.00
Cd-113m	6.331E-05	5.758E-05	5.236E-05	4.761E-05	3.754E-05	2.960E-05	1.779E-25
In-114	6.499E-15	2.353E-19	8.519E-24	0.00	0.00	0.00	0.00
In-114m	6.790E-15	2.459E-19	8.901E-24	0.00	0.00	0.00	0.00
Cd-115m	1.657E-13	1.942E-18	2.276E-23	0.00	0.00	0.00	0.00
Sn-119m	2.842E-06	3.599E-07	4.558E-08	5.771E-09	3.295E-11	1.880E-13	0.00
Sn-121m	2.520E-07	2.451E-07	2.384E-07	2.319E-07	2.164E-07	2.019E-07	2.521E-13
Sn-123	9.123E-07	1.810E-08	3.591E-10	7.125E-12	3.950E-16	2.190E-20	0.00
Te-123m	3.904E-09	5.676E-11	8.253E-13	1.200E-14	3.058E-19	7.793E-24	0.00
Sb-124	5.881E-11	1.307E-14	2.906E-18	6.460E-22	0.00	0.00	0.00
Sb-125	5.279E-03	3.200E-03	1.940E-03	1.176E-03	3.366E-04	9.631E-05	0.00
Te-125m	1.288E-03	7.811E-04	4.735E-04	2.871E-04	8.212E-05	2.350E-05	0.00
Sn-126	9.956E-07	9.956E-07	9.956E-07	9.956E-07	9.955E-07	9.955E-07	9.888E-07
Sb-126	1.394E-07	1.394E-07	1.394E-07	1.394E-07	1.394E-07	1.394E-07	1.384E-07
Sb-126m	9.956E-07	9.956E-07	9.956E-07	9.956E-07	9.955E-07	9.955E-07	9.888E-07

TABLE D.1.e. Fission Product Radioactivity by Isotope at 40 MWd/kgM, Ci/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Te-127	8.616E-07	8.279E-09	7.955E-11	7.643E-13	6.915E-18	6.258E-23	0.00
Te-127m	8.796E-07	8.452E-09	8.121E-11	7.803E-13	7.060E-18	6.389E-23	0.00
Te-129	1.523E-15	4.344E-22	0.00	0.00	0.00	0.00	0.00
Te-129m	2.339E-15	6.673E-22	0.00	0.00	0.00	0.00	0.00
I-129	3.892E-08	3.892E-08	3.892E-08	3.892E-08	3.892E-08	3.892E-08	3.892E-08
Cs-134	4.693E-02	2.396E-02	1.223E-02	6.245E-03	1.163E-03	2.166E-04	0.00
Cs-135	5.314E-07	5.314E-07	5.314E-07	5.314E-07	5.314E-07	5.314E-07	5.313E-07
Cs-137	1.112E-01	1.061E-01	1.013E-01	9.677E-02	8.621E-02	7.681E-02	1.126E-11
Ba-137m	1.052E-01	1.004E-01	9.587E-02	9.154E-02	8.156E-02	7.266E-02	1.065E-11
Ce-141	2.643E-14	4.553E-21	0.00	0.00	0.00	0.00	0.00
Ce-142	3.213E-11	3.213E-11	3.213E-11	3.213E-11	3.213E-11	3.213E-11	3.213E-11
Ce-144	1.974E-02	3.325E-03	5.601E-04	9.433E-05	1.098E-06	1.279E-08	0.00
Pr-144	1.974E-02	3.325E-03	5.601E-04	9.433E-05	1.098E-06	1.279E-08	0.00
Pr-144m	2.369E-04	3.990E-05	6.721E-06	1.132E-06	1.318E-08	1.534E-10	0.00
Nd-144	1.943E-15	1.949E-15	1.950E-15	1.950E-15	1.950E-15	1.950E-15	1.950E-15
Pm-146	2.073E-06	1.611E-06	1.252E-06	9.730E-07	5.182E-07	2.759E-07	0.00
Sm-146	4.683E-13	4.818E-13	4.922E-13	5.003E-13	5.135E-13	5.206E-13	5.286E-13
Pm-147	3.810E-02	2.246E-02	1.324E-02	7.806E-03	2.083E-03	5.559E-04	0.00
Sm-147	4.107E-12	4.490E-12	4.716E-12	4.849E-12	4.990E-12	5.027E-12	5.041E-12
Pm-148	2.707E-14	1.281E-19	6.061E-25	0.00	0.00	0.00	0.00
Pm-148m	4.806E-13	2.274E-18	1.076E-23	0.00	0.00	0.00	0.00
Eu-150	2.506E-11	2.412E-11	2.321E-11	2.233E-11	2.028E-11	1.842E-11	1.177E-19
Sm-151	3.285E-04	3.234E-04	3.185E-04	3.136E-04	3.018E-04	2.904E-04	1.531E-07
Eu-152	7.395E-06	6.679E-06	6.032E-06	5.447E-06	4.222E-06	3.272E-06	0.00
Gd-153	9.897E-07	1.221E-07	1.507E-08	1.860E-09	9.951E-12	5.324E-14	0.00
Eu-154	1.043E-02	8.876E-03	7.554E-03	6.430E-03	4.297E-03	2.872E-03	0.00
Eu-155	5.000E-03	3.781E-03	2.859E-03	2.162E-03	1.075E-03	5.343E-04	0.00
Tb-160	8.380E-10	7.618E-13	6.926E-16	6.296E-19	0.00	0.00	0.00
Ho-166m	5.592E-09	5.586E-09	5.579E-09	5.573E-09	5.557E-09	5.541E-09	3.146E-09
Tm-170	3.189E-11	6.216E-13	1.212E-14	2.361E-16	1.253E-20	6.645E-25	0.00
Tm-171	3.736E-10	1.815E-10	8.816E-11	4.283E-11	7.043E-12	1.158E-12	0.00
Total	5.766E-01	4.368E-01	3.785E-01	3.447E-01	2.923E-01	2.557E-01	2.273E-05

Chris McKenny
Don Carlson

Ci 3.7×10^{10} dis/sec
energy

TABLE D.1.f. Fission Product Radioactivity by Isotope at 45 MWd/kgM, Ci/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-3	5.829E-04	5.210E-04	4.657E-04	4.162E-04	3.144E-04	2.374E-04	0.00
Be-10	3.936E-12	3.936E-12	3.936E-12	3.936E-12	3.936E-12	3.936E-12	3.934E-12
C-14	1.586E-10	1.586E-10	1.585E-10	1.585E-10	1.584E-10	1.583E-10	1.406E-10
Se-79	5.399E-07	5.398E-07	5.398E-07	5.398E-07	5.398E-07	5.398E-07	5.341E-07
Kr-81	9.454E-13	9.454E-13	9.454E-13	9.454E-13	9.453E-13	9.453E-13	9.423E-13
Kr-85	8.244E-03	7.244E-03	6.365E-03	5.593E-03	4.048E-03	2.930E-03	0.00
Rb-87	2.633E-11	2.633E-11	2.633E-11	2.633E-11	2.633E-11	2.633E-11	2.633E-11
Sr-89	8.387E-10	3.706E-14	1.637E-18	7.236E-23	0.00	0.00	0.00
Sr-90	7.841E-02	7.476E-02	7.129E-02	6.797E-02	6.035E-02	5.358E-02	3.968E-12
Y-90	7.843E-02	7.478E-02	7.130E-02	6.799E-02	6.036E-02	5.359E-02	3.969E-12
Y-91	1.786E-08	3.114E-12	5.429E-16	9.466E-20	0.00	0.00	0.00
Zr-93	2.299E-06	2.299E-06	2.299E-06	2.299E-06	2.299E-06	2.299E-06	2.298E-06
Nb-93m	6.497E-07	7.983E-07	9.326E-07	1.054E-06	1.308E-06	1.505E-06	2.183E-06
Nb-94	2.205E-10	2.205E-10	2.205E-10	2.205E-10	2.205E-10	2.204E-10	2.132E-10
Zr-95	1.256E-07	4.591E-11	1.679E-14	6.137E-18	0.00	0.00	0.00
Nb-95	2.788E-07	1.019E-10	3.727E-14	1.363E-17	0.00	0.00	0.00
Nb-95m	9.315E-10	3.406E-13	1.245E-16	4.553E-20	0.00	0.00	0.00
Tc-98	1.093E-11	1.093E-11	1.093E-11	1.093E-11	1.093E-11	1.093E-11	1.093E-11
Tc-99	1.672E-05	1.672E-05	1.672E-05	1.672E-05	1.672E-05	1.672E-05	1.667E-05
Rh-102	7.986E-07	4.951E-07	3.070E-07	1.903E-07	5.761E-08	1.744E-08	0.00
Ru-103	7.094E-12	1.790E-17	4.518E-23	0.00	0.00	0.00	0.00
Rh-103m	6.395E-12	1.614E-17	4.073E-23	0.00	0.00	0.00	0.00
Ru-106	3.630E-02	9.176E-03	2.319E-03	5.863E-04	1.883E-05	6.049E-07	0.00
Rh-106	3.630E-02	9.176E-03	2.319E-03	5.863E-04	1.883E-05	6.049E-07	0.00
Pd-107	1.890E-07	1.890E-07	1.890E-07	1.890E-07	1.890E-07	1.890E-07	1.890E-07
Ag-108	4.836E-12	4.784E-12	4.732E-12	4.680E-12	4.554E-12	4.432E-12	2.108E-14
Ag-108m	5.434E-11	5.375E-11	5.316E-11	5.259E-11	5.117E-11	4.979E-11	2.368E-13
Ag-109m	3.759E-10	1.262E-10	4.239E-11	1.423E-11	9.300E-13	6.077E-14	0.00
Cd-109	3.759E-10	1.262E-10	4.239E-11	1.423E-11	9.300E-13	6.077E-14	0.00
Ag-110	1.506E-06	1.985E-07	2.616E-08	3.449E-09	2.176E-11	1.373E-13	0.00
Ag-110m	1.132E-04	1.492E-05	1.967E-06	2.593E-07	1.636E-09	1.032E-11	0.00
Cd-113m	7.803E-05	7.095E-05	6.452E-05	5.867E-05	4.627E-05	3.648E-05	2.193E-25
In-114	8.976E-15	3.250E-19	1.177E-23	0.00	0.00	0.00	0.00
In-114m	9.379E-15	3.396E-19	1.229E-23	0.00	0.00	0.00	0.00
Cd-115m	1.945E-13	2.280E-18	2.671E-23	0.00	0.00	0.00	0.00
Sn-119m	3.422E-06	4.334E-07	5.487E-08	6.948E-09	3.963E-11	2.261E-13	0.00
Sn-121m	2.930E-07	2.850E-07	2.772E-07	2.696E-07	2.515E-07	2.347E-07	2.930E-13
Sn-123	1.051E-06	2.085E-08	4.137E-10	8.208E-12	4.550E-16	2.523E-20	0.00
Te-123m	5.967E-09	8.676E-11	1.261E-12	1.834E-14	4.673E-19	1.191E-23	0.00
Sb-124	7.814E-11	1.737E-14	3.861E-18	8.584E-22	0.00	0.00	0.00
Sb-125	6.097E-03	3.696E-03	2.241E-03	1.358E-03	3.887E-04	1.112E-04	0.00
Te-125m	1.488E-03	9.021E-04	5.469E-04	3.315E-04	9.484E-05	2.714E-05	0.00
Sn-126	1.145E-06	1.145E-06	1.145E-06	1.145E-06	1.145E-06	1.145E-06	1.137E-06
Sb-126	1.603E-07	1.603E-07	1.603E-07	1.603E-07	1.603E-07	1.603E-07	1.592E-07
Sb-126m	1.145E-06	1.145E-06	1.145E-06	1.145E-06	1.145E-06	1.145E-06	1.137E-06

TABLE D.1.f. Fission Product Radioactivity by Isotope at 45 MWd/kgM, Ci/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Te-127	9.964E-07	9.574E-09	9.199E-11	8.839E-13	7.998E-18	7.237E-23	0.00
Te-127m	1.017E-06	9.775E-09	9.392E-11	9.024E-13	8.165E-18	7.389E-23	0.00
Te-129	1.740E-15	4.963E-22	0.00	0.00	0.00	0.00	0.00
Te-129m	2.673E-15	7.625E-22	0.00	0.00	0.00	0.00	0.00
I-129	4.392E-08	4.392E-08	4.392E-08	4.392E-08	4.392E-08	4.392E-08	4.392E-08
Cs-134	5.848E-02	2.986E-02	1.524E-02	7.781E-03	1.449E-03	2.699E-04	0.00
Cs-135	5.577E-07	5.577E-07	5.577E-07	5.577E-07	5.577E-07	5.577E-07	5.575E-07
Cs-137	1.251E-01	1.194E-01	1.140E-01	1.089E-01	9.702E-02	8.643E-02	1.267E-11
Ba-137m	1.183E-01	1.130E-01	1.079E-01	1.030E-01	9.178E-02	8.177E-02	1.198E-11
Ce-141	2.944E-14	5.072E-21	0.00	0.00	0.00	0.00	0.00
Ce-142	3.586E-11	3.586E-11	3.586E-11	3.586E-11	3.586E-11	3.586E-11	3.586E-11
Ce-144	2.181E-02	3.674E-03	6.188E-04	1.042E-04	1.213E-06	1.412E-08	0.00
Pr-144	2.181E-02	3.674E-03	6.188E-04	1.042E-04	1.213E-06	1.412E-08	0.00
Pr-144m	2.618E-04	4.409E-05	7.426E-06	1.251E-06	1.456E-08	1.695E-10	0.00
Nd-144	2.231E-15	2.238E-15	2.239E-15	2.239E-15	2.239E-15	2.239E-15	2.239E-15
Pm-146	2.489E-06	1.935E-06	1.504E-06	1.169E-06	6.223E-07	3.314E-07	0.00
Sm-146	5.581E-13	5.742E-13	5.867E-13	5.964E-13	6.123E-13	6.208E-13	6.304E-13
Pm-147	3.841E-02	2.264E-02	1.335E-02	7.869E-03	2.100E-03	5.604E-04	0.00
Sm-147	4.085E-12	4.471E-12	4.699E-12	4.834E-12	4.975E-12	5.013E-12	5.027E-12
Pm-148	2.796E-14	1.323E-19	6.261E-25	0.00	0.00	0.00	0.00
Pm-148m	4.965E-13	2.349E-18	1.112E-23	0.00	0.00	0.00	0.00
Eu-150	2.634E-11	2.534E-11	2.438E-11	2.346E-11	2.131E-11	1.935E-11	1.236E-19
Sm-151	3.460E-04	3.408E-04	3.355E-04	3.304E-04	3.179E-04	3.059E-04	1.613E-07
Eu-152	6.706E-06	6.056E-06	5.469E-06	4.939E-06	3.828E-06	2.967E-06	0.00
Gd-153	1.056E-06	1.303E-07	1.608E-08	1.984E-09	1.061E-11	5.679E-14	0.00
Eu-154	1.255E-02	1.068E-02	9.088E-03	7.735E-03	5.170E-03	3.455E-03	0.00
Eu-155	6.056E-03	4.579E-03	3.463E-03	2.618E-03	1.302E-03	6.471E-04	0.00
Tb-160	1.168E-09	1.062E-12	9.650E-16	8.773E-19	0.00	0.00	0.00
Ho-166m	8.669E-09	8.659E-09	8.649E-09	8.639E-09	8.614E-09	8.589E-09	4.877E-09
Tm-170	5.415E-11	1.056E-12	2.057E-14	4.011E-16	2.128E-20	1.129E-24	0.00
Tm-171	7.302E-10	3.547E-10	1.723E-10	8.370E-11	1.376E-11	2.264E-12	0.00
Total	6.492E-01	4.883E-01	4.216E-01	3.834E-01	3.248E-01	2.840E-01	2.507E-05

TABLE D.1.g. Fission Product Radioactivity by Isotope at 50 MWd/kgM, Ci/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-3	6.562E-04	5.865E-04	5.242E-04	4.685E-04	3.539E-04	2.673E-04	0.00
Be-10	4.366E-12	4.366E-12	4.366E-12	4.366E-12	4.366E-12	4.366E-12	4.364E-12
C-14	1.760E-10	1.759E-10	1.759E-10	1.758E-10	1.757E-10	1.756E-10	1.560E-10
Se-79	5.932E-07	5.932E-07	5.932E-07	5.932E-07	5.931E-07	5.931E-07	5.869E-07
Kr-81	1.185E-12	1.185E-12	1.185E-12	1.185E-12	1.185E-12	1.185E-12	1.181E-12
Kr-85	8.914E-03	7.833E-03	6.883E-03	6.048E-03	4.377E-03	3.168E-03	0.00
Rb-87	2.835E-11	2.835E-11	2.835E-11	2.835E-11	2.835E-11	2.835E-11	2.835E-11
Sr-89	8.760E-10	3.871E-14	1.710E-18	7.558E-23	0.00	0.00	0.00
Sr-90	8.421E-02	8.030E-02	7.656E-02	7.301E-02	6.481E-02	5.754E-02	4.262E-12
Y-90	8.423E-02	8.032E-02	7.658E-02	7.302E-02	6.483E-02	5.756E-02	4.263E-12
Y-91	1.887E-08	3.291E-12	5.738E-16	1.000E-19	0.00	0.00	0.00
Zr-93	2.498E-06	2.498E-06	2.498E-06	2.498E-06	2.498E-06	2.498E-06	2.497E-06
Nb-93m	7.079E-07	8.692E-07	1.015E-06	1.147E-06	1.423E-06	1.636E-06	2.372E-06
Nb-94	2.524E-10	2.524E-10	2.524E-10	2.523E-10	2.523E-10	2.523E-10	2.440E-10
Zr-95	1.370E-07	5.009E-11	1.831E-14	6.696E-18	0.00	0.00	0.00
Nb-95	3.041E-07	1.112E-10	4.066E-14	1.487E-17	0.00	0.00	0.00
Nb-95m	1.016E-09	3.716E-13	1.359E-16	4.967E-20	0.00	0.00	0.00
Tc-98	1.369E-11	1.369E-11	1.369E-11	1.369E-11	1.369E-11	1.369E-11	1.369E-11
Tc-99	1.813E-05	1.813E-05	1.813E-05	1.813E-05	1.813E-05	1.813E-05	1.807E-05
Rh-102	9.802E-07	6.077E-07	3.768E-07	2.336E-07	7.071E-08	2.140E-08	0.00
Ru-103	8.061E-12	2.034E-17	5.134E-23	0.00	0.00	0.00	0.00
Rh-103m	7.267E-12	1.834E-17	4.628E-23	0.00	0.00	0.00	0.00
Ru-106	4.254E-02	1.075E-02	2.718E-03	6.870E-04	2.207E-05	7.088E-07	0.00
Rh-106	4.254E-02	1.075E-02	2.718E-03	6.870E-04	2.207E-05	7.088E-07	0.00
Pd-107	2.220E-07	2.220E-07	2.220E-07	2.220E-07	2.220E-07	2.220E-07	2.220E-07
Ag-108	5.807E-12	5.744E-12	5.681E-12	5.620E-12	5.468E-12	5.321E-12	2.530E-14
Ag-108m	6.524E-11	6.453E-11	6.383E-11	6.314E-11	6.144E-11	5.979E-11	2.843E-13
Ag-109m	5.467E-10	1.836E-10	6.164E-11	2.070E-11	1.353E-12	8.838E-14	0.00
Cd-109	5.467E-10	1.836E-10	6.164E-11	2.070E-11	1.353E-12	8.838E-14	0.00
Ag-110	1.949E-06	2.570E-07	3.387E-08	4.465E-09	2.818E-11	1.778E-13	0.00
Ag-110m	1.466E-04	1.932E-05	2.547E-06	3.357E-07	2.119E-09	1.337E-11	0.00
Cd-113m	9.465E-05	8.607E-05	7.826E-05	7.117E-05	5.612E-05	4.425E-05	2.660E-25
In-114	1.201E-14	4.349E-19	1.574E-23	0.00	0.00	0.00	0.00
In-114m	1.255E-14	4.544E-19	1.645E-23	0.00	0.00	0.00	0.00
Cd-115m	2.242E-13	2.628E-18	3.080E-23	0.00	0.00	0.00	0.00
Sn-119m	4.052E-06	5.131E-07	6.497E-08	8.227E-09	4.694E-11	2.678E-13	0.00
Sn-121m	3.349E-07	3.258E-07	3.169E-07	3.082E-07	2.875E-07	2.683E-07	3.351E-13
Sn-123	1.191E-06	2.363E-08	4.688E-10	9.301E-12	5.156E-16	2.859E-20	0.00
Te-123m	8.755E-09	1.273E-10	1.850E-12	2.690E-14	6.856E-19	1.747E-23	0.00
Sb-124	1.006E-10	2.235E-14	4.969E-18	1.105E-21	0.00	0.00	0.00
Sb-125	6.932E-03	4.203E-03	2.548E-03	1.545E-03	4.420E-04	1.265E-04	0.00
Te-125m	1.691E-03	1.026E-03	6.218E-04	3.769E-04	1.078E-04	3.086E-05	0.00
Sn-126	1.298E-06	1.298E-06	1.298E-06	1.298E-06	1.298E-06	1.298E-06	1.289E-06
Sb-126	1.817E-07	1.817E-07	1.817E-07	1.817E-07	1.817E-07	1.817E-07	1.805E-07
Sb-126m	1.298E-06	1.298E-06	1.298E-06	1.298E-06	1.298E-06	1.298E-06	1.289E-06

TABLE D.1.g. Fission Product Radioactivity by Isotope at 50 MWd/kgM, Ci/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Te-127	1.132E-06	1.088E-08	1.045E-10	1.004E-12	9.089E-18	8.224E-23	0.00
Te-127m	1.156E-06	1.111E-08	1.067E-10	1.025E-12	9.279E-18	8.396E-23	0.00
Te-129	1.958E-15	5.584E-22	0.00	0.00	0.00	0.00	0.00
Te-129m	3.008E-15	8.579E-22	0.00	0.00	0.00	0.00	0.00
I-129	4.883E-08	4.883E-08	4.883E-08	4.883E-08	4.883E-08	4.883E-08	4.883E-08
Cs-134	7.073E-02	3.611E-02	1.843E-02	9.411E-03	1.752E-03	3.264E-04	0.00
Cs-135	5.869E-07	5.869E-07	5.869E-07	5.869E-07	5.869E-07	5.869E-07	5.867E-07
Cs-137	1.390E-01	1.327E-01	1.267E-01	1.210E-01	1.078E-01	9.606E-02	1.408E-11
Ba-137m	1.315E-01	1.256E-01	1.199E-01	1.145E-01	1.020E-01	9.087E-02	1.332E-11
Ce-141	3.243E-14	5.587E-21	0.00	0.00	0.00	0.00	0.00
Ce-142	3.955E-11	3.955E-11	3.955E-11	3.955E-11	3.955E-11	3.955E-11	3.955E-11
Ce-144	2.384E-02	4.016E-03	6.764E-04	1.139E-04	1.326E-06	1.544E-08	0.00
Pr-144	2.385E-02	4.016E-03	6.764E-04	1.139E-04	1.326E-06	1.544E-08	0.00
Pr-144m	2.861E-04	4.819E-05	8.117E-06	1.367E-06	1.591E-08	1.853E-10	0.00
Nd-144	2.525E-15	2.533E-15	2.534E-15	2.534E-15	2.534E-15	2.534E-15	2.534E-15
Pm-146	2.916E-06	2.267E-06	1.762E-06	1.369E-06	7.291E-07	3.882E-07	0.00
Sm-146	6.470E-13	6.659E-13	6.806E-13	6.920E-13	7.106E-13	7.205E-13	7.318E-13
Pm-147	3.851E-02	2.270E-02	1.338E-02	7.890E-03	2.106E-03	5.619E-04	0.00
Sm-147	4.027E-12	4.415E-12	4.643E-12	4.778E-12	4.920E-12	4.958E-12	4.971E-12
Pm-148	2.858E-14	1.352E-19	6.399E-25	0.00	0.00	0.00	0.00
Pm-148m	5.074E-13	2.401E-18	1.136E-23	0.00	0.00	0.00	0.00
Eu-150	2.756E-11	2.652E-11	2.552E-11	2.456E-11	2.230E-11	2.026E-11	1.295E-19
Sm-151	3.633E-04	3.577E-04	3.522E-04	3.469E-04	3.338E-04	3.212E-04	1.693E-07
Eu-152	6.154E-06	5.557E-06	5.019E-06	4.532E-06	3.513E-06	2.723E-06	0.00
Gd-153	1.114E-06	1.375E-07	1.697E-08	2.094E-09	1.121E-11	5.996E-14	0.00
Eu-154	1.457E-02	1.240E-02	1.055E-02	8.983E-03	6.003E-03	4.012E-03	0.00
Eu-155	7.083E-03	5.356E-03	4.050E-03	3.062E-03	1.522E-03	7.568E-04	0.00
Tb-160	1.570E-09	1.427E-12	1.297E-15	1.179E-18	0.00	0.00	0.00
Ho-166m	1.295E-08	1.294E-08	1.292E-08	1.291E-08	1.287E-08	1.283E-08	7.286E-09
Tm-170	8.797E-11	1.715E-12	3.343E-14	6.516E-16	3.457E-20	1.834E-24	0.00
Tm-171	1.340E-09	6.510E-10	3.162E-10	1.536E-10	2.526E-11	4.155E-12	0.00
Total	7.218E-01	5.392E-01	4.641E-01	4.214E-01	3.566E-01	3.117E-01	2.732E-05

TABLE D.2.a. Actinide Radioactivity by Isotope at 20 MWd/kgM, Ci/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Tl-207	3.303E-12	4.452E-12	5.605E-12	6.764E-12	9.676E-12	1.262E-11	6.326E-10
Tl-208	2.614E-09	3.198E-09	3.579E-09	3.808E-09	3.982E-09	3.911E-09	3.914E-13
Tl-209	2.022E-15	2.082E-15	2.147E-15	2.218E-15	2.422E-15	2.660E-15	1.488E-12
Pb-209	9.361E-14	9.637E-14	9.940E-14	1.027E-13	1.121E-13	1.232E-13	6.890E-11
Pb-210	1.736E-14	3.015E-14	4.815E-14	7.213E-14	1.631E-13	3.067E-13	2.435E-09
Pb-211	3.312E-12	4.464E-12	5.621E-12	6.783E-12	9.703E-12	1.265E-11	6.344E-10
Pb-212	7.275E-09	8.901E-09	9.961E-09	1.060E-08	1.108E-08	1.089E-08	1.089E-12
Pb-214	1.860E-13	2.760E-13	3.843E-13	5.110E-13	9.083E-13	1.422E-12	2.436E-09
Bi-210	1.737E-14	3.016E-14	4.816E-14	7.216E-14	1.632E-13	3.068E-13	2.435E-09
Bi-211	3.312E-12	4.464E-12	5.621E-12	6.783E-12	9.703E-12	1.265E-11	6.344E-10
Bi-212	7.275E-09	8.901E-09	9.961E-09	1.060E-08	1.108E-08	1.089E-08	1.089E-12
Bi-213	9.361E-14	9.637E-14	9.940E-14	1.027E-13	1.121E-13	1.232E-13	6.890E-11
Bi-214	1.860E-13	2.760E-13	3.843E-13	5.110E-13	9.083E-13	1.422E-12	2.436E-09
Po-210	1.473E-14	2.614E-14	4.253E-14	6.465E-14	1.632E-13	3.068E-13	2.435E-09
Po-211	9.273E-15	1.250E-14	1.574E-14	1.899E-14	2.717E-14	3.543E-14	1.776E-12
Po-212	4.661E-09	5.703E-09	6.382E-09	6.790E-09	7.101E-09	6.974E-09	6.980E-13
Po-213	9.159E-14	9.429E-14	9.725E-14	1.005E-13	1.097E-13	1.205E-13	6.742E-11
Po-214	1.860E-13	2.760E-13	3.843E-13	5.109E-13	9.081E-13	1.421E-12	2.435E-09
Po-215	3.312E-12	4.464E-12	5.621E-12	6.783E-12	9.703E-12	1.265E-11	6.344E-10
Po-216	7.275E-09	8.901E-09	9.961E-09	1.060E-08	1.108E-08	1.089E-08	1.089E-12
Po-218	1.860E-13	2.761E-13	3.844E-13	5.111E-13	9.085E-13	1.422E-12	2.436E-09
At-217	9.361E-14	9.637E-14	9.940E-14	1.027E-13	1.121E-13	1.232E-13	6.890E-11
Rn-219	3.312E-12	4.464E-12	5.621E-12	6.783E-12	9.703E-12	1.265E-11	6.344E-10
Rn-220	7.275E-09	8.901E-09	9.961E-09	1.060E-08	1.108E-08	1.089E-08	1.089E-12
Rn-222	1.860E-13	2.761E-13	3.844E-13	5.111E-13	9.085E-13	1.422E-12	2.436E-09
Fr-221	9.361E-14	9.637E-14	9.940E-14	1.027E-13	1.121E-13	1.232E-13	6.890E-11
Fr-223	4.566E-14	6.151E-14	7.743E-14	9.343E-14	1.337E-13	1.744E-13	8.754E-12
Ra-223	3.312E-12	4.464E-12	5.621E-12	6.783E-12	9.703E-12	1.265E-11	6.344E-10
Ra-224	7.275E-09	8.901E-09	9.961E-09	1.060E-08	1.108E-08	1.089E-08	1.089E-12
Ra-225	9.361E-14	9.637E-14	9.940E-14	1.027E-13	1.121E-13	1.232E-13	6.890E-11
Ra-226	1.860E-13	2.761E-13	3.844E-13	5.111E-13	9.085E-13	1.422E-12	2.436E-09
Ac-225	9.361E-14	9.637E-14	9.940E-14	1.027E-13	1.121E-13	1.232E-13	6.890E-11
Ac-227	3.309E-12	4.457E-12	5.611E-12	6.771E-12	9.690E-12	1.264E-11	6.344E-10
Th-227	3.266E-12	4.403E-12	5.543E-12	6.689E-12	9.570E-12	1.248E-11	6.256E-10
Th-228	7.269E-09	8.883E-09	9.938E-09	1.057E-08	1.107E-08	1.088E-08	1.089E-12
Th-229	9.361E-14	9.637E-14	9.940E-14	1.027E-13	1.121E-13	1.232E-13	6.890E-11
Th-230	9.357E-11	1.147E-10	1.360E-10	1.573E-10	2.111E-10	2.653E-10	1.312E-08
Th-231	2.927E-08	2.928E-08	2.928E-08	2.928E-08	2.928E-08	2.928E-08	2.955E-08
Th-232	6.576E-17	8.443E-17	1.031E-16	1.218E-16	1.685E-16	2.152E-16	9.595E-15
Th-234	3.214E-07	3.214E-07	3.214E-07	3.214E-07	3.214E-07	3.214E-07	3.214E-07
Pa-231	2.130E-11	2.254E-11	2.378E-11	2.502E-11	2.812E-11	3.121E-11	6.341E-10
Pa-233	1.559E-07	1.563E-07	1.568E-07	1.575E-07	1.594E-07	1.619E-07	5.625E-07
Pa-243m	3.214E-07	3.214E-07	3.214E-07	3.214E-07	3.214E-07	3.214E-07	3.214E-07
Pa-234	4.178E-10	4.178E-10	4.178E-10	4.178E-10	4.178E-10	4.178E-10	4.178E-10
U-232	9.935E-09	1.069E-08	1.107E-08	1.122E-08	1.109E-08	1.068E-08	1.056E-12

TABLE D.2.a. Actinide Radioactivity by Isotope at 20 MWd/kgM, Ci/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
U-233	1.394E-11	1.538E-11	1.682E-11	1.827E-11	2.173E-11	2.524E-11	1.781E-09
U-234	1.173E-06	1.178E-06	1.183E-06	1.188E-06	1.200E-06	1.212E-06	1.501E-06
U-235	2.927E-08	2.928E-08	2.928E-08	2.928E-08	2.928E-08	2.928E-08	2.955E-08
U-236	1.892E-07	1.892E-07	1.892E-07	1.893E-07	1.893E-07	1.894E-07	1.985E-07
U-237	1.450E-06	1.317E-06	1.196E-06	1.086E-06	8.536E-07	6.710E-07	2.152E-13
U-238	3.214E-07	3.214E-07	3.214E-07	3.214E-07	3.214E-07	3.214E-07	3.214E-07
U-240	2.801E-14	2.801E-14	2.801E-14	2.801E-14	2.801E-14	2.801E-14	2.801E-14
Np-235	1.362E-10	3.794E-11	1.056E-11	2.942E-12	1.204E-13	4.926E-15	0.00
Np-236	2.237E-12	2.237E-12	2.237E-12	2.237E-12	2.237E-12	2.237E-12	2.224E-12
Np-237	1.559E-07	1.563E-07	1.568E-07	1.575E-07	1.594E-07	1.619E-07	5.625E-07
Np-238	4.261E-08	4.222E-08	4.184E-08	4.146E-08	4.053E-08	3.961E-08	4.540E-10
Np-239	3.159E-06	3.159E-06	3.158E-06	3.157E-06	3.156E-06	3.155E-06	2.877E-06
Np-240m	2.801E-14	2.801E-14	2.801E-14	2.801E-14	2.801E-14	2.801E-14	2.801E-14
Pu-236	6.281E-08	3.862E-08	2.375E-08	1.460E-08	4.331E-09	1.284E-09	2.002E-13
Pu-238	9.098E-04	8.959E-04	8.820E-04	8.683E-04	8.349E-04	8.028E-04	5.198E-07
Pu-239	2.847E-04	2.846E-04	2.846E-04	2.846E-04	2.846E-04	2.845E-04	2.767E-04
Pu-240	3.331E-04	3.331E-04	3.330E-04	3.330E-04	3.329E-04	3.327E-04	3.001E-04
Pu-241	5.909E-02	5.367E-02	4.874E-02	4.427E-02	3.480E-02	2.735E-02	8.783E-09
Pu-242	5.466E-07	5.466E-07	5.466E-07	5.466E-07	5.466E-07	5.466E-07	5.462E-07
Pu-243	1.621E-15	1.621E-15	1.621E-15	1.621E-15	1.621E-15	1.621E-15	1.621E-15
Pu-244	2.805E-14	2.805E-14	2.805E-14	2.805E-14	2.805E-14	2.805E-14	2.805E-14
Am-241	5.738E-04	7.524E-04	9.138E-04	1.060E-03	1.365E-03	1.601E-03	5.284E-04
Am-242m	8.522E-06	8.445E-06	8.368E-06	8.292E-06	8.105E-06	7.922E-06	9.080E-08
Am-242	8.479E-06	8.402E-06	8.326E-06	8.251E-06	8.065E-06	7.883E-06	9.035E-08
Am-243	3.159E-06	3.159E-06	3.158E-06	3.157E-06	3.156E-06	3.155E-06	2.877E-06
Cm-242	4.778E-05	8.793E-06	6.981E-06	6.839E-06	6.672E-06	6.522E-06	7.472E-08
Cm-243	4.527E-06	4.312E-06	4.108E-06	3.913E-06	3.465E-06	3.068E-06	1.367E-16
Cm-244	1.607E-04	1.488E-04	1.379E-04	1.277E-04	1.055E-04	8.709E-05	4.466E-21
Cm-245	9.510E-09	9.509E-09	9.507E-09	9.506E-09	9.502E-09	9.498E-09	8.768E-09
Cm-246	1.067E-09	1.066E-09	1.066E-09	1.066E-09	1.065E-09	1.064E-09	9.219E-10
Cm-247	1.621E-15	1.621E-15	1.621E-15	1.621E-15	1.621E-15	1.621E-15	1.621E-15
Cm-248	1.976E-15	1.976E-15	1.976E-15	1.976E-15	1.976E-15	1.976E-15	1.972E-15
Bk-249	1.711E-13	3.516E-14	7.226E-15	1.485E-15	2.843E-17	5.602E-19	0.00
Cf-249	1.261E-14	1.289E-14	1.291E-14	1.288E-14	1.275E-14	1.263E-14	1.818E-15
Cf-250	3.671E-14	3.302E-14	2.970E-14	2.671E-14	2.049E-14	1.572E-14	2.782E-24
Cf-251	1.929E-16	1.926E-16	1.923E-16	1.920E-16	1.912E-16	1.905E-16	8.940E-17
Cf-252	6.574E-15	3.887E-15	2.298E-15	1.359E-15	3.653E-16	9.820E-17	0.00
Total	6.143E-02	5.612E-02	5.133E-02	4.698E-02	3.776E-02	3.050E-02	1.116E-03

TABLE D.2.b. Actinide Radioactivity by Isotope at 25 MWD/kgM, Ci/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Tl-207	3.457E-12	4.640E-12	5.809E-12	6.966E-12	9.810E-12	1.260E-11	5.088E-10
Tl-208	4.019E-09	4.997E-09	5.646E-09	6.042E-09	6.361E-09	6.262E-09	6.199E-13
Tl-209	3.204E-15	3.273E-15	3.350E-15	3.435E-15	3.683E-15	3.979E-15	1.998E-12
Pb-209	1.483E-13	1.515E-13	1.551E-13	1.590E-13	1.705E-13	1.842E-13	9.252E-11
Pb-210	1.684E-14	2.862E-14	4.523E-14	6.740E-14	1.517E-13	2.853E-13	2.606E-09
Pb-211	3.467E-12	4.653E-12	5.825E-12	6.986E-12	9.838E-12	1.264E-11	5.102E-10
Pb-212	1.119E-08	1.391E-08	1.571E-08	1.682E-08	1.771E-08	1.743E-08	1.725E-12
Pb-214	1.722E-13	2.554E-13	3.557E-13	4.733E-13	8.434E-13	1.324E-12	2.606E-09
Bi-210	1.684E-14	2.863E-14	4.525E-14	6.743E-14	1.518E-13	2.853E-13	2.606E-09
Bi-211	3.467E-12	4.653E-12	5.825E-12	6.986E-12	9.838E-12	1.264E-11	5.102E-10
Bi-212	1.119E-08	1.391E-08	1.571E-08	1.682E-08	1.771E-08	1.743E-08	1.725E-12
Bi-213	1.483E-13	1.515E-13	1.551E-13	1.590E-13	1.705E-13	1.842E-13	9.252E-11
Bi-214	1.722E-13	2.554E-13	3.557E-13	4.733E-13	8.434E-13	1.324E-12	2.606E-09
Po-210	1.440E-14	2.492E-14	4.004E-14	6.047E-14	1.518E-13	2.854E-13	2.606E-09
Po-211	9.708E-15	1.303E-14	1.631E-14	1.956E-14	2.755E-14	3.538E-14	1.429E-12
Po-212	7.167E-09	8.911E-09	1.007E-08	1.077E-08	1.134E-08	1.117E-08	1.105E-12
Po-213	1.451E-13	1.482E-13	1.517E-13	1.556E-13	1.668E-13	1.802E-13	9.052E-11
Po-214	1.722E-13	2.554E-13	3.556E-13	4.732E-13	8.432E-13	1.323E-12	2.606E-09
Po-215	3.467E-12	4.653E-12	5.825E-12	6.986E-12	9.838E-12	1.264E-11	5.102E-10
Po-216	1.119E-08	1.391E-08	1.571E-08	1.682E-08	1.771E-08	1.743E-08	1.725E-12
Po-218	1.723E-13	2.555E-13	3.558E-13	4.734E-13	8.435E-13	1.324E-12	2.607E-09
At-217	1.483E-13	1.515E-13	1.551E-13	1.590E-13	1.705E-13	1.842E-13	9.252E-11
Rn-219	3.467E-12	4.653E-12	5.825E-12	6.986E-12	9.838E-12	1.264E-11	5.102E-10
Rn-220	1.119E-08	1.391E-08	1.571E-08	1.682E-08	1.771E-08	1.743E-08	1.725E-12
Rn-222	1.723E-13	2.555E-13	3.558E-13	4.734E-13	8.435E-13	1.324E-12	2.607E-09
Fr-221	1.483E-13	1.515E-13	1.551E-13	1.590E-13	1.705E-13	1.842E-13	9.252E-11
Fr-223	4.780E-14	6.410E-14	8.025E-14	9.623E-14	1.356E-13	1.741E-13	7.041E-12
Ra-223	3.467E-12	4.653E-12	5.825E-12	6.986E-12	9.838E-12	1.264E-11	5.102E-10
Ra-224	1.119E-08	1.391E-08	1.571E-08	1.682E-08	1.771E-08	1.743E-08	1.725E-12
Ra-225	1.483E-13	1.515E-13	1.551E-13	1.590E-13	1.705E-13	1.842E-13	9.252E-11
Ra-226	1.723E-13	2.555E-13	3.558E-13	4.734E-13	8.435E-13	1.324E-12	2.607E-09
Ac-225	1.483E-13	1.515E-13	1.551E-13	1.590E-13	1.705E-13	1.842E-13	9.252E-11
Ac-227	3.463E-12	4.645E-12	5.815E-12	6.973E-12	9.824E-12	1.262E-11	5.102E-10
Th-227	3.419E-12	4.589E-12	5.745E-12	6.890E-12	9.702E-12	1.246E-11	5.032E-10
Th-228	1.118E-08	1.388E-08	1.568E-08	1.678E-08	1.769E-08	1.741E-08	1.725E-12
Th-229	1.483E-13	1.515E-13	1.551E-13	1.590E-13	1.705E-13	1.842E-13	9.252E-11
Th-230	8.636E-11	1.061E-10	1.261E-10	1.462E-10	1.971E-10	2.488E-10	1.421E-08
Th-231	2.328E-08	2.328E-08	2.328E-08	2.328E-08	2.328E-08	2.328E-08	2.357E-08
Th-234	3.201E-07	3.201E-07	3.201E-07	3.201E-07	3.201E-07	3.201E-07	3.201E-07
Pa-231	2.212E-11	2.311E-11	2.409E-11	2.508E-11	2.754E-11	3.000E-11	5.100E-10
Pa-233	2.140E-07	2.146E-07	2.153E-07	2.161E-07	2.187E-07	2.219E-07	7.521E-07
Pa-243m	3.201E-07	3.201E-07	3.201E-07	3.201E-07	3.201E-07	3.201E-07	3.201E-07
Pa-234	4.161E-10	4.161E-10	4.161E-10	4.161E-10	4.161E-10	4.161E-10	4.161E-10
U-232	1.560E-08	1.694E-08	1.763E-08	1.791E-08	1.775E-08	1.712E-08	1.677E-12
U-233	1.606E-11	1.803E-11	2.001E-11	2.200E-11	2.675E-11	3.156E-11	2.388E-09

TABLE D.2.b. Actinide Radioactivity by Isotope at 25 MWd/kgM, Ci/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
U-234	1.095E-06	1.103E-06	1.112E-06	1.120E-06	1.141E-06	1.161E-06	1.653E-06
U-235	2.328E-08	2.328E-08	2.328E-08	2.328E-08	2.328E-08	2.328E-08	2.357E-08
U-236	2.160E-07	2.160E-07	2.160E-07	2.161E-07	2.161E-07	2.162E-07	2.277E-07
U-237	1.925E-06	1.748E-06	1.588E-06	1.442E-06	1.133E-06	8.909E-07	7.969E-13
U-238	3.201E-07	3.201E-07	3.201E-07	3.201E-07	3.201E-07	3.201E-07	3.201E-07
U-240	8.649E-14	8.649E-14	8.649E-14	8.649E-14	8.649E-14	8.649E-14	8.649E-14
Np-235	2.241E-10	6.240E-11	1.738E-11	4.839E-12	1.980E-13	8.103E-15	0.00
Np-236	3.402E-12	3.402E-12	3.402E-12	3.402E-12	3.402E-12	3.402E-12	3.382E-12
Np-237	2.140E-07	2.146E-07	2.153E-07	2.161E-07	2.187E-07	2.219E-07	7.521E-07
Np-238	5.750E-08	5.698E-08	5.646E-08	5.595E-08	5.469E-08	5.345E-08	6.127E-10
Np-239	7.166E-06	7.165E-06	7.164E-06	7.162E-06	7.159E-06	7.155E-06	6.526E-06
Np-240m	8.649E-14	8.649E-14	8.649E-14	8.649E-14	8.649E-14	8.649E-14	8.649E-14
Pu-236	1.085E-07	6.671E-08	4.102E-08	2.523E-08	7.480E-09	2.218E-09	3.044E-13
Pu-238	1.549E-03	1.525E-03	1.502E-03	1.478E-03	1.421E-03	1.367E-03	8.245E-07
Pu-239	2.996E-04	2.996E-04	2.996E-04	2.996E-04	2.995E-04	2.995E-04	2.913E-04
Pu-240	4.176E-04	4.176E-04	4.176E-04	4.176E-04	4.176E-04	4.175E-04	3.770E-04
Pu-241	7.846E-02	7.125E-02	6.471E-02	5.877E-02	4.620E-02	3.632E-02	3.253E-08
Pu-242	9.703E-07	9.703E-07	9.703E-07	9.703E-07	9.704E-07	9.704E-07	9.694E-07
Pu-243	1.059E-14	1.059E-14	1.059E-14	1.059E-14	1.059E-14	1.059E-14	1.059E-14
Pu-244	8.660E-14	8.660E-14	8.660E-14	8.660E-14	8.660E-14	8.660E-14	8.660E-14
Am-241	7.504E-04	9.875E-04	1.202E-03	1.396E-03	1.801E-03	2.115E-03	6.993E-04
Am-242m	1.150E-05	1.140E-05	1.129E-05	1.119E-05	1.094E-05	1.069E-05	1.225E-07
Am-242	1.144E-05	1.134E-05	1.124E-05	1.113E-05	1.088E-05	1.064E-05	1.219E-07
Am-243	7.166E-06	7.165E-06	7.164E-06	7.162E-06	7.159E-06	7.155E-06	6.526E-06
Cm-242	7.718E-05	1.244E-05	9.445E-06	9.230E-06	9.004E-06	8.801E-06	1.008E-07
Cm-243	9.705E-06	9.244E-06	8.805E-06	8.387E-06	7.427E-06	6.576E-06	2.930E-16
Cm-244	4.896E-04	4.536E-04	4.201E-04	3.892E-04	3.214E-04	2.654E-04	1.361E-20
Cm-245	3.522E-08	3.521E-08	3.521E-08	3.520E-08	3.519E-08	3.517E-08	3.247E-08
Cm-246	5.320E-09	5.318E-09	5.316E-09	5.315E-09	5.311E-09	5.307E-09	4.597E-09
Cm-247	1.059E-14	1.059E-14	1.059E-14	1.059E-14	1.059E-14	1.059E-14	1.059E-14
Cm-248	1.710E-14	1.710E-14	1.710E-14	1.710E-14	1.710E-14	1.710E-14	1.706E-14
Bk-249	1.826E-12	3.753E-13	7.713E-14	1.585E-14	3.036E-16	5.823E-18	0.00
Cf-249	1.330E-13	1.361E-13	1.363E-13	1.359E-13	1.346E-13	1.333E-13	1.919E-14
Cf-250	4.461E-13	4.012E-13	3.609E-13	3.246E-13	2.490E-13	1.911E-13	5.333E-23
Cf-251	2.668E-15	2.664E-15	2.660E-15	2.656E-15	2.646E-15	2.636E-15	1.237E-15
Cf-252	1.201E-13	7.103E-14	4.200E-14	2.483E-14	6.675E-15	1.794E-15	0.00
Total	8.209E-02	7.500E-02	6.862E-02	6.281E-02	5.052E-02	4.084E-02	1.387E-03

TABLE D.2.c. Actinide Radioactivity by Isotope at 30 MWd/kgM, Ci/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Tl-207	3.529E-12	4.724E-12	5.891E-12	7.034E-12	9.789E-12	1.243E-11	4.037E-10
Tl-208	5.742E-09	7.232E-09	8.231E-09	8.850E-09	9.367E-09	9.236E-09	9.031E-13
Tl-209	4.794E-15	4.871E-15	4.958E-15	5.056E-15	5.344E-15	5.695E-15	2.468E-12
Pb-209	2.219E-13	2.255E-13	2.296E-13	2.341E-13	2.474E-13	2.637E-13	1.143E-10
Pb-210	1.664E-14	2.744E-14	4.270E-14	6.310E-14	1.410E-13	2.650E-13	2.858E-09
Pb-211	3.539E-12	4.737E-12	5.908E-12	7.054E-12	9.817E-12	1.246E-11	4.049E-10
Pb-212	1.598E-08	2.013E-08	2.291E-08	2.463E-08	2.607E-08	2.571E-08	2.514E-12
Pb-214	1.589E-13	2.355E-13	3.282E-13	4.371E-13	7.816E-13	1.232E-12	2.858E-09
Bi-210	1.664E-14	2.745E-14	4.271E-14	6.313E-14	1.411E-13	2.651E-13	2.858E-09
Bi-211	3.539E-12	4.737E-12	5.908E-12	7.054E-12	9.817E-12	1.246E-11	4.049E-10
Bi-212	1.598E-08	2.013E-08	2.291E-08	2.463E-08	2.607E-08	2.571E-08	2.514E-12
Bi-213	2.219E-13	2.255E-13	2.296E-13	2.341E-13	2.474E-13	2.637E-13	1.143E-10
Bi-214	1.589E-13	2.355E-13	3.282E-13	4.371E-13	7.816E-13	1.232E-12	2.858E-09
Po-210	1.440E-14	2.404E-14	3.791E-14	5.671E-14	1.411E-13	2.651E-13	2.858E-09
Po-211	9.909E-15	1.326E-14	1.654E-14	1.975E-14	2.749E-14	3.489E-14	1.134E-12
Po-212	1.024E-08	1.290E-08	1.468E-08	1.578E-08	1.670E-08	1.647E-08	1.610E-12
Po-213	2.171E-13	2.206E-13	2.246E-13	2.290E-13	2.421E-13	2.580E-13	1.118E-10
Po-214	1.589E-13	2.355E-13	3.281E-13	4.370E-13	7.814E-13	1.231E-12	2.858E-09
Po-215	3.539E-12	4.737E-12	5.908E-12	7.054E-12	9.817E-12	1.246E-11	4.049E-10
Po-216	1.598E-08	2.013E-08	2.291E-08	2.463E-08	2.607E-08	2.571E-08	2.514E-12
Po-218	1.589E-13	2.356E-13	3.282E-13	4.372E-13	7.817E-13	1.232E-12	2.859E-09
At-217	2.219E-13	2.255E-13	2.296E-13	2.341E-13	2.474E-13	2.637E-13	1.143E-10
Rn-219	3.539E-12	4.737E-12	5.908E-12	7.054E-12	9.817E-12	1.246E-11	4.049E-10
Rn-220	1.598E-08	2.013E-08	2.291E-08	2.463E-08	2.607E-08	2.571E-08	2.514E-12
Rn-222	1.589E-13	2.356E-13	3.282E-13	4.372E-13	7.817E-13	1.232E-12	2.859E-09
Fr-221	2.219E-13	2.255E-13	2.296E-13	2.341E-13	2.474E-13	2.637E-13	1.143E-10
Fr-223	4.879E-14	6.527E-14	8.139E-14	9.717E-14	1.353E-13	1.717E-13	5.587E-12
Ra-223	3.539E-12	4.737E-12	5.908E-12	7.054E-12	9.817E-12	1.246E-11	4.049E-10
Ra-224	1.598E-08	2.013E-08	2.291E-08	2.463E-08	2.607E-08	2.571E-08	2.514E-12
Ra-225	2.219E-13	2.255E-13	2.296E-13	2.341E-13	2.474E-13	2.637E-13	1.143E-10
Ra-226	1.589E-13	2.356E-13	3.282E-13	4.372E-13	7.817E-13	1.232E-12	2.859E-09
Ac-225	2.219E-13	2.255E-13	2.296E-13	2.341E-13	2.474E-13	2.637E-13	1.143E-10
Ac-227	3.535E-12	4.730E-12	5.898E-12	7.041E-12	9.803E-12	1.244E-11	4.049E-10
Th-227	3.490E-12	4.672E-12	5.827E-12	6.957E-12	9.681E-12	1.229E-11	3.993E-10
Th-228	1.597E-08	2.009E-08	2.286E-08	2.457E-08	2.605E-08	2.568E-08	2.514E-12
Th-229	2.219E-13	2.255E-13	2.296E-13	2.341E-13	2.474E-13	2.637E-13	1.143E-10
Th-230	7.941E-11	9.791E-11	1.166E-10	1.356E-10	1.840E-10	2.337E-10	1.577E-08
Th-231	1.820E-08	1.820E-08	1.820E-08	1.821E-08	1.821E-08	1.821E-08	1.850E-08
Th-234	3.187E-07	3.187E-07	3.187E-07	3.187E-07	3.187E-07	3.187E-07	3.187E-07
Pa-231	2.251E-11	2.328E-11	2.405E-11	2.482E-11	2.674E-11	2.867E-11	4.047E-10
Pa-233	2.746E-07	2.753E-07	2.761E-07	2.771E-07	2.802E-07	2.840E-07	9.184E-07
Pa-243m	3.187E-07	3.187E-07	3.187E-07	3.187E-07	3.187E-07	3.187E-07	3.187E-07
Pa-234	4.143E-10	4.143E-10	4.143E-10	4.143E-10	4.143E-10	4.143E-10	4.143E-10
U-232	2.267E-08	2.479E-08	2.588E-08	2.635E-08	2.618E-08	2.526E-08	2.446E-12
U-233	1.778E-11	2.031E-11	2.285E-11	2.540E-11	3.149E-11	3.765E-11	2.936E-09

TABLE D.2.c. Actinide Radioactivity by Isotope at 30 MWd/kgM, Ci/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
U-234	1.021E-06	1.034E-06	1.047E-06	1.060E-06	1.091E-06	1.121E-06	1.865E-06
U-235	1.820E-08	1.820E-08	1.820E-08	1.821E-08	1.821E-08	1.821E-08	1.850E-08
U-236	2.365E-07	2.366E-07	2.366E-07	2.366E-07	2.367E-07	2.368E-07	2.505E-07
U-237	2.313E-06	2.101E-06	1.908E-06	1.733E-06	1.362E-06	1.071E-06	2.252E-12
U-238	3.187E-07	3.187E-07	3.187E-07	3.187E-07	3.187E-07	3.187E-07	3.187E-07
U-240	2.137E-13	2.137E-13	2.137E-13	2.137E-13	2.137E-13	2.137E-13	2.137E-13
Np-235	3.326E-10	9.261E-11	2.579E-11	7.182E-12	2.939E-13	1.203E-14	0.00
Np-236	4.699E-12	4.699E-12	4.699E-12	4.699E-12	4.699E-12	4.699E-12	4.671E-12
Np-237	2.746E-07	2.753E-07	2.761E-07	2.771E-07	2.802E-07	2.840E-07	9.184E-07
Np-238	6.745E-08	6.684E-08	6.624E-08	6.563E-08	6.415E-08	6.271E-08	7.187E-10
Np-239	1.355E-05	1.355E-05	1.355E-05	1.354E-05	1.354E-05	1.353E-05	1.234E-05
Np-240m	2.137E-13	2.137E-13	2.137E-13	2.137E-13	2.137E-13	2.137E-13	2.137E-13
Pu-236	1.689E-07	1.039E-07	6.388E-08	3.928E-08	1.165E-08	3.454E-09	4.204E-13
Pu-238	2.345E-03	2.309E-03	2.273E-03	2.238E-03	2.151E-03	2.068E-03	1.169E-06
Pu-239	3.092E-04	3.092E-04	3.092E-04	3.092E-04	3.091E-04	3.091E-04	3.008E-04
Pu-240	4.973E-04	4.975E-04	4.976E-04	4.977E-04	4.979E-04	4.980E-04	4.504E-04
Pu-241	9.428E-02	8.563E-02	7.777E-02	7.063E-02	5.552E-02	4.364E-02	9.193E-08
Pu-242	1.483E-06	1.483E-06	1.483E-06	1.483E-06	1.483E-06	1.483E-06	1.482E-06
Pu-243	4.804E-14	4.804E-14	4.804E-14	4.804E-14	4.804E-14	4.804E-14	4.804E-14
Pu-244	2.140E-13	2.140E-13	2.140E-13	2.140E-13	2.140E-13	2.140E-13	2.139E-13
Am-241	8.842E-04	1.169E-03	1.427E-03	1.660E-03	2.148E-03	2.524E-03	8.368E-04
Am-242m	1.349E-05	1.337E-05	1.325E-05	1.313E-05	1.283E-05	1.254E-05	1.437E-07
Am-242	1.342E-05	1.330E-05	1.318E-05	1.306E-05	1.277E-05	1.248E-05	1.430E-07
Am-243	1.355E-05	1.355E-05	1.355E-05	1.354E-05	1.354E-05	1.353E-05	1.234E-05
Am-245	1.812E-16	3.724E-17	7.653E-18	1.573E-18	3.012E-20	5.767E-22	0.00
Cm-242	1.089E-04	1.542E-05	1.112E-05	1.083E-05	1.056E-05	1.032E-05	1.183E-07
Cm-243	1.728E-05	1.646E-05	1.568E-05	1.493E-05	1.322E-05	1.171E-05	5.216E-16
Cm-244	1.187E-03	1.100E-03	1.019E-03	9.436E-04	7.792E-04	6.435E-04	3.300E-20
Cm-245	9.954E-08	9.953E-08	9.951E-08	9.950E-08	9.945E-08	9.941E-08	9.178E-08
Cm-246	1.933E-08	1.932E-08	1.932E-08	1.931E-08	1.930E-08	1.928E-08	1.670E-08
Cm-247	4.804E-14	4.804E-14	4.804E-14	4.804E-14	4.804E-14	4.804E-14	4.804E-14
Cm-248	9.843E-14	9.844E-14	9.844E-14	9.844E-14	9.844E-14	9.844E-14	9.824E-14
Bk-249	1.249E-11	2.567E-12	5.277E-13	1.084E-13	2.077E-15	3.975E-17	0.00
Cf-249	8.958E-13	9.170E-13	9.185E-13	9.159E-13	9.071E-13	8.982E-13	1.293E-13
Cf-250	3.350E-12	3.013E-12	2.710E-12	2.438E-12	1.870E-12	1.435E-12	5.059E-22
Cf-251	2.204E-14	2.200E-14	2.197E-14	2.194E-14	2.185E-14	2.177E-14	1.022E-14
Cf-252	1.265E-12	7.478E-13	4.422E-13	2.614E-13	7.027E-14	1.889E-14	0.00
Total	9.969E-02	9.110E-02	8.338E-02	7.636E-02	6.149E-02	4.977E-02	1.621E-03

TABLE D.2.d. Actinide Radioactivity by Isotope at 35 MWd/kgM, Ci/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Tl-207	3.526E-12	4.714E-12	5.864E-12	6.980E-12	9.628E-12	1.211E-11	3.173E-10
Tl-208	7.759E-09	9.879E-09	1.131E-08	1.221E-08	1.298E-08	1.281E-08	1.238E-12
Tl-209	6.826E-15	6.909E-15	7.005E-15	7.114E-15	7.440E-15	7.842E-15	2.944E-12
Pb-209	3.160E-13	3.199E-13	3.243E-13	3.294E-13	3.445E-13	3.631E-13	1.363E-10
Pb-210	1.684E-14	2.667E-14	4.060E-14	5.930E-14	1.311E-13	2.460E-13	3.180E-09
Pb-211	3.536E-12	4.728E-12	5.881E-12	7.000E-12	9.655E-12	1.214E-11	3.182E-10
Pb-212	2.160E-08	2.749E-08	3.149E-08	3.398E-08	3.611E-08	3.566E-08	3.445E-12
Pb-214	1.460E-13	2.163E-13	3.017E-13	4.024E-13	7.229E-13	1.145E-12	3.180E-09
Bi-210	1.685E-14	2.668E-14	4.062E-14	5.932E-14	1.311E-13	2.461E-13	3.180E-09
Bi-211	3.536E-12	4.728E-12	5.881E-12	7.000E-12	9.655E-12	1.214E-11	3.182E-10
Bi-212	2.160E-08	2.749E-08	3.149E-08	3.398E-08	3.611E-08	3.566E-08	3.445E-12
Bi-213	3.160E-13	3.199E-13	3.243E-13	3.294E-13	3.445E-13	3.631E-13	1.363E-10
Bi-214	1.460E-13	2.163E-13	3.017E-13	4.024E-13	7.229E-13	1.145E-12	3.180E-09
Po-210	1.480E-14	2.356E-14	3.622E-14	5.343E-14	1.311E-13	2.461E-13	3.180E-09
Po-211	9.901E-15	1.324E-14	1.647E-14	1.960E-14	2.703E-14	3.400E-14	8.910E-13
Po-212	1.384E-08	1.762E-08	2.017E-08	2.177E-08	2.314E-08	2.285E-08	2.207E-12
Po-213	3.092E-13	3.130E-13	3.173E-13	3.223E-13	3.370E-13	3.552E-13	1.334E-10
Po-214	1.460E-13	2.163E-13	3.017E-13	4.023E-13	7.227E-13	1.145E-12	3.180E-09
Po-215	3.536E-12	4.728E-12	5.881E-12	7.000E-12	9.655E-12	1.214E-11	3.182E-10
Po-216	2.160E-08	2.749E-08	3.149E-08	3.398E-08	3.611E-08	3.566E-08	3.445E-12
Po-218	1.460E-13	2.164E-13	3.018E-13	4.025E-13	7.230E-13	1.145E-12	3.181E-09
At-217	3.160E-13	3.199E-13	3.243E-13	3.294E-13	3.445E-13	3.631E-13	1.363E-10
Rn-219	3.536E-12	4.728E-12	5.881E-12	7.000E-12	9.655E-12	1.214E-11	3.182E-10
Rn-220	2.160E-08	2.749E-08	3.149E-08	3.398E-08	3.611E-08	3.566E-08	3.445E-12
Rn-222	1.460E-13	2.164E-13	3.018E-13	4.025E-13	7.230E-13	1.145E-12	3.181E-09
Fr-221	3.160E-13	3.199E-13	3.243E-13	3.294E-13	3.445E-13	3.631E-13	1.363E-10
Fr-223	4.875E-14	6.513E-14	8.101E-14	9.642E-14	1.331E-13	1.673E-13	4.391E-12
Ra-223	3.536E-12	4.728E-12	5.881E-12	7.000E-12	9.655E-12	1.214E-11	3.182E-10
Ra-224	2.160E-08	2.749E-08	3.149E-08	3.398E-08	3.611E-08	3.566E-08	3.445E-12
Ra-225	3.160E-13	3.199E-13	3.243E-13	3.294E-13	3.445E-13	3.631E-13	1.363E-10
Ra-226	1.460E-13	2.164E-13	3.018E-13	4.025E-13	7.230E-13	1.145E-12	3.181E-09
Ac-225	3.160E-13	3.199E-13	3.243E-13	3.294E-13	3.445E-13	3.631E-13	1.363E-10
Ac-227	3.533E-12	4.720E-12	5.871E-12	6.987E-12	9.641E-12	1.212E-11	3.182E-10
Th-227	3.487E-12	4.662E-12	5.800E-12	6.903E-12	9.522E-12	1.198E-11	3.138E-10
Th-228	2.158E-08	2.744E-08	3.142E-08	3.390E-08	3.608E-08	3.563E-08	3.445E-12
Th-229	3.160E-13	3.199E-13	3.243E-13	3.294E-13	3.445E-13	3.631E-13	1.363E-10
Th-230	7.275E-11	9.003E-11	1.076E-10	1.256E-10	1.718E-10	2.199E-10	1.775E-08
Th-231	1.405E-08	1.405E-08	1.405E-08	1.405E-08	1.405E-08	1.405E-08	1.435E-08
Th-234	3.172E-07	3.172E-07	3.172E-07	3.172E-07	3.172E-07	3.172E-07	3.172E-07
Pa-231	2.248E-11	2.307E-11	2.367E-11	2.426E-11	2.575E-11	2.723E-11	3.181E-10
Pa-233	3.362E-07	3.369E-07	3.379E-07	3.391E-07	3.427E-07	3.471E-07	1.087E-06
Pa-243m	3.172E-07	3.172E-07	3.172E-07	3.172E-07	3.172E-07	3.172E-07	3.172E-07
Pa-234	4.124E-10	4.124E-10	4.124E-10	4.124E-10	4.124E-10	4.124E-10	4.124E-10
U-232	3.106E-08	3.416E-08	3.577E-08	3.648E-08	3.631E-08	3.505E-08	3.356E-12
U-233	1.916E-11	2.226E-11	2.537E-11	2.849E-11	3.594E-11	4.348E-11	3.490E-09

TABLE D.2.d. Actinide Radioactivity by Isotope at 35 MWd/kgM, Ci/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
U-234	9.509E-07	9.693E-07	9.874E-07	1.005E-06	1.049E-06	1.090E-06	2.128E-06
U-235	1.405E-08	1.405E-08	1.405E-08	1.405E-08	1.405E-08	1.405E-08	1.435E-08
U-236	2.510E-07	2.510E-07	2.510E-07	2.511E-07	2.512E-07	2.512E-07	2.668E-07
U-237	2.712E-06	2.463E-06	2.237E-06	2.032E-06	1.597E-06	1.255E-06	5.242E-12
U-238	3.172E-07	3.172E-07	3.172E-07	3.172E-07	3.172E-07	3.172E-07	3.172E-07
U-240	4.514E-13	4.514E-13	4.514E-13	4.514E-13	4.514E-13	4.514E-13	4.514E-13
Np-235	4.578E-10	1.275E-10	3.550E-11	9.885E-12	4.045E-13	1.655E-14	0.00
Np-236	6.076E-12	6.075E-12	6.075E-12	6.075E-12	6.075E-12	6.075E-12	6.039E-12
Np-237	3.362E-07	3.369E-07	3.379E-07	3.391E-07	3.427E-07	3.471E-07	1.087E-06
Np-238	7.279E-08	7.213E-08	7.148E-08	7.083E-08	6.923E-08	6.767E-08	7.756E-10
Np-239	2.272E-05	2.272E-05	2.271E-05	2.271E-05	2.270E-05	2.269E-05	2.069E-05
Np-240m	4.514E-13	4.514E-13	4.514E-13	4.514E-13	4.514E-13	4.514E-13	4.514E-13
Pu-236	2.442E-07	1.502E-07	9.235E-08	5.679E-08	1.684E-08	4.994E-09	5.435E-13
Pu-238	3.274E-03	3.224E-03	3.173E-03	3.124E-03	3.003E-03	2.887E-03	1.546E-06
Pu-239	3.145E-04	3.145E-04	3.145E-04	3.145E-04	3.144E-04	3.144E-04	3.063E-04
Pu-240	5.589E-04	5.593E-04	5.596E-04	5.599E-04	5.606E-04	5.610E-04	5.090E-04
Pu-241	1.105E-01	1.004E-01	9.118E-02	8.281E-02	6.510E-02	5.117E-02	2.140E-07
Pu-242	2.076E-06	2.076E-06	2.076E-06	2.076E-06	2.076E-06	2.076E-06	2.073E-06
Pu-243	1.705E-13	1.705E-13	1.705E-13	1.705E-13	1.705E-13	1.705E-13	1.705E-13
Pu-244	4.520E-13	4.520E-13	4.520E-13	4.520E-13	4.520E-13	4.520E-13	4.520E-13
Am-241	1.009E-03	1.344E-03	1.646E-03	1.919E-03	2.491E-03	2.933E-03	9.758E-04
Am-242m	1.456E-05	1.443E-05	1.429E-05	1.416E-05	1.385E-05	1.353E-05	1.551E-07
Am-242	1.449E-05	1.435E-05	1.422E-05	1.409E-05	1.378E-05	1.347E-05	1.543E-07
Am-243	2.272E-05	2.272E-05	2.271E-05	2.271E-05	2.270E-05	2.269E-05	2.069E-05
Am-245	9.133E-16	1.877E-16	3.858E-17	7.929E-18	1.518E-19	2.907E-21	0.00
Cm-242	1.399E-04	1.764E-05	1.204E-05	1.169E-05	1.140E-05	1.114E-05	1.276E-07
Cm-243	2.695E-05	2.567E-05	2.445E-05	2.329E-05	2.062E-05	1.826E-05	8.136E-16
Cm-244	2.445E-03	2.265E-03	2.098E-03	1.944E-03	1.605E-03	1.325E-03	6.796E-20
Cm-245	2.317E-07	2.316E-07	2.316E-07	2.316E-07	2.315E-07	2.314E-07	2.136E-07
Cm-246	5.647E-08	5.645E-08	5.643E-08	5.642E-08	5.637E-08	5.633E-08	4.880E-08
Cm-247	1.705E-13	1.705E-13	1.705E-13	1.705E-13	1.705E-13	1.705E-13	1.705E-13
Cm-248	4.313E-13	4.314E-13	4.314E-13	4.314E-13	4.314E-13	4.314E-13	4.305E-13
Bk-249	6.297E-11	1.294E-11	2.660E-12	5.467E-13	1.047E-14	2.005E-16	0.00
Bk-250	3.067E-16	4.887E-17	7.813E-18	1.248E-18	1.596E-20	3.551E-21	3.415E-21
Cf-249	4.456E-12	4.563E-12	4.570E-12	4.558E-12	4.514E-12	4.470E-12	6.435E-13
Cf-250	1.815E-11	1.632E-11	1.468E-11	1.320E-11	1.013E-11	7.773E-12	3.415E-21
Cf-251	1.284E-13	1.282E-13	1.280E-13	1.278E-13	1.273E-13	1.268E-13	5.952E-14
Cf-252	9.133E-12	5.400E-12	3.193E-12	1.888E-12	5.075E-13	1.364E-13	0.00
Es-254	3.065E-16	4.881E-17	7.806E-18	1.223E-18	0.00	0.00	0.00
Total	1.184E-01	1.082E-01	9.909E-02	9.079E-02	7.319E-02	5.930E-02	1.843E-03

TABLE D.2.e. Actinide Radioactivity by Isotope at 40 MWd/kgM, Ci/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Tl-207	3.457E-12	4.619E-12	5.736E-12	6.812E-12	9.335E-12	1.166E-11	2.475E-10
Tl-208	1.001E-08	1.286E-08	1.480E-08	1.601E-08	1.708E-08	1.688E-08	1.613E-12
Tl-209	9.283E-15	9.372E-15	9.476E-15	9.594E-15	9.953E-15	1.040E-14	3.386E-12
Pb-209	4.298E-13	4.339E-13	4.387E-13	4.442E-13	4.608E-13	4.816E-13	1.567E-10
Pb-210	1.751E-14	2.639E-14	3.904E-14	5.609E-14	1.220E-13	2.286E-13	3.562E-09
Pb-211	3.467E-12	4.632E-12	5.752E-12	6.831E-12	9.361E-12	1.169E-11	2.482E-10
Pb-212	2.785E-08	3.578E-08	4.118E-08	4.457E-08	4.753E-08	4.698E-08	4.490E-12
Pb-214	1.337E-13	1.981E-13	2.767E-13	3.697E-13	6.681E-13	1.065E-12	3.563E-09
Bi-210	1.751E-14	2.640E-14	3.905E-14	5.611E-14	1.221E-13	2.286E-13	3.562E-09
Bi-211	3.467E-12	4.632E-12	5.752E-12	6.831E-12	9.361E-12	1.169E-11	2.482E-10
Bi-212	2.785E-08	3.578E-08	4.118E-08	4.457E-08	4.753E-08	4.698E-08	4.490E-12
Bi-213	4.298E-13	4.339E-13	4.387E-13	4.442E-13	4.608E-13	4.816E-13	1.567E-10
Bi-214	1.337E-13	1.981E-13	2.767E-13	3.697E-13	6.681E-13	1.065E-12	3.563E-09
Po-210	1.566E-14	2.355E-14	3.503E-14	5.071E-14	1.221E-13	2.286E-13	3.562E-09
Po-211	9.706E-15	1.297E-14	1.611E-14	1.913E-14	2.621E-14	3.273E-14	6.950E-13
Po-212	1.785E-08	2.292E-08	2.638E-08	2.855E-08	3.045E-08	3.010E-08	2.877E-12
Po-213	4.205E-13	4.245E-13	4.292E-13	4.346E-13	4.509E-13	4.712E-13	1.534E-10
Po-214	1.337E-13	1.981E-13	2.766E-13	3.697E-13	6.679E-13	1.064E-12	3.562E-09
Po-215	3.467E-12	4.632E-12	5.752E-12	6.831E-12	9.361E-12	1.169E-11	2.482E-10
Po-216	2.785E-08	3.578E-08	4.118E-08	4.457E-08	4.753E-08	4.698E-08	4.490E-12
Po-218	1.338E-13	1.982E-13	2.767E-13	3.698E-13	6.682E-13	1.065E-12	3.564E-09
At-217	4.298E-13	4.339E-13	4.387E-13	4.442E-13	4.608E-13	4.816E-13	1.567E-10
Rn-219	3.467E-12	4.632E-12	5.752E-12	6.831E-12	9.361E-12	1.169E-11	2.482E-10
Rn-220	2.785E-08	3.578E-08	4.118E-08	4.457E-08	4.753E-08	4.698E-08	4.490E-12
Rn-222	1.338E-13	1.982E-13	2.767E-13	3.698E-13	6.682E-13	1.065E-12	3.564E-09
Fr-221	4.298E-13	4.339E-13	4.387E-13	4.442E-13	4.608E-13	4.816E-13	1.567E-10
Fr-223	4.779E-14	6.382E-14	7.924E-14	9.410E-14	1.290E-13	1.611E-13	3.426E-12
Ra-223	3.467E-12	4.632E-12	5.752E-12	6.831E-12	9.361E-12	1.169E-11	2.482E-10
Ra-224	2.785E-08	3.578E-08	4.118E-08	4.457E-08	4.753E-08	4.698E-08	4.490E-12
Ra-225	4.298E-13	4.339E-13	4.387E-13	4.442E-13	4.608E-13	4.816E-13	1.567E-10
Ra-226	1.338E-13	1.982E-13	2.767E-13	3.698E-13	6.682E-13	1.065E-12	3.564E-09
Ac-225	4.298E-13	4.339E-13	4.387E-13	4.442E-13	4.608E-13	4.816E-13	1.567E-10
Ac-227	3.463E-12	4.625E-12	5.742E-12	6.819E-12	9.348E-12	1.167E-11	2.482E-10
Th-227	3.419E-12	4.568E-12	5.673E-12	6.737E-12	9.232E-12	1.153E-11	2.448E-10
Th-228	2.783E-08	3.571E-08	4.109E-08	4.446E-08	4.749E-08	4.694E-08	4.490E-12
Th-229	4.298E-13	4.339E-13	4.387E-13	4.442E-13	4.608E-13	4.816E-13	1.567E-10
Th-230	6.646E-11	8.263E-11	9.924E-11	1.163E-10	1.607E-10	2.076E-10	2.007E-08
Th-231	1.071E-08	1.071E-08	1.071E-08	1.071E-08	1.071E-08	1.072E-08	1.102E-08
Th-234	3.157E-07	3.157E-07	3.157E-07	3.157E-07	3.157E-07	3.157E-07	3.157E-07
Pa-231	2.206E-11	2.251E-11	2.297E-11	2.342E-11	2.455E-11	2.568E-11	2.481E-10
Pa-233	3.955E-07	3.964E-07	3.974E-07	3.987E-07	4.028E-07	4.077E-07	1.240E-06
Pa-243m	3.157E-07	3.157E-07	3.157E-07	3.157E-07	3.157E-07	3.157E-07	3.157E-07
Pa-234	4.104E-10	4.104E-10	4.104E-10	4.104E-10	4.104E-10	4.104E-10	4.104E-10
U-232	4.053E-08	4.477E-08	4.700E-08	4.800E-08	4.783E-08	4.620E-08	4.375E-12
U-233	2.025E-11	2.390E-11	2.755E-11	3.122E-11	3.998E-11	4.883E-11	4.001E-09

TABLE D.2.e. Actinide Radioactivity by Isotope at 40 MWd/kgM, Ci/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
U-234	8.864E-07	9.106E-07	9.345E-07	9.580E-07	1.015E-06	1.070E-06	2.436E-06
U-235	1.071E-08	1.071E-08	1.071E-08	1.071E-08	1.071E-08	1.072E-08	1.102E-08
U-236	2.601E-07	2.601E-07	2.601E-07	2.602E-07	2.603E-07	2.603E-07	2.773E-07
U-237	3.067E-06	2.786E-06	2.530E-06	2.298E-06	1.806E-06	1.420E-06	1.058E-11
U-238	3.157E-07	3.157E-07	3.157E-07	3.157E-07	3.157E-07	3.157E-07	3.157E-07
U-240	8.529E-13	8.529E-13	8.529E-13	8.529E-13	8.529E-13	8.529E-13	8.529E-13
Np-235	5.924E-10	1.650E-10	4.594E-11	1.279E-11	5.235E-13	2.142E-14	0.00
Np-236	7.459E-12	7.459E-12	7.458E-12	7.458E-12	7.458E-12	7.458E-12	7.414E-12
Np-237	3.955E-07	3.964E-07	3.974E-07	3.987E-07	4.028E-07	4.077E-07	1.240E-06
Np-238	7.546E-08	7.478E-08	7.410E-08	7.343E-08	7.177E-08	7.015E-08	8.041E-10
Np-239	3.477E-05	3.476E-05	3.475E-05	3.475E-05	3.473E-05	3.471E-05	3.166E-05
Np-240m	8.529E-13	8.529E-13	8.529E-13	8.529E-13	8.529E-13	8.529E-13	8.529E-13
Pu-236	3.322E-07	2.043E-07	1.256E-07	7.724E-08	2.290E-08	6.792E-09	6.673E-13
Pu-237	1.667E-16	2.509E-21	0.00	0.00	0.00	0.00	0.00
Pu-238	4.313E-03	4.246E-03	4.180E-03	4.114E-03	3.955E-03	3.803E-03	1.955E-06
Pu-239	3.168E-04	3.168E-04	3.168E-04	3.168E-04	3.167E-04	3.167E-04	3.088E-04
Pu-240	6.032E-04	6.040E-04	6.047E-04	6.053E-04	6.067E-04	6.078E-04	5.540E-04
Pu-241	1.250E-01	1.136E-01	1.031E-01	9.367E-02	7.363E-02	5.788E-02	4.317E-07
Pu-242	2.734E-06	2.734E-06	2.734E-06	2.734E-06	2.734E-06	2.734E-06	2.730E-06
Pu-243	4.981E-13	4.981E-13	4.981E-13	4.981E-13	4.981E-13	4.981E-13	4.981E-13
Pu-244	8.540E-13	8.540E-13	8.540E-13	8.540E-13	8.540E-13	8.540E-13	8.540E-13
Am-241	1.115E-03	1.493E-03	1.835E-03	2.144E-03	2.792E-03	3.292E-03	1.098E-03
Am-242m	1.509E-05	1.496E-05	1.482E-05	1.468E-05	1.435E-05	1.403E-05	1.608E-07
Am-242	1.502E-05	1.488E-05	1.475E-05	1.461E-05	1.428E-05	1.396E-05	1.600E-07
Am-243	3.477E-05	3.476E-05	3.475E-05	3.475E-05	3.473E-05	3.471E-05	3.166E-05
Am-245	3.612E-15	7.424E-16	1.526E-16	3.136E-17	6.005E-19	1.150E-20	0.00
Cm-242	1.703E-04	1.942E-05	1.254E-05	1.212E-05	1.182E-05	1.155E-05	1.323E-07
Cm-243	3.840E-05	3.658E-05	3.484E-05	3.319E-05	2.939E-05	2.602E-05	1.159E-15
Cm-244	4.497E-03	4.166E-03	3.859E-03	3.575E-03	2.952E-03	2.438E-03	1.250E-19
Cm-245	4.675E-07	4.674E-07	4.673E-07	4.673E-07	4.671E-07	4.669E-07	4.310E-07
Cm-246	1.393E-07	1.393E-07	1.393E-07	1.392E-07	1.391E-07	1.390E-07	1.204E-07
Cm-247	4.981E-13	4.981E-13	4.981E-13	4.981E-13	4.981E-13	4.981E-13	4.981E-13
Cm-248	1.520E-12	1.520E-12	1.520E-12	1.521E-12	1.521E-12	1.521E-12	1.518E-12
Bk-249	2.491E-10	5.119E-11	1.052E-11	2.162E-12	4.140E-14	7.928E-16	0.00
Bk-250	2.167E-15	3.454E-16	5.507E-17	8.816E-18	1.076E-19	4.542E-20	1.769E-20
Cf-249	1.741E-11	1.784E-11	1.787E-11	1.782E-11	1.765E-11	1.747E-11	2.516E-12
Cf-250	7.584E-11	6.821E-11	6.135E-11	5.518E-11	4.234E-11	3.248E-11	1.769E-20
Cf-251	5.674E-13	5.665E-13	5.656E-13	5.648E-13	5.626E-13	5.604E-13	2.630E-13
Cf-252	4.883E-11	2.887E-11	1.707E-11	1.009E-11	2.713E-12	7.293E-13	0.00
Es-254	2.166E-15	3.453E-16	5.498E-17	8.793E-18	7.627E-20	2.703E-20	0.00
Total	1.362E-01	1.246E-01	1.141E-01	1.046E-01	8.441E-02	6.848E-02	2.037E-03

TABLE D.2.f. Actinide Radioactivity by Isotope at 45 MWd/kgM, Ci/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Tl-207	3.333E-12	4.454E-12	5.525E-12	6.551E-12	8.933E-12	1.109E-11	1.921E-10
Tl-208	1.241E-08	1.606E-08	1.856E-08	2.013E-08	2.153E-08	2.130E-08	2.015E-12
Tl-209	1.213E-14	1.222E-14	1.233E-14	1.246E-14	1.284E-14	1.333E-14	3.771E-12
Pb-209	5.615E-13	5.658E-13	5.708E-13	5.767E-13	5.946E-13	6.173E-13	1.746E-10
Pb-210	1.868E-14	2.663E-14	3.804E-14	5.354E-14	1.140E-13	2.127E-13	3.984E-09
Pb-211	3.342E-12	4.466E-12	5.540E-12	6.569E-12	8.958E-12	1.112E-11	1.926E-10
Pb-212	3.453E-08	4.469E-08	5.164E-08	5.603E-08	5.992E-08	5.928E-08	5.608E-12
Pb-214	1.222E-13	1.810E-13	2.532E-13	3.392E-13	6.173E-13	9.910E-13	3.985E-09
Bi-210	1.869E-14	2.664E-14	3.806E-14	5.356E-14	1.140E-13	2.128E-13	3.984E-09
Bi-211	3.342E-12	4.466E-12	5.540E-12	6.569E-12	8.958E-12	1.112E-11	1.926E-10
Bi-212	3.453E-08	4.469E-08	5.164E-08	5.603E-08	5.992E-08	5.928E-08	5.608E-12
Bi-213	5.615E-13	5.658E-13	5.708E-13	5.767E-13	5.946E-13	6.173E-13	1.746E-10
Bi-214	1.222E-13	1.810E-13	2.532E-13	3.392E-13	6.173E-13	9.910E-13	3.985E-09
Po-210	1.702E-14	2.406E-14	3.440E-14	4.862E-14	1.140E-13	2.128E-13	3.984E-09
Po-211	9.358E-15	1.250E-14	1.551E-14	1.839E-14	2.508E-14	3.115E-14	5.394E-13
Po-212	2.213E-08	2.863E-08	3.309E-08	3.590E-08	3.839E-08	3.798E-08	3.593E-12
Po-213	5.493E-13	5.535E-13	5.585E-13	5.642E-13	5.818E-13	6.040E-13	1.708E-10
Po-214	1.221E-13	1.810E-13	2.532E-13	3.391E-13	6.172E-13	9.908E-13	3.984E-09
Po-215	3.342E-12	4.466E-12	5.540E-12	6.569E-12	8.958E-12	1.112E-11	1.926E-10
Po-216	3.453E-08	4.469E-08	5.164E-08	5.603E-08	5.992E-08	5.928E-08	5.608E-12
Po-218	1.222E-13	1.811E-13	2.533E-13	3.393E-13	6.174E-13	9.912E-13	3.986E-09
At-217	5.615E-13	5.658E-13	5.708E-13	5.767E-13	5.946E-13	6.173E-13	1.746E-10
Rn-219	3.342E-12	4.466E-12	5.540E-12	6.569E-12	8.958E-12	1.112E-11	1.926E-10
Rn-220	3.453E-08	4.469E-08	5.164E-08	5.603E-08	5.992E-08	5.928E-08	5.608E-12
Rn-222	1.222E-13	1.811E-13	2.533E-13	3.393E-13	6.174E-13	9.912E-13	3.986E-09
Fr-221	5.615E-13	5.658E-13	5.708E-13	5.767E-13	5.946E-13	6.173E-13	1.746E-10
Fr-223	4.608E-14	6.153E-14	7.632E-14	9.049E-14	1.234E-13	1.533E-13	2.658E-12
Ra-223	3.342E-12	4.466E-12	5.540E-12	6.569E-12	8.958E-12	1.112E-11	1.926E-10
Ra-224	3.453E-08	4.469E-08	5.164E-08	5.603E-08	5.992E-08	5.928E-08	5.608E-12
Ra-225	5.615E-13	5.658E-13	5.708E-13	5.767E-13	5.946E-13	6.173E-13	1.746E-10
Ra-226	1.222E-13	1.811E-13	2.533E-13	3.393E-13	6.174E-13	9.912E-13	3.986E-09
Ac-225	5.615E-13	5.658E-13	5.708E-13	5.767E-13	5.946E-13	6.173E-13	1.746E-10
Ac-227	3.339E-12	4.459E-12	5.531E-12	6.557E-12	8.945E-12	1.111E-11	1.926E-10
Th-227	3.296E-12	4.404E-12	5.464E-12	6.479E-12	8.834E-12	1.097E-11	1.900E-10
Th-228	3.451E-08	4.460E-08	5.153E-08	5.590E-08	5.987E-08	5.923E-08	5.608E-12
Th-229	5.615E-13	5.658E-13	5.708E-13	5.767E-13	5.946E-13	6.173E-13	1.746E-10
Th-230	6.058E-11	7.574E-11	9.145E-11	1.077E-10	1.506E-10	1.967E-10	2.262E-08
Th-231	8.079E-09	8.080E-09	8.081E-09	8.081E-09	8.083E-09	8.084E-09	8.387E-09
Th-234	3.142E-07	3.142E-07	3.142E-07	3.142E-07	3.142E-07	3.142E-07	3.142E-07
Pa-231	2.132E-11	2.166E-11	2.200E-11	2.234E-11	2.320E-11	2.405E-11	1.926E-10
Pa-233	4.503E-07	4.512E-07	4.524E-07	4.538E-07	4.582E-07	4.635E-07	1.370E-06
Pa-243m	3.142E-07	3.142E-07	3.142E-07	3.142E-07	3.142E-07	3.142E-07	3.142E-07
Pa-234	4.084E-10	4.084E-10	4.084E-10	4.084E-10	4.084E-10	4.084E-10	4.084E-10
U-232	5.073E-08	5.624E-08	5.916E-08	6.048E-08	6.035E-08	5.831E-08	5.467E-12
U-233	2.107E-11	2.522E-11	2.938E-11	3.355E-11	4.352E-11	5.359E-11	4.442E-09

TABLE D.2.f. Actinide Radioactivity by Isotope at 45 MWd/kgM, Ci/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
U-234	8.271E-07	8.576E-07	8.876E-07	9.171E-07	9.889E-07	1.058E-06	2.772E-06
U-235	8.079E-09	8.080E-09	8.081E-09	8.081E-09	8.083E-09	8.084E-09	8.387E-09
U-236	2.646E-07	2.647E-07	2.647E-07	2.647E-07	2.648E-07	2.649E-07	2.829E-07
U-237	3.356E-06	3.048E-06	2.768E-06	2.514E-06	1.976E-06	1.553E-06	1.914E-11
U-238	3.142E-07	3.142E-07	3.142E-07	3.142E-07	3.142E-07	3.142E-07	3.142E-07
U-240	1.473E-12	1.473E-12	1.473E-12	1.473E-12	1.473E-12	1.473E-12	1.473E-12
Np-235	7.295E-10	2.032E-10	5.657E-11	1.575E-11	6.447E-13	2.638E-14	0.00
Np-236	8.782E-12	8.782E-12	8.782E-12	8.782E-12	8.781E-12	8.781E-12	8.729E-12
Np-237	4.503E-07	4.512E-07	4.524E-07	4.538E-07	4.582E-07	4.635E-07	1.370E-06
Np-238	7.581E-08	7.513E-08	7.444E-08	7.377E-08	7.211E-08	7.048E-08	8.078E-10
Np-239	4.948E-05	4.947E-05	4.946E-05	4.945E-05	4.943E-05	4.941E-05	4.506E-05
Np-240m	1.473E-12	1.473E-12	1.473E-12	1.473E-12	1.473E-12	1.473E-12	1.473E-12
Pu-236	4.297E-07	2.643E-07	1.625E-07	9.993E-08	2.963E-08	8.787E-09	7.857E-13
Pu-237	2.327E-16	3.502E-21	5.271E-26	0.00	0.00	0.00	0.00
Pu-238	5.415E-03	5.332E-03	5.248E-03	5.166E-03	4.967E-03	4.775E-03	2.378E-06
Pu-239	3.176E-04	3.176E-04	3.176E-04	3.176E-04	3.175E-04	3.175E-04	3.100E-04
Pu-240	6.329E-04	6.343E-04	6.356E-04	6.368E-04	6.394E-04	6.414E-04	5.884E-04
Pu-241	1.368E-01	1.242E-01	1.128E-01	1.025E-01	8.056E-02	6.333E-02	7.812E-07
Pu-242	3.427E-06	3.427E-06	3.427E-06	3.427E-06	3.427E-06	3.427E-06	3.423E-06
Pu-243	1.252E-12	1.252E-12	1.252E-12	1.252E-12	1.252E-12	1.252E-12	1.252E-12
Pu-244	1.475E-12	1.475E-12	1.475E-12	1.475E-12	1.475E-12	1.475E-12	1.475E-12
Am-241	1.196E-03	1.609E-03	1.984E-03	2.322E-03	3.030E-03	3.578E-03	1.197E-03
Am-242m	1.516E-05	1.502E-05	1.489E-05	1.475E-05	1.442E-05	1.410E-05	1.616E-07
Am-242	1.509E-05	1.495E-05	1.481E-05	1.468E-05	1.435E-05	1.403E-05	1.608E-07
Am-243	4.948E-05	4.947E-05	4.946E-05	4.945E-05	4.943E-05	4.941E-05	4.506E-05
Am-245	1.187E-14	2.439E-15	5.012E-16	1.030E-16	1.973E-18	3.777E-20	0.00
Cm-242	1.982E-04	2.073E-05	1.265E-05	1.218E-05	1.187E-05	1.160E-05	1.329E-07
Cm-243	5.081E-05	4.840E-05	4.610E-05	4.391E-05	3.889E-05	3.443E-05	1.534E-15
Cm-244	7.558E-03	7.001E-03	6.485E-03	6.007E-03	4.961E-03	4.097E-03	2.101E-19
Cm-245	8.459E-07	8.457E-07	8.456E-07	8.454E-07	8.451E-07	8.447E-07	7.799E-07
Cm-246	3.020E-07	3.019E-07	3.018E-07	3.017E-07	3.015E-07	3.013E-07	2.610E-07
Cm-247	1.252E-12	1.252E-12	1.252E-12	1.252E-12	1.252E-12	1.252E-12	1.252E-12
Cm-248	4.534E-12	4.534E-12	4.534E-12	4.535E-12	4.535E-12	4.535E-12	4.526E-12
Bk-249	8.182E-10	1.682E-10	3.456E-11	7.103E-12	1.360E-13	2.604E-15	0.00
Bk-250	1.174E-14	1.870E-15	2.981E-16	4.758E-17	5.782E-19	1.073E-19	7.497E-20
Cf-249	5.660E-11	5.799E-11	5.810E-11	5.794E-11	5.738E-11	5.682E-11	8.180E-12
Cf-250	2.603E-10	2.341E-10	2.106E-10	1.894E-10	1.453E-10	1.115E-10	7.497E-20
Cf-251	2.035E-12	2.032E-12	2.029E-12	2.026E-12	2.018E-12	2.010E-12	9.436E-13
Cf-252	2.082E-10	1.231E-10	7.278E-11	4.303E-11	1.157E-11	3.110E-12	0.00
Es-254	1.173E-14	1.869E-15	2.979E-16	4.745E-17	5.000E-19	2.933E-20	0.00
Total	1.523E-01	1.393E-01	1.277E-01	1.171E-01	9.466E-02	7.692E-02	2.200E-03

TABLE D.2.g. Actinide Radioactivity by Isotope at 50 MWd/kgM, Ci/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Tl-207	3.168E-12	4.235E-12	5.250E-12	6.219E-12	8.449E-12	1.045E-11	1.487E-10
Tl-208	1.487E-08	1.936E-08	2.245E-08	2.441E-08	2.616E-08	2.590E-08	2.428E-12
Tl-209	1.529E-14	1.538E-14	1.550E-14	1.563E-14	1.604E-14	1.657E-14	4.090E-12
Pb-209	7.078E-13	7.122E-13	7.175E-13	7.237E-13	7.427E-13	7.670E-13	1.893E-10
Pb-210	2.038E-14	2.742E-14	3.766E-14	5.167E-14	1.070E-13	1.985E-13	4.425E-09
Pb-211	3.177E-12	4.247E-12	5.265E-12	6.236E-12	8.473E-12	1.048E-11	1.491E-10
Pb-212	4.139E-08	5.389E-08	6.249E-08	6.793E-08	7.281E-08	7.209E-08	6.758E-12
Pb-214	1.113E-13	1.651E-13	2.315E-13	3.109E-13	5.706E-13	9.239E-13	4.426E-09
Bi-210	2.039E-14	2.744E-14	3.767E-14	5.169E-14	1.070E-13	1.986E-13	4.425E-09
Bi-211	3.177E-12	4.247E-12	5.265E-12	6.236E-12	8.473E-12	1.048E-11	1.491E-10
Bi-212	4.139E-08	5.389E-08	6.249E-08	6.793E-08	7.281E-08	7.209E-08	6.758E-12
Bi-213	7.078E-13	7.122E-13	7.175E-13	7.237E-13	7.427E-13	7.670E-13	1.893E-10
Bi-214	1.113E-13	1.651E-13	2.315E-13	3.109E-13	5.706E-13	9.239E-13	4.426E-09
Po-210	1.891E-14	2.511E-14	3.436E-14	4.719E-14	1.070E-13	1.986E-13	4.425E-09
Po-211	8.895E-15	1.189E-14	1.474E-14	1.746E-14	2.372E-14	2.934E-14	4.175E-13
Po-212	2.652E-08	3.453E-08	4.004E-08	4.352E-08	4.665E-08	4.619E-08	4.330E-12
Po-213	6.925E-13	6.968E-13	7.020E-13	7.080E-13	7.267E-13	7.505E-13	1.852E-10
Po-214	1.113E-13	1.651E-13	2.314E-13	3.109E-13	5.705E-13	9.237E-13	4.425E-09
Po-215	3.177E-12	4.247E-12	5.265E-12	6.236E-12	8.473E-12	1.048E-11	1.491E-10
Po-216	4.139E-08	5.389E-08	6.249E-08	6.793E-08	7.281E-08	7.209E-08	6.758E-12
Po-218	1.114E-13	1.651E-13	2.315E-13	3.110E-13	5.707E-13	9.241E-13	4.426E-09
At-217	7.078E-13	7.122E-13	7.175E-13	7.237E-13	7.427E-13	7.670E-13	1.893E-10
Rn-219	3.177E-12	4.247E-12	5.265E-12	6.236E-12	8.473E-12	1.048E-11	1.491E-10
Rn-220	4.139E-08	5.389E-08	6.249E-08	6.793E-08	7.281E-08	7.209E-08	6.758E-12
Rn-222	1.114E-13	1.651E-13	2.315E-13	3.110E-13	5.707E-13	9.241E-13	4.426E-09
Fr-221	7.078E-13	7.122E-13	7.175E-13	7.237E-13	7.427E-13	7.670E-13	1.893E-10
Fr-223	4.380E-14	5.851E-14	7.253E-14	8.590E-14	1.168E-13	1.444E-13	2.058E-12
Ra-223	3.177E-12	4.247E-12	5.265E-12	6.236E-12	8.473E-12	1.048E-11	1.491E-10
Ra-224	4.139E-08	5.389E-08	6.249E-08	6.793E-08	7.281E-08	7.209E-08	6.758E-12
Ra-225	7.078E-13	7.122E-13	7.175E-13	7.237E-13	7.427E-13	7.670E-13	1.893E-10
Ra-226	1.114E-13	1.651E-13	2.315E-13	3.110E-13	5.707E-13	9.241E-13	4.426E-09
Ac-225	7.078E-13	7.122E-13	7.175E-13	7.237E-13	7.427E-13	7.670E-13	1.893E-10
Ac-227	3.174E-12	4.240E-12	5.256E-12	6.225E-12	8.461E-12	1.046E-11	1.491E-10
Th-227	3.133E-12	4.188E-12	5.192E-12	6.150E-12	8.356E-12	1.033E-11	1.471E-10
Th-228	4.136E-08	5.379E-08	6.235E-08	6.777E-08	7.275E-08	7.203E-08	6.758E-12
Th-229	7.078E-13	7.122E-13	7.175E-13	7.236E-13	7.427E-13	7.670E-13	1.893E-10
Th-230	5.513E-11	6.938E-11	8.428E-11	9.983E-11	1.415E-10	1.869E-10	2.527E-08
Th-231	6.039E-09	6.040E-09	6.041E-09	6.041E-09	6.043E-09	6.044E-09	6.347E-09
Th-234	3.125E-07	3.125E-07	3.125E-07	3.125E-07	3.125E-07	3.125E-07	3.125E-07
Pa-231	2.033E-11	2.058E-11	2.084E-11	2.109E-11	2.173E-11	2.237E-11	1.491E-10
Pa-233	4.990E-07	5.000E-07	5.012E-07	5.027E-07	5.073E-07	5.129E-07	1.474E-06
Pa-243m	3.125E-07	3.125E-07	3.125E-07	3.125E-07	3.125E-07	3.125E-07	3.125E-07
Pa-234	4.063E-10	4.063E-10	4.063E-10	4.063E-10	4.063E-10	4.063E-10	4.063E-10
U-232	6.128E-08	6.816E-08	7.180E-08	7.348E-08	7.338E-08	7.093E-08	6.588E-12
U-233	2.165E-11	2.625E-11	3.086E-11	3.549E-11	4.652E-11	5.767E-11	4.800E-09

TABLE D.2.g. Actinide Radioactivity by Isotope at 50 MWd/kgM, Ci/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
U-234	7.730E-07	8.097E-07	8.460E-07	8.816E-07	9.683E-07	1.052E-06	3.120E-06
U-235	6.039E-09	6.040E-09	6.041E-09	6.041E-09	6.043E-09	6.044E-09	6.347E-09
U-236	2.655E-07	2.655E-07	2.655E-07	2.656E-07	2.657E-07	2.658E-07	2.846E-07
U-237	3.568E-06	3.240E-06	2.943E-06	2.673E-06	2.101E-06	1.651E-06	3.181E-11
U-238	3.125E-07	3.125E-07	3.125E-07	3.125E-07	3.125E-07	3.125E-07	3.125E-07
U-240	2.371E-12	2.371E-12	2.371E-12	2.371E-12	2.371E-12	2.371E-12	2.371E-12
Np-235	8.625E-10	2.402E-10	6.689E-11	1.863E-11	7.622E-13	3.119E-14	0.00
Np-236	9.994E-12	9.993E-12	9.993E-12	9.993E-12	9.993E-12	9.993E-12	9.934E-12
Np-237	4.990E-07	5.000E-07	5.012E-07	5.027E-07	5.073E-07	5.129E-07	1.474E-06
Np-238	7.421E-08	7.354E-08	7.287E-08	7.221E-08	7.058E-08	6.899E-08	7.907E-10
Np-239	6.651E-05	6.649E-05	6.648E-05	6.647E-05	6.644E-05	6.641E-05	6.057E-05
Np-240m	2.371E-12	2.371E-12	2.371E-12	2.371E-12	2.371E-12	2.371E-12	2.371E-12
Pu-236	5.332E-07	3.279E-07	2.016E-07	1.240E-07	3.676E-08	1.090E-08	8.941E-13
Pu-237	3.080E-16	4.636E-21	6.977E-26	0.00	0.00	0.00	0.00
Pu-238	6.540E-03	6.438E-03	6.338E-03	6.238E-03	5.997E-03	5.765E-03	2.802E-06
Pu-239	3.177E-04	3.177E-04	3.177E-04	3.176E-04	3.176E-04	3.176E-04	3.106E-04
Pu-240	6.526E-04	6.549E-04	6.570E-04	6.589E-04	6.631E-04	6.665E-04	6.167E-04
Pu-241	1.454E-01	1.321E-01	1.200E-01	1.089E-01	8.564E-02	6.732E-02	1.299E-06
Pu-242	4.122E-06	4.122E-06	4.122E-06	4.122E-06	4.122E-06	4.122E-06	4.117E-06
Pu-243	2.795E-12	2.795E-12	2.795E-12	2.795E-12	2.795E-12	2.795E-12	2.795E-12
Pu-244	2.374E-12	2.374E-12	2.374E-12	2.374E-12	2.374E-12	2.374E-12	2.374E-12
Am-241	1.249E-03	1.689E-03	2.087E-03	2.446E-03	3.200E-03	3.782E-03	1.269E-03
Am-242m	1.484E-05	1.471E-05	1.457E-05	1.444E-05	1.412E-05	1.380E-05	1.581E-07
Am-242	1.477E-05	1.463E-05	1.450E-05	1.437E-05	1.404E-05	1.373E-05	1.573E-07
Am-243	6.651E-05	6.649E-05	6.648E-05	6.647E-05	6.644E-05	6.641E-05	6.057E-05
Am-245	3.350E-14	6.885E-15	1.415E-15	2.908E-16	5.569E-18	1.066E-19	0.00
Cm-242	2.224E-04	2.156E-05	1.244E-05	1.192E-05	1.162E-05	1.136E-05	1.301E-07
Cm-243	6.346E-05	6.044E-05	5.757E-05	5.484E-05	4.856E-05	4.300E-05	1.916E-15
Cm-244	1.182E-02	1.095E-02	1.014E-02	9.397E-03	7.760E-03	6.409E-03	3.286E-19
Cm-245	1.406E-06	1.406E-06	1.406E-06	1.405E-06	1.405E-06	1.404E-06	1.296E-06
Cm-246	5.912E-07	5.911E-07	5.909E-07	5.907E-07	5.903E-07	5.899E-07	5.110E-07
Cm-247	2.795E-12	2.795E-12	2.795E-12	2.795E-12	2.795E-12	2.795E-12	2.795E-12
Cm-248	1.180E-11	1.180E-11	1.180E-11	1.181E-11	1.181E-11	1.181E-11	1.178E-11
Bk-249	2.310E-09	4.747E-10	9.756E-11	2.005E-11	3.839E-13	7.352E-15	0.00
Bk-250	5.097E-14	8.122E-15	1.295E-15	2.066E-16	2.372E-18	3.011E-19	2.694E-19
Cf-249	1.582E-10	1.622E-10	1.625E-10	1.620E-10	1.605E-10	1.589E-10	2.287E-11
Cf-250	7.606E-10	6.841E-10	6.153E-10	5.535E-10	4.246E-10	3.258E-10	2.694E-19
Cf-251	6.160E-12	6.150E-12	6.141E-12	6.131E-12	6.108E-12	6.084E-12	2.856E-12
Cf-252	7.366E-10	4.355E-10	2.575E-10	1.522E-10	4.093E-11	1.100E-11	0.00
Es-254	5.094E-14	8.118E-15	1.294E-15	2.062E-16	2.069E-18	0.00	0.00
Total	1.665E-01	1.524E-01	1.397E-01	1.282E-01	1.038E-01	8.449E-02	2.335E-03

TABLE D.3.a. Fission Product Inventory by Isotope at 20 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-3	2.461E-08	2.200E-08	1.966E-08	1.757E-08	1.327E-08	1.002E-08	1.292E-32
Li-6	1.509E-10	1.509E-10	1.509E-10	1.509E-10	1.509E-10	1.509E-10	1.509E-10
Li-7	6.145E-12	6.145E-12	6.145E-12	6.145E-12	6.145E-12	6.145E-12	6.145E-12
Be-9	1.183E-11	1.183E-11	1.183E-11	1.183E-11	1.183E-11	1.183E-11	1.183E-11
Be-10	7.896E-11	7.896E-11	7.896E-11	7.896E-11	7.896E-11	7.896E-11	7.892E-11
C-14	1.595E-11	1.595E-11	1.595E-11	1.594E-11	1.593E-11	1.592E-11	1.414E-11
Zn-66	2.431E-14	2.431E-14	2.431E-14	2.431E-14	2.431E-14	2.431E-14	2.431E-14
Zn-67	1.023E-15	1.023E-15	1.023E-15	1.023E-15	1.023E-15	1.023E-15	1.023E-15
Ga-71	5.077E-13	5.077E-13	5.077E-13	5.077E-13	5.077E-13	5.077E-13	5.077E-13
Ge-72	1.241E-08	1.241E-08	1.241E-08	1.241E-08	1.241E-08	1.241E-08	1.241E-08
Ge-73	2.700E-08	2.700E-08	2.700E-08	2.700E-08	2.700E-08	2.700E-08	2.700E-08
Ge-74	5.808E-08	5.808E-08	5.808E-08	5.808E-08	5.808E-08	5.808E-08	5.808E-08
As-75	1.240E-07	1.240E-07	1.240E-07	1.240E-07	1.240E-07	1.240E-07	1.240E-07
Ge-76	3.118E-07	3.118E-07	3.118E-07	3.118E-07	3.118E-07	3.118E-07	3.118E-07
Se-76	1.983E-09	1.983E-09	1.983E-09	1.983E-09	1.983E-09	1.983E-09	1.983E-09
Se-77	6.556E-07	6.556E-07	6.556E-07	6.556E-07	6.556E-07	6.556E-07	6.556E-07
Se-78	1.471E-06	1.471E-06	1.471E-06	1.471E-06	1.471E-06	1.471E-06	1.471E-06
Se-79	3.651E-06	3.651E-06	3.651E-06	3.651E-06	3.651E-06	3.651E-06	3.613E-06
Br-79	2.663E-10	3.442E-10	4.221E-10	5.000E-10	6.948E-10	8.896E-10	3.886E-08
Se-80	8.346E-06	8.346E-06	8.346E-06	8.346E-06	8.346E-06	8.346E-06	8.346E-06
Kr-80	1.204E-10	1.204E-10	1.204E-10	1.204E-10	1.204E-10	1.204E-10	1.204E-10
Br-81	1.387E-05	1.387E-05	1.387E-05	1.387E-05	1.387E-05	1.387E-05	1.387E-05
Kr-81	8.864E-12	8.864E-12	8.864E-12	8.864E-12	8.864E-12	8.864E-12	8.835E-12
Se-82	2.140E-05	2.140E-05	2.140E-05	2.140E-05	2.140E-05	2.140E-05	2.140E-05
Kr-82	3.822E-07	3.822E-07	3.822E-07	3.822E-07	3.822E-07	3.822E-07	3.822E-07
Kr-83	2.941E-05	2.941E-05	2.941E-05	2.941E-05	2.941E-05	2.941E-05	2.941E-05
Kr-84	6.965E-05	6.965E-05	6.965E-05	6.965E-05	6.965E-05	6.965E-05	6.965E-05
Kr-85	1.089E-05	9.568E-06	8.407E-06	7.387E-06	5.347E-06	3.870E-06	1.177E-33
Rb-85	6.786E-05	6.918E-05	7.034E-05	7.136E-05	7.340E-05	7.488E-05	7.875E-05
Kr-86	1.237E-04	1.237E-04	1.237E-04	1.237E-04	1.237E-04	1.237E-04	1.237E-04
Sr-86	1.532E-07	1.532E-07	1.532E-07	1.532E-07	1.532E-07	1.532E-07	1.532E-07
Rb-87	1.592E-04	1.592E-04	1.592E-04	1.592E-04	1.592E-04	1.592E-04	1.592E-04
Sr-87	1.136E-09	1.136E-09	1.136E-09	1.136E-09	1.136E-09	1.136E-09	1.138E-09
Sr-88	2.286E-04	2.286E-04	2.286E-04	2.286E-04	2.286E-04	2.286E-04	2.286E-04
Sr-89	1.850E-14	8.176E-19	3.613E-23	1.596E-27	0.00	0.00	0.00
Y-89	2.994E-04	2.994E-04	2.994E-04	2.994E-04	2.994E-04	2.994E-04	2.994E-04
Sr-90	3.076E-04	2.933E-04	2.797E-04	2.667E-04	2.367E-04	2.102E-04	1.557E-14
Y-90	7.714E-08	7.355E-08	7.013E-08	6.687E-08	5.937E-08	5.271E-08	3.904E-18
Zr-90	5.534E-05	6.965E-05	8.328E-05	9.629E-05	1.262E-04	1.528E-04	3.630E-04
Y-91	4.395E-13	7.662E-17	1.336E-20	2.329E-24	9.349E-34	0.00	0.00
Zr-91	3.836E-04	3.836E-04	3.836E-04	3.836E-04	3.836E-04	3.836E-04	3.836E-04
Zr-92	4.106E-04	4.106E-04	4.106E-04	4.106E-04	4.106E-04	4.106E-04	4.106E-04
Zr-93	4.588E-04	4.588E-04	4.588E-04	4.588E-04	4.588E-04	4.588E-04	4.586E-04
Nb-93	2.963E-10	4.467E-10	6.227E-10	8.220E-10	1.408E-09	2.095E-09	2.045E-07
Nb-93m	1.136E-09	1.402E-09	1.641E-09	1.858E-09	2.311E-09	2.663E-09	3.873E-09

TABLE D.3.a. Fission Product Inventory by Isotope at 20 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Zr-94	4.636E-04	4.636E-04	4.636E-04	4.636E-04	4.636E-04	4.636E-04	4.636E-04
Nb-94	3.855E-10	3.855E-10	3.855E-10	3.855E-10	3.854E-10	3.853E-10	3.726E-10
Zr-95	2.927E-12	1.070E-15	3.913E-19	1.431E-22	3.657E-31	0.00	0.00
Nb-95	3.571E-12	1.306E-15	4.773E-19	1.745E-22	3.308E-33	0.00	0.00
Nb-95m	1.225E-15	4.479E-19	1.637E-22	5.987E-26	0.00	0.00	0.00
Mo-95	4.798E-04	4.798E-04	4.798E-04	4.798E-04	4.798E-04	4.798E-04	4.798E-04
Zr-96	4.960E-04	4.960E-04	4.960E-04	4.960E-04	4.960E-04	4.960E-04	4.960E-04
Mo-96	1.362E-05	1.362E-05	1.362E-05	1.362E-05	1.362E-05	1.362E-05	1.362E-05
Mo-97	4.861E-04	4.861E-04	4.861E-04	4.861E-04	4.861E-04	4.861E-04	4.861E-04
Mo-98	5.014E-04	5.014E-04	5.014E-04	5.014E-04	5.014E-04	5.014E-04	5.014E-04
Tc-98	2.245E-09	2.245E-09	2.245E-09	2.245E-09	2.245E-09	2.245E-09	2.245E-09
Tc-99	4.894E-04	4.894E-04	4.894E-04	4.894E-04	4.894E-04	4.894E-04	4.878E-04
Ru-99	1.074E-08	1.393E-08	1.711E-08	2.030E-08	2.826E-08	3.622E-08	1.594E-06
Mo-100	5.621E-04	5.621E-04	5.621E-04	5.621E-04	5.621E-04	5.621E-04	5.621E-04
Ru-100	3.402E-05	3.402E-05	3.402E-05	3.402E-05	3.402E-05	3.402E-05	3.402E-05
Ru-101	4.685E-04	4.685E-04	4.685E-04	4.685E-04	4.685E-04	4.685E-04	4.685E-04
Ru-102	4.450E-04	4.450E-04	4.450E-04	4.450E-04	4.450E-04	4.450E-04	4.450E-04
Rh-102	1.243E-10	7.707E-11	4.778E-11	2.962E-11	8.967E-12	2.714E-12	0.00
Ru-103	8.201E-17	2.070E-22	5.223E-28	1.318E-33	0.00	0.00	0.00
Rh-103	3.033E-04	3.033E-04	3.033E-04	3.033E-04	3.033E-04	3.033E-04	3.033E-04
Ru-104	2.927E-04	2.927E-04	2.927E-04	2.927E-04	2.927E-04	2.927E-04	2.927E-04
Pd-104	8.482E-05	8.482E-05	8.482E-05	8.482E-05	8.482E-05	8.482E-05	8.482E-05
Pd-105	2.094E-04	2.094E-04	2.094E-04	2.094E-04	2.094E-04	2.094E-04	2.094E-04
Ru-106	3.115E-06	7.872E-07	1.990E-07	5.030E-08	1.616E-09	5.190E-11	0.00
Rh-106	2.928E-12	7.400E-13	1.870E-13	4.728E-14	1.519E-15	4.878E-17	0.00
Pd-106	1.600E-04	1.623E-04	1.629E-04	1.630E-04	1.631E-04	1.631E-04	1.631E-04
Pd-107	1.043E-04	1.043E-04	1.043E-04	1.043E-04	1.043E-04	1.043E-04	1.043E-04
Ag-107	6.853E-11	9.078E-11	1.130E-10	1.353E-10	1.909E-10	2.465E-10	1.115E-08
Pd-108	7.056E-05	7.056E-05	7.056E-05	7.056E-05	7.056E-05	7.056E-05	7.056E-05
Ag-108m	5.276E-13	5.218E-13	5.162E-13	5.106E-13	4.968E-13	4.834E-13	2.299E-15
Cd-108	1.143E-10	1.143E-10	1.143E-10	1.143E-10	1.143E-10	1.143E-10	1.144E-10
Ag-109	3.931E-05	3.931E-05	3.931E-05	3.931E-05	3.931E-05	3.931E-05	3.931E-05
Cd-109	7.540E-15	2.532E-15	8.502E-16	2.855E-16	1.865E-17	1.219E-18	0.00
Pd-110	2.331E-05	2.331E-05	2.331E-05	2.331E-05	2.331E-05	2.331E-05	2.331E-05
Ag-110	4.430E-17	5.840E-18	7.698E-19	1.015E-19	6.402E-22	4.040E-24	0.00
Ag-110m	2.923E-09	3.853E-10	5.080E-11	6.696E-12	4.225E-14	2.666E-16	0.00
Cd-110	9.737E-06	9.739E-06	9.739E-06	9.740E-06	9.740E-06	9.740E-06	9.740E-06
Cd-111	1.339E-05	1.339E-05	1.339E-05	1.339E-05	1.339E-05	1.339E-05	1.339E-05
Cd-112	8.350E-06	8.350E-06	8.350E-06	8.350E-06	8.350E-06	8.350E-06	8.350E-06
CD113	1.353E-07	1.353E-07	1.353E-07	1.353E-07	1.353E-07	1.353E-07	1.354E-07
Cd-113m	9.891E-08	8.994E-08	8.179E-08	7.437E-08	5.865E-08	4.625E-08	2.780E-28
In-113	3.411E-08	4.307E-08	5.121E-08	5.862E-08	7.433E-08	8.672E-08	1.329E-07
Cd-114	1.195E-05	1.195E-05	1.195E-05	1.195E-05	1.195E-05	1.195E-05	1.195E-05
Sn-114	7.282E-10	7.282E-10	7.282E-10	7.282E-10	7.282E-10	7.282E-10	7.282E-10
In-115	2.057E-06	2.057E-06	2.057E-06	2.057E-06	2.057E-06	2.057E-06	2.057E-06

TABLE D.3.a. Fission Product Inventory by Isotope at 20 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Sn-115	1.813E-07	1.813E-07	1.813E-07	1.813E-07	1.813E-07	1.813E-07	1.813E-07
Cd-116	4.678E-06	4.678E-06	4.678E-06	4.678E-06	4.678E-06	4.678E-06	4.678E-06
Sn-116	3.330E-06	3.330E-06	3.330E-06	3.330E-06	3.330E-06	3.330E-06	3.330E-06
Sn-117	4.742E-06	4.742E-06	4.742E-06	4.742E-06	4.742E-06	4.742E-06	4.742E-06
Sn-118	4.801E-06	4.801E-06	4.801E-06	4.801E-06	4.801E-06	4.801E-06	4.801E-06
Sn-119	4.769E-06	4.770E-06	4.770E-06	4.770E-06	4.770E-06	4.770E-06	4.770E-06
Sn-119m	2.347E-10	2.972E-11	3.764E-12	4.766E-13	2.720E-15	1.552E-17	0.00
Sn-120	4.875E-06	4.875E-06	4.875E-06	4.875E-06	4.875E-06	4.875E-06	4.875E-06
Sn-121m	1.746E-09	1.698E-09	1.652E-09	1.607E-09	1.499E-09	1.399E-09	1.747E-15
Sb-121	4.894E-06	4.894E-06	4.894E-06	4.894E-06	4.894E-06	4.894E-06	4.895E-06
Sn-122	5.384E-06	5.384E-06	5.384E-06	5.384E-06	5.384E-06	5.384E-06	5.384E-06
Te-122	1.881E-07	1.881E-07	1.881E-07	1.881E-07	1.881E-07	1.881E-07	1.881E-07
Sn-123	4.903E-11	9.727E-13	1.930E-14	3.829E-16	2.123E-20	1.177E-24	0.00
Sb-123	5.984E-06	5.984E-06	5.984E-06	5.984E-06	5.984E-06	5.984E-06	5.984E-06
Te-123	1.855E-09	1.855E-09	1.855E-09	1.855E-09	1.855E-09	1.855E-09	1.855E-09
Te-123m	3.889E-14	5.653E-16	8.219E-18	1.195E-19	3.045E-24	7.760E-29	0.00
Sn-124	7.335E-06	7.335E-06	7.335E-06	7.335E-06	7.335E-06	7.335E-06	7.335E-06
Sb-124	6.545E-16	1.455E-19	3.234E-23	7.190E-27	5.298E-36	0.00	0.00
Te-124	1.440E-07	1.440E-07	1.440E-07	1.440E-07	1.440E-07	1.440E-07	1.440E-07
Sb-125	2.220E-06	1.346E-06	8.158E-07	4.946E-07	1.415E-07	4.050E-08	0.00
Te-125	8.438E-06	9.325E-06	9.862E-06	1.019E-05	1.055E-05	1.065E-05	1.069E-05
Te-125m	3.105E-08	1.883E-08	1.141E-08	6.919E-09	1.979E-09	5.664E-10	0.00
Sn-126	1.559E-05	1.559E-05	1.559E-05	1.559E-05	1.559E-05	1.559E-05	1.548E-05
Sb-126	7.407E-13	7.407E-13	7.407E-13	7.407E-13	7.406E-13	7.406E-13	7.356E-13
Sb-126m	5.632E-15	5.631E-15	5.631E-15	5.631E-15	5.631E-15	5.631E-15	5.593E-15
Te-126	3.782E-07	3.785E-07	3.787E-07	3.789E-07	3.794E-07	3.800E-07	4.855E-07
Te-127	1.379E-13	1.325E-15	1.273E-17	1.223E-19	1.107E-24	1.001E-29	0.00
Te-127m	3.938E-11	3.784E-13	3.636E-15	3.494E-17	3.161E-22	2.861E-27	0.00
I-127	3.170E-05	3.170E-05	3.170E-05	3.170E-05	3.170E-05	3.170E-05	3.170E-05
Te-128	6.369E-05	6.369E-05	6.369E-05	6.369E-05	6.369E-05	6.369E-05	6.369E-05
Xe-128	9.857E-07	9.857E-07	9.857E-07	9.857E-07	9.857E-07	9.857E-07	9.857E-07
I-129	1.057E-04	1.057E-04	1.057E-04	1.057E-04	1.057E-04	1.057E-04	1.057E-04
Xe-129	3.260E-09	3.270E-09	3.279E-09	3.288E-09	3.312E-09	3.335E-09	7.911E-09
Te-130	2.075E-04	2.075E-04	2.075E-04	2.075E-04	2.075E-04	2.075E-04	2.075E-04
Xe-130	4.160E-06	4.160E-06	4.160E-06	4.160E-06	4.160E-06	4.160E-06	4.160E-06
Xe-131	2.950E-04	2.950E-04	2.950E-04	2.950E-04	2.950E-04	2.950E-04	2.950E-04
Xe-132	6.026E-04	6.026E-04	6.026E-04	6.026E-04	6.026E-04	6.026E-04	6.026E-04
Ba-132	6.735E-10	6.735E-10	6.735E-10	6.735E-10	6.735E-10	6.735E-10	6.735E-10
Cs-133	7.259E-04	7.259E-04	7.259E-04	7.259E-04	7.259E-04	7.259E-04	7.259E-04
Xe-134	8.907E-04	8.907E-04	8.907E-04	8.907E-04	8.907E-04	8.907E-04	8.907E-04
Cs-134	9.267E-06	4.731E-06	2.415E-06	1.233E-06	2.296E-07	4.276E-08	0.00
Ba-134	5.148E-05	5.601E-05	5.833E-05	5.951E-05	6.052E-05	6.070E-05	6.075E-05
Cs-135	3.561E-04	3.561E-04	3.561E-04	3.561E-04	3.561E-04	3.561E-04	3.560E-04
Ba-135	9.345E-08	9.366E-08	9.388E-08	9.409E-08	9.463E-08	9.517E-08	2.003E-07
Xe-136	1.221E-03	1.221E-03	1.221E-03	1.221E-03	1.221E-03	1.221E-03	1.221E-03

TABLE D.3.a. Fission Product Inventory by Isotope at 20 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Ba-136	9.998E-06	9.998E-06	9.998E-06	9.998E-06	9.998E-06	9.998E-06	9.998E-06
Cs-137	6.372E-04	6.084E-04	5.809E-04	5.547E-04	4.942E-04	4.402E-04	6.453E-14
Ba-137	1.069E-04	1.356E-04	1.631E-04	1.893E-04	2.499E-04	3.038E-04	7.440E-04
Ba-137m	9.748E-11	9.307E-11	8.887E-11	8.486E-11	7.560E-11	6.735E-11	9.872E-21
Ba-138	7.830E-04	7.830E-04	7.830E-04	7.830E-04	7.830E-04	7.830E-04	7.830E-04
La-138	4.342E-09	4.342E-09	4.342E-09	4.342E-09	4.342E-09	4.342E-09	4.342E-09
La-139	7.498E-04	7.498E-04	7.498E-04	7.498E-04	7.498E-04	7.498E-04	7.498E-04
Ce-140	7.545E-04	7.545E-04	7.545E-04	7.545E-04	7.545E-04	7.545E-04	7.545E-04
Pr-141	6.924E-04	6.924E-04	6.924E-04	6.924E-04	6.924E-04	6.924E-04	6.924E-04
Ce-142	6.931E-04	6.931E-04	6.931E-04	6.931E-04	6.931E-04	6.931E-04	6.931E-04
Nd-142	9.467E-06	9.467E-06	9.467E-06	9.467E-06	9.467E-06	9.467E-06	9.467E-06
Nd-143	5.576E-04	5.576E-04	5.576E-04	5.576E-04	5.576E-04	5.576E-04	5.576E-04
Ce-144	3.367E-06	5.671E-07	9.551E-08	1.609E-08	1.873E-10	2.180E-12	0.00
Pr-144	1.422E-10	2.394E-11	4.033E-12	6.792E-13	7.907E-15	9.205E-17	0.00
Pr-144m	7.107E-13	1.197E-13	2.016E-14	3.395E-15	3.953E-17	4.602E-19	0.00
Nd-144	7.439E-04	7.467E-04	7.472E-04	7.473E-04	7.473E-04	7.473E-04	7.473E-04
Nd-145	4.371E-04	4.371E-04	4.371E-04	4.371E-04	4.371E-04	4.371E-04	4.371E-04
Nd-146	3.993E-04	3.993E-04	3.993E-04	3.993E-04	3.993E-04	3.993E-04	3.993E-04
Pm-146	1.440E-09	1.119E-09	8.696E-10	6.759E-10	3.599E-10	1.917E-10	0.00
Sm-146	4.176E-09	4.295E-09	4.387E-09	4.458E-09	4.575E-09	4.638E-09	4.709E-09
Pm-147	3.316E-05	1.955E-05	1.152E-05	6.794E-06	1.813E-06	4.838E-07	0.00
Sm-147	1.487E-04	1.623E-04	1.704E-04	1.751E-04	1.801E-04	1.814E-04	1.819E-04
Nd-148	2.229E-04	2.229E-04	2.229E-04	2.229E-04	2.229E-04	2.229E-04	2.229E-04
Sm-148	8.493E-05	8.493E-05	8.493E-05	8.493E-05	8.493E-05	8.493E-05	8.493E-05
Sm-149	1.697E-06	1.697E-06	1.697E-06	1.697E-06	1.697E-06	1.697E-06	1.697E-06
Nd-150	1.028E-04	1.028E-04	1.028E-04	1.028E-04	1.028E-04	1.028E-04	1.028E-04
Sm-150	1.439E-04	1.439E-04	1.439E-04	1.439E-04	1.439E-04	1.439E-04	1.439E-04
Eu-150	2.831E-13	2.724E-13	2.621E-13	2.522E-13	2.291E-13	2.080E-13	1.330E-21
Sm-151	9.697E-06	9.548E-06	9.402E-06	9.259E-06	8.909E-06	8.572E-06	4.519E-09
Eu-151	3.288E-07	4.770E-07	6.230E-07	7.667E-07	1.116E-06	1.453E-06	1.002E-05
Sm-152	8.414E-05	8.414E-05	8.415E-05	8.415E-05	8.416E-05	8.417E-05	8.419E-05
Eu-152	6.703E-08	6.053E-08	5.467E-08	4.937E-08	3.826E-08	2.966E-08	6.040E-30
Gd-152	3.394E-08	3.575E-08	3.738E-08	3.886E-08	4.195E-08	4.435E-08	5.261E-08
Eu-153	5.526E-05	5.526E-05	5.526E-05	5.526E-05	5.526E-05	5.526E-05	5.526E-05
Gd-153	1.641E-10	2.025E-11	2.499E-12	3.084E-13	1.650E-15	8.830E-18	0.00
Sm-154	1.939E-05	1.939E-05	1.939E-05	1.939E-05	1.939E-05	1.939E-05	1.939E-05
Eu-154	1.009E-05	8.586E-06	7.308E-06	6.220E-06	4.157E-06	2.778E-06	0.00
Gd-154	5.788E-06	7.290E-06	8.568E-06	9.656E-06	1.172E-05	1.310E-05	1.588E-05
Eu-155	3.074E-06	2.324E-06	1.757E-06	1.329E-06	6.606E-07	3.284E-07	0.00
Gd-155	2.401E-06	3.150E-06	3.717E-06	4.145E-06	4.814E-06	5.146E-06	5.474E-06
Gd-156	2.099E-05	2.099E-05	2.099E-05	2.099E-05	2.099E-05	2.099E-05	2.099E-05
Gd-157	4.740E-08	4.740E-08	4.740E-08	4.740E-08	4.740E-08	4.740E-08	4.740E-08
Gd-158	7.371E-06	7.371E-06	7.371E-06	7.371E-06	7.371E-06	7.371E-06	7.371E-06
Tb-159	1.207E-06	1.207E-06	1.207E-06	1.207E-06	1.207E-06	1.207E-06	1.207E-06
Gd-160	5.901E-07	5.901E-07	5.901E-07	5.901E-07	5.901E-07	5.901E-07	5.901E-07

TABLE D.3.a. Fission Product Inventory by Isotope at 20 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Tb-160	1.086E-14	9.874E-18	8.976E-21	8.160E-24	2.033E-31	0.00	0.00
Dy-160	8.710E-08	8.710E-08	8.710E-08	8.710E-08	8.710E-08	8.710E-08	8.710E-08
Dy-161	2.113E-07	2.113E-07	2.113E-07	2.113E-07	2.113E-07	2.113E-07	2.113E-07
Dy-162	1.740E-07	1.740E-07	1.740E-07	1.740E-07	1.740E-07	1.740E-07	1.740E-07
Dy-163	1.122E-07	1.122E-07	1.122E-07	1.122E-07	1.122E-07	1.122E-07	1.122E-07
Dy-164	1.901E-08	1.901E-08	1.901E-08	1.901E-08	1.901E-08	1.901E-08	1.901E-08
Ho-165	4.929E-08	4.929E-08	4.929E-08	4.929E-08	4.929E-08	4.929E-08	4.929E-08
Ho-166m	3.131E-10	3.127E-10	3.124E-10	3.120E-10	3.111E-10	3.102E-10	1.761E-10
Er-166	1.473E-08	1.473E-08	1.473E-08	1.473E-08	1.473E-08	1.473E-08	1.487E-08
Er-167	1.790E-09	1.790E-09	1.790E-09	1.790E-09	1.790E-09	1.790E-09	1.790E-09
Er-168	2.983E-09	2.983E-09	2.983E-09	2.983E-09	2.983E-09	2.983E-09	2.983E-09
Tm-169	1.334E-11	1.334E-11	1.334E-11	1.334E-11	1.334E-11	1.334E-11	1.334E-11
Er-170	3.674E-15	3.675E-15	3.675E-15	3.675E-15	3.675E-15	3.675E-15	3.675E-15
Tm-170	2.801E-16	5.460E-18	1.064E-19	2.061E-21	1.093E-25	5.800E-30	0.00
Yb-170	2.477E-12	2.477E-12	2.477E-12	2.477E-12	2.477E-12	2.477E-12	2.477E-12
Tm-171	7.905E-15	3.840E-15	1.865E-15	9.061E-16	1.490E-16	2.451E-17	0.00
Yb-171	7.810E-14	8.216E-14	8.414E-14	8.509E-14	8.585E-14	8.598E-14	8.600E-14
Yb-172	1.860E-15	1.860E-15	1.860E-15	1.860E-15	1.860E-15	1.860E-15	1.860E-15
Total	2.061E-02	2.061E-02	2.061E-02	2.061E-02	2.061E-02	2.061E-02	2.061E-02

TABLE D.3.b. Fission Product Inventory by Isotope at 25 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-3	3.140E-08	2.806E-08	2.508E-08	2.242E-08	1.693E-08	1.279E-08	1.649E-32
Li-6	1.633E-10	1.633E-10	1.633E-10	1.633E-10	1.633E-10	1.633E-10	1.633E-10
Li-7	7.666E-12	7.666E-12	7.666E-12	7.666E-12	7.666E-12	7.666E-12	7.666E-12
Be-9	1.476E-11	1.476E-11	1.476E-11	1.476E-11	1.476E-11	1.476E-11	1.476E-11
Be-10	9.850E-11	9.850E-11	9.850E-11	9.850E-11	9.850E-11	9.850E-11	9.846E-11
C-14	1.990E-11	1.990E-11	1.989E-11	1.989E-11	1.988E-11	1.986E-11	1.764E-11
Zn-66	2.895E-14	2.895E-14	2.895E-14	2.895E-14	2.895E-14	2.895E-14	2.895E-14
Zn-67	1.214E-15	1.214E-15	1.214E-15	1.214E-15	1.214E-15	1.214E-15	1.214E-15
Ga-71	6.547E-13	6.547E-13	6.547E-13	6.547E-13	6.547E-13	6.547E-13	6.547E-13
Ge-72	1.595E-08	1.595E-08	1.595E-08	1.595E-08	1.595E-08	1.595E-08	1.595E-08
Ge-73	3.389E-08	3.389E-08	3.389E-08	3.389E-08	3.389E-08	3.389E-08	3.389E-08
Ge-74	7.297E-08	7.297E-08	7.297E-08	7.297E-08	7.297E-08	7.297E-08	7.297E-08
As-75	1.538E-07	1.538E-07	1.538E-07	1.538E-07	1.538E-07	1.538E-07	1.538E-07
Ge-76	3.838E-07	3.838E-07	3.838E-07	3.838E-07	3.838E-07	3.838E-07	3.838E-07
Se-76	3.128E-09	3.128E-09	3.128E-09	3.128E-09	3.128E-09	3.128E-09	3.128E-09
Se-77	7.987E-07	7.987E-07	7.987E-07	7.987E-07	7.987E-07	7.987E-07	7.987E-07
Se-78	1.835E-06	1.835E-06	1.835E-06	1.835E-06	1.835E-06	1.835E-06	1.835E-06
Se-79	4.509E-06	4.509E-06	4.509E-06	4.509E-06	4.508E-06	4.508E-06	4.461E-06
Br-79	3.290E-10	4.252E-10	5.215E-10	6.177E-10	8.582E-10	1.099E-09	4.800E-08
Se-80	1.028E-05	1.028E-05	1.028E-05	1.028E-05	1.028E-05	1.028E-05	1.028E-05
Kr-80	1.626E-10	1.626E-10	1.626E-10	1.626E-10	1.626E-10	1.626E-10	1.626E-10
Br-81	1.692E-05	1.692E-05	1.692E-05	1.692E-05	1.692E-05	1.692E-05	1.692E-05
Kr-81	1.357E-11	1.357E-11	1.357E-11	1.357E-11	1.357E-11	1.357E-11	1.352E-11
Se-82	2.612E-05	2.612E-05	2.612E-05	2.612E-05	2.612E-05	2.612E-05	2.612E-05
Kr-82	5.844E-07	5.844E-07	5.844E-07	5.844E-07	5.844E-07	5.844E-07	5.844E-07
Kr-83	3.422E-05	3.422E-05	3.422E-05	3.422E-05	3.422E-05	3.422E-05	3.422E-05
Kr-84	8.609E-05	8.609E-05	8.609E-05	8.609E-05	8.609E-05	8.609E-05	8.609E-05
Kr-85	1.317E-05	1.157E-05	1.017E-05	8.932E-06	6.465E-06	4.679E-06	1.420E-33
Rb-85	8.201E-05	8.361E-05	8.501E-05	8.624E-05	8.871E-05	9.050E-05	9.517E-05
Kr-86	1.491E-04	1.491E-04	1.491E-04	1.491E-04	1.491E-04	1.491E-04	1.491E-04
Sr-86	2.374E-07	2.374E-07	2.374E-07	2.374E-07	2.374E-07	2.374E-07	2.374E-07
Rb-87	1.917E-04	1.917E-04	1.917E-04	1.917E-04	1.917E-04	1.917E-04	1.917E-04
Sr-87	1.791E-09	1.791E-09	1.791E-09	1.791E-09	1.791E-09	1.791E-09	1.794E-09
Sr-88	2.752E-04	2.752E-04	2.752E-04	2.752E-04	2.752E-04	2.752E-04	2.752E-04
Sr-89	2.151E-14	9.503E-19	4.199E-23	1.855E-27	0.00	0.00	0.00
Y-89	3.597E-04	3.597E-04	3.597E-04	3.597E-04	3.597E-04	3.597E-04	3.597E-04
Sr-90	3.696E-04	3.524E-04	3.360E-04	3.204E-04	2.845E-04	2.526E-04	1.871E-14
Y-90	9.269E-08	8.838E-08	8.427E-08	8.035E-08	7.134E-08	6.333E-08	4.691E-18
Zr-90	6.691E-05	8.410E-05	1.005E-04	1.161E-04	1.521E-04	1.840E-04	4.366E-04
Y-91	5.160E-13	8.997E-17	1.569E-20	2.735E-24	1.098E-33	0.00	0.00
Zr-91	4.630E-04	4.630E-04	4.630E-04	4.630E-04	4.630E-04	4.630E-04	4.630E-04
Zr-92	4.986E-04	4.986E-04	4.986E-04	4.986E-04	4.986E-04	4.986E-04	4.986E-04
Zr-93	5.589E-04	5.589E-04	5.589E-04	5.589E-04	5.589E-04	5.589E-04	5.586E-04
Nb-93	3.638E-10	5.473E-10	7.622E-10	1.005E-09	1.719E-09	2.558E-09	2.492E-07
Nb-93m	1.388E-09	1.711E-09	2.003E-09	2.266E-09	2.818E-09	3.246E-09	4.718E-09

TABLE D.3.b. Fission Product Inventory by Isotope at 25 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Zr-94	5.698E-04	5.698E-04	5.698E-04	5.698E-04	5.698E-04	5.698E-04	5.698E-04
Nb-94	5.291E-10	5.291E-10	5.291E-10	5.290E-10	5.289E-10	5.288E-10	5.114E-10
Zr-95	3.565E-12	1.303E-15	4.765E-19	1.742E-22	4.453E-31	0.00	0.00
Nb-95	4.348E-12	1.590E-15	5.812E-19	2.125E-22	4.028E-33	0.00	0.00
Nb-95m	1.492E-15	5.453E-19	1.994E-22	7.290E-26	0.00	0.00	0.00
Mo-95	5.861E-04	5.861E-04	5.861E-04	5.861E-04	5.861E-04	5.861E-04	5.861E-04
Zr-96	6.123E-04	6.123E-04	6.123E-04	6.123E-04	6.123E-04	6.123E-04	6.123E-04
Mo-96	2.162E-05	2.162E-05	2.162E-05	2.162E-05	2.162E-05	2.162E-05	2.162E-05
Mo-97	6.031E-04	6.031E-04	6.031E-04	6.031E-04	6.031E-04	6.031E-04	6.031E-04
Mo-98	6.253E-04	6.253E-04	6.253E-04	6.253E-04	6.253E-04	6.253E-04	6.253E-04
Tc-98	3.577E-09	3.577E-09	3.577E-09	3.577E-09	3.577E-09	3.577E-09	3.577E-09
Tc-99	5.998E-04	5.998E-04	5.998E-04	5.998E-04	5.998E-04	5.997E-04	5.978E-04
Ru-99	1.317E-08	1.707E-08	2.097E-08	2.488E-08	3.464E-08	4.439E-08	1.954E-06
Mo-100	7.030E-04	7.030E-04	7.030E-04	7.030E-04	7.030E-04	7.030E-04	7.030E-04
Ru-100	5.415E-05	5.415E-05	5.415E-05	5.415E-05	5.415E-05	5.415E-05	5.415E-05
Ru-101	5.855E-04	5.855E-04	5.855E-04	5.855E-04	5.855E-04	5.855E-04	5.855E-04
Ru-102	5.682E-04	5.682E-04	5.682E-04	5.682E-04	5.682E-04	5.682E-04	5.682E-04
Rh-102	1.974E-10	1.224E-10	7.590E-11	4.706E-11	1.424E-11	4.311E-12	0.00
Ru-103	1.067E-16	2.692E-22	6.793E-28	1.714E-33	0.00	0.00	0.00
Rh-103	3.675E-04	3.675E-04	3.675E-04	3.675E-04	3.675E-04	3.675E-04	3.675E-04
Ru-104	3.870E-04	3.870E-04	3.870E-04	3.870E-04	3.870E-04	3.870E-04	3.870E-04
Pd-104	1.346E-04	1.346E-04	1.346E-04	1.346E-04	1.346E-04	1.346E-04	1.346E-04
Pd-105	2.792E-04	2.792E-04	2.792E-04	2.792E-04	2.792E-04	2.792E-04	2.792E-04
Ru-106	4.381E-06	1.107E-06	2.799E-07	7.075E-08	2.272E-09	7.300E-11	0.00
Rh-106	4.118E-12	1.041E-12	2.631E-13	6.650E-14	2.136E-15	6.861E-17	0.00
Pd-106	2.264E-04	2.297E-04	2.305E-04	2.308E-04	2.308E-04	2.308E-04	2.308E-04
Pd-107	1.473E-04	1.473E-04	1.473E-04	1.473E-04	1.473E-04	1.473E-04	1.473E-04
Ag-107	9.632E-11	1.278E-10	1.592E-10	1.906E-10	2.692E-10	3.478E-10	1.575E-08
Pd-108	1.006E-04	1.006E-04	1.006E-04	1.006E-04	1.006E-04	1.006E-04	1.006E-04
Ag-108m	7.660E-13	7.576E-13	7.494E-13	7.413E-13	7.213E-13	7.019E-13	3.338E-15
Cd-108	2.041E-10	2.041E-10	2.041E-10	2.041E-10	2.041E-10	2.041E-10	2.041E-10
Ag-109	5.398E-05	5.398E-05	5.398E-05	5.398E-05	5.398E-05	5.398E-05	5.398E-05
Cd-109	1.688E-14	5.669E-15	1.904E-15	6.392E-16	4.177E-17	2.729E-18	0.00
Pd-110	3.302E-05	3.302E-05	3.302E-05	3.302E-05	3.302E-05	3.302E-05	3.302E-05
Ag-110	7.875E-17	1.038E-17	1.368E-18	1.804E-19	1.138E-21	7.183E-24	0.00
Ag-110m	5.196E-09	6.850E-10	9.030E-11	1.190E-11	7.511E-14	4.740E-16	0.00
Cd-110	1.735E-05	1.735E-05	1.735E-05	1.735E-05	1.735E-05	1.735E-05	1.735E-05
Cd-111	1.860E-05	1.860E-05	1.860E-05	1.860E-05	1.860E-05	1.860E-05	1.860E-05
Cd-112	1.137E-05	1.137E-05	1.137E-05	1.137E-05	1.137E-05	1.137E-05	1.137E-05
Cd-113	1.429E-07	1.429E-07	1.429E-07	1.429E-07	1.429E-07	1.429E-07	1.430E-07
Cd-113m	1.367E-07	1.243E-07	1.130E-07	1.028E-07	8.105E-08	6.391E-08	3.842E-28
In-113	4.636E-08	5.873E-08	6.999E-08	8.023E-08	1.019E-07	1.191E-07	1.829E-07
Cd-114	1.582E-05	1.582E-05	1.582E-05	1.582E-05	1.582E-05	1.582E-05	1.582E-05
Sn-114	1.238E-09	1.238E-09	1.238E-09	1.238E-09	1.238E-09	1.238E-09	1.238E-09
In-115	2.207E-06	2.207E-06	2.207E-06	2.207E-06	2.207E-06	2.207E-06	2.207E-06

TABLE D.3.b. Fission Product Inventory by Isotope at 25 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Sn-115	2.336E-07	2.336E-07	2.336E-07	2.336E-07	2.336E-07	2.336E-07	2.336E-07
Cd-116	6.024E-06	6.024E-06	6.024E-06	6.024E-06	6.024E-06	6.024E-06	6.024E-06
Sn-116	4.796E-06	4.796E-06	4.796E-06	4.796E-06	4.796E-06	4.796E-06	4.796E-06
Sn-117	6.098E-06	6.098E-06	6.098E-06	6.098E-06	6.098E-06	6.098E-06	6.098E-06
Sn-118	6.169E-06	6.169E-06	6.169E-06	6.169E-06	6.169E-06	6.169E-06	6.169E-06
Sn-119	6.135E-06	6.136E-06	6.136E-06	6.136E-06	6.136E-06	6.136E-06	6.136E-06
Sn-119m	3.164E-10	4.006E-11	5.073E-12	6.424E-13	3.665E-15	2.091E-17	0.00
Sn-120	6.264E-06	6.264E-06	6.264E-06	6.264E-06	6.264E-06	6.264E-06	6.264E-06
Sn-121m	2.327E-09	2.263E-09	2.202E-09	2.141E-09	1.998E-09	1.864E-09	2.328E-15
Sb-121	6.215E-06	6.215E-06	6.215E-06	6.215E-06	6.215E-06	6.215E-06	6.217E-06
Sn-122	6.907E-06	6.907E-06	6.907E-06	6.907E-06	6.907E-06	6.907E-06	6.907E-06
Te-122	3.061E-07	3.061E-07	3.061E-07	3.061E-07	3.061E-07	3.061E-07	3.061E-07
Sn-123	6.316E-11	1.253E-12	2.486E-14	4.932E-16	2.734E-20	1.516E-24	0.00
Sb-123	7.621E-06	7.621E-06	7.621E-06	7.621E-06	7.621E-06	7.621E-06	7.621E-06
Te-123	3.493E-09	3.494E-09	3.494E-09	3.494E-09	3.494E-09	3.494E-09	3.494E-09
Te-123m	8.168E-14	1.188E-15	1.726E-17	2.510E-19	6.397E-24	1.630E-28	0.00
Sn-124	9.382E-06	9.382E-06	9.382E-06	9.382E-06	9.382E-06	9.382E-06	9.382E-06
Sb-124	1.078E-15	2.396E-19	5.326E-23	1.184E-26	8.723E-36	0.00	0.00
Te-124	2.354E-07	2.354E-07	2.354E-07	2.354E-07	2.354E-07	2.354E-07	2.354E-07
Sb-125	2.891E-06	1.752E-06	1.062E-06	6.440E-07	1.843E-07	5.273E-08	0.00
Te-125	1.093E-05	1.209E-05	1.279E-05	1.321E-05	1.368E-05	1.381E-05	1.386E-05
Te-125m	4.043E-08	2.452E-08	1.486E-08	9.011E-09	2.578E-09	7.376E-10	0.00
Sn-126	2.017E-05	2.017E-05	2.017E-05	2.017E-05	2.017E-05	2.017E-05	2.003E-05
Sb-126	9.584E-13	9.584E-13	9.584E-13	9.584E-13	9.584E-13	9.583E-13	9.518E-13
Sb-126m	7.287E-15	7.287E-15	7.287E-15	7.287E-15	7.286E-15	7.286E-15	7.237E-15
Te-126	5.164E-07	5.167E-07	5.170E-07	5.173E-07	5.180E-07	5.187E-07	6.552E-07
Te-127	1.809E-13	1.738E-15	1.670E-17	1.605E-19	1.452E-24	1.314E-29	0.00
Te-127m	5.169E-11	4.966E-13	4.771E-15	4.584E-17	4.148E-22	3.753E-27	0.00
I-127	4.096E-05	4.096E-05	4.096E-05	4.096E-05	4.096E-05	4.096E-05	4.096E-05
Te-128	8.166E-05	8.166E-05	8.166E-05	8.166E-05	8.166E-05	8.166E-05	8.166E-05
Xe-128	1.639E-06	1.639E-06	1.639E-06	1.639E-06	1.639E-06	1.639E-06	1.639E-06
I-129	1.343E-04	1.343E-04	1.343E-04	1.343E-04	1.343E-04	1.343E-04	1.343E-04
Xe-129	6.814E-09	6.826E-09	6.838E-09	6.850E-09	6.879E-09	6.909E-09	1.272E-08
Te-130	2.638E-04	2.638E-04	2.638E-04	2.638E-04	2.638E-04	2.638E-04	2.638E-04
Xe-130	6.775E-06	6.775E-06	6.775E-06	6.775E-06	6.775E-06	6.775E-06	6.775E-06
Xe-131	3.510E-04	3.510E-04	3.510E-04	3.510E-04	3.510E-04	3.510E-04	3.510E-04
Xe-132	7.796E-04	7.796E-04	7.796E-04	7.796E-04	7.796E-04	7.796E-04	7.796E-04
Ba-132	1.070E-09	1.070E-09	1.070E-09	1.070E-09	1.070E-09	1.070E-09	1.070E-09
Cs-133	8.848E-04	8.848E-04	8.848E-04	8.848E-04	8.848E-04	8.848E-04	8.848E-04
Xe-134	1.111E-03	1.111E-03	1.111E-03	1.111E-03	1.111E-03	1.111E-03	1.111E-03
Cs-134	1.441E-05	7.359E-06	3.757E-06	1.918E-06	3.572E-07	6.651E-08	0.00
Ba-134	8.003E-05	8.708E-05	9.069E-05	9.253E-05	9.409E-05	9.438E-05	9.444E-05
Cs-135	3.900E-04	3.900E-04	3.900E-04	3.900E-04	3.900E-04	3.900E-04	3.899E-04
Ba-135	1.871E-07	1.873E-07	1.876E-07	1.878E-07	1.884E-07	1.890E-07	3.041E-07
Xe-136	1.589E-03	1.589E-03	1.589E-03	1.589E-03	1.589E-03	1.589E-03	1.589E-03

TABLE D.3.b. Fission Product Inventory by Isotope at 25 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Ba-136	1.398E-05	1.398E-05	1.398E-05	1.398E-05	1.398E-05	1.398E-05	1.398E-05
Cs-137	7.971E-04	7.611E-04	7.267E-04	6.939E-04	6.182E-04	5.507E-04	8.073E-14
Ba-137	1.337E-04	1.696E-04	2.040E-04	2.368E-04	3.125E-04	3.800E-04	9.307E-04
Ba-137m	1.219E-10	1.164E-10	1.112E-10	1.062E-10	9.458E-11	8.426E-11	1.235E-20
Ba-138	9.710E-04	9.710E-04	9.710E-04	9.710E-04	9.710E-04	9.710E-04	9.710E-04
La-138	4.894E-09	4.894E-09	4.894E-09	4.894E-09	4.894E-09	4.894E-09	4.894E-09
La-139	9.288E-04	9.288E-04	9.288E-04	9.288E-04	9.288E-04	9.288E-04	9.288E-04
Ce-140	9.388E-04	9.388E-04	9.388E-04	9.388E-04	9.388E-04	9.388E-04	9.388E-04
Pr-141	8.558E-04	8.558E-04	8.558E-04	8.558E-04	8.558E-04	8.558E-04	8.558E-04
Ce-142	8.582E-04	8.582E-04	8.582E-04	8.582E-04	8.582E-04	8.582E-04	8.582E-04
Nd-142	1.513E-05	1.513E-05	1.513E-05	1.513E-05	1.513E-05	1.513E-05	1.513E-05
Nd-143	6.489E-04	6.489E-04	6.489E-04	6.489E-04	6.489E-04	6.489E-04	6.489E-04
Ce-144	4.113E-06	6.927E-07	1.167E-07	1.965E-08	2.287E-10	2.663E-12	0.00
Pr-144	1.737E-10	2.925E-11	4.926E-12	8.297E-13	9.659E-15	1.125E-16	0.00
Pr-144m	8.682E-13	1.462E-13	2.463E-14	4.148E-15	4.828E-17	5.622E-19	0.00
Nd-144	9.543E-04	9.577E-04	9.583E-04	9.584E-04	9.584E-04	9.584E-04	9.584E-04
Nd-145	5.301E-04	5.301E-04	5.301E-04	5.301E-04	5.301E-04	5.301E-04	5.301E-04
Nd-146	5.057E-04	5.057E-04	5.057E-04	5.057E-04	5.057E-04	5.057E-04	5.057E-04
Pm-146	2.126E-09	1.653E-09	1.284E-09	9.982E-10	5.316E-10	2.831E-10	0.00
Sm-146	6.169E-09	6.345E-09	6.481E-09	6.587E-09	6.759E-09	6.851E-09	6.956E-09
Pm-147	3.673E-05	2.165E-05	1.276E-05	7.525E-06	2.008E-06	5.359E-07	0.00
Sm-147	1.644E-04	1.795E-04	1.884E-04	1.936E-04	1.991E-04	2.006E-04	2.011E-04
Nd-148	2.784E-04	2.784E-04	2.784E-04	2.784E-04	2.784E-04	2.784E-04	2.784E-04
Sm-148	1.207E-04	1.207E-04	1.207E-04	1.207E-04	1.207E-04	1.207E-04	1.207E-04
Sm-149	1.815E-06	1.815E-06	1.815E-06	1.815E-06	1.815E-06	1.815E-06	1.815E-06
Nd-150	1.310E-04	1.310E-04	1.310E-04	1.310E-04	1.310E-04	1.310E-04	1.310E-04
Sm-150	1.793E-04	1.793E-04	1.793E-04	1.793E-04	1.793E-04	1.793E-04	1.793E-04
Eu-150	3.115E-13	2.997E-13	2.884E-13	2.775E-13	2.520E-13	2.289E-13	1.462E-21
Sm-151	1.051E-05	1.035E-05	1.019E-05	1.003E-05	9.654E-06	9.289E-06	4.896E-09
Eu-151	3.497E-07	5.103E-07	6.685E-07	8.242E-07	1.203E-06	1.568E-06	1.085E-05
Sm-152	1.018E-04	1.018E-04	1.018E-04	1.018E-04	1.018E-04	1.018E-04	1.018E-04
Eu-152	6.024E-08	5.440E-08	4.913E-08	4.437E-08	3.439E-08	2.665E-08	5.430E-30
Gd-152	3.060E-08	3.223E-08	3.370E-08	3.502E-08	3.780E-08	3.996E-08	4.738E-08
Eu-153	7.504E-05	7.504E-05	7.504E-05	7.504E-05	7.504E-05	7.504E-05	7.504E-05
Gd-153	1.999E-10	2.467E-11	3.044E-12	3.757E-13	2.010E-15	1.076E-17	0.00
Sm-154	2.591E-05	2.591E-05	2.591E-05	2.591E-05	2.591E-05	2.591E-05	2.591E-05
Eu-154	1.602E-05	1.364E-05	1.161E-05	9.879E-06	6.602E-06	4.413E-06	0.00
Gd-154	9.185E-06	1.157E-05	1.360E-05	1.533E-05	1.861E-05	2.080E-05	2.521E-05
Eu-155	4.581E-06	3.464E-06	2.619E-06	1.980E-06	9.846E-07	4.895E-07	0.00
Gd-155	3.549E-06	4.667E-06	5.511E-06	6.150E-06	7.146E-06	7.641E-06	8.130E-06
Gd-156	3.402E-05	3.402E-05	3.402E-05	3.402E-05	3.402E-05	3.402E-05	3.402E-05
Gd-157	5.829E-08	5.829E-08	5.829E-08	5.829E-08	5.829E-08	5.829E-08	5.829E-08
Gd-158	1.073E-05	1.073E-05	1.073E-05	1.073E-05	1.073E-05	1.073E-05	1.073E-05
Tb-159	1.714E-06	1.714E-06	1.714E-06	1.714E-06	1.714E-06	1.714E-06	1.714E-06
Gd-160	8.394E-07	8.394E-07	8.394E-07	8.394E-07	8.394E-07	8.394E-07	8.394E-07

TABLE D.3.b. Fission Product Inventory by Isotope at 25 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Tb-160	1.970E-14	1.791E-17	1.628E-20	1.480E-23	3.689E-31	0.00	0.00
Dy-160	1.500E-07	1.500E-07	1.500E-07	1.500E-07	1.500E-07	1.500E-07	1.500E-07
Dy-161	2.861E-07	2.861E-07	2.861E-07	2.861E-07	2.861E-07	2.861E-07	2.861E-07
Dy-162	2.467E-07	2.467E-07	2.467E-07	2.467E-07	2.467E-07	2.467E-07	2.467E-07
Dy-163	1.735E-07	1.735E-07	1.735E-07	1.735E-07	1.735E-07	1.735E-07	1.735E-07
Dy-164	2.721E-08	2.721E-08	2.721E-08	2.721E-08	2.721E-08	2.721E-08	2.721E-08
Ho-165	7.931E-08	7.931E-08	7.931E-08	7.931E-08	7.931E-08	7.931E-08	7.931E-08
Ho-166m	6.229E-10	6.222E-10	6.214E-10	6.207E-10	6.189E-10	6.172E-10	3.504E-10
Er-166	2.406E-08	2.406E-08	2.406E-08	2.406E-08	2.407E-08	2.407E-08	2.434E-08
Er-167	2.231E-09	2.231E-09	2.231E-09	2.231E-09	2.231E-09	2.231E-09	2.231E-09
Er-168	4.706E-09	4.706E-09	4.706E-09	4.706E-09	4.706E-09	4.706E-09	4.706E-09
Tm-169	2.582E-11	2.582E-11	2.582E-11	2.582E-11	2.582E-11	2.582E-11	2.582E-11
Er-170	9.168E-15	9.169E-15	9.169E-15	9.169E-15	9.169E-15	9.169E-15	9.169E-15
Tm-170	6.995E-16	1.363E-17	2.658E-19	5.189E-21	2.752E-25	1.460E-29	0.00
Yb-170	6.155E-12	6.156E-12	6.156E-12	6.156E-12	6.156E-12	6.156E-12	6.156E-12
Tm-171	2.570E-14	1.249E-14	6.065E-15	2.946E-15	4.846E-16	7.969E-17	0.00
Yb-171	2.501E-13	2.633E-13	2.698E-13	2.729E-13	2.754E-13	2.758E-13	2.758E-13
Yb-172	7.660E-15	7.660E-15	7.660E-15	7.660E-15	7.660E-15	7.660E-15	7.660E-15
Total	2.573E-02	2.573E-02	2.573E-02	2.573E-02	2.573E-02	2.573E-02	2.573E-02

TABLE D.3.c. Fission Product Inventory by Isotope at 30 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-3	3.838E-08	3.431E-08	3.066E-08	2.741E-08	2.070E-08	1.563E-08	2.017E-32
Li-6	1.692E-10	1.692E-10	1.692E-10	1.692E-10	1.692E-10	1.692E-10	1.692E-10
Li-7	9.183E-12	9.183E-12	9.183E-12	9.183E-12	9.183E-12	9.183E-12	9.183E-12
Be-9	1.768E-11	1.768E-11	1.768E-11	1.768E-11	1.768E-11	1.768E-11	1.768E-11
Be-10	1.180E-10	1.180E-10	1.180E-10	1.180E-10	1.180E-10	1.180E-10	1.179E-10
C-14	2.384E-11	2.383E-11	2.383E-11	2.382E-11	2.381E-11	2.379E-11	2.113E-11
Zn-66	3.318E-14	3.318E-14	3.318E-14	3.318E-14	3.318E-14	3.318E-14	3.318E-14
Zn-67	1.386E-15	1.386E-15	1.386E-15	1.386E-15	1.386E-15	1.386E-15	1.386E-15
Ga-71	8.052E-13	8.052E-13	8.052E-13	8.052E-13	8.052E-13	8.052E-13	8.052E-13
Ge-72	1.966E-08	1.966E-08	1.966E-08	1.966E-08	1.966E-08	1.966E-08	1.966E-08
Ge-73	4.085E-08	4.085E-08	4.085E-08	4.085E-08	4.085E-08	4.085E-08	4.085E-08
Ge-74	8.807E-08	8.807E-08	8.807E-08	8.807E-08	8.807E-08	8.807E-08	8.807E-08
As-75	1.831E-07	1.831E-07	1.831E-07	1.831E-07	1.831E-07	1.831E-07	1.831E-07
Ge-76	4.539E-07	4.539E-07	4.539E-07	4.539E-07	4.539E-07	4.539E-07	4.539E-07
Se-76	4.560E-09	4.560E-09	4.560E-09	4.560E-09	4.560E-09	4.560E-09	4.560E-09
Se-77	9.341E-07	9.341E-07	9.341E-07	9.341E-07	9.341E-07	9.341E-07	9.341E-07
Se-78	2.198E-06	2.198E-06	2.198E-06	2.198E-06	2.198E-06	2.198E-06	2.198E-06
Se-79	5.348E-06	5.348E-06	5.347E-06	5.347E-06	5.347E-06	5.347E-06	5.291E-06
Br-79	3.902E-10	5.043E-10	6.184E-10	7.325E-10	1.018E-09	1.303E-09	5.692E-08
Se-80	1.217E-05	1.217E-05	1.217E-05	1.217E-05	1.217E-05	1.217E-05	1.217E-05
Kr-80	2.074E-10	2.074E-10	2.074E-10	2.074E-10	2.074E-10	2.074E-10	2.074E-10
Br-81	1.981E-05	1.981E-05	1.981E-05	1.981E-05	1.981E-05	1.981E-05	1.981E-05
Kr-81	1.941E-11	1.941E-11	1.941E-11	1.941E-11	1.941E-11	1.941E-11	1.935E-11
Se-82	3.064E-05	3.064E-05	3.064E-05	3.064E-05	3.064E-05	3.064E-05	3.064E-05
Kr-82	8.285E-07	8.285E-07	8.285E-07	8.285E-07	8.285E-07	8.285E-07	8.285E-07
Kr-83	3.816E-05	3.816E-05	3.816E-05	3.816E-05	3.816E-05	3.816E-05	3.816E-05
Kr-84	1.023E-04	1.023E-04	1.023E-04	1.023E-04	1.023E-04	1.023E-04	1.023E-04
Kr-85	1.531E-05	1.345E-05	1.182E-05	1.039E-05	7.518E-06	5.441E-06	1.645E-33
Rb-85	9.530E-05	9.715E-05	9.879E-05	1.002E-04	1.031E-04	1.052E-04	1.106E-04
Kr-86	1.729E-04	1.729E-04	1.729E-04	1.729E-04	1.729E-04	1.729E-04	1.729E-04
Sr-86	3.417E-07	3.417E-07	3.417E-07	3.417E-07	3.417E-07	3.417E-07	3.417E-07
Rb-87	2.220E-04	2.220E-04	2.220E-04	2.220E-04	2.220E-04	2.220E-04	2.220E-04
Sr-87	2.687E-09	2.687E-09	2.687E-09	2.687E-09	2.687E-09	2.687E-09	2.690E-09
Sr-88	3.185E-04	3.185E-04	3.185E-04	3.185E-04	3.185E-04	3.185E-04	3.185E-04
Sr-89	2.395E-14	1.058E-18	4.677E-23	2.067E-27	0.00	0.00	0.00
Y-89	4.157E-04	4.157E-04	4.157E-04	4.157E-04	4.157E-04	4.157E-04	4.157E-04
Sr-90	4.271E-04	4.073E-04	3.883E-04	3.703E-04	3.287E-04	2.919E-04	2.162E-14
Y-90	1.071E-07	1.021E-07	9.738E-08	9.286E-08	8.244E-08	7.319E-08	5.421E-18
Zr-90	7.780E-05	9.766E-05	1.166E-04	1.347E-04	1.762E-04	2.131E-04	5.050E-04
Y-91	5.817E-13	1.014E-16	1.768E-20	3.083E-24	1.237E-33	0.00	0.00
Zr-91	5.374E-04	5.374E-04	5.374E-04	5.374E-04	5.374E-04	5.374E-04	5.374E-04
Zr-92	5.821E-04	5.821E-04	5.821E-04	5.821E-04	5.821E-04	5.821E-04	5.821E-04
Zr-93	6.544E-04	6.544E-04	6.544E-04	6.544E-04	6.544E-04	6.544E-04	6.541E-04
Nb-93	4.290E-10	6.444E-10	8.964E-10	1.181E-09	2.018E-09	3.000E-09	2.918E-07
Nb-93m	1.630E-09	2.008E-09	2.349E-09	2.657E-09	3.302E-09	3.803E-09	5.524E-09

TABLE D.3.c. Fission Product Inventory by Isotope at 30 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Zr-94	6.730E-04	6.730E-04	6.730E-04	6.730E-04	6.730E-04	6.730E-04	6.730E-04
Nb-94	6.819E-10	6.819E-10	6.818E-10	6.818E-10	6.817E-10	6.816E-10	6.591E-10
Zr-95	4.173E-12	1.526E-15	5.578E-19	2.040E-22	5.213E-31	0.00	0.00
Nb-95	5.090E-12	1.861E-15	6.804E-19	2.488E-22	4.715E-33	0.00	0.00
Nb-95m	1.746E-15	6.384E-19	2.334E-22	8.534E-26	0.00	0.00	0.00
Mo-95	6.873E-04	6.873E-04	6.873E-04	6.873E-04	6.873E-04	6.873E-04	6.873E-04
Zr-96	7.261E-04	7.261E-04	7.261E-04	7.261E-04	7.261E-04	7.261E-04	7.261E-04
Mo-96	3.173E-05	3.173E-05	3.173E-05	3.173E-05	3.173E-05	3.173E-05	3.173E-05
Mo-97	7.185E-04	7.185E-04	7.185E-04	7.185E-04	7.185E-04	7.185E-04	7.185E-04
Mo-98	7.488E-04	7.488E-04	7.488E-04	7.488E-04	7.488E-04	7.488E-04	7.488E-04
Tc-98	5.265E-09	5.265E-09	5.265E-09	5.265E-09	5.265E-09	5.265E-09	5.264E-09
Tc-99	7.048E-04	7.048E-04	7.048E-04	7.048E-04	7.048E-04	7.047E-04	7.025E-04
Ru-99	1.548E-08	2.007E-08	2.465E-08	2.924E-08	4.071E-08	5.217E-08	2.296E-06
Mo-100	8.437E-04	8.437E-04	8.437E-04	8.437E-04	8.437E-04	8.437E-04	8.437E-04
Ru-100	7.959E-05	7.959E-05	7.959E-05	7.959E-05	7.959E-05	7.959E-05	7.959E-05
Ru-101	7.020E-04	7.020E-04	7.020E-04	7.020E-04	7.020E-04	7.020E-04	7.020E-04
Ru-102	6.957E-04	6.957E-04	6.957E-04	6.957E-04	6.957E-04	6.957E-04	6.957E-04
Rh-102	2.886E-10	1.790E-10	1.110E-10	6.879E-11	2.082E-11	6.302E-12	0.00
Ru-103	1.332E-16	3.362E-22	8.485E-28	2.141E-33	0.00	0.00	0.00
Rh-103	4.244E-04	4.244E-04	4.244E-04	4.244E-04	4.244E-04	4.244E-04	4.244E-04
Ru-104	4.878E-04	4.878E-04	4.878E-04	4.878E-04	4.878E-04	4.878E-04	4.878E-04
Pd-104	1.965E-04	1.965E-04	1.965E-04	1.965E-04	1.965E-04	1.965E-04	1.965E-04
Pd-105	3.531E-04	3.531E-04	3.531E-04	3.531E-04	3.531E-04	3.531E-04	3.531E-04
Ru-106	5.788E-06	1.463E-06	3.698E-07	9.348E-08	3.003E-09	9.645E-11	0.00
Rh-106	5.441E-12	1.375E-12	3.476E-13	8.787E-14	2.822E-15	9.066E-17	0.00
Pd-106	3.024E-04	3.067E-04	3.078E-04	3.081E-04	3.082E-04	3.082E-04	3.082E-04
Pd-107	1.954E-04	1.954E-04	1.954E-04	1.954E-04	1.954E-04	1.954E-04	1.954E-04
Ag-107	1.272E-10	1.690E-10	2.107E-10	2.524E-10	3.566E-10	4.609E-10	2.090E-08
Pd-108	1.343E-04	1.343E-04	1.343E-04	1.343E-04	1.343E-04	1.343E-04	1.343E-04
Ag-108m	1.040E-12	1.029E-12	1.018E-12	1.007E-12	9.796E-13	9.532E-13	4.533E-15
Cd-108	3.296E-10	3.296E-10	3.296E-10	3.296E-10	3.296E-10	3.296E-10	3.297E-10
Ag-109	6.934E-05	6.934E-05	6.934E-05	6.934E-05	6.934E-05	6.934E-05	6.934E-05
Cd-109	3.296E-14	1.107E-14	3.717E-15	1.248E-15	8.155E-17	5.329E-18	0.00
Pd-110	4.400E-05	4.400E-05	4.400E-05	4.400E-05	4.400E-05	4.400E-05	4.400E-05
Ag-110	1.271E-16	1.675E-17	2.208E-18	2.911E-19	1.837E-21	1.159E-23	0.00
Ag-110m	8.387E-09	1.106E-09	1.457E-10	1.921E-11	1.212E-13	7.647E-16	0.00
Cd-110	2.795E-05	2.796E-05	2.796E-05	2.796E-05	2.796E-05	2.796E-05	2.796E-05
Cd-111	2.446E-05	2.446E-05	2.446E-05	2.446E-05	2.446E-05	2.446E-05	2.446E-05
Cd-112	1.476E-05	1.476E-05	1.476E-05	1.476E-05	1.476E-05	1.476E-05	1.476E-05
Cd-113	1.466E-07	1.466E-07	1.466E-07	1.466E-07	1.466E-07	1.466E-07	1.467E-07
Cd-113m	1.809E-07	1.645E-07	1.496E-07	1.360E-07	1.073E-07	8.457E-08	5.083E-28
In-113	6.035E-08	7.672E-08	9.162E-08	1.052E-07	1.339E-07	1.565E-07	2.410E-07
Cd-114	2.004E-05	2.004E-05	2.004E-05	2.004E-05	2.004E-05	2.004E-05	2.004E-05
Sn-114	1.945E-09	1.945E-09	1.945E-09	1.945E-09	1.945E-09	1.945E-09	1.945E-09
In-115	2.302E-06	2.302E-06	2.302E-06	2.302E-06	2.302E-06	2.302E-06	2.302E-06

TABLE D.3.c. Fission Product Inventory by Isotope at 30 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Sn-115	2.886E-07	2.886E-07	2.886E-07	2.886E-07	2.886E-07	2.886E-07	2.886E-07
Cd-116	7.438E-06	7.438E-06	7.438E-06	7.438E-06	7.438E-06	7.438E-06	7.438E-06
Sn-116	6.426E-06	6.426E-06	6.426E-06	6.426E-06	6.426E-06	6.426E-06	6.426E-06
Sn-117	7.520E-06	7.520E-06	7.520E-06	7.520E-06	7.520E-06	7.520E-06	7.520E-06
Sn-118	7.602E-06	7.602E-06	7.602E-06	7.602E-06	7.602E-06	7.602E-06	7.602E-06
Sn-119	7.568E-06	7.568E-06	7.568E-06	7.568E-06	7.568E-06	7.568E-06	7.568E-06
Sn-119m	4.101E-10	5.193E-11	6.576E-12	8.327E-13	4.752E-15	2.711E-17	0.00
Sn-120	7.720E-06	7.720E-06	7.720E-06	7.720E-06	7.720E-06	7.720E-06	7.720E-06
Sn-121m	2.942E-09	2.862E-09	2.783E-09	2.707E-09	2.526E-09	2.357E-09	2.943E-15
Sb-121	7.564E-06	7.564E-06	7.564E-06	7.564E-06	7.564E-06	7.565E-06	7.567E-06
Sn-122	8.497E-06	8.497E-06	8.497E-06	8.497E-06	8.497E-06	8.497E-06	8.497E-06
Te-122	4.598E-07	4.598E-07	4.598E-07	4.598E-07	4.598E-07	4.598E-07	4.598E-07
Sn-123	7.861E-11	1.560E-12	3.094E-14	6.139E-16	3.403E-20	1.887E-24	0.00
Sb-123	9.303E-06	9.303E-06	9.303E-06	9.303E-06	9.303E-06	9.303E-06	9.303E-06
Te-123	5.871E-09	5.871E-09	5.871E-09	5.871E-09	5.871E-09	5.871E-09	5.871E-09
Te-123m	1.561E-13	2.269E-15	3.299E-17	4.797E-19	1.222E-23	3.115E-28	0.00
Sn-124	1.150E-05	1.150E-05	1.150E-05	1.150E-05	1.150E-05	1.150E-05	1.150E-05
Sb-124	1.676E-15	3.725E-19	8.280E-23	1.841E-26	1.356E-35	0.00	0.00
Te-124	3.559E-07	3.559E-07	3.559E-07	3.559E-07	3.559E-07	3.559E-07	3.559E-07
Sb-125	3.598E-06	2.181E-06	1.322E-06	8.015E-07	2.294E-07	6.563E-08	0.00
Te-125	1.354E-05	1.498E-05	1.585E-05	1.638E-05	1.696E-05	1.713E-05	1.719E-05
Te-125m	5.032E-08	3.051E-08	1.850E-08	1.121E-08	3.208E-09	9.180E-10	0.00
Sn-126	2.496E-05	2.496E-05	2.496E-05	2.496E-05	2.496E-05	2.495E-05	2.479E-05
Sb-126	1.186E-12	1.186E-12	1.186E-12	1.186E-12	1.186E-12	1.186E-12	1.178E-12
Sb-126m	9.015E-15	9.015E-15	9.015E-15	9.015E-15	9.014E-15	9.014E-15	8.953E-15
Te-126	6.722E-07	6.725E-07	6.729E-07	6.732E-07	6.741E-07	6.749E-07	8.439E-07
Te-127	2.273E-13	2.184E-15	2.098E-17	2.016E-19	1.824E-24	1.651E-29	0.00
Te-127m	6.492E-11	6.238E-13	5.993E-15	5.758E-17	5.211E-22	4.715E-27	0.00
I-127	5.049E-05	5.049E-05	5.049E-05	5.049E-05	5.049E-05	5.049E-05	5.049E-05
Te-128	1.002E-04	1.002E-04	1.002E-04	1.002E-04	1.002E-04	1.002E-04	1.002E-04
Xe-128	2.508E-06	2.508E-06	2.508E-06	2.508E-06	2.508E-06	2.508E-06	2.508E-06
I-129	1.630E-04	1.630E-04	1.630E-04	1.630E-04	1.630E-04	1.630E-04	1.630E-04
Xe-129	1.269E-08	1.270E-08	1.272E-08	1.273E-08	1.277E-08	1.280E-08	1.986E-08
Te-130	3.213E-04	3.213E-04	3.213E-04	3.213E-04	3.213E-04	3.213E-04	3.213E-04
Xe-130	1.018E-05	1.018E-05	1.018E-05	1.018E-05	1.018E-05	1.018E-05	1.018E-05
Xe-131	3.993E-04	3.993E-04	3.993E-04	3.993E-04	3.993E-04	3.993E-04	3.993E-04
Xe-132	9.668E-04	9.668E-04	9.668E-04	9.668E-04	9.668E-04	9.668E-04	9.668E-04
Ba-132	1.568E-09	1.568E-09	1.568E-09	1.568E-09	1.568E-09	1.568E-09	1.568E-09
Cs-133	1.034E-03	1.034E-03	1.034E-03	1.034E-03	1.034E-03	1.034E-03	1.034E-03
Xe-134	1.330E-03	1.330E-03	1.330E-03	1.330E-03	1.330E-03	1.330E-03	1.330E-03
Cs-134	2.070E-05	1.057E-05	5.394E-06	2.754E-06	5.128E-07	9.550E-08	0.00
Ba-134	1.147E-04	1.249E-04	1.300E-04	1.327E-04	1.349E-04	1.353E-04	1.354E-04
Cs-135	4.167E-04	4.167E-04	4.167E-04	4.167E-04	4.167E-04	4.167E-04	4.166E-04
Ba-135	3.337E-07	3.339E-07	3.342E-07	3.344E-07	3.351E-07	3.357E-07	4.587E-07
Xe-136	1.968E-03	1.968E-03	1.968E-03	1.968E-03	1.968E-03	1.968E-03	1.968E-03

TABLE D.3.c. Fission Product Inventory by Isotope at 30 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Ba-136	1.838E-05	1.838E-05	1.838E-05	1.838E-05	1.838E-05	1.838E-05	1.838E-05
Cs-137	9.571E-04	9.139E-04	8.726E-04	8.332E-04	7.423E-04	6.613E-04	9.693E-14
Ba-137	1.604E-04	2.037E-04	2.449E-04	2.843E-04	3.753E-04	4.562E-04	1.118E-03
Ba-137m	1.464E-10	1.398E-10	1.335E-10	1.275E-10	1.136E-10	1.012E-10	1.483E-20
Ba-138	1.157E-03	1.157E-03	1.157E-03	1.157E-03	1.157E-03	1.157E-03	1.157E-03
La-138	5.278E-09	5.278E-09	5.278E-09	5.278E-09	5.278E-09	5.278E-09	5.278E-09
La-139	1.105E-03	1.105E-03	1.105E-03	1.105E-03	1.105E-03	1.105E-03	1.105E-03
Ce-140	1.122E-03	1.122E-03	1.122E-03	1.122E-03	1.122E-03	1.122E-03	1.122E-03
Pr-141	1.015E-03	1.015E-03	1.015E-03	1.015E-03	1.015E-03	1.015E-03	1.015E-03
Ce-142	1.021E-03	1.021E-03	1.021E-03	1.021E-03	1.021E-03	1.021E-03	1.021E-03
Nd-142	2.234E-05	2.234E-05	2.234E-05	2.234E-05	2.234E-05	2.234E-05	2.234E-05
Nd-143	7.231E-04	7.231E-04	7.231E-04	7.231E-04	7.231E-04	7.231E-04	7.231E-04
Ce-144	4.832E-06	8.138E-07	1.371E-07	2.308E-08	2.687E-10	3.128E-12	0.00
Pr-144	2.040E-10	3.436E-11	5.787E-12	9.747E-13	1.135E-14	1.321E-16	0.00
Pr-144m	1.020E-12	1.718E-13	2.893E-14	4.872E-15	5.672E-17	6.603E-19	0.00
Nd-144	1.175E-03	1.179E-03	1.179E-03	1.180E-03	1.180E-03	1.180E-03	1.180E-03
Nd-145	6.170E-04	6.170E-04	6.170E-04	6.170E-04	6.170E-04	6.170E-04	6.170E-04
Nd-146	6.156E-04	6.156E-04	6.156E-04	6.156E-04	6.156E-04	6.156E-04	6.156E-04
Pm-146	2.904E-09	2.257E-09	1.754E-09	1.363E-09	7.260E-10	3.866E-10	0.00
Sm-146	8.415E-09	8.654E-09	8.840E-09	8.985E-09	9.221E-09	9.346E-09	9.489E-09
Pm-147	3.903E-05	2.301E-05	1.357E-05	7.997E-06	2.134E-06	5.695E-07	0.00
Sm-147	1.742E-04	1.902E-04	1.997E-04	2.052E-04	2.111E-04	2.127E-04	2.132E-04
Nd-148	3.339E-04	3.339E-04	3.339E-04	3.339E-04	3.339E-04	3.339E-04	3.339E-04
Sm-148	1.592E-04	1.592E-04	1.592E-04	1.592E-04	1.592E-04	1.592E-04	1.592E-04
Sm-149	1.866E-06	1.866E-06	1.866E-06	1.866E-06	1.866E-06	1.866E-06	1.866E-06
Nd-150	1.600E-04	1.600E-04	1.600E-04	1.600E-04	1.600E-04	1.600E-04	1.600E-04
Sm-150	2.146E-04	2.146E-04	2.146E-04	2.146E-04	2.146E-04	2.146E-04	2.146E-04
Eu-150	3.364E-13	3.237E-13	3.115E-13	2.997E-13	2.722E-13	2.472E-13	1.579E-21
Sm-151	1.114E-05	1.097E-05	1.080E-05	1.064E-05	1.024E-05	9.851E-06	5.193E-09
Eu-151	3.660E-07	5.364E-07	7.041E-07	8.693E-07	1.271E-06	1.658E-06	1.150E-05
Sm-152	1.174E-04	1.174E-04	1.174E-04	1.174E-04	1.174E-04	1.174E-04	1.174E-04
Eu-152	5.381E-08	4.859E-08	4.389E-08	3.963E-08	3.072E-08	2.381E-08	4.851E-30
Gd-152	2.730E-08	2.875E-08	3.006E-08	3.125E-08	3.373E-08	3.566E-08	4.229E-08
Eu-153	9.523E-05	9.523E-05	9.523E-05	9.523E-05	9.523E-05	9.523E-05	9.523E-05
Gd-153	2.319E-10	2.862E-11	3.532E-12	4.359E-13	2.332E-15	1.248E-17	0.00
Sm-154	3.299E-05	3.299E-05	3.299E-05	3.299E-05	3.299E-05	3.299E-05	3.299E-05
Eu-154	2.300E-05	1.958E-05	1.666E-05	1.418E-05	9.479E-06	6.335E-06	0.00
Gd-154	1.319E-05	1.661E-05	1.953E-05	2.201E-05	2.671E-05	2.986E-05	3.619E-05
Eu-155	6.409E-06	4.846E-06	3.664E-06	2.771E-06	1.378E-06	6.848E-07	0.00
Gd-155	4.935E-06	6.499E-06	7.680E-06	8.574E-06	9.967E-06	1.066E-05	1.134E-05
Gd-156	5.234E-05	5.234E-05	5.234E-05	5.234E-05	5.234E-05	5.234E-05	5.234E-05
Gd-157	7.118E-08	7.118E-08	7.118E-08	7.118E-08	7.118E-08	7.118E-08	7.118E-08
Gd-158	1.488E-05	1.488E-05	1.488E-05	1.488E-05	1.488E-05	1.488E-05	1.488E-05
Tb-159	2.287E-06	2.287E-06	2.287E-06	2.287E-06	2.287E-06	2.287E-06	2.287E-06
Gd-160	1.121E-06	1.121E-06	1.121E-06	1.121E-06	1.121E-06	1.121E-06	1.121E-06

TABLE D.3.c. Fission Product Inventory by Isotope at 30 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Tb-160	3.299E-14	2.999E-17	2.726E-20	2.478E-23	6.175E-31	0.00	0.00
Dy-160	2.343E-07	2.343E-07	2.343E-07	2.343E-07	2.343E-07	2.343E-07	2.343E-07
Dy-161	3.670E-07	3.670E-07	3.670E-07	3.670E-07	3.670E-07	3.670E-07	3.670E-07
Dy-162	3.278E-07	3.278E-07	3.278E-07	3.278E-07	3.278E-07	3.278E-07	3.278E-07
Dy-163	2.501E-07	2.501E-07	2.501E-07	2.501E-07	2.501E-07	2.501E-07	2.501E-07
Dy-164	3.742E-08	3.742E-08	3.742E-08	3.742E-08	3.742E-08	3.742E-08	3.742E-08
Ho-165	1.205E-07	1.205E-07	1.205E-07	1.205E-07	1.205E-07	1.205E-07	1.205E-07
Ho-166m	1.130E-09	1.129E-09	1.128E-09	1.126E-09	1.123E-09	1.120E-09	6.358E-10
Er-166	3.759E-08	3.759E-08	3.759E-08	3.760E-08	3.760E-08	3.760E-08	3.809E-08
Er-167	2.760E-09	2.760E-09	2.760E-09	2.760E-09	2.760E-09	2.760E-09	2.760E-09
Er-168	6.960E-09	6.960E-09	6.960E-09	6.960E-09	6.960E-09	6.960E-09	6.960E-09
Tm-169	4.468E-11	4.468E-11	4.468E-11	4.468E-11	4.468E-11	4.468E-11	4.468E-11
Er-170	1.959E-14	1.959E-14	1.959E-14	1.959E-14	1.959E-14	1.959E-14	1.959E-14
Tm-170	1.519E-15	2.960E-17	5.770E-19	1.124E-20	5.964E-25	3.164E-29	0.00
Yb-170	1.309E-11	1.309E-11	1.309E-11	1.309E-11	1.309E-11	1.309E-11	1.309E-11
Tm-171	6.885E-14	3.344E-14	1.625E-14	7.892E-15	1.298E-15	2.134E-16	0.00
Yb-171	6.584E-13	6.938E-13	7.110E-13	7.193E-13	7.259E-13	7.270E-13	7.272E-13
Yb-172	2.495E-14	2.495E-14	2.495E-14	2.495E-14	2.495E-14	2.495E-14	2.495E-14
Total	3.084E-02	3.084E-02	3.084E-02	3.084E-02	3.084E-02	3.084E-02	3.084E-02

TABLE D.3.d. Fission Product Inventory by Isotope at 35 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-3	4.555E-08	4.072E-08	3.639E-08	3.253E-08	2.457E-08	1.856E-08	2.394E-32
Li-6	1.703E-10	1.703E-10	1.703E-10	1.703E-10	1.703E-10	1.703E-10	1.703E-10
Li-7	1.070E-11	1.070E-11	1.070E-11	1.070E-11	1.070E-11	1.070E-11	1.070E-11
Be-9	2.058E-11	2.058E-11	2.058E-11	2.058E-11	2.058E-11	2.058E-11	2.058E-11
Be-10	1.374E-10	1.374E-10	1.374E-10	1.374E-10	1.374E-10	1.374E-10	1.373E-10
C-14	2.776E-11	2.776E-11	2.775E-11	2.774E-11	2.773E-11	2.771E-11	2.461E-11
Zn-66	3.699E-14	3.699E-14	3.699E-14	3.699E-14	3.699E-14	3.699E-14	3.699E-14
Zn-67	1.538E-15	1.538E-15	1.538E-15	1.538E-15	1.538E-15	1.538E-15	1.538E-15
Ga-71	9.584E-13	9.584E-13	9.584E-13	9.584E-13	9.584E-13	9.584E-13	9.584E-13
Ge-72	2.354E-08	2.354E-08	2.354E-08	2.354E-08	2.354E-08	2.354E-08	2.354E-08
Ge-73	4.785E-08	4.785E-08	4.785E-08	4.785E-08	4.785E-08	4.785E-08	4.785E-08
Ge-74	1.034E-07	1.034E-07	1.034E-07	1.034E-07	1.034E-07	1.034E-07	1.034E-07
As-75	2.121E-07	2.121E-07	2.121E-07	2.121E-07	2.121E-07	2.121E-07	2.121E-07
Ge-76	5.224E-07	5.224E-07	5.224E-07	5.224E-07	5.224E-07	5.224E-07	5.224E-07
Se-76	6.291E-09	6.291E-09	6.291E-09	6.291E-09	6.291E-09	6.291E-09	6.291E-09
Se-77	1.062E-06	1.062E-06	1.062E-06	1.062E-06	1.062E-06	1.062E-06	1.062E-06
Se-78	2.558E-06	2.558E-06	2.558E-06	2.558E-06	2.558E-06	2.558E-06	2.558E-06
Se-79	6.166E-06	6.166E-06	6.166E-06	6.166E-06	6.166E-06	6.165E-06	6.101E-06
Br-79	4.496E-10	5.812E-10	7.128E-10	8.444E-10	1.173E-09	1.502E-09	6.564E-08
Se-80	1.400E-05	1.400E-05	1.400E-05	1.400E-05	1.400E-05	1.400E-05	1.400E-05
Kr-80	2.543E-10	2.543E-10	2.543E-10	2.543E-10	2.543E-10	2.543E-10	2.543E-10
Br-81	2.254E-05	2.254E-05	2.254E-05	2.254E-05	2.254E-05	2.254E-05	2.254E-05
Kr-81	2.654E-11	2.654E-11	2.654E-11	2.654E-11	2.654E-11	2.654E-11	2.645E-11
Se-82	3.496E-05	3.496E-05	3.496E-05	3.496E-05	3.496E-05	3.496E-05	3.496E-05
Kr-82	1.114E-06	1.114E-06	1.114E-06	1.114E-06	1.114E-06	1.114E-06	1.114E-06
Kr-83	4.125E-05	4.125E-05	4.125E-05	4.125E-05	4.125E-05	4.125E-05	4.125E-05
Kr-84	1.184E-04	1.184E-04	1.184E-04	1.184E-04	1.184E-04	1.184E-04	1.184E-04
Kr-85	1.732E-05	1.522E-05	1.337E-05	1.175E-05	8.505E-06	6.156E-06	1.863E-33
Rb-85	1.077E-04	1.098E-04	1.117E-04	1.133E-04	1.165E-04	1.189E-04	1.250E-04
Kr-86	1.951E-04	1.951E-04	1.951E-04	1.951E-04	1.951E-04	1.951E-04	1.951E-04
Sr-86	4.668E-07	4.668E-07	4.668E-07	4.668E-07	4.668E-07	4.668E-07	4.668E-07
Rb-87	2.501E-04	2.501E-04	2.501E-04	2.501E-04	2.501E-04	2.501E-04	2.501E-04
Sr-87	3.892E-09	3.892E-09	3.892E-09	3.892E-09	3.892E-09	3.892E-09	3.895E-09
Sr-88	3.587E-04	3.587E-04	3.587E-04	3.587E-04	3.587E-04	3.587E-04	3.587E-04
Sr-89	2.589E-14	1.144E-18	5.055E-23	2.234E-27	0.00	0.00	0.00
Y-89	4.673E-04	4.673E-04	4.673E-04	4.673E-04	4.673E-04	4.673E-04	4.673E-04
Sr-90	4.801E-04	4.578E-04	4.365E-04	4.162E-04	3.695E-04	3.281E-04	2.430E-14
Y-90	1.204E-07	1.148E-07	1.095E-07	1.044E-07	9.267E-08	8.227E-08	6.094E-18
Zr-90	8.803E-05	1.104E-04	1.317E-04	1.520E-04	1.987E-04	2.401E-04	5.683E-04
Y-91	6.366E-13	1.110E-16	1.935E-20	3.374E-24	1.354E-33	0.00	0.00
Zr-91	6.069E-04	6.069E-04	6.069E-04	6.069E-04	6.069E-04	6.069E-04	6.069E-04
Zr-92	6.612E-04	6.612E-04	6.612E-04	6.612E-04	6.612E-04	6.612E-04	6.612E-04
Zr-93	7.452E-04	7.452E-04	7.452E-04	7.452E-04	7.452E-04	7.452E-04	7.449E-04
Nb-93	4.920E-10	7.378E-10	1.025E-09	1.350E-09	2.304E-09	3.423E-09	3.323E-07
Nb-93m	1.862E-09	2.291E-09	2.679E-09	3.030E-09	3.764E-09	4.333E-09	6.291E-09

TABLE D.3.d. Fission Product Inventory by Isotope at 35 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Zr-94	7.733E-04	7.733E-04	7.733E-04	7.733E-04	7.733E-04	7.733E-04	7.733E-04
Nb-94	8.424E-10	8.423E-10	8.423E-10	8.422E-10	8.421E-10	8.419E-10	8.142E-10
Zr-95	4.749E-12	1.736E-15	6.348E-19	2.321E-22	5.933E-31	0.00	0.00
Nb-95	5.792E-12	2.118E-15	7.743E-19	2.831E-22	5.366E-33	0.00	0.00
Nb-95m	1.987E-15	7.265E-19	2.656E-22	9.712E-26	0.00	0.00	0.00
Mo-95	7.834E-04	7.834E-04	7.834E-04	7.834E-04	7.834E-04	7.834E-04	7.834E-04
Zr-96	8.375E-04	8.375E-04	8.375E-04	8.375E-04	8.375E-04	8.375E-04	8.375E-04
Mo-96	4.408E-05	4.408E-05	4.408E-05	4.408E-05	4.408E-05	4.408E-05	4.408E-05
Mo-97	8.324E-04	8.324E-04	8.324E-04	8.324E-04	8.324E-04	8.324E-04	8.324E-04
Mo-98	8.718E-04	8.718E-04	8.718E-04	8.718E-04	8.718E-04	8.718E-04	8.718E-04
Tc-98	7.329E-09	7.329E-09	7.329E-09	7.329E-09	7.329E-09	7.329E-09	7.328E-09
Tc-99	8.041E-04	8.041E-04	8.041E-04	8.041E-04	8.041E-04	8.041E-04	8.015E-04
Ru-99	1.767E-08	2.290E-08	2.814E-08	3.337E-08	4.645E-08	5.954E-08	2.620E-06
Mo-100	9.843E-04	9.843E-04	9.843E-04	9.843E-04	9.843E-04	9.843E-04	9.843E-04
Ru-100	1.107E-04	1.107E-04	1.107E-04	1.107E-04	1.107E-04	1.107E-04	1.107E-04
Ru-101	8.176E-04	8.176E-04	8.176E-04	8.176E-04	8.176E-04	8.176E-04	8.176E-04
Ru-102	8.275E-04	8.275E-04	8.275E-04	8.275E-04	8.275E-04	8.275E-04	8.275E-04
Rh-102	3.975E-10	2.465E-10	1.528E-10	9.474E-11	2.868E-11	8.680E-12	0.00
Ru-103	1.622E-16	4.092E-22	1.033E-27	2.606E-33	0.00	0.00	0.00
Rh-103	4.740E-04	4.740E-04	4.740E-04	4.740E-04	4.740E-04	4.740E-04	4.740E-04
Ru-104	5.949E-04	5.949E-04	5.949E-04	5.949E-04	5.949E-04	5.949E-04	5.949E-04
Pd-104	2.703E-04	2.703E-04	2.703E-04	2.703E-04	2.703E-04	2.703E-04	2.703E-04
Pd-105	4.306E-04	4.306E-04	4.306E-04	4.306E-04	4.306E-04	4.306E-04	4.306E-04
Ru-106	7.355E-06	1.859E-06	4.699E-07	1.188E-07	3.815E-09	1.225E-10	0.00
Rh-106	6.913E-12	1.747E-12	4.417E-13	1.116E-13	3.586E-15	1.152E-16	0.00
Pd-106	3.883E-04	3.937E-04	3.951E-04	3.955E-04	3.956E-04	3.956E-04	3.956E-04
Pd-107	2.485E-04	2.485E-04	2.485E-04	2.485E-04	2.485E-04	2.485E-04	2.485E-04
Ag-107	1.611E-10	2.141E-10	2.672E-10	3.202E-10	4.528E-10	5.854E-10	2.657E-08
Pd-108	1.716E-04	1.716E-04	1.716E-04	1.716E-04	1.716E-04	1.716E-04	1.716E-04
Ag-108m	1.352E-12	1.337E-12	1.323E-12	1.308E-12	1.273E-12	1.239E-12	5.892E-15
Cd-108	4.958E-10	4.958E-10	4.958E-10	4.958E-10	4.958E-10	4.958E-10	4.959E-10
Ag-109	8.519E-05	8.519E-05	8.519E-05	8.519E-05	8.519E-05	8.519E-05	8.519E-05
Cd-109	5.825E-14	1.956E-14	6.568E-15	2.205E-15	1.441E-16	9.416E-18	0.00
Pd-110	5.625E-05	5.625E-05	5.625E-05	5.625E-05	5.625E-05	5.625E-05	5.625E-05
Ag-110	1.902E-16	2.508E-17	3.306E-18	4.358E-19	2.749E-21	1.735E-23	0.00
Ag-110m	1.255E-08	1.655E-09	2.182E-10	2.876E-11	1.814E-13	1.145E-15	0.00
Cd-110	4.193E-05	4.194E-05	4.194E-05	4.194E-05	4.194E-05	4.194E-05	4.194E-05
Cd-111	3.102E-05	3.102E-05	3.102E-05	3.102E-05	3.102E-05	3.102E-05	3.102E-05
Cd-112	1.855E-05	1.855E-05	1.855E-05	1.855E-05	1.855E-05	1.855E-05	1.855E-05
Cd-113	1.517E-07	1.518E-07	1.518E-07	1.518E-07	1.518E-07	1.519E-07	1.520E-07
Cd-113m	2.324E-07	2.113E-07	1.922E-07	1.748E-07	1.378E-07	1.087E-07	6.532E-28
In-113	7.630E-08	9.734E-08	1.165E-07	1.339E-07	1.708E-07	1.999E-07	3.085E-07
Cd-114	2.462E-05	2.462E-05	2.462E-05	2.462E-05	2.462E-05	2.462E-05	2.462E-05
Sn-114	2.889E-09	2.889E-09	2.889E-09	2.889E-09	2.889E-09	2.889E-09	2.889E-09
In-115	2.366E-06	2.366E-06	2.366E-06	2.366E-06	2.366E-06	2.366E-06	2.366E-06

TABLE D.3.d. Fission Product Inventory by Isotope at 35 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Sn-115	3.462E-07	3.462E-07	3.462E-07	3.462E-07	3.462E-07	3.462E-07	3.462E-07
Cd-116	8.923E-06	8.923E-06	8.923E-06	8.923E-06	8.923E-06	8.923E-06	8.923E-06
Sn-116	8.200E-06	8.200E-06	8.200E-06	8.200E-06	8.200E-06	8.200E-06	8.200E-06
Sn-117	9.010E-06	9.010E-06	9.010E-06	9.010E-06	9.010E-06	9.010E-06	9.010E-06
Sn-118	9.104E-06	9.104E-06	9.104E-06	9.104E-06	9.104E-06	9.104E-06	9.104E-06
Sn-119	9.068E-06	9.069E-06	9.069E-06	9.069E-06	9.069E-06	9.069E-06	9.069E-06
Sn-119m	5.165E-10	6.540E-11	8.282E-12	1.049E-12	5.983E-15	3.414E-17	0.00
Sn-120	9.244E-06	9.244E-06	9.244E-06	9.244E-06	9.244E-06	9.244E-06	9.244E-06
Sn-121m	3.589E-09	3.490E-09	3.395E-09	3.302E-09	3.081E-09	2.874E-09	3.590E-15
Sb-121	8.938E-06	8.938E-06	8.938E-06	8.938E-06	8.939E-06	8.939E-06	8.942E-06
Sn-122	1.016E-05	1.016E-05	1.016E-05	1.016E-05	1.016E-05	1.016E-05	1.016E-05
Te-122	6.530E-07	6.530E-07	6.530E-07	6.530E-07	6.530E-07	6.530E-07	6.530E-07
Sn-123	9.458E-11	1.876E-12	3.723E-14	7.386E-16	4.095E-20	2.270E-24	0.00
Sb-123	1.103E-05	1.103E-05	1.103E-05	1.103E-05	1.103E-05	1.103E-05	1.103E-05
Te-123	9.133E-09	9.133E-09	9.133E-09	9.133E-09	9.133E-09	9.133E-09	9.133E-09
Te-123m	2.706E-13	3.934E-15	5.719E-17	8.315E-19	2.119E-23	5.401E-28	0.00
Sn-124	1.370E-05	1.370E-05	1.370E-05	1.370E-05	1.370E-05	1.370E-05	1.370E-05
Sb-124	2.432E-15	5.407E-19	1.202E-22	2.672E-26	1.969E-35	0.00	0.00
Te-124	5.096E-07	5.096E-07	5.096E-07	5.096E-07	5.096E-07	5.096E-07	5.096E-07
Sb-125	4.340E-06	2.631E-06	1.595E-06	9.670E-07	2.767E-07	7.918E-08	0.00
Te-125	1.627E-05	1.800E-05	1.905E-05	1.969E-05	2.039E-05	2.059E-05	2.067E-05
Te-125m	6.071E-08	3.681E-08	2.232E-08	1.353E-08	3.871E-09	1.108E-09	0.00
Sn-126	2.994E-05	2.994E-05	2.993E-05	2.993E-05	2.993E-05	2.993E-05	2.973E-05
Sb-126	1.422E-12	1.422E-12	1.422E-12	1.422E-12	1.422E-12	1.422E-12	1.412E-12
Sb-126m	1.081E-14	1.081E-14	1.081E-14	1.081E-14	1.081E-14	1.081E-14	1.074E-14
Te-126	8.469E-07	8.473E-07	8.478E-07	8.482E-07	8.492E-07	8.502E-07	1.053E-06
Te-127	2.761E-13	2.653E-15	2.549E-17	2.449E-19	2.216E-24	2.005E-29	0.00
Te-127m	7.887E-11	7.578E-13	7.282E-15	6.995E-17	6.330E-22	5.728E-27	0.00
I-127	6.025E-05	6.025E-05	6.025E-05	6.025E-05	6.025E-05	6.025E-05	6.025E-05
Te-128	1.192E-04	1.192E-04	1.192E-04	1.192E-04	1.192E-04	1.192E-04	1.192E-04
Xe-128	3.618E-06	3.618E-06	3.618E-06	3.618E-06	3.618E-06	3.618E-06	3.618E-06
I-129	1.918E-04	1.918E-04	1.918E-04	1.918E-04	1.918E-04	1.918E-04	1.918E-04
Xe-129	2.176E-08	2.178E-08	2.180E-08	2.182E-08	2.186E-08	2.190E-08	3.020E-08
Te-130	3.798E-04	3.798E-04	3.798E-04	3.798E-04	3.798E-04	3.798E-04	3.798E-04
Xe-130	1.445E-05	1.445E-05	1.445E-05	1.445E-05	1.445E-05	1.445E-05	1.445E-05
Xe-131	4.400E-04	4.400E-04	4.400E-04	4.400E-04	4.400E-04	4.400E-04	4.400E-04
Xe-132	1.164E-03	1.164E-03	1.164E-03	1.164E-03	1.164E-03	1.164E-03	1.164E-03
Ba-132	2.175E-09	2.175E-09	2.175E-09	2.175E-09	2.175E-09	2.175E-09	2.175E-09
Cs-133	1.172E-03	1.172E-03	1.172E-03	1.172E-03	1.172E-03	1.172E-03	1.172E-03
Xe-134	1.548E-03	1.548E-03	1.548E-03	1.548E-03	1.548E-03	1.548E-03	1.548E-03
Cs-134	2.804E-05	1.432E-05	7.308E-06	3.731E-06	6.948E-07	1.294E-07	0.00
Ba-134	1.553E-04	1.691E-04	1.761E-04	1.796E-04	1.827E-04	1.832E-04	1.834E-04
Cs-135	4.395E-04	4.395E-04	4.395E-04	4.395E-04	4.395E-04	4.395E-04	4.393E-04
Ba-135	5.481E-07	5.484E-07	5.487E-07	5.489E-07	5.496E-07	5.503E-07	6.800E-07
Xe-136	2.355E-03	2.355E-03	2.355E-03	2.355E-03	2.355E-03	2.355E-03	2.355E-03

TABLE D.3.d. Fission Product Inventory by Isotope at 35 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Ba-136	2.320E-05	2.320E-05	2.320E-05	2.320E-05	2.320E-05	2.320E-05	2.320E-05
Cs-137	1.117E-03	1.067E-03	1.019E-03	9.726E-04	8.665E-04	7.719E-04	1.131E-13
Ba-137	1.872E-04	2.377E-04	2.859E-04	3.319E-04	4.380E-04	5.325E-04	1.304E-03
Ba-137m	1.709E-10	1.632E-10	1.558E-10	1.488E-10	1.326E-10	1.181E-10	1.731E-20
Ba-138	1.341E-03	1.341E-03	1.341E-03	1.341E-03	1.341E-03	1.341E-03	1.341E-03
La-138	5.504E-09	5.504E-09	5.504E-09	5.504E-09	5.504E-09	5.504E-09	5.504E-09
La-139	1.278E-03	1.278E-03	1.278E-03	1.278E-03	1.278E-03	1.278E-03	1.278E-03
Ce-140	1.305E-03	1.305E-03	1.305E-03	1.305E-03	1.305E-03	1.305E-03	1.305E-03
Pr-141	1.171E-03	1.171E-03	1.171E-03	1.171E-03	1.171E-03	1.171E-03	1.171E-03
Ce-142	1.181E-03	1.181E-03	1.181E-03	1.181E-03	1.181E-03	1.181E-03	1.181E-03
Nd-142	3.122E-05	3.122E-05	3.122E-05	3.122E-05	3.122E-05	3.122E-05	3.122E-05
Nd-143	7.809E-04	7.809E-04	7.809E-04	7.809E-04	7.809E-04	7.809E-04	7.809E-04
Ce-144	5.521E-06	9.298E-07	1.566E-07	2.637E-08	3.070E-10	3.574E-12	0.00
Pr-144	2.331E-10	3.926E-11	6.612E-12	1.114E-12	1.296E-14	1.509E-16	0.00
Pr-144m	1.165E-12	1.963E-13	3.305E-14	5.567E-15	6.481E-17	7.545E-19	0.00
Nd-144	1.404E-03	1.409E-03	1.410E-03	1.410E-03	1.410E-03	1.410E-03	1.410E-03
Nd-145	6.976E-04	6.976E-04	6.976E-04	6.976E-04	6.976E-04	6.976E-04	6.976E-04
Nd-146	7.293E-04	7.293E-04	7.293E-04	7.293E-04	7.293E-04	7.293E-04	7.293E-04
Pm-146	3.753E-09	2.917E-09	2.267E-09	1.762E-09	9.383E-10	4.997E-10	0.00
Sm-146	1.085E-08	1.116E-08	1.140E-08	1.159E-08	1.189E-08	1.205E-08	1.224E-08
Pm-147	4.037E-05	2.380E-05	1.403E-05	8.271E-06	2.207E-06	5.889E-07	0.00
Sm-147	1.791E-04	1.957E-04	2.055E-04	2.112E-04	2.173E-04	2.189E-04	2.195E-04
Nd-148	3.892E-04	3.892E-04	3.892E-04	3.892E-04	3.892E-04	3.892E-04	3.892E-04
Sm-148	1.992E-04	1.992E-04	1.992E-04	1.992E-04	1.992E-04	1.992E-04	1.992E-04
Sm-149	1.945E-06	1.945E-06	1.945E-06	1.945E-06	1.945E-06	1.945E-06	1.945E-06
Nd-150	1.897E-04	1.897E-04	1.897E-04	1.897E-04	1.897E-04	1.897E-04	1.897E-04
Sm-150	2.493E-04	2.493E-04	2.493E-04	2.493E-04	2.493E-04	2.493E-04	2.493E-04
Eu-150	3.583E-13	3.447E-13	3.317E-13	3.192E-13	2.899E-13	2.633E-13	1.682E-21
Sm-151	1.181E-05	1.163E-05	1.145E-05	1.127E-05	1.085E-05	1.044E-05	5.501E-09
Eu-151	3.843E-07	5.648E-07	7.425E-07	9.175E-07	1.343E-06	1.753E-06	1.218E-05
Sm-152	1.310E-04	1.310E-04	1.310E-04	1.310E-04	1.310E-04	1.310E-04	1.310E-04
Eu-152	4.773E-08	4.311E-08	3.893E-08	3.516E-08	2.725E-08	2.112E-08	4.302E-30
Gd-152	2.412E-08	2.541E-08	2.657E-08	2.763E-08	2.983E-08	3.154E-08	3.742E-08
Eu-153	1.151E-04	1.151E-04	1.151E-04	1.151E-04	1.151E-04	1.151E-04	1.151E-04
Gd-153	2.587E-10	3.193E-11	3.941E-12	4.864E-13	2.602E-15	1.392E-17	0.00
Sm-154	4.062E-05	4.062E-05	4.062E-05	4.062E-05	4.062E-05	4.062E-05	4.062E-05
Eu-154	3.068E-05	2.611E-05	2.222E-05	1.892E-05	1.264E-05	8.449E-06	0.00
Gd-154	1.761E-05	2.218E-05	2.607E-05	2.938E-05	3.565E-05	3.984E-05	4.829E-05
Eu-155	8.506E-06	6.431E-06	4.863E-06	3.677E-06	1.828E-06	9.088E-07	0.00
Gd-155	6.523E-06	8.597E-06	1.017E-05	1.135E-05	1.320E-05	1.412E-05	1.503E-05
Gd-156	7.717E-05	7.717E-05	7.717E-05	7.717E-05	7.717E-05	7.717E-05	7.717E-05
Gd-157	8.826E-08	8.826E-08	8.826E-08	8.826E-08	8.826E-08	8.826E-08	8.826E-08
Gd-158	2.006E-05	2.006E-05	2.006E-05	2.006E-05	2.006E-05	2.006E-05	2.006E-05
Tb-159	2.931E-06	2.931E-06	2.931E-06	2.931E-06	2.931E-06	2.931E-06	2.931E-06
Gd-160	1.436E-06	1.436E-06	1.436E-06	1.436E-06	1.436E-06	1.436E-06	1.436E-06

TABLE D.3.d. Fission Product Inventory by Isotope at 35 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Tb-160	5.092E-14	4.629E-17	4.208E-20	3.826E-23	9.534E-31	0.00	0.00
Dy-160	3.415E-07	3.415E-07	3.415E-07	3.415E-07	3.415E-07	3.415E-07	3.415E-07
Dy-161	4.563E-07	4.563E-07	4.563E-07	4.563E-07	4.563E-07	4.563E-07	4.563E-07
Dy-162	4.170E-07	4.170E-07	4.170E-07	4.170E-07	4.170E-07	4.170E-07	4.170E-07
Dy-163	3.427E-07	3.427E-07	3.427E-07	3.427E-07	3.427E-07	3.427E-07	3.427E-07
Dy-164	4.991E-08	4.991E-08	4.991E-08	4.991E-08	4.991E-08	4.991E-08	4.991E-08
Ho-165	1.758E-07	1.758E-07	1.758E-07	1.758E-07	1.758E-07	1.758E-07	1.758E-07
Ho-166m	1.925E-09	1.923E-09	1.921E-09	1.918E-09	1.913E-09	1.907E-09	1.083E-09
Er-166	5.703E-08	5.703E-08	5.703E-08	5.704E-08	5.704E-08	5.705E-08	5.787E-08
Er-167	3.457E-09	3.457E-09	3.457E-09	3.457E-09	3.457E-09	3.457E-09	3.457E-09
Er-168	9.920E-09	9.920E-09	9.920E-09	9.920E-09	9.920E-09	9.920E-09	9.920E-09
Tm-169	7.196E-11	7.196E-11	7.196E-11	7.196E-11	7.196E-11	7.196E-11	7.196E-11
Er-170	3.771E-14	3.771E-14	3.771E-14	3.771E-14	3.771E-14	3.771E-14	3.771E-14
Tm-170	2.961E-15	5.773E-17	1.125E-18	2.193E-20	1.163E-24	6.170E-29	0.00
Yb-170	2.509E-11	2.509E-11	2.509E-11	2.509E-11	2.509E-11	2.509E-11	2.509E-11
Tm-171	1.619E-13	7.866E-14	3.821E-14	1.856E-14	3.053E-15	5.020E-16	0.00
Yb-171	1.517E-12	1.600E-12	1.641E-12	1.660E-12	1.676E-12	1.678E-12	1.679E-12
Yb-172	6.912E-14	6.912E-14	6.912E-14	6.912E-14	6.912E-14	6.912E-14	6.912E-14
Total	3.594E-02	3.594E-02	3.594E-02	3.594E-02	3.594E-02	3.594E-02	3.594E-02

TABLE D.3.e. Fission Product Inventory by Isotope at 40 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-3	5.290E-08	4.728E-08	4.226E-08	3.777E-08	2.853E-08	2.155E-08	2.779E-32
Li-6	1.683E-10	1.683E-10	1.683E-10	1.683E-10	1.683E-10	1.683E-10	1.683E-10
Li-7	1.220E-11	1.220E-11	1.220E-11	1.220E-11	1.220E-11	1.220E-11	1.220E-11
Be-9	2.347E-11	2.347E-11	2.347E-11	2.347E-11	2.347E-11	2.347E-11	2.347E-11
Be-10	1.568E-10	1.568E-10	1.568E-10	1.568E-10	1.568E-10	1.568E-10	1.567E-10
C-14	3.167E-11	3.167E-11	3.166E-11	3.165E-11	3.163E-11	3.161E-11	2.808E-11
Zn-66	4.043E-14	4.043E-14	4.043E-14	4.043E-14	4.043E-14	4.043E-14	4.043E-14
Zn-67	1.672E-15	1.672E-15	1.672E-15	1.672E-15	1.672E-15	1.672E-15	1.672E-15
Ga-71	1.113E-12	1.113E-12	1.113E-12	1.113E-12	1.113E-12	1.113E-12	1.113E-12
Ge-72	2.757E-08	2.757E-08	2.757E-08	2.757E-08	2.757E-08	2.757E-08	2.757E-08
Ge-73	5.486E-08	5.486E-08	5.486E-08	5.486E-08	5.486E-08	5.486E-08	5.486E-08
Ge-74	1.189E-07	1.189E-07	1.189E-07	1.189E-07	1.189E-07	1.189E-07	1.189E-07
As-75	2.405E-07	2.405E-07	2.405E-07	2.405E-07	2.405E-07	2.405E-07	2.405E-07
Ge-76	5.891E-07	5.891E-07	5.891E-07	5.891E-07	5.891E-07	5.891E-07	5.891E-07
Se-76	8.312E-09	8.312E-09	8.312E-09	8.312E-09	8.312E-09	8.312E-09	8.312E-09
Se-77	1.182E-06	1.182E-06	1.182E-06	1.182E-06	1.182E-06	1.182E-06	1.182E-06
Se-78	2.917E-06	2.917E-06	2.917E-06	2.917E-06	2.917E-06	2.917E-06	2.917E-06
Se-79	6.965E-06	6.965E-06	6.965E-06	6.965E-06	6.965E-06	6.964E-06	6.892E-06
Br-79	5.073E-10	6.560E-10	8.046E-10	9.533E-10	1.325E-09	1.696E-09	7.414E-08
Se-80	1.577E-05	1.577E-05	1.577E-05	1.577E-05	1.577E-05	1.577E-05	1.577E-05
Kr-80	3.029E-10	3.029E-10	3.029E-10	3.029E-10	3.029E-10	3.029E-10	3.029E-10
Br-81	2.512E-05	2.512E-05	2.512E-05	2.512E-05	2.512E-05	2.512E-05	2.512E-05
Kr-81	3.503E-11	3.503E-11	3.503E-11	3.503E-11	3.503E-11	3.503E-11	3.491E-11
Se-82	3.911E-05	3.911E-05	3.911E-05	3.911E-05	3.911E-05	3.911E-05	3.911E-05
Kr-82	1.437E-06	1.437E-06	1.437E-06	1.437E-06	1.437E-06	1.437E-06	1.437E-06
Kr-83	4.361E-05	4.361E-05	4.361E-05	4.361E-05	4.361E-05	4.361E-05	4.361E-05
Kr-84	1.342E-04	1.342E-04	1.342E-04	1.342E-04	1.342E-04	1.342E-04	1.342E-04
Kr-85	1.921E-05	1.688E-05	1.484E-05	1.304E-05	9.435E-06	6.828E-06	2.062E-33
Rb-85	1.194E-04	1.217E-04	1.238E-04	1.256E-04	1.292E-04	1.318E-04	1.386E-04
Kr-86	2.157E-04	2.157E-04	2.157E-04	2.157E-04	2.157E-04	2.157E-04	2.157E-04
Sr-86	6.123E-07	6.123E-07	6.123E-07	6.123E-07	6.123E-07	6.123E-07	6.123E-07
Rb-87	2.763E-04	2.763E-04	2.763E-04	2.763E-04	2.763E-04	2.763E-04	2.763E-04
Sr-87	5.467E-09	5.467E-09	5.467E-09	5.467E-09	5.467E-09	5.467E-09	5.471E-09
Sr-88	3.960E-04	3.960E-04	3.960E-04	3.960E-04	3.960E-04	3.960E-04	3.960E-04
Sr-89	2.748E-14	1.214E-18	5.365E-23	2.371E-27	0.00	0.00	0.00
Sr-89	5.150E-04	5.150E-04	5.150E-04	5.150E-04	5.150E-04	5.150E-04	5.150E-04
Sr-90	5.291E-04	5.045E-04	4.811E-04	4.587E-04	4.072E-04	3.615E-04	2.678E-14
Y-90	1.327E-07	1.265E-07	1.206E-07	1.150E-07	1.021E-07	9.066E-08	6.716E-18
Zr-90	9.766E-05	1.223E-04	1.457E-04	1.681E-04	2.196E-04	2.653E-04	6.269E-04
Y-91	6.844E-13	1.193E-16	2.081E-20	3.628E-24	1.456E-33	0.00	0.00
Zr-91	6.718E-04	6.718E-04	6.718E-04	6.718E-04	6.718E-04	6.718E-04	6.718E-04
Zr-92	7.364E-04	7.364E-04	7.364E-04	7.364E-04	7.364E-04	7.364E-04	7.364E-04
Zr-93	8.318E-04	8.318E-04	8.318E-04	8.318E-04	8.318E-04	8.318E-04	8.314E-04
Nb-93	5.530E-10	8.279E-10	1.149E-09	1.512E-09	2.578E-09	3.828E-09	3.709E-07
Nb-93m	2.084E-09	2.563E-09	2.995E-09	3.386E-09	4.204E-09	4.839E-09	7.021E-09

TABLE D.3.e. Fission Product Inventory by Isotope at 40 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Zr-94	8.711E-04	8.711E-04	8.711E-04	8.711E-04	8.711E-04	8.711E-04	8.711E-04
Nb-94	1.008E-09	1.008E-09	1.008E-09	1.008E-09	1.008E-09	1.008E-09	9.744E-10
Zr-95	5.303E-12	1.939E-15	7.089E-19	2.592E-22	6.625E-31	0.00	0.00
Nb-95	6.468E-12	2.365E-15	8.646E-19	3.161E-22	5.992E-33	0.00	0.00
Nb-95m	2.219E-15	8.113E-19	2.966E-22	1.085E-25	0.00	0.00	0.00
Mo-95	8.746E-04	8.746E-04	8.746E-04	8.746E-04	8.746E-04	8.746E-04	8.746E-04
Zr-96	9.465E-04	9.465E-04	9.465E-04	9.465E-04	9.465E-04	9.465E-04	9.465E-04
Mo-96	5.864E-05	5.864E-05	5.864E-05	5.864E-05	5.864E-05	5.864E-05	5.864E-05
Mo-97	9.446E-04	9.446E-04	9.446E-04	9.446E-04	9.446E-04	9.446E-04	9.446E-04
Mo-98	9.944E-04	9.944E-04	9.944E-04	9.944E-04	9.944E-04	9.944E-04	9.944E-04
Tc-98	9.769E-09	9.769E-09	9.769E-09	9.769E-09	9.769E-09	9.769E-09	9.767E-09
Tc-99	8.978E-04	8.978E-04	8.978E-04	8.978E-04	8.978E-04	8.978E-04	8.949E-04
Ru-99	1.974E-08	2.558E-08	3.143E-08	3.727E-08	5.188E-08	6.649E-08	2.925E-06
Mo-100	1.125E-03	1.125E-03	1.125E-03	1.125E-03	1.125E-03	1.125E-03	1.125E-03
Ru-100	1.473E-04	1.473E-04	1.473E-04	1.473E-04	1.473E-04	1.473E-04	1.473E-04
Ru-101	9.323E-04	9.323E-04	9.323E-04	9.323E-04	9.323E-04	9.323E-04	9.323E-04
Ru-102	9.636E-04	9.636E-04	9.636E-04	9.636E-04	9.636E-04	9.636E-04	9.636E-04
Rh-102	5.221E-10	3.237E-10	2.007E-10	1.244E-10	3.766E-11	1.140E-11	0.00
Ru-103	1.906E-16	4.809E-22	1.213E-27	3.062E-33	0.00	0.00	0.00
Rh-103	5.167E-04	5.167E-04	5.167E-04	5.167E-04	5.167E-04	5.167E-04	5.167E-04
Ru-104	7.077E-04	7.077E-04	7.077E-04	7.077E-04	7.077E-04	7.077E-04	7.077E-04
Pd-104	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04	3.551E-04
Pd-105	5.109E-04	5.109E-04	5.109E-04	5.109E-04	5.109E-04	5.109E-04	5.109E-04
Ru-106	9.050E-06	2.288E-06	5.782E-07	1.461E-07	4.695E-09	1.508E-10	0.00
Rh-106	8.507E-12	2.150E-12	5.435E-13	1.374E-13	4.413E-15	1.417E-16	0.00
Pd-106	4.838E-04	4.906E-04	4.923E-04	4.927E-04	4.929E-04	4.929E-04	4.929E-04
Pd-107	3.061E-04	3.061E-04	3.061E-04	3.061E-04	3.061E-04	3.061E-04	3.061E-04
Ag-107	1.976E-10	2.630E-10	3.283E-10	3.936E-10	5.569E-10	7.202E-10	3.273E-08
Pd-108	2.122E-04	2.122E-04	2.122E-04	2.122E-04	2.122E-04	2.122E-04	2.122E-04
Ag-108m	1.700E-12	1.682E-12	1.664E-12	1.646E-12	1.601E-12	1.558E-12	7.410E-15
Cd-108	7.060E-10	7.060E-10	7.060E-10	7.060E-10	7.060E-10	7.060E-10	7.061E-10
Ag-109	1.013E-04	1.013E-04	1.013E-04	1.013E-04	1.013E-04	1.013E-04	1.013E-04
Cd-109	9.505E-14	3.192E-14	1.072E-14	3.599E-15	2.352E-16	1.537E-17	0.00
Pd-110	6.969E-05	6.969E-05	6.969E-05	6.969E-05	6.969E-05	6.969E-05	6.969E-05
Ag-10	2.683E-16	3.537E-17	4.662E-18	6.146E-19	3.877E-21	2.446E-23	0.00
Ag-110m	1.770E-08	2.334E-09	3.076E-10	4.055E-11	2.558E-13	1.614E-15	0.00
Cd-110	5.951E-05	5.953E-05	5.953E-05	5.953E-05	5.953E-05	5.953E-05	5.953E-05
Cd-111	3.828E-05	3.828E-05	3.828E-05	3.828E-05	3.828E-05	3.828E-05	3.828E-05
Cd-112	2.272E-05	2.272E-05	2.272E-05	2.272E-05	2.272E-05	2.272E-05	2.272E-05
Cd-113	1.557E-07	1.558E-07	1.558E-07	1.558E-07	1.558E-07	1.559E-07	1.560E-07
Cd-113m	2.918E-07	2.654E-07	2.413E-07	2.195E-07	1.731E-07	1.365E-07	8.202E-28
In-113	9.436E-08	1.208E-07	1.448E-07	1.667E-07	2.130E-07	2.496E-07	3.859E-07
Cd-114	2.944E-05	2.944E-05	2.944E-05	2.944E-05	2.944E-05	2.944E-05	2.944E-05
Sn-114	4.100E-09	4.100E-09	4.100E-09	4.100E-09	4.100E-09	4.100E-09	4.100E-09
In-115	2.416E-06	2.416E-06	2.416E-06	2.416E-06	2.416E-06	2.416E-06	2.416E-06

TABLE D.3.e. Fission Product Inventory by Isotope at 40 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Sn-115	4.060E-07	4.060E-07	4.060E-07	4.060E-07	4.060E-07	4.060E-07	4.060E-07
Cd-116	1.047E-05	1.047E-05	1.047E-05	1.047E-05	1.047E-05	1.047E-05	1.047E-05
Sn-116	1.009E-05	1.009E-05	1.009E-05	1.009E-05	1.009E-05	1.009E-05	1.009E-05
Sn-117	1.056E-05	1.056E-05	1.056E-05	1.056E-05	1.056E-05	1.056E-05	1.056E-05
Sn-118	1.067E-05	1.067E-05	1.067E-05	1.067E-05	1.067E-05	1.067E-05	1.067E-05
Sn-119	1.063E-05	1.063E-05	1.063E-05	1.063E-05	1.063E-05	1.063E-05	1.063E-05
Sn-119m	6.345E-10	8.034E-11	1.017E-11	1.288E-12	7.355E-15	4.195E-17	0.00
Sn-120	1.083E-05	1.083E-05	1.083E-05	1.083E-05	1.083E-05	1.083E-05	1.083E-05
Sn-121m	4.261E-09	4.144E-09	4.031E-09	3.920E-09	3.658E-09	3.413E-09	4.262E-15
Sb-121	1.033E-05	1.033E-05	1.033E-05	1.033E-05	1.033E-05	1.033E-05	1.033E-05
Sn-122	1.188E-05	1.188E-05	1.188E-05	1.188E-05	1.188E-05	1.188E-05	1.188E-05
Te-122	8.874E-07	8.874E-07	8.874E-07	8.874E-07	8.874E-07	8.874E-07	8.874E-07
Sn-123	1.110E-10	2.201E-12	4.367E-14	8.665E-16	4.804E-20	2.663E-24	0.00
Sb-123	1.278E-05	1.278E-05	1.278E-05	1.278E-05	1.278E-05	1.278E-05	1.278E-05
Te-123	1.338E-08	1.338E-08	1.338E-08	1.338E-08	1.338E-08	1.338E-08	1.338E-08
Te-123m	4.400E-13	6.396E-15	9.300E-17	1.352E-18	3.446E-23	8.782E-28	0.00
Sn-124	1.597E-05	1.597E-05	1.597E-05	1.597E-05	1.597E-05	1.597E-05	1.597E-05
Sb-124	3.360E-15	7.470E-19	1.661E-22	3.691E-26	2.720E-35	0.00	0.00
Te-124	6.992E-07	6.992E-07	6.992E-07	6.992E-07	6.992E-07	6.992E-07	6.992E-07
Sb-125	5.111E-06	3.098E-06	1.878E-06	1.139E-06	3.258E-07	9.324E-08	0.00
Te-125	1.908E-05	2.112E-05	2.236E-05	2.311E-05	2.393E-05	2.417E-05	2.427E-05
Te-125m	7.148E-08	4.335E-08	2.628E-08	1.593E-08	4.557E-09	1.304E-09	0.00
Sn-126	3.508E-05	3.508E-05	3.508E-05	3.508E-05	3.508E-05	3.507E-05	3.484E-05
Sb-126	1.667E-12	1.667E-12	1.666E-12	1.666E-12	1.666E-12	1.666E-12	1.655E-12
Sb-126m	1.267E-14	1.267E-14	1.267E-14	1.267E-14	1.267E-14	1.267E-14	1.258E-14
Te-126	1.041E-06	1.042E-06	1.042E-06	1.043E-06	1.044E-06	1.045E-06	1.282E-06
Te-127	3.263E-13	3.136E-15	3.013E-17	2.895E-19	2.619E-24	2.370E-29	0.00
Te-127m	9.322E-11	8.957E-13	8.607E-15	8.269E-17	7.482E-22	6.770E-27	0.00
I-127	7.016E-05	7.016E-05	7.016E-05	7.016E-05	7.016E-05	7.016E-05	7.016E-05
Te-128	1.386E-04	1.386E-04	1.386E-04	1.386E-04	1.386E-04	1.386E-04	1.386E-04
Xe-128	4.987E-06	4.987E-06	4.987E-06	4.987E-06	4.987E-06	4.987E-06	4.987E-06
I-129	2.204E-04	2.204E-04	2.204E-04	2.204E-04	2.204E-04	2.204E-04	2.204E-04
Xe-129	3.497E-08	3.499E-08	3.501E-08	3.503E-08	3.508E-08	3.512E-08	4.466E-08
Te-130	4.392E-04	4.392E-04	4.392E-04	4.392E-04	4.392E-04	4.392E-04	4.392E-04
Xe-130	1.963E-05	1.963E-05	1.963E-05	1.963E-05	1.963E-05	1.963E-05	1.963E-05
Xe-131	4.738E-04	4.738E-04	4.738E-04	4.738E-04	4.738E-04	4.738E-04	4.738E-04
Xe-132	1.370E-03	1.370E-03	1.370E-03	1.370E-03	1.370E-03	1.370E-03	1.370E-03
Ba-132	2.887E-09	2.887E-09	2.887E-09	2.887E-09	2.887E-09	2.887E-09	2.887E-09
Cs-133	1.300E-03	1.300E-03	1.300E-03	1.300E-03	1.300E-03	1.300E-03	1.300E-03
Xe-134	1.767E-03	1.767E-03	1.767E-03	1.767E-03	1.767E-03	1.767E-03	1.767E-03
Cs-134	3.626E-05	1.851E-05	9.450E-06	4.824E-06	8.984E-07	1.673E-07	0.00
Ba-134	2.012E-04	2.189E-04	2.280E-04	2.326E-04	2.365E-04	2.372E-04	2.374E-04
Cs-135	4.613E-04	4.613E-04	4.613E-04	4.613E-04	4.613E-04	4.613E-04	4.612E-04
Ba-135	8.435E-07	8.438E-07	8.441E-07	8.444E-07	8.451E-07	8.457E-07	9.820E-07
Xe-136	2.747E-03	2.747E-03	2.747E-03	2.747E-03	2.747E-03	2.747E-03	2.747E-03

TABLE D.3.e. Fission Product Inventory by Isotope at 40 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Ba-136	2.841E-05	2.841E-05	2.841E-05	2.841E-05	2.841E-05	2.841E-05	2.841E-05
Cs-137	1.277E-03	1.220E-03	1.165E-03	1.112E-03	9.907E-04	8.826E-04	1.294E-13
Ba-137	2.140E-04	2.717E-04	3.268E-04	3.794E-04	5.007E-04	6.088E-04	1.491E-03
Ba-137m	1.954E-10	1.866E-10	1.782E-10	1.701E-10	1.516E-10	1.350E-10	1.979E-20
Ba-138	1.522E-03	1.522E-03	1.522E-03	1.522E-03	1.522E-03	1.522E-03	1.522E-03
La-138	5.599E-09	5.599E-09	5.599E-09	5.599E-09	5.599E-09	5.599E-09	5.599E-09
La-139	1.449E-03	1.449E-03	1.449E-03	1.449E-03	1.449E-03	1.449E-03	1.449E-03
Ce-140	1.486E-03	1.486E-03	1.486E-03	1.486E-03	1.486E-03	1.486E-03	1.486E-03
Pr-141	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03
Ce-142	1.338E-03	1.338E-03	1.338E-03	1.338E-03	1.338E-03	1.338E-03	1.338E-03
Nd-142	4.178E-05	4.178E-05	4.178E-05	4.178E-05	4.178E-05	4.178E-05	4.178E-05
Nd-143	8.245E-04	8.245E-04	8.245E-04	8.245E-04	8.245E-04	8.245E-04	8.245E-04
Ce-144	6.187E-06	1.042E-06	1.755E-07	2.956E-08	3.441E-10	4.006E-12	0.00
Pr-144	2.612E-10	4.400E-11	7.410E-12	1.248E-12	1.453E-14	1.692E-16	0.00
Pr-144m	1.306E-12	2.199E-13	3.704E-14	6.239E-15	7.263E-17	8.456E-19	0.00
Nd-144	1.642E-03	1.647E-03	1.648E-03	1.648E-03	1.648E-03	1.648E-03	1.648E-03
Nd-145	7.723E-04	7.723E-04	7.723E-04	7.723E-04	7.723E-04	7.723E-04	7.723E-04
Nd-146	8.467E-04	8.467E-04	8.467E-04	8.467E-04	8.467E-04	8.467E-04	8.467E-04
Pm-146	4.653E-09	3.617E-09	2.811E-09	2.185E-09	1.163E-09	6.195E-10	0.00
Sm-146	1.338E-08	1.377E-08	1.407E-08	1.430E-08	1.467E-08	1.488E-08	1.510E-08
Pm-147	4.108E-05	2.422E-05	1.428E-05	8.418E-06	2.246E-06	5.994E-07	0.00
Sm-147	1.806E-04	1.975E-04	2.074E-04	2.133E-04	2.195E-04	2.211E-04	2.217E-04
Nd-148	4.445E-04	4.445E-04	4.445E-04	4.445E-04	4.445E-04	4.445E-04	4.445E-04
Sm-148	2.391E-04	2.391E-04	2.391E-04	2.391E-04	2.391E-04	2.391E-04	2.391E-04
Sm-149	2.037E-06	2.037E-06	2.037E-06	2.037E-06	2.037E-06	2.037E-06	2.037E-06
Nd-150	2.201E-04	2.201E-04	2.201E-04	2.201E-04	2.201E-04	2.201E-04	2.201E-04
Sm-150	2.836E-04	2.836E-04	2.836E-04	2.836E-04	2.836E-04	2.836E-04	2.836E-04
Eu-150	3.784E-13	3.641E-13	3.504E-13	3.371E-13	3.062E-13	2.781E-13	1.777E-21
Sm-151	1.248E-05	1.229E-05	1.210E-05	1.192E-05	1.147E-05	1.103E-05	5.816E-09
Eu-151	4.037E-07	5.944E-07	7.823E-07	9.673E-07	1.417E-06	1.851E-06	1.288E-05
Sm-152	1.430E-04	1.430E-04	1.430E-04	1.430E-04	1.430E-04	1.430E-04	1.430E-04
Eu-152	4.275E-08	3.860E-08	3.486E-08	3.148E-08	2.440E-08	1.891E-08	3.853E-30
Gd-152	2.145E-08	2.260E-08	2.365E-08	2.459E-08	2.656E-08	2.809E-08	3.336E-08
Eu-153	1.340E-04	1.340E-04	1.340E-04	1.340E-04	1.340E-04	1.340E-04	1.340E-04
Gd-153	2.805E-10	3.462E-11	4.273E-12	5.273E-13	2.821E-15	1.509E-17	0.00
Sm-154	4.879E-05	4.879E-05	4.879E-05	4.879E-05	4.879E-05	4.879E-05	4.879E-05
Eu-154	3.862E-05	3.287E-05	2.797E-05	2.381E-05	1.591E-05	1.063E-05	0.00
Gd-154	2.224E-05	2.799E-05	3.288E-05	3.705E-05	4.494E-05	5.022E-05	6.085E-05
Eu-155	1.075E-05	8.126E-06	6.144E-06	4.646E-06	2.310E-06	1.148E-06	0.00
Gd-155	8.217E-06	1.084E-05	1.282E-05	1.432E-05	1.665E-05	1.782E-05	1.896E-05
Gd-156	1.094E-04	1.094E-04	1.094E-04	1.094E-04	1.094E-04	1.094E-04	1.094E-04
Gd-157	1.095E-07	1.095E-07	1.095E-07	1.095E-07	1.095E-07	1.095E-07	1.095E-07
Gd-158	2.651E-05	2.651E-05	2.651E-05	2.651E-05	2.651E-05	2.651E-05	2.651E-05
Tb-159	3.646E-06	3.646E-06	3.646E-06	3.646E-06	3.646E-06	3.646E-06	3.646E-06
Gd-160	1.781E-06	1.781E-06	1.781E-06	1.781E-06	1.781E-06	1.781E-06	1.781E-06

TABLE D.3.e. Fission Product Inventory by Isotope at 40 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Tb-160	7.421E-14	6.747E-17	6.133E-20	5.576E-23	1.389E-30	0.00	0.00
Dy-160	4.718E-07	4.718E-07	4.718E-07	4.718E-07	4.718E-07	4.718E-07	4.718E-07
Dy-161	5.557E-07	5.557E-07	5.557E-07	5.557E-07	5.557E-07	5.557E-07	5.557E-07
Dy-162	5.143E-07	5.143E-07	5.143E-07	5.143E-07	5.143E-07	5.143E-07	5.143E-07
Dy-163	4.512E-07	4.512E-07	4.512E-07	4.512E-07	4.512E-07	4.512E-07	4.512E-07
Dy-164	6.469E-08	6.469E-08	6.469E-08	6.469E-08	6.469E-08	6.469E-08	6.469E-08
Ho-165	2.477E-07	2.477E-07	2.477E-07	2.477E-07	2.477E-07	2.477E-07	2.477E-07
Ho-166m	3.115E-09	3.111E-09	3.108E-09	3.104E-09	3.095E-09	3.086E-09	1.752E-09
Er-166	8.436E-08	8.436E-08	8.437E-08	8.437E-08	8.438E-08	8.439E-08	8.572E-08
Er-167	4.405E-09	4.405E-09	4.405E-09	4.405E-09	4.405E-09	4.405E-09	4.405E-09
Er-168	1.384E-08	1.384E-08	1.384E-08	1.384E-08	1.384E-08	1.384E-08	1.384E-08
Tm-169	1.102E-10	1.102E-10	1.102E-10	1.102E-10	1.102E-10	1.102E-10	1.102E-10
Er-170	6.710E-14	6.710E-14	6.710E-14	6.710E-14	6.710E-14	6.710E-14	6.710E-14
Tm-170	5.337E-15	1.040E-16	2.028E-18	3.951E-20	2.096E-24	1.112E-28	0.00
Yb-170	4.443E-11	4.444E-11	4.444E-11	4.444E-11	4.444E-11	4.444E-11	4.444E-11
Tm-171	3.430E-13	1.666E-13	8.093E-14	3.931E-14	6.466E-15	1.063E-15	0.00
Yb-171	3.153E-12	3.329E-12	3.415E-12	3.457E-12	3.490E-12	3.495E-12	3.496E-12
Yb-172	1.688E-13	1.688E-13	1.688E-13	1.688E-13	1.688E-13	1.688E-13	1.688E-13
Total	4.103E-02	4.103E-02	4.103E-02	4.103E-02	4.103E-02	4.103E-02	4.103E-02

TABLE D.3.f. Fission Product Inventory by Isotope at 45 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-3	6.038E-08	5.396E-08	4.823E-08	4.311E-08	3.256E-08	2.459E-08	3.171E-32
Li-6	1.647E-10	1.647E-10	1.647E-10	1.647E-10	1.647E-10	1.647E-10	1.647E-10
Li-7	1.371E-11	1.371E-11	1.371E-11	1.371E-11	1.371E-11	1.371E-11	1.371E-11
Be-9	2.635E-11	2.635E-11	2.635E-11	2.635E-11	2.635E-11	2.635E-11	2.635E-11
Be-10	1.761E-10	1.761E-10	1.761E-10	1.761E-10	1.761E-10	1.761E-10	1.760E-10
C-14	3.557E-11	3.556E-11	3.556E-11	3.555E-11	3.553E-11	3.550E-11	3.153E-11
Zn-66	4.355E-14	4.355E-14	4.355E-14	4.355E-14	4.355E-14	4.355E-14	4.355E-14
Zn-67	1.792E-15	1.792E-15	1.792E-15	1.792E-15	1.792E-15	1.792E-15	1.792E-15
Ga-71	1.268E-12	1.268E-12	1.268E-12	1.268E-12	1.268E-12	1.268E-12	1.268E-12
Ge-72	3.171E-08	3.171E-08	3.171E-08	3.171E-08	3.171E-08	3.171E-08	3.171E-08
Ge-73	6.187E-08	6.187E-08	6.187E-08	6.187E-08	6.187E-08	6.187E-08	6.187E-08
Ge-74	1.346E-07	1.346E-07	1.346E-07	1.346E-07	1.346E-07	1.346E-07	1.346E-07
As-75	2.684E-07	2.684E-07	2.684E-07	2.684E-07	2.684E-07	2.684E-07	2.684E-07
Ge-76	6.544E-07	6.544E-07	6.544E-07	6.544E-07	6.544E-07	6.544E-07	6.544E-07
Se-76	1.061E-08	1.061E-08	1.061E-08	1.061E-08	1.061E-08	1.061E-08	1.061E-08
Se-77	1.294E-06	1.294E-06	1.294E-06	1.294E-06	1.294E-06	1.294E-06	1.294E-06
Se-78	3.273E-06	3.273E-06	3.273E-06	3.273E-06	3.273E-06	3.273E-06	3.273E-06
Se-79	7.746E-06	7.746E-06	7.746E-06	7.746E-06	7.745E-06	7.745E-06	7.664E-06
Br-79	5.634E-10	7.287E-10	8.940E-10	1.059E-09	1.473E-09	1.886E-09	8.245E-08
Se-80	1.750E-05	1.750E-05	1.750E-05	1.750E-05	1.750E-05	1.750E-05	1.750E-05
Kr-80	3.525E-10	3.525E-10	3.525E-10	3.525E-10	3.525E-10	3.525E-10	3.525E-10
Br-81	2.756E-05	2.756E-05	2.756E-05	2.756E-05	2.756E-05	2.756E-05	2.756E-05
Kr-81	4.493E-11	4.493E-11	4.493E-11	4.493E-11	4.493E-11	4.493E-11	4.479E-11
Se-82	4.309E-05	4.309E-05	4.309E-05	4.309E-05	4.309E-05	4.309E-05	4.309E-05
Kr-82	1.794E-06	1.794E-06	1.794E-06	1.794E-06	1.794E-06	1.794E-06	1.794E-06
Kr-83	4.534E-05	4.534E-05	4.534E-05	4.534E-05	4.534E-05	4.534E-05	4.534E-05
Kr-84	1.499E-04	1.499E-04	1.499E-04	1.499E-04	1.499E-04	1.499E-04	1.499E-04
Kr-85	2.100E-05	1.846E-05	1.622E-05	1.425E-05	1.031E-05	7.465E-06	2.257E-33
Rb-85	1.303E-04	1.329E-04	1.351E-04	1.371E-04	1.410E-04	1.439E-04	1.513E-04
Kr-86	2.351E-04	2.351E-04	2.351E-04	2.351E-04	2.351E-04	2.351E-04	2.351E-04
Sr-86	7.777E-07	7.777E-07	7.777E-07	7.777E-07	7.777E-07	7.777E-07	7.777E-07
Rb-87	3.008E-04	3.008E-04	3.008E-04	3.008E-04	3.008E-04	3.008E-04	3.008E-04
Sr-87	7.476E-09	7.476E-09	7.476E-09	7.476E-09	7.476E-09	7.476E-09	7.481E-09
Sr-88	4.309E-04	4.309E-04	4.309E-04	4.309E-04	4.309E-04	4.309E-04	4.309E-04
Sr-89	2.885E-14	1.275E-18	5.634E-23	2.489E-27	0.00	0.00	0.00
Y-89	5.593E-04	5.593E-04	5.593E-04	5.593E-04	5.593E-04	5.593E-04	5.593E-04
Sr-90	5.746E-04	5.479E-04	5.224E-04	4.981E-04	4.422E-04	3.926E-04	2.908E-14
Y-90	1.441E-07	1.374E-07	1.310E-07	1.249E-07	1.109E-07	9.846E-08	7.293E-18
Zr-90	1.068E-04	1.335E-04	1.589E-04	1.832E-04	2.391E-04	2.888E-04	6.815E-04
Y-91	7.279E-13	1.269E-16	2.213E-20	3.858E-24	1.549E-33	0.00	0.00
Zr-91	7.328E-04	7.328E-04	7.328E-04	7.328E-04	7.328E-04	7.328E-04	7.328E-04
Zr-92	8.080E-04	8.080E-04	8.080E-04	8.080E-04	8.080E-04	8.080E-04	8.080E-04
Zr-93	9.144E-04	9.144E-04	9.144E-04	9.144E-04	9.144E-04	9.144E-04	9.140E-04
Nb-93	6.119E-10	9.148E-10	1.269E-09	1.668E-09	2.841E-09	4.216E-09	4.077E-07
Nb-93m	2.298E-09	2.823E-09	3.298E-09	3.727E-09	4.626E-09	5.322E-09	7.719E-09

TABLE D.3.f. Fission Product Inventory by Isotope at 45 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Zr-94	9.665E-04	9.665E-04	9.665E-04	9.665E-04	9.665E-04	9.665E-04	9.665E-04
Nb-94	1.177E-09	1.177E-09	1.176E-09	1.176E-09	1.176E-09	1.176E-09	1.137E-09
Zr-95	5.843E-12	2.136E-15	7.810E-19	2.856E-22	7.299E-31	0.00	0.00
Nb-95	7.126E-12	2.606E-15	9.526E-19	3.483E-22	6.602E-33	0.00	0.00
Nb-95m	2.445E-15	8.939E-19	3.268E-22	1.195E-25	0.00	0.00	0.00
Mo-95	9.612E-04	9.612E-04	9.612E-04	9.612E-04	9.612E-04	9.612E-04	9.612E-04
Zr-96	1.054E-03	1.054E-03	1.054E-03	1.054E-03	1.054E-03	1.054E-03	1.054E-03
Mo-96	7.539E-05	7.539E-05	7.539E-05	7.539E-05	7.539E-05	7.539E-05	7.539E-05
Mo-97	1.055E-03	1.055E-03	1.055E-03	1.055E-03	1.055E-03	1.055E-03	1.055E-03
Mo-98	1.117E-03	1.117E-03	1.117E-03	1.117E-03	1.117E-03	1.117E-03	1.117E-03
Tc-98	1.258E-08	1.258E-08	1.258E-08	1.258E-08	1.258E-08	1.258E-08	1.258E-08
Tc-99	9.860E-04	9.860E-04	9.860E-04	9.860E-04	9.860E-04	9.860E-04	9.828E-04
Ru-99	2.169E-08	2.811E-08	3.453E-08	4.094E-08	5.699E-08	7.303E-08	3.212E-06
Mo-100	1.265E-03	1.265E-03	1.265E-03	1.265E-03	1.265E-03	1.265E-03	1.265E-03
Ru-100	1.894E-04	1.894E-04	1.894E-04	1.894E-04	1.894E-04	1.894E-04	1.894E-04
Ru-101	1.046E-03	1.046E-03	1.046E-03	1.046E-03	1.046E-03	1.046E-03	1.046E-03
Ru-102	1.104E-03	1.104E-03	1.104E-03	1.104E-03	1.104E-03	1.104E-03	1.104E-03
Rh-102	6.605E-10	4.095E-10	2.539E-10	1.574E-10	4.765E-11	1.442E-11	0.00
Ru-103	2.197E-16	5.545E-22	1.399E-27	3.531E-33	0.00	0.00	0.00
Rh-103	5.529E-04	5.529E-04	5.529E-04	5.529E-04	5.529E-04	5.529E-04	5.529E-04
Ru-104	8.254E-04	8.254E-04	8.254E-04	8.254E-04	8.254E-04	8.254E-04	8.254E-04
Pd-104	4.496E-04	4.496E-04	4.496E-04	4.496E-04	4.496E-04	4.496E-04	4.496E-04
Pd-105	5.929E-04	5.929E-04	5.929E-04	5.929E-04	5.929E-04	5.929E-04	5.929E-04
Ru-106	1.085E-05	2.741E-06	6.929E-07	1.751E-07	5.626E-09	1.807E-10	0.00
Rh-106	1.019E-11	2.577E-12	6.513E-13	1.646E-13	5.288E-15	1.699E-16	0.00
Pd-106	5.885E-04	5.966E-04	5.986E-04	5.991E-04	5.993E-04	5.993E-04	5.993E-04
Pd-107	3.673E-04	3.673E-04	3.673E-04	3.673E-04	3.673E-04	3.673E-04	3.673E-04
Ag-107	2.364E-10	3.147E-10	3.931E-10	4.715E-10	6.675E-10	8.635E-10	3.927E-08
Pd-108	2.553E-04	2.553E-04	2.553E-04	2.553E-04	2.553E-04	2.553E-04	2.553E-04
Ag-108m	2.084E-12	2.061E-12	2.039E-12	2.017E-12	1.963E-12	1.910E-12	9.082E-15
Cd-108	9.621E-10	9.621E-10	9.621E-10	9.621E-10	9.621E-10	9.621E-10	9.623E-10
Ag-109	1.173E-04	1.173E-04	1.173E-04	1.173E-04	1.173E-04	1.173E-04	1.173E-04
Cd-109	1.455E-13	4.887E-14	1.641E-14	5.511E-15	3.601E-16	2.353E-17	0.00
Pd-110	8.415E-05	8.415E-05	8.415E-05	8.415E-05	8.415E-05	8.415E-05	8.415E-05
Ag-110	3.610E-16	4.758E-17	6.272E-18	8.268E-19	5.216E-21	3.292E-23	0.00
Ag-110m	2.382E-08	3.140E-09	4.139E-10	5.456E-11	3.442E-13	2.172E-15	0.00
Cd-110	8.082E-05	8.085E-05	8.085E-05	8.085E-05	8.085E-05	8.085E-05	8.085E-05
Cd-111	4.620E-05	4.620E-05	4.620E-05	4.620E-05	4.620E-05	4.620E-05	4.620E-05
Cd-112	2.727E-05	2.727E-05	2.727E-05	2.727E-05	2.727E-05	2.727E-05	2.727E-05
Cd-113	1.591E-07	1.591E-07	1.592E-07	1.592E-07	1.592E-07	1.593E-07	1.595E-07
Cd-113m	3.597E-07	3.271E-07	2.974E-07	2.705E-07	2.133E-07	1.682E-07	1.011E-27
In-113	1.146E-07	1.472E-07	1.768E-07	2.038E-07	2.609E-07	3.059E-07	4.740E-07
Cd-114	3.453E-05	3.453E-05	3.453E-05	3.453E-05	3.453E-05	3.453E-05	3.453E-05
Sn-114	5.613E-09	5.613E-09	5.613E-09	5.613E-09	5.613E-09	5.613E-09	5.613E-09
In-115	2.456E-06	2.456E-06	2.456E-06	2.456E-06	2.456E-06	2.456E-06	2.456E-06

TABLE D.3.f. Fission Product Inventory by Isotope at 45 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Sn-115	4.676E-07	4.676E-07	4.676E-07	4.676E-07	4.676E-07	4.676E-07	4.676E-07
Cd-116	1.207E-05	1.207E-05	1.207E-05	1.207E-05	1.207E-05	1.207E-05	1.207E-05
Sn-116	1.209E-05	1.209E-05	1.209E-05	1.209E-05	1.209E-05	1.209E-05	1.209E-05
Sn-117	1.216E-05	1.216E-05	1.216E-05	1.216E-05	1.216E-05	1.216E-05	1.216E-05
Sn-118	1.228E-05	1.228E-05	1.228E-05	1.228E-05	1.228E-05	1.228E-05	1.228E-05
Sn-119	1.224E-05	1.224E-05	1.224E-05	1.224E-05	1.224E-05	1.224E-05	1.224E-05
Sn-119m	7.639E-10	9.673E-11	1.225E-11	1.551E-12	8.847E-15	5.047E-17	0.00
Sn-120	1.246E-05	1.246E-05	1.246E-05	1.246E-05	1.246E-05	1.246E-05	1.246E-05
Sn-121m	4.953E-09	4.818E-09	4.686E-09	4.558E-09	4.252E-09	3.967E-09	4.954E-15
Sb-121	1.172E-05	1.172E-05	1.172E-05	1.172E-05	1.172E-05	1.172E-05	1.172E-05
Sn-122	1.365E-05	1.365E-05	1.365E-05	1.365E-05	1.365E-05	1.365E-05	1.365E-05
Te-122	1.164E-06	1.164E-06	1.164E-06	1.164E-06	1.164E-06	1.164E-06	1.164E-06
Sn-123	1.278E-10	2.536E-12	5.032E-14	9.982E-16	5.534E-20	3.068E-24	0.00
Sb-123	1.455E-05	1.455E-05	1.455E-05	1.455E-05	1.455E-05	1.455E-05	1.455E-05
Te-123	1.871E-08	1.872E-08	1.872E-08	1.872E-08	1.872E-08	1.872E-08	1.872E-08
Te-123m	6.724E-13	9.777E-15	1.421E-16	2.066E-18	5.266E-23	1.342E-27	0.00
Sn-124	1.829E-05	1.829E-05	1.829E-05	1.829E-05	1.829E-05	1.829E-05	1.829E-05
Sb-124	4.465E-15	9.925E-19	2.206E-22	4.905E-26	3.614E-35	0.00	0.00
Te-124	9.271E-07	9.271E-07	9.271E-07	9.271E-07	9.271E-07	9.271E-07	9.271E-07
Sb-125	5.902E-06	3.578E-06	2.169E-06	1.315E-06	3.763E-07	1.077E-07	0.00
Te-125	2.198E-05	2.433E-05	2.576E-05	2.663E-05	2.758E-05	2.785E-05	2.796E-05
Te-125m	8.256E-08	5.006E-08	3.035E-08	1.840E-08	5.264E-09	1.506E-09	0.00
Sn-126	4.035E-05	4.035E-05	4.035E-05	4.035E-05	4.035E-05	4.035E-05	4.008E-05
Sb-126	1.917E-12	1.917E-12	1.917E-12	1.917E-12	1.917E-12	1.917E-12	1.904E-12
Sb-126m	1.458E-14	1.458E-14	1.458E-14	1.458E-14	1.458E-14	1.457E-14	1.448E-14
Te-126	1.255E-06	1.255E-06	1.256E-06	1.257E-06	1.258E-06	1.259E-06	1.532E-06
Te-127	3.774E-13	3.626E-15	3.484E-17	3.348E-19	3.029E-24	2.741E-29	0.00
Te-127m	1.078E-10	1.036E-12	9.953E-15	9.563E-17	8.653E-22	7.830E-27	0.00
I-127	8.012E-05	8.012E-05	8.012E-05	8.012E-05	8.012E-05	8.012E-05	8.012E-05
Te-128	1.584E-04	1.584E-04	1.584E-04	1.584E-04	1.584E-04	1.584E-04	1.584E-04
Xe-128	6.624E-06	6.624E-06	6.624E-06	6.624E-06	6.624E-06	6.624E-06	6.624E-06
I-129	2.487E-04	2.487E-04	2.487E-04	2.487E-04	2.487E-04	2.487E-04	2.487E-04
Xe-129	5.328E-08	5.330E-08	5.332E-08	5.335E-08	5.340E-08	5.346E-08	6.422E-08
Te-130	4.993E-04	4.993E-04	4.993E-04	4.993E-04	4.993E-04	4.993E-04	4.993E-04
Xe-130	2.574E-05	2.574E-05	2.574E-05	2.574E-05	2.574E-05	2.574E-05	2.574E-05
Xe-131	5.013E-04	5.013E-04	5.013E-04	5.013E-04	5.013E-04	5.013E-04	5.013E-04
Xe-132	1.584E-03	1.584E-03	1.584E-03	1.584E-03	1.584E-03	1.584E-03	1.584E-03
Ba-132	3.702E-09	3.702E-09	3.702E-09	3.702E-09	3.702E-09	3.702E-09	3.702E-09
Cs-133	1.418E-03	1.418E-03	1.418E-03	1.418E-03	1.418E-03	1.418E-03	1.418E-03
Xe-134	1.984E-03	1.984E-03	1.984E-03	1.984E-03	1.984E-03	1.984E-03	1.984E-03
Cs-134	4.518E-05	2.307E-05	1.178E-05	6.012E-06	1.119E-06	2.085E-07	0.00
Ba-134	2.515E-04	2.736E-04	2.849E-04	2.906E-04	2.955E-04	2.964E-04	2.966E-04
Cs-135	4.842E-04	4.842E-04	4.842E-04	4.842E-04	4.842E-04	4.842E-04	4.840E-04
Ba-135	1.232E-06	1.233E-06	1.233E-06	1.233E-06	1.234E-06	1.235E-06	1.378E-06
Xe-136	3.144E-03	3.144E-03	3.144E-03	3.144E-03	3.144E-03	3.144E-03	3.144E-03

TABLE D.3.f. Fission Product Inventory by Isotope at 45 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Ba-136	3.401E-05	3.401E-05	3.401E-05	3.401E-05	3.401E-05	3.401E-05	3.401E-05
Cs-137	1.437E-03	1.373E-03	1.311E-03	1.251E-03	1.115E-03	9.932E-04	1.456E-13
Ba-137	2.408E-04	3.057E-04	3.677E-04	4.268E-04	5.634E-04	6.850E-04	1.678E-03
Ba-137m	2.199E-10	2.100E-10	2.005E-10	1.914E-10	1.706E-10	1.520E-10	2.227E-20
Ba-138	1.702E-03	1.702E-03	1.702E-03	1.702E-03	1.702E-03	1.702E-03	1.702E-03
La-138	5.590E-09	5.590E-09	5.590E-09	5.590E-09	5.590E-09	5.590E-09	5.590E-09
La-139	1.617E-03	1.617E-03	1.617E-03	1.617E-03	1.617E-03	1.617E-03	1.617E-03
Ce-140	1.668E-03	1.668E-03	1.668E-03	1.668E-03	1.668E-03	1.668E-03	1.668E-03
Pr-141	1.472E-03	1.472E-03	1.472E-03	1.472E-03	1.472E-03	1.472E-03	1.472E-03
Ce-142	1.494E-03	1.494E-03	1.494E-03	1.494E-03	1.494E-03	1.494E-03	1.494E-03
Nd-142	5.404E-05	5.404E-05	5.404E-05	5.404E-05	5.404E-05	5.404E-05	5.404E-05
Nd-143	8.562E-04	8.562E-04	8.562E-04	8.562E-04	8.562E-04	8.562E-04	8.562E-04
Ce-144	6.835E-06	1.151E-06	1.939E-07	3.266E-08	3.802E-10	4.426E-12	0.00
Pr-144	2.886E-10	4.861E-11	8.187E-12	1.379E-12	1.605E-14	1.869E-16	0.00
Pr-144m	1.443E-12	2.430E-13	4.093E-14	6.893E-15	8.025E-17	9.342E-19	0.00
Nd-144	1.885E-03	1.891E-03	1.892E-03	1.892E-03	1.892E-03	1.892E-03	1.892E-03
Nd-145	8.414E-04	8.414E-04	8.414E-04	8.414E-04	8.414E-04	8.414E-04	8.414E-04
Nd-146	9.678E-04	9.678E-04	9.679E-04	9.679E-04	9.679E-04	9.679E-04	9.679E-04
Pm-146	5.589E-09	4.343E-09	3.376E-09	2.624E-09	1.397E-09	7.440E-10	0.00
Sm-146	1.595E-08	1.641E-08	1.677E-08	1.704E-08	1.750E-08	1.774E-08	1.801E-08
Pm-147	4.141E-05	2.441E-05	1.439E-05	8.485E-06	2.264E-06	6.042E-07	0.00
Sm-147	1.797E-04	1.967E-04	2.067E-04	2.126E-04	2.188E-04	2.205E-04	2.211E-04
Nd-148	4.997E-04	4.997E-04	4.997E-04	4.997E-04	4.997E-04	4.997E-04	4.997E-04
Sm-148	2.784E-04	2.784E-04	2.784E-04	2.784E-04	2.784E-04	2.784E-04	2.784E-04
Sm-149	2.139E-06	2.139E-06	2.139E-06	2.139E-06	2.139E-06	2.139E-06	2.139E-06
Nd-150	2.510E-04	2.510E-04	2.510E-04	2.510E-04	2.510E-04	2.510E-04	2.510E-04
Sm-150	3.172E-04	3.172E-04	3.172E-04	3.172E-04	3.172E-04	3.172E-04	3.172E-04
Eu-150	3.976E-13	3.826E-13	3.682E-13	3.542E-13	3.217E-13	2.922E-13	1.866E-21
Sm-151	1.315E-05	1.295E-05	1.275E-05	1.255E-05	1.208E-05	1.162E-05	6.127E-09
Eu-151	4.233E-07	6.242E-07	8.221E-07	1.017E-06	1.491E-06	1.948E-06	1.357E-05
Sm-152	1.537E-04	1.537E-04	1.537E-04	1.537E-04	1.537E-04	1.537E-04	1.537E-04
Eu-152	3.876E-08	3.500E-08	3.161E-08	2.855E-08	2.213E-08	1.715E-08	3.493E-30
Gd-152	1.928E-08	2.032E-08	2.127E-08	2.212E-08	2.391E-08	2.530E-08	3.008E-08
Eu-153	1.515E-04	1.515E-04	1.515E-04	1.515E-04	1.515E-04	1.515E-04	1.515E-04
Gd-153	2.992E-10	3.693E-11	4.557E-12	5.624E-13	3.008E-15	1.610E-17	0.00
Sm-154	5.742E-05	5.742E-05	5.742E-05	5.742E-05	5.742E-05	5.742E-05	5.742E-05
Eu-154	4.646E-05	3.954E-05	3.366E-05	2.865E-05	1.914E-05	1.279E-05	0.00
Gd-154	2.686E-05	3.378E-05	3.966E-05	4.467E-05	5.417E-05	6.052E-05	7.332E-05
Eu-155	1.302E-05	9.842E-06	7.442E-06	5.627E-06	2.798E-06	1.391E-06	0.00
Gd-155	9.941E-06	1.312E-05	1.552E-05	1.733E-05	2.016E-05	2.157E-05	2.296E-05
Gd-156	1.494E-04	1.494E-04	1.494E-04	1.494E-04	1.494E-04	1.494E-04	1.494E-04
Gd-157	1.351E-07	1.351E-07	1.351E-07	1.351E-07	1.351E-07	1.351E-07	1.351E-07
Gd-158	3.450E-05	3.450E-05	3.450E-05	3.450E-05	3.450E-05	3.450E-05	3.450E-05
Tb-159	4.433E-06	4.433E-06	4.433E-06	4.433E-06	4.433E-06	4.433E-06	4.433E-06
Gd-160	2.152E-06	2.152E-06	2.152E-06	2.152E-06	2.152E-06	2.152E-06	2.152E-06

TABLE D.3.f. Fission Product Inventory by Isotope at 45 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Tb-160	1.034E-13	9.401E-17	8.546E-20	7.769E-23	1.936E-30	0.00	0.00
Dy-160	6.252E-07	6.252E-07	6.252E-07	6.252E-07	6.252E-07	6.252E-07	6.252E-07
Dy-161	6.660E-07	6.660E-07	6.660E-07	6.660E-07	6.660E-07	6.660E-07	6.660E-07
Dy-162	6.196E-07	6.196E-07	6.196E-07	6.196E-07	6.196E-07	6.196E-07	6.196E-07
Dy-163	5.748E-07	5.748E-07	5.748E-07	5.748E-07	5.748E-07	5.748E-07	5.748E-07
Dy-164	8.167E-08	8.167E-08	8.167E-08	8.167E-08	8.167E-08	8.167E-08	8.167E-08
Ho-165	3.384E-07	3.384E-07	3.384E-07	3.384E-07	3.384E-07	3.384E-07	3.384E-07
Ho-166m	4.828E-09	4.823E-09	4.817E-09	4.812E-09	4.798E-09	4.784E-09	2.716E-09
Er-166	1.219E-07	1.219E-07	1.219E-07	1.219E-07	1.219E-07	1.219E-07	1.240E-07
Er-167	5.696E-09	5.696E-09	5.696E-09	5.696E-09	5.696E-09	5.696E-09	5.696E-09
Er-168	1.907E-08	1.907E-08	1.907E-08	1.907E-08	1.907E-08	1.907E-08	1.907E-08
Tm-169	1.628E-10	1.628E-10	1.628E-10	1.628E-10	1.628E-10	1.628E-10	1.628E-10
Er-170	1.125E-13	1.125E-13	1.125E-13	1.125E-13	1.125E-13	1.125E-13	1.125E-13
Tm-170	9.062E-15	1.766E-16	3.443E-18	6.712E-20	3.561E-24	1.889E-28	0.00
Yb-170	7.416E-11	7.417E-11	7.417E-11	7.417E-11	7.417E-11	7.417E-11	7.417E-11
Tm-171	6.703E-13	3.256E-13	1.582E-13	7.683E-14	1.264E-14	2.078E-15	0.00
Yb-171	6.051E-12	6.395E-12	6.563E-12	6.644E-12	6.708E-12	6.719E-12	6.721E-12
Yb-172	3.734E-13	3.734E-13	3.734E-13	3.734E-13	3.734E-13	3.734E-13	3.734E-13
Total	4.612E-02	4.612E-02	4.612E-02	4.612E-02	4.612E-02	4.612E-02	4.612E-02

TABLE D.3.g. Fission Product Inventory by Isotope at 50 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-3	6.797E-08	6.075E-08	5.430E-08	4.853E-08	3.666E-08	2.769E-08	3.571E-32
Li-6	1.602E-10	1.602E-10	1.602E-10	1.602E-10	1.602E-10	1.602E-10	1.602E-10
Li-7	1.520E-11	1.520E-11	1.520E-11	1.520E-11	1.520E-11	1.520E-11	1.520E-11
Be-9	2.923E-11	2.923E-11	2.923E-11	2.923E-11	2.923E-11	2.923E-11	2.923E-11
Be-10	1.953E-10	1.953E-10	1.953E-10	1.953E-10	1.953E-10	1.953E-10	1.952E-10
C-14	3.946E-11	3.945E-11	3.944E-11	3.943E-11	3.941E-11	3.939E-11	3.498E-11
Zn-66	4.640E-14	4.640E-14	4.640E-14	4.640E-14	4.640E-14	4.640E-14	4.640E-14
Zn-67	1.898E-15	1.898E-15	1.898E-15	1.898E-15	1.898E-15	1.898E-15	1.898E-15
Zn-68	5.351E-17	5.351E-17	5.351E-17	5.351E-17	5.351E-17	5.351E-17	5.351E-17
Ga-71	1.424E-12	1.424E-12	1.424E-12	1.424E-12	1.424E-12	1.424E-12	1.424E-12
Ge-72	3.596E-08	3.596E-08	3.596E-08	3.596E-08	3.596E-08	3.596E-08	3.596E-08
Ge-73	6.883E-08	6.883E-08	6.883E-08	6.883E-08	6.883E-08	6.883E-08	6.883E-08
Ge-74	1.504E-07	1.504E-07	1.504E-07	1.504E-07	1.504E-07	1.504E-07	1.504E-07
As-75	2.958E-07	2.958E-07	2.958E-07	2.958E-07	2.958E-07	2.958E-07	2.958E-07
Ge-76	7.184E-07	7.184E-07	7.184E-07	7.184E-07	7.184E-07	7.184E-07	7.184E-07
Se-76	1.318E-08	1.318E-08	1.318E-08	1.318E-08	1.318E-08	1.318E-08	1.318E-08
Se-77	1.401E-06	1.401E-06	1.401E-06	1.401E-06	1.401E-06	1.401E-06	1.401E-06
Se-78	3.628E-06	3.628E-06	3.628E-06	3.628E-06	3.628E-06	3.628E-06	3.628E-06
Se-79	8.512E-06	8.512E-06	8.511E-06	8.511E-06	8.511E-06	8.510E-06	8.422E-06
Br-79	6.179E-10	7.996E-10	9.812E-10	1.163E-09	1.617E-09	2.071E-09	9.060E-08
Se-80	1.919E-05	1.919E-05	1.919E-05	1.919E-05	1.919E-05	1.919E-05	1.919E-05
Kr-80	4.028E-10	4.028E-10	4.028E-10	4.028E-10	4.028E-10	4.028E-10	4.028E-10
Br-81	2.987E-05	2.987E-05	2.987E-05	2.987E-05	2.987E-05	2.987E-05	2.987E-05
Kr-81	5.633E-11	5.632E-11	5.632E-11	5.632E-11	5.632E-11	5.632E-11	5.614E-11
Se-82	4.694E-05	4.694E-05	4.694E-05	4.694E-05	4.694E-05	4.694E-05	4.694E-05
Kr-82	2.181E-06	2.181E-06	2.181E-06	2.181E-06	2.181E-06	2.181E-06	2.181E-06
Kr-83	4.654E-05	4.654E-05	4.654E-05	4.654E-05	4.654E-05	4.654E-05	4.654E-05
Kr-84	1.653E-04	1.653E-04	1.653E-04	1.653E-04	1.653E-04	1.653E-04	1.653E-04
Kr-85	2.271E-05	1.996E-05	1.754E-05	1.541E-05	1.115E-05	8.072E-06	2.446E-33
Rb-85	1.407E-04	1.435E-04	1.459E-04	1.480E-04	1.523E-04	1.554E-04	1.634E-04
Kr-86	2.535E-04	2.535E-04	2.535E-04	2.535E-04	2.535E-04	2.535E-04	2.535E-04
Sr-86	9.626E-07	9.626E-07	9.626E-07	9.626E-07	9.626E-07	9.626E-07	9.626E-07
Rb-87	3.238E-04	3.238E-04	3.238E-04	3.238E-04	3.238E-04	3.238E-04	3.238E-04
Sr-87	9.981E-09	9.981E-09	9.981E-09	9.981E-09	9.981E-09	9.981E-09	9.986E-09
Sr-88	4.636E-04	4.636E-04	4.636E-04	4.636E-04	4.636E-04	4.636E-04	4.636E-04
Sr-89	3.014E-14	1.332E-18	5.885E-23	2.600E-27	0.00	0.00	0.00
Y-89	6.006E-04	6.006E-04	6.006E-04	6.006E-04	6.006E-04	6.006E-04	6.006E-04
Sr-90	6.171E-04	5.884E-04	5.611E-04	5.350E-04	4.750E-04	4.217E-04	3.123E-14
Y-90	1.548E-07	1.476E-07	1.407E-07	1.342E-07	1.191E-07	1.057E-07	7.833E-18
Zr-90	1.154E-04	1.441E-04	1.714E-04	1.975E-04	2.576E-04	3.109E-04	7.327E-04
Y-91	7.693E-13	1.341E-16	2.338E-20	4.077E-24	1.637E-33	0.00	0.00
Zr-91	7.905E-04	7.905E-04	7.905E-04	7.905E-04	7.905E-04	7.905E-04	7.905E-04
Zr-92	8.767E-04	8.767E-04	8.767E-04	8.767E-04	8.767E-04	8.767E-04	8.767E-04
Zr-93	9.938E-04	9.938E-04	9.938E-04	9.938E-04	9.938E-04	9.938E-04	9.934E-04
Nb-93	6.691E-10	9.989E-10	1.384E-09	1.819E-09	3.095E-09	4.590E-09	4.431E-07

TABLE D.3.g. Fission Product Inventory by Isotope at 50 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Nb-93m	2.503E-09	3.074E-09	3.590E-09	4.055E-09	5.031E-09	5.787E-09	8.389E-09
Zr-94	1.060E-03	1.060E-03	1.060E-03	1.060E-03	1.060E-03	1.060E-03	1.060E-03
Nb-94	1.347E-09	1.346E-09	1.346E-09	1.346E-09	1.346E-09	1.346E-09	1.302E-09
Zr-95	6.374E-12	2.331E-15	8.521E-19	3.115E-22	7.963E-31	0.00	0.00
Nb-95	7.775E-12	2.843E-15	1.039E-18	3.800E-22	7.203E-33	0.00	0.00
Nb-95m	2.667E-15	9.752E-19	3.565E-22	1.304E-25	0.00	0.00	0.00
Mo-95	1.044E-03	1.044E-03	1.044E-03	1.044E-03	1.044E-03	1.044E-03	1.044E-03
Zr-96	1.159E-03	1.159E-03	1.159E-03	1.159E-03	1.159E-03	1.159E-03	1.159E-03
Mo-96	9.429E-05	9.429E-05	9.429E-05	9.429E-05	9.429E-05	9.429E-05	9.429E-05
Mo-97	1.165E-03	1.165E-03	1.165E-03	1.165E-03	1.165E-03	1.165E-03	1.165E-03
Mo-98	1.239E-03	1.239E-03	1.239E-03	1.239E-03	1.239E-03	1.239E-03	1.239E-03
Tc-98	1.575E-08	1.575E-08	1.575E-08	1.575E-08	1.575E-08	1.575E-08	1.575E-08
Tc-99	1.069E-03	1.069E-03	1.069E-03	1.069E-03	1.069E-03	1.069E-03	1.065E-03
Ru-99	2.352E-08	3.048E-08	3.744E-08	4.439E-08	6.178E-08	7.917E-08	3.482E-06
Mo-100	1.404E-03	1.404E-03	1.404E-03	1.404E-03	1.404E-03	1.404E-03	1.404E-03
Ru-100	2.368E-04	2.368E-04	2.368E-04	2.368E-04	2.368E-04	2.368E-04	2.368E-04
Ru-101	1.158E-03	1.158E-03	1.158E-03	1.158E-03	1.158E-03	1.158E-03	1.158E-03
Ru-102	1.247E-03	1.247E-03	1.247E-03	1.247E-03	1.247E-03	1.247E-03	1.247E-03
Rh-102	8.107E-10	5.026E-10	3.116E-10	1.932E-10	5.848E-11	1.770E-11	0.00
Ru-103	2.497E-16	6.301E-22	1.590E-27	4.013E-33	0.00	0.00	0.00
Rh-103	5.832E-04	5.832E-04	5.832E-04	5.832E-04	5.832E-04	5.832E-04	5.832E-04
Ru-104	9.472E-04	9.472E-04	9.472E-04	9.472E-04	9.472E-04	9.472E-04	9.472E-04
Pd-104	5.529E-04	5.529E-04	5.529E-04	5.529E-04	5.529E-04	5.529E-04	5.529E-04
Pd-105	6.757E-04	6.757E-04	6.757E-04	6.757E-04	6.757E-04	6.757E-04	6.757E-04
Ru-106	1.271E-05	3.212E-06	8.120E-07	2.052E-07	6.592E-09	2.118E-10	0.00
Rh-106	1.195E-11	3.019E-12	7.632E-13	1.929E-13	6.197E-15	1.990E-16	0.00
Pd-106	7.015E-04	7.110E-04	7.134E-04	7.140E-04	7.142E-04	7.142E-04	7.142E-04
Pd-107	4.314E-04	4.314E-04	4.314E-04	4.314E-04	4.314E-04	4.314E-04	4.314E-04
Ag-107	2.768E-10	3.689E-10	4.609E-10	5.530E-10	7.832E-10	1.013E-09	4.613E-08
Pd-108	3.005E-04	3.005E-04	3.005E-04	3.005E-04	3.005E-04	3.005E-04	3.005E-04
Ag-108m	2.502E-12	2.475E-12	2.448E-12	2.422E-12	2.356E-12	2.293E-12	1.090E-14
Cd-108	1.265E-09	1.265E-09	1.265E-09	1.265E-09	1.265E-09	1.265E-09	1.266E-09
Ag-109	1.329E-04	1.329E-04	1.329E-04	1.329E-04	1.329E-04	1.329E-04	1.329E-04
Cd-109	2.117E-13	7.107E-14	2.387E-14	8.014E-15	5.237E-16	3.422E-17	0.00
Pd-110	9.947E-05	9.947E-05	9.947E-05	9.947E-05	9.947E-05	9.947E-05	9.947E-05
Ag-110	4.674E-16	6.161E-17	8.121E-18	1.071E-18	6.756E-21	4.262E-23	0.00
Ag-110m	3.084E-08	4.065E-09	5.359E-10	7.064E-11	4.458E-13	2.812E-15	0.00
Cd-110	1.059E-04	1.059E-04	1.059E-04	1.059E-04	1.059E-04	1.059E-04	1.059E-04
Cd-111	5.475E-05	5.475E-05	5.475E-05	5.475E-05	5.475E-05	5.475E-05	5.475E-05
Cd-112	3.218E-05	3.218E-05	3.218E-05	3.218E-05	3.218E-05	3.218E-05	3.218E-05
Cd-113	1.618E-07	1.618E-07	1.618E-07	1.619E-07	1.619E-07	1.620E-07	1.622E-07
Cd-113m	4.363E-07	3.967E-07	3.608E-07	3.281E-07	2.587E-07	2.040E-07	1.226E-27
In-113	1.373E-07	1.768E-07	2.127E-07	2.454E-07	3.147E-07	3.693E-07	5.731E-07
Cd-114	3.983E-05	3.983E-05	3.983E-05	3.983E-05	3.983E-05	3.983E-05	3.983E-05
Sn-114	7.461E-09	7.461E-09	7.461E-09	7.461E-09	7.461E-09	7.461E-09	7.461E-09

TABLE D.3.g. Fission Product Inventory by Isotope at 50 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
In-115	2.492E-06	2.492E-06	2.492E-06	2.492E-06	2.492E-06	2.492E-06	2.492E-06
Sn-115	5.304E-07	5.304E-07	5.304E-07	5.304E-07	5.304E-07	5.304E-07	5.304E-07
Cd-116	1.371E-05	1.371E-05	1.371E-05	1.371E-05	1.371E-05	1.371E-05	1.371E-05
Sn-116	1.417E-05	1.417E-05	1.417E-05	1.417E-05	1.417E-05	1.417E-05	1.417E-05
Sn-117	1.381E-05	1.381E-05	1.381E-05	1.381E-05	1.381E-05	1.381E-05	1.381E-05
Sn-118	1.394E-05	1.394E-05	1.394E-05	1.394E-05	1.394E-05	1.394E-05	1.394E-05
Sn-119	1.390E-05	1.390E-05	1.390E-05	1.390E-05	1.390E-05	1.390E-05	1.390E-05
Sn-119m	9.044E-10	1.145E-10	1.450E-11	1.836E-12	1.048E-14	5.978E-17	0.00
Sn-120	1.414E-05	1.414E-05	1.414E-05	1.414E-05	1.414E-05	1.414E-05	1.414E-05
Sn-121m	5.663E-09	5.508E-09	5.357E-09	5.211E-09	4.861E-09	4.536E-09	5.665E-15
Sb-121	1.310E-05	1.310E-05	1.310E-05	1.310E-05	1.310E-05	1.310E-05	1.310E-05
Sn-122	1.546E-05	1.546E-05	1.546E-05	1.546E-05	1.546E-05	1.546E-05	1.546E-05
Te-122	1.484E-06	1.484E-06	1.484E-06	1.484E-06	1.484E-06	1.484E-06	1.484E-06
Sn-123	1.449E-10	2.874E-12	5.702E-14	1.131E-15	6.271E-20	3.477E-24	0.00
Sb-123	1.634E-05	1.634E-05	1.634E-05	1.634E-05	1.634E-05	1.634E-05	1.634E-05
Te-123	2.521E-08	2.521E-08	2.521E-08	2.521E-08	2.521E-08	2.521E-08	2.521E-08
Te-123m	9.865E-13	1.434E-14	2.085E-16	3.031E-18	7.726E-23	1.969E-27	0.00
Sn-124	2.065E-05	2.065E-05	2.065E-05	2.065E-05	2.065E-05	2.065E-05	2.065E-05
Sb-124	5.746E-15	1.277E-18	2.840E-22	6.312E-26	4.651E-35	0.00	0.00
Te-124	1.195E-06	1.195E-06	1.195E-06	1.195E-06	1.195E-06	1.195E-06	1.195E-06
Sb-125	6.711E-06	4.068E-06	2.466E-06	1.495E-06	4.279E-07	1.224E-07	0.00
Te-125	2.494E-05	2.762E-05	2.924E-05	3.023E-05	3.131E-05	3.162E-05	3.174E-05
Te-125m	9.387E-08	5.692E-08	3.451E-08	2.092E-08	5.985E-09	1.712E-09	0.00
Sn-126	4.574E-05	4.574E-05	4.574E-05	4.574E-05	4.574E-05	4.573E-05	4.542E-05
Sb-126	2.173E-12	2.173E-12	2.173E-12	2.173E-12	2.173E-12	2.173E-12	2.158E-12
Sb-126m	1.652E-14	1.652E-14	1.652E-14	1.652E-14	1.652E-14	1.652E-14	1.641E-14
Te-126	1.489E-06	1.489E-06	1.490E-06	1.491E-06	1.492E-06	1.494E-06	1.803E-06
Te-127	4.289E-13	4.121E-15	3.960E-17	3.804E-19	3.442E-24	3.115E-29	0.00
Te-127m	1.225E-10	1.177E-12	1.131E-14	1.087E-16	9.833E-22	8.898E-27	0.00
I-127	9.008E-05	9.008E-05	9.008E-05	9.008E-05	9.008E-05	9.008E-05	9.008E-05
Te-128	1.784E-04	1.784E-04	1.784E-04	1.784E-04	1.784E-04	1.784E-04	1.784E-04
Xe-128	8.541E-06	8.541E-06	8.541E-06	8.541E-06	8.541E-06	8.541E-06	8.541E-06
I-129	2.765E-04	2.765E-04	2.765E-04	2.765E-04	2.765E-04	2.765E-04	2.765E-04
Xe-129	7.771E-08	7.773E-08	7.776E-08	7.778E-08	7.784E-08	7.790E-08	8.987E-08
Te-130	5.600E-04	5.600E-04	5.600E-04	5.600E-04	5.600E-04	5.600E-04	5.600E-04
Xe-130	3.279E-05	3.279E-05	3.279E-05	3.279E-05	3.279E-05	3.279E-05	3.279E-05
Xe-131	5.234E-04	5.234E-04	5.234E-04	5.234E-04	5.234E-04	5.234E-04	5.234E-04
Xe-132	1.806E-03	1.806E-03	1.806E-03	1.806E-03	1.806E-03	1.806E-03	1.806E-03
Ba-132	4.617E-09	4.617E-09	4.617E-09	4.617E-09	4.617E-09	4.617E-09	4.617E-09
Cs-133	1.527E-03	1.527E-03	1.527E-03	1.527E-03	1.527E-03	1.527E-03	1.527E-03
Xe-134	2.201E-03	2.201E-03	2.201E-03	2.201E-03	2.201E-03	2.201E-03	2.201E-03
Cs-134	5.464E-05	2.789E-05	1.424E-05	7.270E-06	1.354E-06	2.521E-07	0.00
Ba-134	3.055E-04	3.322E-04	3.459E-04	3.529E-04	3.588E-04	3.599E-04	3.601E-04
Cs-135	5.095E-04	5.095E-04	5.095E-04	5.095E-04	5.095E-04	5.095E-04	5.094E-04
Ba-135	1.726E-06	1.726E-06	1.726E-06	1.726E-06	1.727E-06	1.728E-06	1.878E-06

TABLE D.3.g. Fission Product Inventory by Isotope at 50 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Xe-136	3.544E-03	3.544E-03	3.544E-03	3.544E-03	3.544E-03	3.544E-03	3.544E-03
Ba-136	4.004E-05	4.004E-05	4.004E-05	4.004E-05	4.004E-05	4.004E-05	4.004E-05
Cs-137	1.598E-03	1.525E-03	1.457E-03	1.391E-03	1.239E-03	1.104E-03	1.618E-13
Ba-137	2.675E-04	3.396E-04	4.085E-04	4.743E-04	6.260E-04	7.612E-04	1.865E-03
Ba-137m	2.444E-10	2.334E-10	2.228E-10	2.128E-10	1.896E-10	1.689E-10	2.475E-20
Ba-138	1.881E-03	1.881E-03	1.881E-03	1.881E-03	1.881E-03	1.881E-03	1.881E-03
La-138	5.501E-09	5.501E-09	5.501E-09	5.501E-09	5.501E-09	5.501E-09	5.501E-09
La-139	1.783E-03	1.783E-03	1.783E-03	1.783E-03	1.783E-03	1.783E-03	1.783E-03
Ce-140	1.849E-03	1.849E-03	1.849E-03	1.849E-03	1.849E-03	1.849E-03	1.849E-03
Pr-141	1.617E-03	1.617E-03	1.617E-03	1.617E-03	1.617E-03	1.617E-03	1.617E-03
Ce-142	1.648E-03	1.648E-03	1.648E-03	1.648E-03	1.648E-03	1.648E-03	1.648E-03
Nd-142	6.799E-05	6.799E-05	6.799E-05	6.799E-05	6.799E-05	6.799E-05	6.799E-05
Nd-143	8.780E-04	8.780E-04	8.780E-04	8.780E-04	8.780E-04	8.780E-04	8.780E-04
Ce-144	7.472E-06	1.258E-06	2.119E-07	3.570E-08	4.156E-10	4.838E-12	0.00
Pr-144	3.155E-10	5.314E-11	8.949E-12	1.507E-12	1.755E-14	2.043E-16	0.00
Pr-144m	1.577E-12	2.656E-13	4.474E-14	7.535E-15	8.771E-17	1.021E-18	0.00
Nd-144	2.134E-03	2.140E-03	2.141E-03	2.141E-03	2.141E-03	2.142E-03	2.142E-03
Nd-145	9.054E-04	9.054E-04	9.054E-04	9.054E-04	9.054E-04	9.054E-04	9.054E-04
Nd-146	1.093E-03	1.093E-03	1.093E-03	1.093E-03	1.093E-03	1.093E-03	1.093E-03
Pm-146	6.548E-09	5.089E-09	3.955E-09	3.074E-09	1.637E-09	8.717E-10	0.00
Sm-146	1.849E-08	1.903E-08	1.945E-08	1.977E-08	2.030E-08	2.059E-08	2.091E-08
Pm-147	4.152E-05	2.448E-05	1.443E-05	8.508E-06	2.270E-06	6.059E-07	0.00
Sm-147	1.771E-04	1.942E-04	2.042E-04	2.101E-04	2.164E-04	2.180E-04	2.187E-04
Nd-148	5.547E-04	5.547E-04	5.547E-04	5.547E-04	5.547E-04	5.547E-04	5.547E-04
Sm-148	3.164E-04	3.164E-04	3.164E-04	3.164E-04	3.164E-04	3.164E-04	3.164E-04
Sm-149	2.247E-06	2.247E-06	2.247E-06	2.247E-06	2.247E-06	2.247E-06	2.247E-06
Nd-150	2.823E-04	2.823E-04	2.823E-04	2.823E-04	2.823E-04	2.823E-04	2.823E-04
Sm-150	3.499E-04	3.499E-04	3.499E-04	3.499E-04	3.499E-04	3.499E-04	3.499E-04
Eu-150	4.162E-13	4.004E-13	3.853E-13	3.708E-13	3.367E-13	3.058E-13	1.955E-21
Sm-151	1.380E-05	1.359E-05	1.338E-05	1.318E-05	1.268E-05	1.220E-05	6.432E-09
Eu-151	4.427E-07	6.537E-07	8.615E-07	1.066E-06	1.564E-06	2.043E-06	1.424E-05
Sm-152	1.633E-04	1.633E-04	1.633E-04	1.633E-04	1.633E-04	1.633E-04	1.633E-04
Eu-152	3.557E-08	3.212E-08	2.901E-08	2.620E-08	2.031E-08	1.574E-08	3.206E-30
Gd-152	1.752E-08	1.848E-08	1.935E-08	2.013E-08	2.177E-08	2.305E-08	2.743E-08
Eu-153	1.675E-04	1.675E-04	1.675E-04	1.675E-04	1.675E-04	1.675E-04	1.675E-04
Gd-153	3.157E-10	3.897E-11	4.809E-12	5.935E-13	3.177E-15	1.700E-17	0.00
Sm-154	6.648E-05	6.648E-05	6.648E-05	6.648E-05	6.648E-05	6.648E-05	6.648E-05
Eu-154	5.395E-05	4.592E-05	3.908E-05	3.326E-05	2.223E-05	1.486E-05	0.00
Gd-154	3.133E-05	3.936E-05	4.620E-05	5.202E-05	6.305E-05	7.042E-05	8.528E-05
Eu-155	1.522E-05	1.151E-05	8.704E-06	6.581E-06	3.272E-06	1.627E-06	0.00
Gd-155	1.160E-05	1.532E-05	1.812E-05	2.025E-05	2.356E-05	2.520E-05	2.683E-05
Gd-156	1.968E-04	1.968E-04	1.968E-04	1.968E-04	1.968E-04	1.968E-04	1.968E-04
Gd-157	1.648E-07	1.648E-07	1.648E-07	1.648E-07	1.648E-07	1.648E-07	1.648E-07
Gd-158	4.428E-05	4.428E-05	4.428E-05	4.428E-05	4.428E-05	4.428E-05	4.428E-05
Tb-159	5.294E-06	5.294E-06	5.294E-06	5.294E-06	5.294E-06	5.294E-06	5.294E-06

TABLE D.3.g. Fission Product Inventory by Isotope at 50 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Gd-160	2.545E-06	2.545E-06	2.545E-06	2.545E-06	2.545E-06	2.545E-06	2.545E-06
Tb-160	1.390E-13	1.264E-16	1.149E-19	1.044E-22	2.603E-30	0.00	0.00
Dy-160	8.015E-07	8.015E-07	8.015E-07	8.015E-07	8.015E-07	8.015E-07	8.015E-07
Dy-161	7.880E-07	7.880E-07	7.880E-07	7.880E-07	7.880E-07	7.880E-07	7.880E-07
Dy-162	7.335E-07	7.335E-07	7.335E-07	7.335E-07	7.335E-07	7.335E-07	7.335E-07
Dy-163	7.133E-07	7.133E-07	7.133E-07	7.133E-07	7.133E-07	7.133E-07	7.133E-07
Dy-164	1.008E-07	1.008E-07	1.008E-07	1.008E-07	1.008E-07	1.008E-07	1.008E-07
Ho-165	4.499E-07	4.499E-07	4.499E-07	4.499E-07	4.499E-07	4.499E-07	4.499E-07
Ho-166m	7.214E-09	7.206E-09	7.197E-09	7.189E-09	7.168E-09	7.148E-09	4.058E-09
Er-166	1.722E-07	1.723E-07	1.723E-07	1.723E-07	1.723E-07	1.723E-07	1.754E-07
Er-167	7.435E-09	7.435E-09	7.435E-09	7.435E-09	7.435E-09	7.435E-09	7.435E-09
Er-168	2.610E-08	2.610E-08	2.610E-08	2.610E-08	2.610E-08	2.610E-08	2.610E-08
Tm-169	2.350E-10	2.350E-10	2.350E-10	2.350E-10	2.350E-10	2.350E-10	2.350E-10
Er-170	1.803E-13	1.803E-13	1.803E-13	1.803E-13	1.803E-13	1.803E-13	1.803E-13
Tm-170	1.472E-14	2.870E-16	5.594E-18	1.090E-19	5.784E-24	3.069E-28	0.00
Yb-170	1.183E-10	1.183E-10	1.183E-10	1.183E-10	1.183E-10	1.183E-10	1.183E-10
Tm-171	1.230E-12	5.976E-13	2.903E-13	1.410E-13	2.319E-14	3.814E-15	0.00
Yb-171	1.090E-11	1.153E-11	1.184E-11	1.199E-11	1.211E-11	1.213E-11	1.213E-11
Yb-172	7.628E-13	7.628E-13	7.628E-13	7.628E-13	7.628E-13	7.628E-13	7.628E-13
Total	5.119E-02	5.119E-02	5.119E-02	5.119E-02	5.119E-02	5.119E-02	5.119E-02

TABLE D.4.a. Actinide Inventory by Isotope at 20 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
He-4	4.022E-07	4.389E-07	4.777E-07	5.185E-07	6.279E-07	7.456E-07	1.575E-05
Pb-207	4.119E-15	7.212E-15	1.123E-14	1.618E-14	3.264E-14	5.500E-14	1.264E-10
Pb-208	9.233E-12	1.580E-11	2.343E-11	3.174E-11	5.379E-11	7.602E-11	5.378E-10
Pb-212	5.234E-15	6.404E-15	7.166E-15	7.624E-15	7.973E-15	7.831E-15	7.838E-19
Ra-224	4.566E-14	5.586E-14	6.251E-14	6.651E-14	6.955E-14	6.831E-14	6.837E-18
Ra-226	1.881E-13	2.791E-13	3.886E-13	5.167E-13	9.185E-13	1.438E-12	2.463E-09
Ac-227	4.572E-14	6.159E-14	7.754E-14	9.356E-14	1.339E-13	1.746E-13	8.766E-12
Th-228	8.865E-12	1.083E-11	1.212E-11	1.289E-11	1.350E-11	1.326E-11	1.329E-15
Th-229	4.399E-13	4.528E-13	4.671E-13	4.826E-13	5.268E-13	5.787E-13	3.238E-10
Th-230	4.633E-09	5.681E-09	6.734E-09	7.791E-09	1.045E-08	1.314E-08	6.497E-07
Th-231	5.505E-14	5.505E-14	5.505E-14	5.505E-14	5.505E-14	5.505E-14	5.556E-14
Th-232	5.993E-10	7.695E-10	9.397E-10	1.110E-09	1.535E-09	1.961E-09	8.746E-08
Th-234	1.387E-11	1.387E-11	1.387E-11	1.387E-11	1.387E-11	1.387E-11	1.387E-11
Pa-231	4.507E-10	4.770E-10	5.032E-10	5.295E-10	5.950E-10	6.605E-10	1.342E-08
Pa-233	7.507E-12	7.527E-12	7.554E-12	7.584E-12	7.680E-12	7.796E-12	2.709E-11
U-232	4.640E-10	4.994E-10	5.171E-10	5.240E-10	5.178E-10	4.990E-10	4.934E-14
U-233	1.439E-09	1.588E-09	1.737E-09	1.886E-09	2.244E-09	2.606E-09	1.839E-07
U-234	1.877E-04	1.885E-04	1.893E-04	1.901E-04	1.920E-04	1.939E-04	2.401E-04
U-235	1.354E-02	1.354E-02	1.354E-02	1.354E-02	1.354E-02	1.354E-02	1.367E-02
U-236	2.923E-03	2.924E-03	2.924E-03	2.924E-03	2.925E-03	2.926E-03	3.067E-03
U-237	1.775E-11	1.612E-11	1.464E-11	1.330E-11	1.045E-11	8.218E-12	2.635E-18
U-238	9.555E-01	9.555E-01	9.555E-01	9.555E-01	9.555E-01	9.555E-01	9.555E-01
Np-235	9.706E-14	2.703E-14	7.527E-15	2.096E-15	8.577E-17	3.510E-18	0.00
Np-236	1.698E-10	1.698E-10	1.698E-10	1.698E-10	1.698E-10	1.698E-10	1.688E-10
Np-237	2.210E-04	2.216E-04	2.224E-04	2.233E-04	2.261E-04	2.295E-04	7.977E-04
Np-238	1.643E-13	1.629E-13	1.614E-13	1.599E-13	1.563E-13	1.528E-13	1.751E-15
Np-239	1.361E-11	1.361E-11	1.361E-11	1.361E-11	1.360E-11	1.359E-11	1.240E-11
Pu-236	1.182E-10	7.266E-11	4.468E-11	2.748E-11	8.147E-12	2.416E-12	3.765E-16
Pu-238	5.313E-05	5.231E-05	5.150E-05	5.070E-05	4.875E-05	4.688E-05	3.035E-08
Pu-239	4.578E-03	4.577E-03	4.577E-03	4.577E-03	4.576E-03	4.576E-03	4.450E-03
Pu-240	1.461E-03	1.461E-03	1.461E-03	1.461E-03	1.460E-03	1.460E-03	1.317E-03
Pu-241	5.733E-04	5.207E-04	4.729E-04	4.295E-04	3.376E-04	2.654E-04	8.522E-11
Pu-242	1.431E-04	1.431E-04	1.431E-04	1.431E-04	1.431E-04	1.431E-04	1.430E-04
Pu-244	1.581E-09	1.581E-09	1.581E-09	1.581E-09	1.581E-09	1.581E-09	1.581E-09
Am-241	1.671E-04	2.191E-04	2.661E-04	3.086E-04	3.977E-04	4.664E-04	1.539E-04
Am-242m	8.765E-07	8.686E-07	8.607E-07	8.529E-07	8.336E-07	8.149E-07	9.340E-09
Am-242	1.049E-11	1.039E-11	1.030E-11	1.020E-11	9.972E-12	9.747E-12	1.117E-13
Am-243	1.584E-05	1.584E-05	1.584E-05	1.583E-05	1.583E-05	1.582E-05	1.443E-05
Cm-242	1.445E-08	2.658E-09	2.110E-09	2.068E-09	2.017E-09	1.972E-09	2.259E-11
Cm-243	8.767E-08	8.351E-08	7.954E-08	7.576E-08	6.709E-08	5.941E-08	2.647E-18
Cm-244	1.985E-06	1.839E-06	1.703E-06	1.578E-06	1.303E-06	1.076E-06	5.517E-23
Cm-245	5.537E-08	5.536E-08	5.535E-08	5.534E-08	5.532E-08	5.530E-08	5.105E-08
Cm-246	3.471E-09	3.470E-09	3.469E-09	3.468E-09	3.466E-09	3.463E-09	3.000E-09
Cm-247	1.747E-11	1.747E-11	1.747E-11	1.747E-11	1.747E-11	1.747E-11	1.747E-11
Cm-248	4.646E-13	4.646E-13	4.646E-13	4.646E-13	4.646E-13	4.646E-13	4.637E-13
Cf-249	3.076E-15	3.146E-15	3.151E-15	3.142E-15	3.112E-15	3.081E-15	4.436E-16
Total	9.793E-01	9.793E-01	9.793E-01	9.793E-01	9.793E-01	9.793E-01	9.793E-01

TABLE D.4.b. Actinide Inventory by Isotope at 25 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
He-4	6.785E-07	7.351E-07	7.940E-07	8.551E-07	1.016E-06	1.187E-06	2.065E-05
Pb-207	4.307E-15	7.538E-15	1.172E-14	1.683E-14	3.365E-14	5.614E-14	1.026E-10
Pb-208	1.367E-11	2.386E-11	3.585E-11	4.900E-11	8.413E-11	1.197E-10	8.598E-10
Pb-212	8.048E-15	1.001E-14	1.130E-14	1.210E-14	1.274E-14	1.254E-14	1.241E-18
Ra-224	7.020E-14	8.728E-14	9.861E-14	1.055E-13	1.111E-13	1.094E-13	1.083E-17
Ra-226	1.742E-13	2.583E-13	3.597E-13	4.786E-13	8.528E-13	1.339E-12	2.635E-09
Ac-227	4.786E-14	6.419E-14	8.036E-14	9.637E-14	1.358E-13	1.744E-13	7.051E-12
Th-228	1.363E-11	1.693E-11	1.912E-11	2.046E-11	2.157E-11	2.124E-11	2.104E-15
Th-229	6.969E-13	7.120E-13	7.288E-13	7.473E-13	8.012E-13	8.656E-13	4.348E-10
Th-230	4.276E-09	5.256E-09	6.243E-09	7.238E-09	9.758E-09	1.232E-08	7.037E-07
Th-231	4.377E-14	4.377E-14	4.377E-14	4.377E-14	4.377E-14	4.377E-14	4.431E-14
Th-232	6.917E-10	8.860E-10	1.080E-09	1.275E-09	1.760E-09	2.246E-09	1.001E-07
Th-234	1.382E-11	1.382E-11	1.382E-11	1.382E-11	1.382E-11	1.382E-11	1.382E-11
Pa-231	4.682E-10	4.890E-10	5.099E-10	5.308E-10	5.829E-10	6.349E-10	1.079E-08
Pa-233	1.031E-11	1.033E-11	1.037E-11	1.041E-11	1.053E-11	1.069E-11	3.622E-11
U-232	7.287E-10	7.912E-10	8.232E-10	8.364E-10	8.290E-10	7.994E-10	7.831E-14
U-233	1.658E-09	1.862E-09	2.066E-09	2.272E-09	2.762E-09	3.259E-09	2.465E-07
U-234	1.751E-04	1.765E-04	1.779E-04	1.792E-04	1.825E-04	1.857E-04	2.644E-04
U-235	1.076E-02	1.076E-02	1.076E-02	1.076E-02	1.077E-02	1.077E-02	1.090E-02
U-236	3.337E-03	3.338E-03	3.338E-03	3.338E-03	3.339E-03	3.340E-03	3.518E-03
U-237	2.357E-11	2.141E-11	1.944E-11	1.766E-11	1.388E-11	1.091E-11	9.759E-18
U-238	9.516E-01	9.516E-01	9.516E-01	9.516E-01	9.516E-01	9.516E-01	9.516E-01
Np-235	1.597E-13	4.446E-14	1.238E-14	3.448E-15	1.411E-16	5.774E-18	0.00
Np-236	2.582E-10	2.582E-10	2.582E-10	2.582E-10	2.582E-10	2.581E-10	2.566E-10
Np-237	3.035E-04	3.043E-04	3.053E-04	3.065E-04	3.102E-04	3.147E-04	1.066E-03
Np-238	2.218E-13	2.198E-13	2.178E-13	2.158E-13	2.109E-13	2.062E-13	2.363E-15
Np-239	3.088E-11	3.088E-11	3.087E-11	3.086E-11	3.085E-11	3.083E-11	2.812E-11
Pu-236	2.041E-10	1.255E-10	7.717E-11	4.746E-11	1.407E-11	4.173E-12	5.726E-16
Pu-238	9.046E-05	8.907E-05	8.768E-05	8.631E-05	8.299E-05	7.980E-05	4.814E-08
Pu-239	4.818E-03	4.818E-03	4.818E-03	4.817E-03	4.817E-03	4.816E-03	4.685E-03
Pu-240	1.832E-03	1.832E-03	1.832E-03	1.832E-03	1.832E-03	1.832E-03	1.654E-03
Pu-241	7.612E-04	6.914E-04	6.279E-04	5.703E-04	4.483E-04	3.524E-04	3.156E-10
Pu-242	2.540E-04	2.540E-04	2.540E-04	2.540E-04	2.540E-04	2.540E-04	2.538E-04
Pu-244	4.881E-09	4.881E-09	4.881E-09	4.881E-09	4.881E-09	4.881E-09	4.881E-09
Am-241	2.185E-04	2.876E-04	3.500E-04	4.065E-04	5.247E-04	6.160E-04	2.037E-04
Am-242m	1.183E-06	1.172E-06	1.161E-06	1.151E-06	1.125E-06	1.100E-06	1.260E-08
Am-242	1.415E-11	1.402E-11	1.389E-11	1.377E-11	1.346E-11	1.315E-11	1.508E-13
Am-243	3.593E-05	3.593E-05	3.592E-05	3.591E-05	3.590E-05	3.588E-05	3.273E-05
Cm-242	2.333E-08	3.760E-09	2.855E-09	2.790E-09	2.722E-09	2.661E-09	3.048E-11
Cm-243	1.879E-07	1.790E-07	1.705E-07	1.624E-07	1.438E-07	1.273E-07	5.674E-18
Cm-244	6.049E-06	5.604E-06	5.191E-06	4.808E-06	3.971E-06	3.279E-06	1.681E-22
Cm-245	2.050E-07	2.050E-07	2.050E-07	2.049E-07	2.049E-07	2.048E-07	1.890E-07
Cm-246	1.731E-08	1.731E-08	1.730E-08	1.730E-08	1.728E-08	1.727E-08	1.496E-08
Cm-247	1.141E-10	1.141E-10	1.141E-10	1.141E-10	1.141E-10	1.141E-10	1.141E-10
Cm-248	4.020E-12	4.020E-12	4.020E-12	4.020E-12	4.020E-12	4.020E-12	4.012E-12

TABLE D.4.b. Actinide Inventory by Isotope at 25 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Bk-249	1.114E-15	2.289E-16	4.705E-17	9.670E-18	1.852E-19	3.552E-21	0.00
Cf-249	3.246E-14	3.321E-14	3.326E-14	3.317E-14	3.285E-14	3.253E-14	4.683E-15
Cf-250	4.079E-15	3.669E-15	3.300E-15	2.968E-15	2.277E-15	1.747E-15	4.876E-25
Cf-251	1.682E-15	1.679E-15	1.677E-15	1.674E-15	1.667E-15	1.661E-15	7.796E-16
Total	9.742E-01	9.742E-01	9.742E-01	9.742E-01	9.742E-01	9.742E-01	9.742E-01

TABLE D.4.c. Actinide Inventory by Isotope at 30 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
He-4	1.017E-06	1.101E-06	1.186E-06	1.273E-06	1.499E-06	1.732E-06	2.517E-05
Pb-207	4.390E-15	7.685E-15	1.193E-14	1.710E-14	3.399E-14	5.629E-14	8.232E-11
Pb-208	1.895E-11	3.360E-11	5.103E-11	7.026E-11	1.219E-10	1.743E-10	1.267E-09
Pb-212	1.150E-14	1.448E-14	1.648E-14	1.772E-14	1.875E-14	1.849E-14	1.808E-18
Bi-212	1.091E-15	1.374E-15	1.563E-15	1.681E-15	1.779E-15	1.754E-15	1.715E-19
Ra-224	1.003E-13	1.263E-13	1.438E-13	1.546E-13	1.636E-13	1.613E-13	1.577E-17
Ra-226	1.607E-13	2.381E-13	3.318E-13	4.420E-13	7.903E-13	1.245E-12	2.890E-09
Ac-227	4.886E-14	6.536E-14	8.150E-14	9.731E-14	1.355E-13	1.719E-13	5.595E-12
Th-228	1.947E-11	2.450E-11	2.788E-11	2.997E-11	3.177E-11	3.132E-11	3.065E-15
Th-229	1.043E-12	1.060E-12	1.079E-12	1.100E-12	1.163E-12	1.239E-12	5.370E-10
Th-230	3.933E-09	4.848E-09	5.776E-09	6.714E-09	9.110E-09	1.157E-08	7.811E-07
Th-231	3.423E-14	3.423E-14	3.423E-14	3.423E-14	3.423E-14	3.424E-14	3.479E-14
Th-232	7.663E-10	9.790E-10	1.192E-09	1.404E-09	1.937E-09	2.469E-09	1.099E-07
Th-234	1.376E-11	1.376E-11	1.376E-11	1.376E-11	1.376E-11	1.376E-11	1.376E-11
Pa-231	4.763E-10	4.926E-10	5.089E-10	5.252E-10	5.659E-10	6.067E-10	8.565E-09
Pa-233	1.323E-11	1.326E-11	1.330E-11	1.335E-11	1.350E-11	1.368E-11	4.423E-11
U-232	1.059E-09	1.158E-09	1.209E-09	1.231E-09	1.222E-09	1.180E-09	1.142E-13
U-233	1.836E-09	2.097E-09	2.359E-09	2.622E-09	3.251E-09	3.888E-09	3.031E-07
U-234	1.633E-04	1.654E-04	1.675E-04	1.695E-04	1.745E-04	1.793E-04	2.983E-04
U-235	8.418E-03	8.418E-03	8.419E-03	8.419E-03	8.420E-03	8.420E-03	8.556E-03
U-236	3.654E-03	3.655E-03	3.655E-03	3.656E-03	3.657E-03	3.658E-03	3.871E-03
U-237	2.832E-11	2.572E-11	2.336E-11	2.122E-11	1.668E-11	1.311E-11	2.758E-17
U-238	9.475E-01	9.475E-01	9.475E-01	9.475E-01	9.475E-01	9.475E-01	9.475E-01
Np-235	2.370E-13	6.599E-14	1.838E-14	5.117E-15	2.094E-16	8.569E-18	0.00
Np-236	3.566E-10	3.566E-10	3.566E-10	3.566E-10	3.566E-10	3.565E-10	3.544E-10
Np-237	3.894E-04	3.903E-04	3.915E-04	3.929E-04	3.973E-04	4.027E-04	1.302E-03
Np-238	2.602E-13	2.578E-13	2.555E-13	2.531E-13	2.474E-13	2.419E-13	2.772E-15
Np-239	5.839E-11	5.838E-11	5.837E-11	5.836E-11	5.833E-11	5.831E-11	5.318E-11
Pu-236	3.178E-10	1.954E-10	1.202E-10	7.390E-11	2.191E-11	6.498E-12	7.909E-16
Pu-238	1.369E-04	1.348E-04	1.327E-04	1.307E-04	1.256E-04	1.208E-04	6.828E-08
Pu-239	4.972E-03	4.972E-03	4.972E-03	4.972E-03	4.971E-03	4.970E-03	4.838E-03
Pu-240	2.182E-03	2.182E-03	2.183E-03	2.183E-03	2.184E-03	2.185E-03	1.976E-03
Pu-241	9.148E-04	8.308E-04	7.546E-04	6.853E-04	5.387E-04	4.235E-04	8.920E-10
Pu-242	3.884E-04	3.884E-04	3.884E-04	3.884E-04	3.884E-04	3.884E-04	3.879E-04
Pu-244	1.206E-08	1.206E-08	1.206E-08	1.206E-08	1.206E-08	1.206E-08	1.206E-08
Am-241	2.575E-04	3.405E-04	4.156E-04	4.834E-04	6.255E-04	7.353E-04	2.437E-04
Am-242m	1.388E-06	1.375E-06	1.362E-06	1.350E-06	1.320E-06	1.290E-06	1.478E-08
Am-242	1.660E-11	1.645E-11	1.630E-11	1.615E-11	1.579E-11	1.543E-11	1.769E-13
Am-243	6.795E-05	6.793E-05	6.792E-05	6.791E-05	6.788E-05	6.785E-05	6.188E-05
Cm-242	3.294E-08	4.660E-09	3.361E-09	3.274E-09	3.193E-09	3.121E-09	3.576E-11
Cm-243	3.346E-07	3.187E-07	3.035E-07	2.891E-07	2.560E-07	2.267E-07	1.010E-17
Cm-244	1.467E-05	1.359E-05	1.259E-05	1.166E-05	9.627E-06	7.950E-06	4.077E-22
Cm-245	5.795E-07	5.794E-07	5.793E-07	5.793E-07	5.790E-07	5.788E-07	5.343E-07
Cm-246	6.289E-08	6.288E-08	6.286E-08	6.284E-08	6.279E-08	6.275E-08	5.435E-08
Cm-247	5.176E-10	5.176E-10	5.176E-10	5.176E-10	5.176E-10	5.176E-10	5.175E-10

TABLE D.4.c. Actinide Inventory by Isotope at 30 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Cm-248	2.314E-11	2.314E-11	2.314E-11	2.314E-11	2.314E-11	2.314E-11	2.310E-11
Bk-249	7.621E-15	1.566E-15	3.219E-16	6.615E-17	1.267E-18	2.425E-20	0.00
Cf-249	2.186E-13	2.238E-13	2.241E-13	2.235E-13	2.213E-13	2.192E-13	3.155E-14
Cf-250	3.063E-14	2.755E-14	2.478E-14	2.229E-14	1.710E-14	1.312E-14	4.626E-24
Cf-251	1.389E-14	1.387E-14	1.385E-14	1.383E-14	1.377E-14	1.372E-14	6.439E-15
Cf-252	2.351E-15	1.390E-15	8.219E-16	4.859E-16	1.306E-16	3.511E-17	0.00
Total	9.691E-01	9.691E-01	9.691E-01	9.691E-01	9.691E-01	9.691E-01	9.691E-01

TABLE D.4.d. Actinide Inventory by Isotope at 35 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
He-4	1.407E-06	1.528E-06	1.649E-06	1.771E-06	2.081E-06	2.393E-06	2.988E-05
Pb-207	4.381E-15	7.672E-15	1.190E-14	1.705E-14	3.372E-14	5.556E-14	6.559E-11
Pb-208	2.497E-11	4.489E-11	6.878E-11	9.525E-11	1.666E-10	2.393E-10	1.756E-09
Pb-212	1.554E-14	1.978E-14	2.265E-14	2.444E-14	2.598E-14	2.565E-14	2.479E-18
Bi-212	1.474E-15	1.876E-15	2.149E-15	2.319E-15	2.464E-15	2.433E-15	2.351E-19
Ra-224	1.355E-13	1.725E-13	1.976E-13	2.132E-13	2.266E-13	2.238E-13	2.162E-17
Ra-226	1.476E-13	2.188E-13	3.051E-13	4.069E-13	7.310E-13	1.158E-12	3.216E-09
Ac-227	4.882E-14	6.523E-14	8.113E-14	9.656E-14	1.332E-13	1.675E-13	4.398E-12
Th-228	2.632E-11	3.346E-11	3.831E-11	4.134E-11	4.401E-11	4.345E-11	4.202E-15
Th-229	1.485E-12	1.503E-12	1.524E-12	1.548E-12	1.619E-12	1.706E-12	6.405E-10
Th-230	3.603E-09	4.458E-09	5.331E-09	6.219E-09	8.508E-09	1.089E-08	8.787E-07
Th-231	2.641E-14	2.641E-14	2.642E-14	2.642E-14	2.642E-14	2.642E-14	2.699E-14
Th-232	8.237E-10	1.049E-09	1.275E-09	1.501E-09	2.065E-09	2.630E-09	1.168E-07
Th-234	1.369E-11	1.369E-11	1.369E-11	1.369E-11	1.369E-11	1.369E-11	1.369E-11
Pa-231	4.757E-10	4.883E-10	5.009E-10	5.135E-10	5.449E-10	5.763E-10	6.732E-09
Pa-233	1.619E-11	1.623E-11	1.627E-11	1.633E-11	1.650E-11	1.672E-11	5.234E-11
U-232	1.451E-09	1.595E-09	1.671E-09	1.704E-09	1.696E-09	1.637E-09	1.567E-13
U-233	1.979E-09	2.299E-09	2.620E-09	2.942E-09	3.711E-09	4.489E-09	3.604E-07
U-234	1.521E-04	1.551E-04	1.580E-04	1.608E-04	1.678E-04	1.744E-04	3.405E-04
U-235	6.496E-03	6.497E-03	6.497E-03	6.497E-03	6.498E-03	6.499E-03	6.637E-03
U-236	3.878E-03	3.878E-03	3.879E-03	3.879E-03	3.880E-03	3.882E-03	4.122E-03
U-237	3.321E-11	3.016E-11	2.739E-11	2.488E-11	1.956E-11	1.537E-11	6.420E-17
U-238	9.432E-01	9.432E-01	9.432E-01	9.432E-01	9.432E-01	9.432E-01	9.432E-01
Np-235	3.262E-13	9.083E-14	2.529E-14	7.043E-15	2.882E-16	1.179E-17	0.00
Np-236	4.610E-10	4.610E-10	4.610E-10	4.610E-10	4.610E-10	4.610E-10	4.583E-10
Np-237	4.767E-04	4.778E-04	4.792E-04	4.808E-04	4.859E-04	4.922E-04	1.541E-03
Np-238	2.807E-13	2.782E-13	2.757E-13	2.732E-13	2.670E-13	2.610E-13	2.991E-15
Np-239	9.791E-11	9.789E-11	9.787E-11	9.785E-11	9.781E-11	9.776E-11	8.917E-11
Pu-236	4.594E-10	2.825E-10	1.737E-10	1.068E-10	3.168E-11	9.394E-12	1.023E-15
Pu-238	1.912E-04	1.882E-04	1.853E-04	1.824E-04	1.754E-04	1.686E-04	9.030E-08
Pu-239	5.058E-03	5.058E-03	5.057E-03	5.057E-03	5.056E-03	5.056E-03	4.925E-03
Pu-240	2.452E-03	2.453E-03	2.455E-03	2.456E-03	2.459E-03	2.461E-03	2.233E-03
Pu-241	1.073E-03	9.741E-04	8.847E-04	8.035E-04	6.316E-04	4.965E-04	2.076E-09
Pu-242	5.435E-04	5.435E-04	5.435E-04	5.435E-04	5.435E-04	5.435E-04	5.428E-04
Pu-244	2.547E-08	2.547E-08	2.547E-08	2.547E-08	2.547E-08	2.547E-08	2.547E-08
Am-241	2.940E-04	3.914E-04	4.794E-04	5.589E-04	7.256E-04	8.544E-04	2.842E-04
Am-242m	1.497E-06	1.484E-06	1.470E-06	1.457E-06	1.424E-06	1.392E-06	1.595E-08
Am-242	1.791E-11	1.775E-11	1.759E-11	1.743E-11	1.704E-11	1.665E-11	1.908E-13
Am-243	1.139E-04	1.139E-04	1.139E-04	1.139E-04	1.138E-04	1.138E-04	1.038E-04
Cm-242	4.230E-08	5.333E-09	3.641E-09	3.534E-09	3.446E-09	3.368E-09	3.859E-11
Cm-243	5.218E-07	4.970E-07	4.734E-07	4.510E-07	3.993E-07	3.536E-07	1.575E-17
Cm-244	3.021E-05	2.799E-05	2.592E-05	2.401E-05	1.983E-05	1.638E-05	8.397E-22
Cm-245	1.349E-06	1.349E-06	1.348E-06	1.348E-06	1.348E-06	1.347E-06	1.244E-06
Cm-246	1.837E-07	1.837E-07	1.836E-07	1.836E-07	1.834E-07	1.833E-07	1.588E-07
Cm-247	1.837E-09	1.837E-09	1.837E-09	1.837E-09	1.837E-09	1.837E-09	1.837E-09

TABLE D.4.d. Actinide Inventory by Isotope at 35 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Cm-248	1.014E-10	1.014E-10	1.014E-10	1.014E-10	1.014E-10	1.014E-10	1.012E-10
Bk-249	3.841E-14	7.895E-15	1.623E-15	3.335E-16	6.385E-18	1.223E-19	0.00
Cf-249	1.087E-12	1.113E-12	1.115E-12	1.112E-12	1.101E-12	1.091E-12	1.570E-13
Cf-250	1.659E-13	1.492E-13	1.342E-13	1.207E-13	9.263E-14	7.107E-14	3.123E-23
Cf-251	8.092E-14	8.080E-14	8.067E-14	8.055E-14	8.024E-14	7.993E-14	3.751E-14
Cf-252	1.698E-14	1.004E-14	5.935E-15	3.509E-15	9.432E-16	2.535E-16	0.00
Total	9.640E-01	9.640E-01	9.640E-01	9.640E-01	9.640E-01	9.640E-01	9.640E-01

TABLE D.4.e. Actinide Inventory by Isotope at 40 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
He-4	1.854E-06	2.025E-06	2.194E-06	2.362E-06	2.780E-06	3.192E-06	3.451E-05
Pb-207	4.292E-15	7.517E-15	1.166E-14	1.668E-14	3.290E-14	5.400E-14	5.201E-11
Pb-208	3.155E-11	5.738E-11	8.855E-11	1.232E-10	2.170E-10	3.127E-10	2.312E-09
Pb-212	2.004E-14	2.574E-14	2.962E-14	3.206E-14	3.419E-14	3.380E-14	3.230E-18
Bi-209	1.309E-15	1.659E-15	2.012E-15	2.370E-15	3.285E-15	4.239E-15	1.930E-11
Bi-212	1.901E-15	2.442E-15	2.810E-15	3.041E-15	3.243E-15	3.206E-15	3.064E-19
Ra-224	1.748E-13	2.245E-13	2.584E-13	2.797E-13	2.983E-13	2.948E-13	2.818E-17
Ra-226	1.352E-13	2.004E-13	2.798E-13	3.739E-13	6.756E-13	1.077E-12	3.603E-09
Ac-227	4.786E-14	6.391E-14	7.935E-14	9.423E-14	1.292E-13	1.613E-13	3.430E-12
Th-228	3.394E-11	4.355E-11	5.011E-11	5.422E-11	5.792E-11	5.725E-11	5.475E-15
Th-229	2.020E-12	2.039E-12	2.061E-12	2.087E-12	2.165E-12	2.263E-12	7.365E-10
Th-230	3.291E-09	4.092E-09	4.914E-09	5.758E-09	7.957E-09	1.028E-08	9.937E-07
Th-231	2.014E-14	2.014E-14	2.014E-14	2.014E-14	2.015E-14	2.015E-14	2.072E-14
Th-232	8.657E-10	1.100E-09	1.334E-09	1.567E-09	2.152E-09	2.738E-09	1.212E-07
Th-234	1.363E-11	1.363E-11	1.363E-11	1.363E-11	1.363E-11	1.363E-11	1.363E-11
Pa-231	4.669E-10	4.765E-10	4.861E-10	4.957E-10	5.196E-10	5.435E-10	5.251E-09
Pa-233	1.905E-11	1.909E-11	1.914E-11	1.920E-11	1.940E-11	1.964E-11	5.973E-11
U-232	1.893E-09	2.091E-09	2.195E-09	2.242E-09	2.234E-09	2.158E-09	2.043E-13
U-233	2.091E-09	2.468E-09	2.845E-09	3.224E-09	4.128E-09	5.043E-09	4.132E-07
U-234	1.418E-04	1.457E-04	1.495E-04	1.533E-04	1.624E-04	1.712E-04	3.897E-04
U-235	4.953E-03	4.953E-03	4.954E-03	4.954E-03	4.955E-03	4.955E-03	5.095E-03
U-236	4.018E-03	4.019E-03	4.019E-03	4.020E-03	4.021E-03	4.022E-03	4.284E-03
U-237	3.756E-11	3.412E-11	3.099E-11	2.814E-11	2.212E-11	1.739E-11	1.295E-16
U-238	9.387E-01	9.387E-01	9.387E-01	9.387E-01	9.387E-01	9.387E-01	9.387E-01
Np-235	4.221E-13	1.175E-13	3.273E-14	9.116E-15	3.730E-16	1.526E-17	0.00
Np-236	5.660E-10	5.660E-10	5.660E-10	5.660E-10	5.659E-10	5.659E-10	5.626E-10
Np-237	5.608E-04	5.620E-04	5.636E-04	5.654E-04	5.711E-04	5.781E-04	1.759E-03
Np-238	2.911E-13	2.884E-13	2.858E-13	2.832E-13	2.768E-13	2.706E-13	3.101E-15
Np-239	1.498E-10	1.498E-10	1.498E-10	1.497E-10	1.497E-10	1.496E-10	1.364E-10
Pu-236	6.249E-10	3.843E-10	2.363E-10	1.453E-10	4.309E-11	1.278E-11	1.255E-15
Pu-238	2.518E-04	2.479E-04	2.440E-04	2.402E-04	2.310E-04	2.220E-04	1.141E-07
Pu-239	5.094E-03	5.094E-03	5.094E-03	5.094E-03	5.093E-03	5.093E-03	4.966E-03
Pu-240	2.646E-03	2.649E-03	2.653E-03	2.656E-03	2.662E-03	2.666E-03	2.430E-03
Pu-241	1.213E-03	1.102E-03	1.001E-03	9.089E-04	7.145E-04	5.616E-04	4.189E-09
Pu-242	7.157E-04	7.157E-04	7.157E-04	7.157E-04	7.157E-04	7.157E-04	7.147E-04
Pu-244	4.813E-08	4.813E-08	4.813E-08	4.813E-08	4.813E-08	4.813E-08	4.813E-08
Am-241	3.248E-04	4.349E-04	5.345E-04	6.245E-04	8.131E-04	9.588E-04	3.199E-04
Am-242m	1.552E-06	1.538E-06	1.524E-06	1.510E-06	1.476E-06	1.443E-06	1.654E-08
Am-242	1.857E-11	1.840E-11	1.823E-11	1.807E-11	1.766E-11	1.726E-11	1.979E-13
Am-243	1.743E-04	1.743E-04	1.743E-04	1.742E-04	1.742E-04	1.741E-04	1.588E-04
Cm-242	5.148E-08	5.871E-09	3.790E-09	3.664E-09	3.572E-09	3.492E-09	4.001E-11
Cm-243	7.436E-07	7.083E-07	6.747E-07	6.427E-07	5.691E-07	5.039E-07	2.245E-17
Cm-244	5.556E-05	5.147E-05	4.768E-05	4.416E-05	3.647E-05	3.012E-05	1.544E-21
Cm-245	2.722E-06	2.721E-06	2.721E-06	2.720E-06	2.719E-06	2.718E-06	2.509E-06
Cm-246	4.534E-07	4.533E-07	4.532E-07	4.530E-07	4.527E-07	4.524E-07	3.919E-07

TABLE D.4.e. Actinide Inventory by Isotope at 40 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Cm-247	5.366E-09	5.366E-09	5.366E-09	5.366E-09	5.366E-09	5.366E-09	5.366E-09
Cm-248	3.574E-10	3.575E-10	3.575E-10	3.575E-10	3.575E-10	3.575E-10	3.568E-10
Bk-249	1.519E-13	3.122E-14	6.417E-15	1.319E-15	2.525E-17	4.836E-19	0.00
Cf-249	4.249E-12	4.352E-12	4.360E-12	4.348E-12	4.306E-12	4.264E-12	6.138E-13
Cf-250	6.934E-13	6.237E-13	5.610E-13	5.046E-13	3.871E-13	2.970E-13	1.617E-22
Cf-251	3.576E-13	3.571E-13	3.565E-13	3.560E-13	3.546E-13	3.532E-13	1.658E-13
Cf-252	9.076E-14	5.366E-14	3.173E-14	1.876E-14	5.043E-15	1.356E-15	0.00
Total	9.589E-01	9.589E-01	9.589E-01	9.589E-01	9.589E-01	9.589E-01	9.589E-01

TABLE D.4.f. Actinide Inventory by Isotope at 45 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
He-4	2.348E-06	2.583E-06	2.814E-06	3.042E-06	3.596E-06	4.130E-06	3.892E-05
Pb-207	4.138E-15	7.248E-15	1.124E-14	1.608E-14	3.164E-14	5.177E-14	4.114E-11
Pb-208	3.846E-11	7.062E-11	1.096E-10	1.532E-10	2.713E-10	3.920E-10	2.915E-09
Pb-212	2.484E-14	3.215E-14	3.715E-14	4.031E-14	4.311E-14	4.265E-14	4.035E-18
Bi-209	1.743E-15	2.200E-15	2.660E-15	3.125E-15	4.310E-15	5.536E-15	2.156E-11
Bi-212	2.357E-15	3.050E-15	3.524E-15	3.823E-15	4.089E-15	4.045E-15	3.827E-19
Ra-224	2.167E-13	2.804E-13	3.241E-13	3.516E-13	3.760E-13	3.720E-13	3.519E-17
Ra-226	1.235E-13	1.831E-13	2.561E-13	3.430E-13	6.242E-13	1.002E-12	4.030E-09
Ac-227	4.614E-14	6.162E-14	7.643E-14	9.062E-14	1.236E-13	1.535E-13	2.662E-12
Th-228	4.209E-11	5.439E-11	6.284E-11	6.817E-11	7.301E-11	7.223E-11	6.839E-15
Th-229	2.638E-12	2.659E-12	2.682E-12	2.710E-12	2.794E-12	2.901E-12	8.204E-10
Th-230	3.000E-09	3.751E-09	4.529E-09	5.333E-09	7.457E-09	9.738E-09	1.120E-06
Th-231	1.519E-14	1.519E-14	1.519E-14	1.520E-14	1.520E-14	1.520E-14	1.577E-14
Th-232	8.944E-10	1.132E-09	1.370E-09	1.608E-09	2.204E-09	2.799E-09	1.236E-07
Th-234	1.356E-11	1.356E-11	1.356E-11	1.356E-11	1.356E-11	1.356E-11	1.356E-11
Pa-231	4.512E-10	4.584E-10	4.656E-10	4.729E-10	4.909E-10	5.090E-10	4.075E-09
Pa-233	2.169E-11	2.173E-11	2.179E-11	2.186E-11	2.207E-11	2.232E-11	6.600E-11
U-232	2.369E-09	2.627E-09	2.763E-09	2.825E-09	2.818E-09	2.723E-09	2.553E-13
U-233	2.175E-09	2.604E-09	3.034E-09	3.465E-09	4.494E-09	5.534E-09	4.587E-07
U-234	1.323E-04	1.372E-04	1.420E-04	1.467E-04	1.582E-04	1.692E-04	4.434E-04
U-235	3.736E-03	3.737E-03	3.737E-03	3.737E-03	3.738E-03	3.739E-03	3.879E-03
U-236	4.088E-03	4.089E-03	4.090E-03	4.090E-03	4.092E-03	4.093E-03	4.371E-03
U-237	4.110E-11	3.732E-11	3.390E-11	3.079E-11	2.420E-11	1.902E-11	2.344E-16
U-238	9.341E-01	9.341E-01	9.341E-01	9.341E-01	9.341E-01	9.341E-01	9.341E-01
Np-235	5.198E-13	1.447E-13	4.031E-14	1.122E-14	4.593E-16	1.880E-17	0.00
Np-236	6.664E-10	6.664E-10	6.664E-10	6.664E-10	6.663E-10	6.663E-10	6.624E-10
Np-237	6.386E-04	6.399E-04	6.415E-04	6.435E-04	6.497E-04	6.573E-04	1.943E-03
Np-238	2.924E-13	2.897E-13	2.871E-13	2.845E-13	2.781E-13	2.718E-13	3.116E-15
Np-239	2.132E-10	2.132E-10	2.132E-10	2.131E-10	2.130E-10	2.129E-10	1.942E-10
Pu-236	8.085E-10	4.971E-10	3.057E-10	1.880E-10	5.574E-11	1.653E-11	1.478E-15
Pu-238	3.162E-04	3.113E-04	3.065E-04	3.017E-04	2.900E-04	2.788E-04	1.389E-07
Pu-239	5.107E-03	5.107E-03	5.107E-03	5.107E-03	5.106E-03	5.106E-03	4.985E-03
Pu-240	2.777E-03	2.783E-03	2.788E-03	2.794E-03	2.805E-03	2.814E-03	2.581E-03
Pu-241	1.327E-03	1.205E-03	1.095E-03	9.943E-04	7.816E-04	6.144E-04	7.580E-09
Pu-242	8.972E-04	8.972E-04	8.972E-04	8.972E-04	8.972E-04	8.972E-04	8.960E-04
Pu-244	8.315E-08	8.315E-08	8.315E-08	8.315E-08	8.315E-08	8.315E-08	8.315E-08
Am-241	3.482E-04	4.688E-04	5.777E-04	6.762E-04	8.826E-04	1.042E-03	3.487E-04
Am-242m	1.560E-06	1.545E-06	1.531E-06	1.517E-06	1.483E-06	1.450E-06	1.662E-08
Am-242	1.866E-11	1.849E-11	1.832E-11	1.815E-11	1.774E-11	1.734E-11	1.988E-13
Am-243	2.481E-04	2.481E-04	2.480E-04	2.480E-04	2.479E-04	2.477E-04	2.260E-04
Cm-242	5.993E-08	6.267E-09	3.824E-09	3.682E-09	3.589E-09	3.508E-09	4.019E-11
Cm-243	9.840E-07	9.372E-07	8.927E-07	8.504E-07	7.530E-07	6.668E-07	2.971E-17
Cm-244	9.338E-05	8.650E-05	8.013E-05	7.422E-05	6.129E-05	5.062E-05	2.595E-21
Cm-245	4.924E-06	4.924E-06	4.923E-06	4.922E-06	4.920E-06	4.918E-06	4.540E-06
Cm-246	9.826E-07	9.824E-07	9.821E-07	9.818E-07	9.811E-07	9.803E-07	8.492E-07

TABLE D.4.f. Actinide Inventory by Isotope at 45 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Cm-247	1.349E-08	1.349E-08	1.349E-08	1.349E-08	1.349E-08	1.349E-08	1.349E-08
Cm-248	1.066E-09	1.066E-09	1.066E-09	1.066E-09	1.066E-09	1.066E-09	1.064E-09
Bk-249	4.991E-13	1.026E-13	2.108E-14	4.333E-15	8.297E-17	1.589E-18	0.00
Cf-249	1.381E-11	1.415E-11	1.418E-11	1.414E-11	1.400E-11	1.386E-11	1.996E-12
Cf-250	2.380E-12	2.141E-12	1.925E-12	1.732E-12	1.329E-12	1.019E-12	6.855E-22
Cf-251	1.283E-12	1.281E-12	1.279E-12	1.277E-12	1.272E-12	1.267E-12	5.947E-13
Cf-252	3.870E-13	2.288E-13	1.353E-13	7.999E-14	2.150E-14	5.780E-15	0.00
Total	9.538E-01	9.538E-01	9.538E-01	9.538E-01	9.538E-01	9.538E-01	9.538E-01

TABLE D.4.g. Actinide Inventory by Isotope at 50 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
He-4	2.884E-06	3.203E-06	3.512E-06	3.814E-06	4.536E-06	5.216E-06	4.311E-05
Pb-207	3.935E-15	6.892E-15	1.069E-14	1.528E-14	3.003E-14	4.903E-14	3.255E-11
Pb-208	4.547E-11	8.415E-11	1.313E-10	1.841E-10	3.275E-10	4.742E-10	3.543E-09
Pb-212	2.978E-14	3.877E-14	4.495E-14	4.887E-14	5.238E-14	5.186E-14	4.862E-18
Bi-209	2.240E-15	2.815E-15	3.394E-15	3.978E-15	5.461E-15	6.989E-15	2.346E-11
Bi-212	2.825E-15	3.678E-15	4.264E-15	4.636E-15	4.969E-15	4.919E-15	4.611E-19
Ra-224	2.597E-13	3.382E-13	3.922E-13	4.263E-13	4.569E-13	4.524E-13	4.241E-17
Ra-226	1.126E-13	1.670E-13	2.340E-13	3.144E-13	5.770E-13	9.343E-13	4.475E-09
Ac-227	4.386E-14	5.859E-14	7.263E-14	8.602E-14	1.169E-13	1.446E-13	2.061E-12
Th-228	5.044E-11	6.559E-11	7.604E-11	8.265E-11	8.872E-11	8.784E-11	8.241E-15
Th-229	3.326E-12	3.347E-12	3.372E-12	3.400E-12	3.490E-12	3.604E-12	8.897E-10
Th-230	2.730E-09	3.436E-09	4.174E-09	4.944E-09	7.006E-09	9.257E-09	1.251E-06
Th-231	1.136E-14	1.136E-14	1.136E-14	1.136E-14	1.136E-14	1.136E-14	1.194E-14
Th-232	9.116E-10	1.150E-09	1.389E-09	1.628E-09	2.225E-09	2.822E-09	1.242E-07
Th-234	1.349E-11	1.349E-11	1.349E-11	1.349E-11	1.349E-11	1.349E-11	1.349E-11
Pa-231	4.302E-10	4.356E-10	4.410E-10	4.464E-10	4.599E-10	4.733E-10	3.155E-09
Pa-233	2.403E-11	2.408E-11	2.414E-11	2.421E-11	2.443E-11	2.470E-11	7.098E-11
U-232	2.862E-09	3.183E-09	3.353E-09	3.432E-09	3.427E-09	3.312E-09	3.077E-13
U-233	2.236E-09	2.711E-09	3.187E-09	3.664E-09	4.804E-09	5.955E-09	4.957E-07
U-234	1.237E-04	1.295E-04	1.353E-04	1.410E-04	1.549E-04	1.682E-04	4.991E-04
U-235	2.793E-03	2.793E-03	2.793E-03	2.794E-03	2.794E-03	2.795E-03	2.935E-03
U-236	4.102E-03	4.102E-03	4.103E-03	4.103E-03	4.105E-03	4.106E-03	4.397E-03
U-237	4.369E-11	3.968E-11	3.604E-11	3.273E-11	2.573E-11	2.022E-11	3.896E-16
U-238	9.293E-01	9.293E-01	9.293E-01	9.293E-01	9.293E-01	9.293E-01	9.293E-01
Np-235	6.145E-13	1.711E-13	4.766E-14	1.327E-14	5.431E-16	2.222E-17	0.00
Np-236	7.583E-10	7.583E-10	7.583E-10	7.583E-10	7.583E-10	7.583E-10	7.538E-10
Np-237	7.076E-04	7.089E-04	7.107E-04	7.128E-04	7.193E-04	7.274E-04	2.090E-03
Np-238	2.862E-13	2.836E-13	2.810E-13	2.785E-13	2.722E-13	2.661E-13	3.050E-15
Np-239	2.866E-10	2.865E-10	2.865E-10	2.864E-10	2.863E-10	2.862E-10	2.610E-10
Pu-236	1.003E-09	6.168E-10	3.793E-10	2.332E-10	6.916E-11	2.051E-11	1.682E-15
Pu-238	3.818E-04	3.759E-04	3.701E-04	3.643E-04	3.502E-04	3.366E-04	1.636E-07
Pu-239	5.109E-03	5.108E-03	5.108E-03	5.108E-03	5.108E-03	5.107E-03	4.994E-03
Pu-240	2.863E-03	2.873E-03	2.882E-03	2.890E-03	2.909E-03	2.924E-03	2.706E-03
Pu-241	1.411E-03	1.282E-03	1.164E-03	1.057E-03	8.309E-04	6.532E-04	1.260E-08
Pu-242	1.079E-03	1.079E-03	1.079E-03	1.079E-03	1.079E-03	1.079E-03	1.078E-03
Pu-244	1.338E-07	1.338E-07	1.338E-07	1.338E-07	1.338E-07	1.338E-07	1.338E-07
Am-241	3.638E-04	4.919E-04	6.078E-04	7.125E-04	9.320E-04	1.102E-03	3.695E-04
Am-242m	1.527E-06	1.513E-06	1.499E-06	1.485E-06	1.452E-06	1.419E-06	1.627E-08
Am-242	1.826E-11	1.809E-11	1.793E-11	1.777E-11	1.737E-11	1.698E-11	1.946E-13
Am-243	3.335E-04	3.334E-04	3.334E-04	3.333E-04	3.331E-04	3.330E-04	3.037E-04
Cm-242	6.723E-08	6.519E-09	3.760E-09	3.605E-09	3.513E-09	3.434E-09	3.934E-11
Cm-243	1.229E-06	1.170E-06	1.115E-06	1.062E-06	9.403E-07	8.327E-07	3.710E-17
Cm-244	1.461E-04	1.353E-04	1.253E-04	1.161E-04	9.588E-05	7.918E-05	4.060E-21
Cm-245	8.186E-06	8.185E-06	8.183E-06	8.182E-06	8.179E-06	8.175E-06	7.547E-06
Cm-246	1.924E-06	1.923E-06	1.923E-06	1.922E-06	1.921E-06	1.919E-06	1.663E-06

TABLE D.4.g. Actinide Inventory by Isotope at 50 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Cm-247	3.011E-08	3.011E-08	3.011E-08	3.011E-08	3.011E-08	3.011E-08	3.011E-08
Cm-248	2.775E-09	2.775E-09	2.775E-09	2.776E-09	2.776E-09	2.776E-09	2.770E-09
Bk-249	1.409E-12	2.896E-13	5.951E-14	1.223E-14	2.342E-16	4.485E-18	0.00
Cf-249	3.861E-11	3.957E-11	3.964E-11	3.953E-11	3.916E-11	3.877E-11	5.582E-12
Cf-250	6.955E-12	6.255E-12	5.626E-12	5.061E-12	3.883E-12	2.979E-12	2.463E-21
Cf-251	3.882E-12	3.876E-12	3.870E-12	3.864E-12	3.849E-12	3.834E-12	1.800E-12
Cf-252	1.369E-12	8.095E-13	4.786E-13	2.830E-13	7.607E-14	2.045E-14	0.00
Total	9.487E-01	9.487E-01	9.487E-01	9.487E-01	9.487E-01	9.487E-01	9.487E-01

TABLE D.5.a. Fission Product Inventory by Element at 20 MWd/kgM, g/gU

Element	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H	2.461E-08	2.200E-08	1.966E-08	1.757E-08	1.327E-08	1.002E-08	1.292E-32
Li	1.570E-10	1.570E-10	1.570E-10	1.570E-10	1.570E-10	1.570E-10	1.570E-10
Be	9.079E-11	9.079E-11	9.079E-11	9.079E-11	9.079E-11	9.079E-11	9.076E-11
C	1.595E-11	1.595E-11	1.595E-11	1.594E-11	1.593E-11	1.592E-11	1.414E-11
Zn	2.534E-14	2.534E-14	2.534E-14	2.534E-14	2.534E-14	2.534E-14	2.534E-14
Ga	5.077E-13	5.077E-13	5.077E-13	5.077E-13	5.077E-13	5.077E-13	5.077E-13
Ge	4.093E-07	4.093E-07	4.093E-07	4.093E-07	4.093E-07	4.093E-07	4.093E-07
As	1.240E-07	1.240E-07	1.240E-07	1.240E-07	1.240E-07	1.240E-07	1.240E-07
Se	3.553E-05	3.553E-05	3.553E-05	3.553E-05	3.553E-05	3.552E-05	3.549E-05
Br	1.387E-05	1.387E-05	1.387E-05	1.387E-05	1.387E-05	1.387E-05	1.391E-05
Kr	2.340E-04	2.327E-04	2.315E-04	2.305E-04	2.285E-04	2.270E-04	2.231E-04
Rb	2.270E-04	2.284E-04	2.295E-04	2.305E-04	2.326E-04	2.341E-04	2.379E-04
Sr	5.364E-04	5.221E-04	5.085E-04	4.955E-04	4.655E-04	4.390E-04	2.288E-04
Y	2.994E-04	2.994E-04	2.994E-04	2.994E-04	2.994E-04	2.994E-04	2.994E-04
Zr	2.268E-03	2.282E-03	2.296E-03	2.309E-03	2.339E-03	2.365E-03	2.575E-03
Nb	1.822E-09	2.234E-09	2.649E-09	3.065E-09	4.104E-09	5.143E-09	2.088E-07
Mo	2.043E-03	2.043E-03	2.043E-03	2.043E-03	2.043E-03	2.043E-03	2.043E-03
Tc	4.894E-04	4.894E-04	4.894E-04	4.894E-04	4.894E-04	4.894E-04	4.878E-04
Ru	1.243E-03	1.241E-03	1.240E-03	1.240E-03	1.240E-03	1.240E-03	1.242E-03
Rh	3.033E-04	3.033E-04	3.033E-04	3.033E-04	3.033E-04	3.033E-04	3.033E-04
Pd	6.524E-04	6.547E-04	6.553E-04	6.554E-04	6.555E-04	6.555E-04	6.555E-04
Ag	3.931E-05	3.931E-05	3.931E-05	3.931E-05	3.931E-05	3.931E-05	3.932E-05
Cd	4.834E-05	4.834E-05	4.833E-05	4.832E-05	4.831E-05	4.830E-05	4.825E-05
In	2.091E-06	2.100E-06	2.108E-06	2.115E-06	2.131E-06	2.143E-06	2.190E-06
Sn	5.101E-05	5.101E-05	5.101E-05	5.101E-05	5.101E-05	5.101E-05	5.090E-05
Sb	1.310E-05	1.222E-05	1.169E-05	1.137E-05	1.102E-05	1.092E-05	1.088E-05
Te	2.804E-04	2.813E-04	2.818E-04	2.821E-04	2.825E-04	2.826E-04	2.828E-04
I	1.374E-04	1.374E-04	1.374E-04	1.374E-04	1.374E-04	1.374E-04	1.374E-04
Xe	3.015E-03	3.015E-03	3.015E-03	3.015E-03	3.015E-03	3.015E-03	3.015E-03
Cs	1.728E-03	1.695E-03	1.665E-03	1.638E-03	1.576E-03	1.522E-03	1.082E-03
Ba	9.514E-04	9.847E-04	1.015E-03	1.042E-03	1.103E-03	1.158E-03	1.598E-03
La	7.498E-04	7.498E-04	7.498E-04	7.498E-04	7.498E-04	7.498E-04	7.498E-04
Ce	1.451E-03	1.448E-03	1.448E-03	1.448E-03	1.448E-03	1.448E-03	1.448E-03
Pr	6.924E-04	6.924E-04	6.924E-04	6.924E-04	6.924E-04	6.924E-04	6.924E-04
Nd	2.473E-03	2.476E-03	2.476E-03	2.477E-03	2.477E-03	2.477E-03	2.477E-03
Pm	3.316E-05	1.955E-05	1.153E-05	6.795E-06	1.813E-06	4.840E-07	0.00
Sm	4.925E-04	5.060E-04	5.139E-04	5.184E-04	5.231E-04	5.241E-04	5.160E-04
Eu	6.882E-05	6.671E-05	6.500E-05	6.363E-05	6.123E-05	5.985E-05	6.528E-05
Gd	3.722E-05	3.947E-05	4.132E-05	4.284E-05	4.557E-05	4.729E-05	5.040E-05
Tb	1.207E-06	1.207E-06	1.207E-06	1.207E-06	1.207E-06	1.207E-06	1.207E-06
Dy	6.037E-07	6.037E-07	6.037E-07	6.037E-07	6.037E-07	6.037E-07	6.037E-07
Ho	4.960E-08	4.960E-08	4.960E-08	4.960E-08	4.960E-08	4.960E-08	4.946E-08
Er	1.950E-08	1.950E-08	1.950E-08	1.950E-08	1.951E-08	1.951E-08	1.964E-08
Tm	1.335E-11	1.334E-11	1.334E-11	1.334E-11	1.334E-11	1.334E-11	1.334E-11
Yb	2.557E-12	2.561E-12	2.563E-12	2.564E-12	2.565E-12	2.565E-12	2.565E-12
Total	2.061E-02	2.061E-02	2.061E-02	2.061E-02	2.061E-02	2.061E-02	2.061E-02

TABLE D.5.b. Fission Product Inventory by Element at 25 MWd/kgM, g/gU

Element	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H	3.140E-08	2.806E-08	2.508E-08	2.242E-08	1.693E-08	1.279E-08	1.649E-32
Li	1.709E-10	1.709E-10	1.709E-10	1.709E-10	1.709E-10	1.709E-10	1.709E-10
Be	1.133E-10	1.133E-10	1.133E-10	1.133E-10	1.133E-10	1.133E-10	1.132E-10
C	1.990E-11	1.990E-11	1.989E-11	1.989E-11	1.988E-11	1.986E-11	1.764E-11
Zn	3.018E-14	3.018E-14	3.018E-14	3.018E-14	3.018E-14	3.018E-14	3.018E-14
Ga	6.547E-13	6.547E-13	6.547E-13	6.547E-13	6.547E-13	6.547E-13	6.547E-13
Ge	5.066E-07	5.066E-07	5.066E-07	5.066E-07	5.066E-07	5.066E-07	5.066E-07
As	1.538E-07	1.538E-07	1.538E-07	1.538E-07	1.538E-07	1.538E-07	1.538E-07
Se	4.355E-05	4.355E-05	4.355E-05	4.355E-05	4.355E-05	4.355E-05	4.350E-05
Br	1.692E-05	1.692E-05	1.692E-05	1.692E-05	1.692E-05	1.692E-05	1.696E-05
Kr	2.832E-04	2.816E-04	2.802E-04	2.790E-04	2.765E-04	2.747E-04	2.700E-04
Rb	2.737E-04	2.753E-04	2.767E-04	2.779E-04	2.804E-04	2.822E-04	2.869E-04
Sr	6.450E-04	6.279E-04	6.115E-04	5.958E-04	5.599E-04	5.280E-04	2.754E-04
Y	3.598E-04	3.598E-04	3.598E-04	3.598E-04	3.598E-04	3.598E-04	3.597E-04
Zr	2.769E-03	2.787E-03	2.803E-03	2.819E-03	2.855E-03	2.886E-03	3.139E-03
Nb	2.286E-09	2.788E-09	3.294E-09	3.800E-09	5.066E-09	6.332E-09	2.544E-07
Mo	2.539E-03	2.539E-03	2.539E-03	2.539E-03	2.539E-03	2.539E-03	2.539E-03
Tc	5.998E-04	5.998E-04	5.998E-04	5.998E-04	5.998E-04	5.998E-04	5.978E-04
Ru	1.599E-03	1.596E-03	1.595E-03	1.595E-03	1.595E-03	1.595E-03	1.597E-03
Rh	3.675E-04	3.675E-04	3.675E-04	3.675E-04	3.675E-04	3.675E-04	3.675E-04
Pd	9.212E-04	9.245E-04	9.253E-04	9.255E-04	9.256E-04	9.256E-04	9.255E-04
Ag	5.399E-05	5.398E-05	5.398E-05	5.398E-05	5.398E-05	5.398E-05	5.400E-05
Cd	6.944E-05	6.943E-05	6.942E-05	6.941E-05	6.939E-05	6.937E-05	6.931E-05
In	2.254E-06	2.266E-06	2.277E-06	2.287E-06	2.309E-06	2.326E-06	2.390E-06
Sn	6.616E-05	6.616E-05	6.616E-05	6.616E-05	6.616E-05	6.616E-05	6.602E-05
Sb	1.673E-05	1.559E-05	1.490E-05	1.448E-05	1.402E-05	1.389E-05	1.384E-05
Te	3.575E-04	3.587E-04	3.594E-04	3.598E-04	3.602E-04	3.604E-04	3.606E-04
I	1.753E-04	1.753E-04	1.753E-04	1.753E-04	1.753E-04	1.753E-04	1.752E-04
Xe	3.839E-03	3.839E-03	3.839E-03	3.839E-03	3.839E-03	3.839E-03	3.839E-03
Cs	2.086E-03	2.043E-03	2.005E-03	1.971E-03	1.893E-03	1.826E-03	1.275E-03
Ba	1.199E-03	1.242E-03	1.280E-03	1.315E-03	1.392E-03	1.460E-03	2.010E-03
La	9.288E-04	9.288E-04	9.288E-04	9.288E-04	9.288E-04	9.288E-04	9.288E-04
Ce	1.801E-03	1.798E-03	1.797E-03	1.797E-03	1.797E-03	1.797E-03	1.797E-03
Pr	8.558E-04	8.558E-04	8.558E-04	8.558E-04	8.558E-04	8.558E-04	8.558E-04
Nd	3.064E-03	3.067E-03	3.068E-03	3.068E-03	3.068E-03	3.068E-03	3.068E-03
Pm	3.673E-05	2.165E-05	1.277E-05	7.526E-06	2.009E-06	5.361E-07	0.00
Sm	6.045E-04	6.195E-04	6.282E-04	6.333E-04	6.384E-04	6.395E-04	6.308E-04
Eu	9.605E-05	9.270E-05	8.998E-05	8.777E-05	8.386E-05	8.153E-05	8.589E-05
Gd	5.841E-05	6.192E-05	6.479E-05	6.716E-05	7.143E-05	7.412E-05	7.903E-05
Tb	1.714E-06	1.714E-06	1.714E-06	1.714E-06	1.714E-06	1.714E-06	1.714E-06
Dy	8.835E-07	8.835E-07	8.835E-07	8.835E-07	8.835E-07	8.835E-07	8.835E-07
Ho	7.993E-08	7.993E-08	7.993E-08	7.993E-08	7.993E-08	7.993E-08	7.966E-08
Er	3.100E-08	3.100E-08	3.100E-08	3.100E-08	3.100E-08	3.101E-08	3.127E-08
Tm	2.584E-11	2.583E-11	2.582E-11	2.582E-11	2.582E-11	2.582E-11	2.582E-11
Yb	6.413E-12	6.427E-12	6.433E-12	6.436E-12	6.439E-12	6.439E-12	6.439E-12
Total	2.573E-02	2.573E-02	2.573E-02	2.573E-02	2.573E-02	2.573E-02	2.573E-02

TABLE D.5.c. Fission Product Inventory by Element at 30 MWd/kgM, g/gU

Element	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H	3.838E-08	3.431E-08	3.066E-08	2.741E-08	2.070E-08	1.563E-08	2.017E-32
Li	1.784E-10	1.784E-10	1.784E-10	1.784E-10	1.784E-10	1.784E-10	1.784E-10
Be	1.357E-10	1.357E-10	1.357E-10	1.357E-10	1.357E-10	1.357E-10	1.356E-10
C	2.384E-11	2.383E-11	2.383E-11	2.382E-11	2.381E-11	2.379E-11	2.113E-11
Zn	3.458E-14	3.458E-14	3.458E-14	3.458E-14	3.458E-14	3.458E-14	3.458E-14
Ga	8.052E-13	8.052E-13	8.052E-13	8.052E-13	8.052E-13	8.052E-13	8.052E-13
Ge	6.025E-07	6.025E-07	6.025E-07	6.025E-07	6.025E-07	6.025E-07	6.025E-07
As	1.831E-07	1.831E-07	1.831E-07	1.831E-07	1.831E-07	1.831E-07	1.831E-07
Se	5.129E-05	5.129E-05	5.129E-05	5.129E-05	5.129E-05	5.129E-05	5.124E-05
Br	1.981E-05	1.981E-05	1.981E-05	1.981E-05	1.981E-05	1.981E-05	1.987E-05
Kr	3.296E-04	3.277E-04	3.261E-04	3.246E-04	3.218E-04	3.197E-04	3.143E-04
Rb	3.173E-04	3.192E-04	3.208E-04	3.222E-04	3.251E-04	3.272E-04	3.326E-04
Sr	7.460E-04	7.262E-04	7.072E-04	6.892E-04	6.476E-04	6.107E-04	3.189E-04
Y	4.158E-04	4.158E-04	4.158E-04	4.158E-04	4.158E-04	4.158E-04	4.157E-04
Zr	3.251E-03	3.271E-03	3.290E-03	3.308E-03	3.349E-03	3.386E-03	3.678E-03
Nb	2.746E-09	3.334E-09	3.927E-09	4.520E-09	6.002E-09	7.485E-09	2.980E-07
Mo	3.030E-03	3.030E-03	3.030E-03	3.030E-03	3.030E-03	3.030E-03	3.030E-03
Tc	7.048E-04	7.048E-04	7.048E-04	7.048E-04	7.048E-04	7.048E-04	7.025E-04
Ru	1.971E-03	1.967E-03	1.965E-03	1.965E-03	1.965E-03	1.965E-03	1.967E-03
Rh	4.244E-04	4.244E-04	4.244E-04	4.244E-04	4.244E-04	4.244E-04	4.244E-04
Pd	1.226E-03	1.230E-03	1.231E-03	1.231E-03	1.231E-03	1.231E-03	1.231E-03
Ag	6.935E-05	6.934E-05	6.934E-05	6.934E-05	6.934E-05	6.934E-05	6.936E-05
Cd	9.498E-05	9.497E-05	9.495E-05	9.494E-05	9.491E-05	9.489E-05	9.480E-05
In	2.362E-06	2.379E-06	2.393E-06	2.407E-06	2.436E-06	2.458E-06	2.543E-06
Sn	8.209E-05	8.209E-05	8.209E-05	8.209E-05	8.209E-05	8.208E-05	8.191E-05
Sb	2.046E-05	1.905E-05	1.819E-05	1.767E-05	1.710E-05	1.693E-05	1.687E-05
Te	4.365E-04	4.380E-04	4.388E-04	4.393E-04	4.399E-04	4.401E-04	4.403E-04
I	2.135E-04	2.135E-04	2.135E-04	2.135E-04	2.135E-04	2.135E-04	2.135E-04
Xe	4.676E-03	4.676E-03	4.676E-03	4.676E-03	4.676E-03	4.676E-03	4.676E-03
Cs	2.428E-03	2.375E-03	2.328E-03	2.286E-03	2.193E-03	2.112E-03	1.450E-03
Ba	1.451E-03	1.504E-03	1.551E-03	1.593E-03	1.686E-03	1.767E-03	2.429E-03
La	1.105E-03	1.105E-03	1.105E-03	1.105E-03	1.105E-03	1.105E-03	1.105E-03
Ce	2.148E-03	2.144E-03	2.143E-03	2.143E-03	2.143E-03	2.143E-03	2.143E-03
Pr	1.015E-03	1.015E-03	1.015E-03	1.015E-03	1.015E-03	1.015E-03	1.015E-03
Nd	3.647E-03	3.651E-03	3.651E-03	3.651E-03	3.651E-03	3.651E-03	3.651E-03
Pm	3.903E-05	2.301E-05	1.357E-05	7.999E-06	2.135E-06	5.699E-07	0.00
Sm	7.114E-04	7.273E-04	7.366E-04	7.420E-04	7.474E-04	7.486E-04	7.394E-04
Eu	1.251E-04	1.202E-04	1.163E-04	1.131E-04	1.074E-04	1.039E-04	1.067E-04
Gd	8.656E-05	9.155E-05	9.565E-05	9.903E-05	1.051E-04	1.090E-04	1.160E-04
Tb	2.287E-06	2.287E-06	2.287E-06	2.287E-06	2.287E-06	2.287E-06	2.287E-06
Dy	1.217E-06	1.217E-06	1.217E-06	1.217E-06	1.217E-06	1.217E-06	1.217E-06
Ho	1.216E-07	1.216E-07	1.216E-07	1.216E-07	1.216E-07	1.216E-07	1.211E-07
Er	4.731E-08	4.731E-08	4.731E-08	4.732E-08	4.732E-08	4.732E-08	4.781E-08
Tm	4.476E-11	4.472E-11	4.470E-11	4.469E-11	4.469E-11	4.468E-11	4.468E-11
Yb	1.378E-11	1.381E-11	1.383E-11	1.384E-11	1.385E-11	1.385E-11	1.385E-11
Total	3.084E-02	3.084E-02	3.084E-02	3.084E-02	3.084E-02	3.084E-02	3.084E-02

TABLE D.5.d. Fission Product Inventory by Element at 35 MWd/kgM, g/gU

Element	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H	4.555E-08	4.072E-08	3.639E-08	3.253E-08	2.457E-08	1.856E-08	2.394E-32
Li	1.810E-10	1.810E-10	1.810E-10	1.810E-10	1.810E-10	1.810E-10	1.810E-10
Be	1.580E-10	1.580E-10	1.580E-10	1.580E-10	1.580E-10	1.580E-10	1.579E-10
C	2.776E-11	2.776E-11	2.775E-11	2.774E-11	2.773E-11	2.771E-11	2.461E-11
Zn	3.855E-14	3.855E-14	3.855E-14	3.855E-14	3.855E-14	3.855E-14	3.855E-14
Ga	9.584E-13	9.584E-13	9.584E-13	9.584E-13	9.584E-13	9.584E-13	9.584E-13
Ge	6.971E-07	6.971E-07	6.971E-07	6.971E-07	6.971E-07	6.971E-07	6.971E-07
As	2.121E-07	2.121E-07	2.121E-07	2.121E-07	2.121E-07	2.121E-07	2.121E-07
Se	5.875E-05	5.875E-05	5.875E-05	5.875E-05	5.875E-05	5.875E-05	5.869E-05
Br	2.254E-05	2.254E-05	2.254E-05	2.254E-05	2.254E-05	2.254E-05	2.261E-05
Kr	3.732E-04	3.711E-04	3.692E-04	3.676E-04	3.643E-04	3.620E-04	3.558E-04
Rb	3.579E-04	3.600E-04	3.618E-04	3.634E-04	3.667E-04	3.690E-04	3.752E-04
Sr	8.393E-04	8.170E-04	7.957E-04	7.754E-04	7.287E-04	6.873E-04	3.592E-04
Y	4.674E-04	4.674E-04	4.674E-04	4.674E-04	4.674E-04	4.674E-04	4.673E-04
Zr	3.712E-03	3.735E-03	3.756E-03	3.776E-03	3.823E-03	3.864E-03	4.192E-03
Nb	3.202E-09	3.872E-09	4.547E-09	5.222E-09	6.910E-09	8.598E-09	3.394E-07
Mo	3.516E-03	3.516E-03	3.516E-03	3.516E-03	3.516E-03	3.516E-03	3.516E-03
Tc	8.041E-04	8.041E-04	8.041E-04	8.041E-04	8.041E-04	8.041E-04	8.015E-04
Ru	2.358E-03	2.353E-03	2.351E-03	2.351E-03	2.351E-03	2.351E-03	2.353E-03
Rh	4.740E-04	4.740E-04	4.740E-04	4.740E-04	4.740E-04	4.740E-04	4.740E-04
Pd	1.566E-03	1.571E-03	1.572E-03	1.573E-03	1.573E-03	1.573E-03	1.573E-03
Ag	8.521E-05	8.520E-05	8.520E-05	8.519E-05	8.520E-05	8.520E-05	8.522E-05
Cd	1.254E-04	1.254E-04	1.254E-04	1.254E-04	1.253E-04	1.253E-04	1.252E-04
In	2.443E-06	2.464E-06	2.483E-06	2.500E-06	2.537E-06	2.566E-06	2.675E-06
Sn	9.878E-05	9.878E-05	9.878E-05	9.878E-05	9.877E-05	9.877E-05	9.857E-05
Sb	2.431E-05	2.260E-05	2.156E-05	2.093E-05	2.024E-05	2.005E-05	1.997E-05
Te	5.173E-04	5.190E-04	5.201E-04	5.207E-04	5.214E-04	5.216E-04	5.219E-04
I	2.520E-04	2.520E-04	2.520E-04	2.520E-04	2.520E-04	2.520E-04	2.520E-04
Xe	5.525E-03	5.525E-03	5.525E-03	5.525E-03	5.525E-03	5.525E-03	5.525E-03
Cs	2.757E-03	2.692E-03	2.637E-03	2.588E-03	2.479E-03	2.383E-03	1.611E-03
Ba	1.707E-03	1.771E-03	1.826E-03	1.876E-03	1.985E-03	2.080E-03	2.852E-03
La	1.278E-03	1.278E-03	1.278E-03	1.278E-03	1.278E-03	1.278E-03	1.278E-03
Ce	2.491E-03	2.486E-03	2.485E-03	2.485E-03	2.485E-03	2.485E-03	2.485E-03
Pr	1.171E-03	1.171E-03	1.171E-03	1.171E-03	1.171E-03	1.171E-03	1.171E-03
Nd	4.222E-03	4.227E-03	4.228E-03	4.228E-03	4.228E-03	4.228E-03	4.228E-03
Pm	4.037E-05	2.380E-05	1.403E-05	8.272E-06	2.208E-06	5.894E-07	0.00
Sm	8.130E-04	8.294E-04	8.390E-04	8.446E-04	8.503E-04	8.515E-04	8.416E-04
Eu	1.547E-04	1.482E-04	1.430E-04	1.386E-04	1.309E-04	1.262E-04	1.273E-04
Gd	1.229E-04	1.296E-04	1.350E-04	1.395E-04	1.476E-04	1.527E-04	1.621E-04
Tb	2.931E-06	2.931E-06	2.931E-06	2.931E-06	2.931E-06	2.931E-06	2.931E-06
Dy	1.607E-06	1.607E-06	1.607E-06	1.607E-06	1.607E-06	1.607E-06	1.607E-06
Ho	1.777E-07	1.777E-07	1.777E-07	1.777E-07	1.777E-07	1.777E-07	1.769E-07
Er	7.041E-08	7.041E-08	7.041E-08	7.041E-08	7.042E-08	7.042E-08	7.125E-08
Tm	7.213E-11	7.204E-11	7.200E-11	7.198E-11	7.197E-11	7.196E-11	7.196E-11
Yb	2.667E-11	2.676E-11	2.680E-11	2.682E-11	2.684E-11	2.684E-11	2.684E-11
Total	3.594E-02	3.594E-02	3.594E-02	3.594E-02	3.594E-02	3.594E-02	3.594E-02

TABLE D.5.e. Fission Product Inventory by Element at 40 MWd/kgM, g/gU

Element	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H	5.290E-08	4.728E-08	4.226E-08	3.777E-08	2.853E-08	2.155E-08	2.779E-32
Li	1.805E-10	1.805E-10	1.805E-10	1.805E-10	1.805E-10	1.805E-10	1.805E-10
Be	1.802E-10	1.802E-10	1.802E-10	1.802E-10	1.802E-10	1.802E-10	1.802E-10
C	3.167E-11	3.167E-11	3.166E-11	3.165E-11	3.163E-11	3.161E-11	2.808E-11
Zn	4.214E-14	4.214E-14	4.214E-14	4.214E-14	4.214E-14	4.214E-14	4.214E-14
Ga	1.113E-12	1.113E-12	1.113E-12	1.113E-12	1.113E-12	1.113E-12	1.113E-12
Ge	7.904E-07	7.904E-07	7.904E-07	7.904E-07	7.904E-07	7.904E-07	7.904E-07
As	2.405E-07	2.405E-07	2.405E-07	2.405E-07	2.405E-07	2.405E-07	2.405E-07
Se	6.595E-05	6.595E-05	6.595E-05	6.595E-05	6.595E-05	6.595E-05	6.588E-05
Br	2.512E-05	2.512E-05	2.513E-05	2.513E-05	2.513E-05	2.513E-05	2.520E-05
Kr	4.142E-04	4.119E-04	4.099E-04	4.081E-04	4.045E-04	4.019E-04	3.950E-04
Rb	3.957E-04	3.980E-04	4.001E-04	4.019E-04	4.055E-04	4.081E-04	4.149E-04
Sr	9.258E-04	9.012E-04	8.777E-04	8.554E-04	8.039E-04	7.582E-04	3.966E-04
Y	5.151E-04	5.151E-04	5.151E-04	5.151E-04	5.151E-04	5.151E-04	5.150E-04
Zr	4.155E-03	4.180E-03	4.203E-03	4.226E-03	4.277E-03	4.323E-03	4.684E-03
Nb	3.652E-09	4.399E-09	5.152E-09	5.906E-09	7.790E-09	9.674E-09	3.789E-07
Mo	3.997E-03	3.997E-03	3.997E-03	3.997E-03	3.997E-03	3.997E-03	3.997E-03
Tc	8.978E-04	8.978E-04	8.978E-04	8.978E-04	8.978E-04	8.978E-04	8.949E-04
Ru	2.760E-03	2.753E-03	2.752E-03	2.751E-03	2.751E-03	2.751E-03	2.754E-03
Rh	5.167E-04	5.167E-04	5.167E-04	5.167E-04	5.167E-04	5.167E-04	5.167E-04
Pd	1.938E-03	1.945E-03	1.946E-03	1.947E-03	1.947E-03	1.947E-03	1.947E-03
Ag	1.013E-04	1.013E-04	1.013E-04	1.013E-04	1.013E-04	1.013E-04	1.013E-04
Cd	1.609E-04	1.609E-04	1.608E-04	1.608E-04	1.608E-04	1.607E-04	1.606E-04
In	2.510E-06	2.536E-06	2.560E-06	2.582E-06	2.629E-06	2.665E-06	2.801E-06
Sn	1.161E-04	1.161E-04	1.161E-04	1.161E-04	1.161E-04	1.161E-04	1.159E-04
Sb	2.822E-05	2.621E-05	2.499E-05	2.425E-05	2.343E-05	2.320E-05	2.311E-05
Te	5.996E-04	6.016E-04	6.028E-04	6.036E-04	6.044E-04	6.046E-04	6.050E-04
I	2.905E-04	2.905E-04	2.905E-04	2.905E-04	2.905E-04	2.905E-04	2.905E-04
Xe	6.383E-03	6.383E-03	6.383E-03	6.383E-03	6.383E-03	6.383E-03	6.383E-03
Cs	3.075E-03	2.999E-03	2.935E-03	2.878E-03	2.753E-03	2.644E-03	1.761E-03
Ba	1.967E-03	2.042E-03	2.106E-03	2.164E-03	2.289E-03	2.398E-03	3.281E-03
La	1.449E-03	1.449E-03	1.449E-03	1.449E-03	1.449E-03	1.449E-03	1.449E-03
Ce	2.831E-03	2.826E-03	2.825E-03	2.825E-03	2.825E-03	2.825E-03	2.825E-03
Pr	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03
Nd	4.792E-03	4.797E-03	4.798E-03	4.798E-03	4.798E-03	4.798E-03	4.798E-03
Pm	4.109E-05	2.422E-05	1.428E-05	8.420E-06	2.247E-06	6.000E-07	0.00
Sm	9.097E-04	9.264E-04	9.361E-04	9.418E-04	9.475E-04	9.487E-04	9.383E-04
Eu	1.838E-04	1.756E-04	1.689E-04	1.634E-04	1.536E-04	1.476E-04	1.468E-04
Gd	1.682E-04	1.766E-04	1.835E-04	1.891E-04	1.994E-04	2.058E-04	2.176E-04
Tb	3.646E-06	3.646E-06	3.646E-06	3.646E-06	3.646E-06	3.646E-06	3.646E-06
Dy	2.058E-06	2.058E-06	2.058E-06	2.058E-06	2.058E-06	2.058E-06	2.058E-06
Ho	2.508E-07	2.508E-07	2.508E-07	2.508E-07	2.508E-07	2.508E-07	2.495E-07
Er	1.026E-07	1.026E-07	1.026E-07	1.026E-07	1.026E-07	1.026E-07	1.040E-07
Tm	1.105E-10	1.103E-10	1.103E-10	1.102E-10	1.102E-10	1.102E-10	1.102E-10
Yb	4.776E-11	4.794E-11	4.802E-11	4.806E-11	4.810E-11	4.810E-11	4.810E-11
Total	4.103E-02	4.103E-02	4.103E-02	4.103E-02	4.103E-02	4.103E-02	4.103E-02

TABLE D.5.f. Fission Product Inventory by Element at 45 MWd/kgM, g/gU

Element	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H	6.038E-08	5.396E-08	4.823E-08	4.311E-08	3.256E-08	2.459E-08	3.171E-32
Li	1.784E-10	1.784E-10	1.784E-10	1.784E-10	1.784E-10	1.784E-10	1.784E-10
Be	2.024E-10	2.024E-10	2.024E-10	2.024E-10	2.024E-10	2.024E-10	2.023E-10
C	3.557E-11	3.556E-11	3.556E-11	3.555E-11	3.553E-11	3.550E-11	3.153E-11
Zn	4.539E-14	4.539E-14	4.539E-14	4.539E-14	4.539E-14	4.539E-14	4.539E-14
Ga	1.268E-12	1.268E-12	1.268E-12	1.268E-12	1.268E-12	1.268E-12	1.268E-12
Ge	8.825E-07	8.825E-07	8.825E-07	8.825E-07	8.825E-07	8.825E-07	8.825E-07
As	2.684E-07	2.684E-07	2.684E-07	2.684E-07	2.684E-07	2.684E-07	2.684E-07
Se	7.292E-05	7.292E-05	7.292E-05	7.292E-05	7.291E-05	7.291E-05	7.283E-05
Br	2.756E-05	2.756E-05	2.756E-05	2.756E-05	2.756E-05	2.756E-05	2.764E-05
Kr	4.532E-04	4.506E-04	4.484E-04	4.464E-04	4.425E-04	4.396E-04	4.322E-04
Rb	4.311E-04	4.337E-04	4.359E-04	4.379E-04	4.418E-04	4.447E-04	4.521E-04
Sr	1.006E-03	9.795E-04	9.541E-04	9.298E-04	8.739E-04	8.243E-04	4.316E-04
Y	5.594E-04	5.594E-04	5.594E-04	5.594E-04	5.594E-04	5.593E-04	5.593E-04
Zr	4.582E-03	4.609E-03	4.634E-03	4.659E-03	4.714E-03	4.764E-03	5.156E-03
Nb	4.093E-09	4.915E-09	5.743E-09	6.572E-09	8.643E-09	1.071E-08	4.166E-07
Mo	4.473E-03	4.473E-03	4.473E-03	4.473E-03	4.473E-03	4.473E-03	4.473E-03
Tc	9.860E-04	9.860E-04	9.860E-04	9.860E-04	9.860E-04	9.860E-04	9.829E-04
Ru	3.175E-03	3.167E-03	3.165E-03	3.164E-03	3.164E-03	3.164E-03	3.167E-03
Rh	5.529E-04	5.529E-04	5.529E-04	5.529E-04	5.529E-04	5.529E-04	5.529E-04
Pd	2.338E-03	2.346E-03	2.348E-03	2.348E-03	2.349E-03	2.349E-03	2.349E-03
Ag	1.173E-04	1.173E-04	1.173E-04	1.173E-04	1.173E-04	1.173E-04	1.173E-04
Cd	2.014E-04	2.014E-04	2.014E-04	2.013E-04	2.013E-04	2.012E-04	2.011E-04
In	2.571E-06	2.604E-06	2.633E-06	2.660E-06	2.717E-06	2.762E-06	2.930E-06
Sn	1.340E-04	1.340E-04	1.340E-04	1.340E-04	1.340E-04	1.340E-04	1.337E-04
Sb	3.217E-05	2.985E-05	2.844E-05	2.759E-05	2.665E-05	2.638E-05	2.628E-05
Te	6.831E-04	6.854E-04	6.868E-04	6.877E-04	6.886E-04	6.889E-04	6.893E-04
I	3.288E-04	3.288E-04	3.288E-04	3.288E-04	3.288E-04	3.288E-04	3.288E-04
Xe	7.247E-03	7.247E-03	7.247E-03	7.247E-03	7.247E-03	7.247E-03	7.247E-03
Cs	3.385E-03	3.298E-03	3.225E-03	3.160E-03	3.018E-03	2.896E-03	1.902E-03
Ba	2.230E-03	2.317E-03	2.390E-03	2.455E-03	2.597E-03	2.719E-03	3.713E-03
La	1.617E-03	1.617E-03	1.617E-03	1.617E-03	1.617E-03	1.617E-03	1.617E-03
Ce	3.169E-03	3.163E-03	3.162E-03	3.162E-03	3.162E-03	3.162E-03	3.162E-03
Pr	1.472E-03	1.472E-03	1.472E-03	1.472E-03	1.472E-03	1.472E-03	1.472E-03
Nd	5.356E-03	5.361E-03	5.362E-03	5.362E-03	5.362E-03	5.362E-03	5.362E-03
Pm	4.142E-05	2.442E-05	1.440E-05	8.488E-06	2.266E-06	6.050E-07	0.00
Sm	1.002E-03	1.018E-03	1.028E-03	1.034E-03	1.040E-03	1.041E-03	1.030E-03
Eu	2.114E-04	2.015E-04	1.934E-04	1.868E-04	1.749E-04	1.676E-04	1.651E-04
Gd	2.230E-04	2.330E-04	2.413E-04	2.482E-04	2.605E-04	2.683E-04	2.824E-04
Tb	4.433E-06	4.433E-06	4.433E-06	4.433E-06	4.433E-06	4.433E-06	4.433E-06
Dy	2.567E-06	2.567E-06	2.567E-06	2.567E-06	2.567E-06	2.567E-06	2.567E-06
Ho	3.433E-07	3.433E-07	3.433E-07	3.433E-07	3.432E-07	3.432E-07	3.412E-07
Er	1.467E-07	1.467E-07	1.467E-07	1.467E-07	1.467E-07	1.467E-07	1.488E-07
Tm	1.635E-10	1.632E-10	1.630E-10	1.629E-10	1.629E-10	1.628E-10	1.628E-10
Yb	8.058E-11	8.094E-11	8.110E-11	8.119E-11	8.125E-11	8.126E-11	8.126E-11
Total	4.612E-02	4.612E-02	4.612E-02	4.612E-02	4.612E-02	4.612E-02	4.612E-02

TABLE D.5.g. Fission Product Inventory by Element at 50 MWd/kgM, g/gU

Element	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H	6.797E-08	6.075E-08	5.430E-08	4.853E-08	3.666E-08	2.769E-08	3.571E-32
Li	1.754E-10	1.754E-10	1.754E-10	1.754E-10	1.754E-10	1.754E-10	1.754E-10
Be	2.245E-10	2.245E-10	2.245E-10	2.245E-10	2.245E-10	2.245E-10	2.244E-10
C	3.946E-11	3.945E-11	3.944E-11	3.943E-11	3.941E-11	3.939E-11	3.498E-11
Zn	4.835E-14	4.835E-14	4.835E-14	4.835E-14	4.835E-14	4.835E-14	4.835E-14
Ga	1.424E-12	1.424E-12	1.424E-12	1.424E-12	1.424E-12	1.424E-12	1.424E-12
Ge	9.736E-07	9.736E-07	9.736E-07	9.736E-07	9.736E-07	9.736E-07	9.736E-07
As	2.958E-07	2.958E-07	2.958E-07	2.958E-07	2.958E-07	2.958E-07	2.958E-07
Se	7.968E-05	7.968E-05	7.968E-05	7.968E-05	7.968E-05	7.968E-05	7.959E-05
Br	2.987E-05	2.987E-05	2.987E-05	2.987E-05	2.987E-05	2.988E-05	2.996E-05
Kr	4.902E-04	4.875E-04	4.851E-04	4.829E-04	4.787E-04	4.756E-04	4.675E-04
Rb	4.645E-04	4.673E-04	4.697E-04	4.718E-04	4.761E-04	4.792E-04	4.873E-04
Sr	1.082E-03	1.053E-03	1.026E-03	9.996E-04	9.395E-04	8.863E-04	4.646E-04
Y	6.008E-04	6.008E-04	6.008E-04	6.008E-04	6.008E-04	6.007E-04	6.006E-04
Zr	4.995E-03	5.024E-03	5.051E-03	5.078E-03	5.138E-03	5.191E-03	5.612E-03
Nb	4.527E-09	5.420E-09	6.320E-09	7.220E-09	9.472E-09	1.172E-08	4.528E-07
Mo	4.946E-03	4.946E-03	4.946E-03	4.946E-03	4.946E-03	4.946E-03	4.946E-03
Tc	1.069E-03	1.069E-03	1.069E-03	1.069E-03	1.069E-03	1.069E-03	1.065E-03
Ru	3.602E-03	3.592E-03	3.590E-03	3.589E-03	3.589E-03	3.589E-03	3.593E-03
Rh	5.832E-04	5.832E-04	5.832E-04	5.832E-04	5.832E-04	5.832E-04	5.832E-04
Pd	2.761E-03	2.771E-03	2.773E-03	2.774E-03	2.774E-03	2.774E-03	2.774E-03
Ag	1.329E-04	1.329E-04	1.329E-04	1.329E-04	1.329E-04	1.329E-04	1.329E-04
Cd	2.470E-04	2.470E-04	2.469E-04	2.469E-04	2.468E-04	2.468E-04	2.466E-04
In	2.629E-06	2.668E-06	2.704E-06	2.737E-06	2.806E-06	2.861E-06	3.065E-06
Sn	1.523E-04	1.523E-04	1.523E-04	1.523E-04	1.523E-04	1.523E-04	1.520E-04
Sb	3.615E-05	3.350E-05	3.190E-05	3.093E-05	2.986E-05	2.956E-05	2.944E-05
Te	7.676E-04	7.703E-04	7.719E-04	7.728E-04	7.739E-04	7.742E-04	7.747E-04
I	3.666E-04	3.666E-04	3.666E-04	3.666E-04	3.666E-04	3.666E-04	3.666E-04
Xe	8.116E-03	8.116E-03	8.116E-03	8.116E-03	8.116E-03	8.116E-03	8.116E-03
Cs	3.688E-03	3.589E-03	3.507E-03	3.434E-03	3.276E-03	3.140E-03	2.036E-03
Ba	2.496E-03	2.595E-03	2.677E-03	2.750E-03	2.908E-03	3.044E-03	4.148E-03
La	1.783E-03	1.783E-03	1.783E-03	1.783E-03	1.783E-03	1.783E-03	1.783E-03
Ce	3.504E-03	3.498E-03	3.497E-03	3.497E-03	3.497E-03	3.497E-03	3.497E-03
Pr	1.617E-03	1.617E-03	1.617E-03	1.617E-03	1.617E-03	1.617E-03	1.617E-03
Nd	5.915E-03	5.921E-03	5.922E-03	5.923E-03	5.923E-03	5.923E-03	5.923E-03
Pm	4.153E-05	2.449E-05	1.444E-05	8.511E-06	2.272E-06	6.067E-07	0.00
Sm	1.089E-03	1.106E-03	1.116E-03	1.122E-03	1.127E-03	1.129E-03	1.117E-03
Eu	2.371E-04	2.256E-04	2.162E-04	2.084E-04	1.946E-04	1.860E-04	1.817E-04
Gd	2.868E-04	2.985E-04	3.081E-04	3.161E-04	3.304E-04	3.395E-04	3.559E-04
Tb	5.294E-06	5.294E-06	5.294E-06	5.294E-06	5.294E-06	5.294E-06	5.294E-06
Dy	3.137E-06	3.137E-06	3.137E-06	3.137E-06	3.137E-06	3.137E-06	3.137E-06
Ho	4.571E-07	4.571E-07	4.571E-07	4.571E-07	4.570E-07	4.570E-07	4.539E-07
Er	2.058E-07	2.058E-07	2.058E-07	2.058E-07	2.058E-07	2.058E-07	2.089E-07
Tm	2.363E-10	2.356E-10	2.353E-10	2.352E-10	2.350E-10	2.350E-10	2.350E-10
Yb	1.300E-10	1.306E-10	1.309E-10	1.311E-10	1.312E-10	1.312E-10	1.312E-10
Total	5.119E-02	5.119E-02	5.119E-02	5.119E-02	5.119E-02	5.119E-02	5.119E-02

TABLE D.6.a. Actinide Inventory by Element at 20 MWd/kgM, g/gU

Element	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
He	4.022E-07	4.389E-07	4.777E-07	5.185E-07	6.279E-07	7.456E-07	1.575E-05
Pb	9.243E-12	1.581E-11	2.345E-11	3.177E-11	5.384E-11	7.609E-11	1.014E-09
Ra	2.338E-13	3.351E-13	4.513E-13	5.834E-13	9.882E-13	1.506E-12	2.463E-09
Ac	4.572E-14	6.159E-14	7.754E-14	9.357E-14	1.339E-13	1.746E-13	8.768E-12
Th	5.256E-09	6.476E-09	7.700E-09	8.928E-09	1.202E-08	1.513E-08	7.375E-07
Pa	4.582E-10	4.845E-10	5.108E-10	5.371E-10	6.027E-10	6.683E-10	1.345E-08
U	9.721E-01	9.721E-01	9.721E-01	9.721E-01	9.721E-01	9.721E-01	9.725E-01
Np	2.210E-04	2.216E-04	2.224E-04	2.233E-04	2.261E-04	2.295E-04	7.977E-04
Pu	6.808E-03	6.755E-03	6.706E-03	6.661E-03	6.566E-03	6.491E-03	5.909E-03
Am	1.838E-04	2.358E-04	2.828E-04	3.253E-04	4.143E-04	4.830E-04	1.683E-04
Cm	2.146E-06	1.984E-06	1.844E-06	1.714E-06	1.431E-06	1.196E-06	5.409E-08
Cf	3.545E-15	3.577E-15	3.548E-15	3.510E-15	3.421E-15	3.345E-15	4.999E-16
Total	9.793E-01	9.793E-01	9.793E-01	9.793E-01	9.793E-01	9.793E-01	9.793E-01

TABLE D.6.b. Actinide Inventory by Element at 25 MWd/kgM, g/gU

Element	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
He	6.785E-07	7.351E-07	7.940E-07	8.551E-07	1.016E-06	1.187E-06	2.065E-05
Pb	1.369E-11	2.388E-11	3.588E-11	4.903E-11	8.418E-11	1.198E-10	1.333E-09
Bi	1.188E-15	1.495E-15	1.742E-15	1.945E-15	2.339E-15	2.680E-15	1.131E-11
Ra	2.444E-13	3.457E-13	4.584E-13	5.843E-13	9.641E-13	1.448E-12	2.635E-09
Ac	4.787E-14	6.420E-14	8.036E-14	9.637E-14	1.358E-13	1.744E-13	7.052E-12
Th	4.996E-09	6.173E-09	7.357E-09	8.548E-09	1.155E-08	1.460E-08	8.042E-07
Pa	4.785E-10	4.994E-10	5.203E-10	5.412E-10	5.934E-10	6.456E-10	1.083E-08
U	9.659E-01	9.659E-01	9.659E-01	9.659E-01	9.659E-01	9.659E-01	9.663E-01
Np	3.035E-04	3.043E-04	3.053E-04	3.065E-04	3.102E-04	3.147E-04	1.066E-03
Pu	7.756E-03	7.684E-03	7.619E-03	7.560E-03	7.434E-03	7.334E-03	6.593E-03
Am	2.557E-04	3.247E-04	3.871E-04	4.435E-04	5.617E-04	6.530E-04	2.364E-04
Cm	6.483E-06	6.009E-06	5.586E-06	5.196E-06	4.340E-06	3.631E-06	2.042E-07
Bk	1.114E-15	2.289E-16	4.705E-17	9.670E-18	1.852E-19	3.552E-21	1.370E-29
Cf	3.844E-14	3.869E-14	3.832E-14	3.786E-14	3.681E-14	3.594E-14	5.463E-15
Total	9.742E-01	9.742E-01	9.742E-01	9.742E-01	9.742E-01	9.742E-01	9.742E-01

TABLE D.6.c. Actinide Inventory by Element at 30 MWd/kgM, g/gU

Element	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
He	1.017E-06	1.101E-06	1.186E-06	1.273E-06	1.499E-06	1.732E-06	2.517E-05
Pb	1.896E-11	3.363E-11	5.106E-11	7.029E-11	1.219E-10	1.744E-10	1.751E-09
Bi	1.740E-15	2.205E-15	2.579E-15	2.884E-15	3.470E-15	3.963E-15	1.401E-11
Ra	2.610E-13	3.646E-13	4.757E-13	5.967E-13	9.541E-13	1.407E-12	2.890E-09
Ac	4.886E-14	6.536E-14	8.151E-14	9.731E-14	1.355E-13	1.719E-13	5.597E-12
Th	4.733E-09	5.867E-09	7.010E-09	8.164E-09	1.109E-08	1.409E-08	8.916E-07
Pa	4.895E-10	5.058E-10	5.222E-10	5.386E-10	5.794E-10	6.203E-10	8.610E-09
U	9.598E-01	9.598E-01	9.598E-01	9.598E-01	9.598E-01	9.598E-01	9.603E-01
Np	3.894E-04	3.903E-04	3.915E-04	3.929E-04	3.973E-04	4.027E-04	1.302E-03
Pu	8.594E-03	8.508E-03	8.430E-03	8.359E-03	8.208E-03	8.087E-03	7.202E-03
Am	3.269E-04	4.098E-04	4.848E-04	5.526E-04	6.947E-04	8.044E-04	3.056E-04
Cm	1.568E-05	1.455E-05	1.353E-05	1.259E-05	1.053E-05	8.822E-06	5.893E-07
Bk	7.621E-15	1.566E-15	3.219E-16	6.615E-17	1.267E-18	2.425E-20	1.300E-28
Cf	2.655E-13	2.666E-13	2.636E-13	2.601E-13	2.524E-13	2.460E-13	3.799E-14
Total	9.691E-01	9.691E-01	9.691E-01	9.691E-01	9.691E-01	9.691E-01	9.691E-01

TABLE D.6.d. Actinide Inventory by Element at 35 MWd/kgM, g/gU

Element	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
He	1.407E-06	1.528E-06	1.649E-06	1.771E-06	2.081E-06	2.393E-06	2.988E-05
Pb	2.499E-11	4.492E-11	6.882E-11	9.530E-11	1.667E-10	2.394E-10	2.263E-09
Bi	2.418E-15	3.078E-15	3.612E-15	4.046E-15	4.874E-15	5.560E-15	1.676E-11
Ra	2.832E-13	3.914E-13	5.028E-13	6.203E-13	9.578E-13	1.382E-12	3.216E-09
Ac	4.882E-14	6.523E-14	8.113E-14	9.656E-14	1.332E-13	1.675E-13	4.400E-12
Th	4.468E-09	5.557E-09	6.659E-09	7.776E-09	1.063E-08	1.358E-08	9.962E-07
Pa	4.919E-10	5.045E-10	5.171E-10	5.298E-10	5.614E-10	5.930E-10	6.784E-09
U	9.538E-01	9.538E-01	9.538E-01	9.538E-01	9.538E-01	9.538E-01	9.543E-01
Np	4.767E-04	4.778E-04	4.792E-04	4.808E-04	4.859E-04	4.922E-04	1.541E-03
Pu	9.317E-03	9.217E-03	9.126E-03	9.043E-03	8.866E-03	8.726E-03	7.701E-03
Am	4.094E-04	5.067E-04	5.947E-04	6.742E-04	8.408E-04	9.695E-04	3.880E-04
Cm	3.231E-05	3.002E-05	2.793E-05	2.600E-05	2.177E-05	1.827E-05	1.404E-06
Bk	3.841E-14	7.895E-15	1.623E-15	3.335E-16	6.385E-18	1.223E-19	8.775E-28
Cf	1.351E-12	1.353E-12	1.336E-12	1.317E-12	1.275E-12	1.242E-12	1.945E-13
Total	9.640E-01	9.640E-01	9.640E-01	9.640E-01	9.640E-01	9.640E-01	9.640E-01

TABLE D.6.e. Actinide Inventory by Element at 40 MWd/kgM, g/gU

Element	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
He	1.854E-06	2.025E-06	2.194E-06	2.362E-06	2.780E-06	3.192E-06	3.451E-05
Pb	3.157E-11	5.741E-11	8.859E-11	1.233E-10	2.171E-10	3.128E-10	2.854E-09
Bi	3.210E-15	4.101E-15	4.823E-15	5.412E-15	6.530E-15	7.447E-15	1.933E-11
Ra	3.101E-13	4.250E-13	5.383E-13	6.537E-13	9.740E-13	1.372E-12	3.603E-09
Ac	4.787E-14	6.391E-14	7.936E-14	9.424E-14	1.292E-13	1.613E-13	3.433E-12
Th	4.206E-09	5.251E-09	6.314E-09	7.395E-09	1.018E-08	1.309E-08	1.116E-06
Pa	4.859E-10	4.956E-10	5.052E-10	5.149E-10	5.390E-10	5.632E-10	5.311E-09
U	9.478E-01	9.478E-01	9.479E-01	9.479E-01	9.479E-01	9.479E-01	9.485E-01
Np	5.608E-04	5.620E-04	5.636E-04	5.654E-04	5.711E-04	5.781E-04	1.759E-03
Pu	9.921E-03	9.809E-03	9.707E-03	9.614E-03	9.416E-03	9.258E-03	8.111E-03
Am	5.007E-04	6.108E-04	7.103E-04	8.003E-04	9.888E-04	1.134E-03	4.787E-04
Cm	5.954E-05	5.536E-05	5.153E-05	4.799E-05	4.022E-05	3.380E-05	2.907E-06
Bk	1.519E-13	3.122E-14	6.417E-15	1.319E-15	2.525E-17	4.836E-19	4.545E-27
Cf	5.390E-12	5.387E-12	5.309E-12	5.227E-12	5.053E-12	4.915E-12	7.796E-13
Total	9.589E-01	9.589E-01	9.589E-01	9.589E-01	9.589E-01	9.589E-01	9.589E-01

TABLE D.6.f. Actinide Inventory by Element at 45 MWd/kgM, g/gU

Element	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
He	2.348E-06	2.583E-06	2.814E-06	3.042E-06	3.596E-06	4.130E-06	3.892E-05
Pb	3.849E-11	7.066E-11	1.097E-10	1.533E-10	2.714E-10	3.921E-10	3.501E-09
Bi	4.100E-15	5.250E-15	6.185E-15	6.949E-15	8.400E-15	9.583E-15	2.159E-11
Ra	3.403E-13	4.636E-13	5.803E-13	6.947E-13	1.000E-12	1.374E-12	4.030E-09
Ac	4.615E-14	6.163E-14	7.644E-14	9.063E-14	1.236E-13	1.535E-13	2.665E-12
Th	3.953E-09	4.954E-09	5.978E-09	7.026E-09	9.750E-09	1.263E-08	1.244E-06
Pa	4.729E-10	4.801E-10	4.874E-10	4.947E-10	5.130E-10	5.313E-10	4.141E-09
U	9.420E-01	9.420E-01	9.420E-01	9.420E-01	9.421E-01	9.421E-01	9.428E-01
Np	6.386E-04	6.399E-04	6.415E-04	6.435E-04	6.497E-04	6.573E-04	1.943E-03
Pu	1.042E-02	1.030E-02	1.019E-02	1.009E-02	9.880E-03	9.710E-03	8.463E-03
Am	5.979E-04	7.184E-04	8.273E-04	9.257E-04	1.132E-03	1.291E-03	5.746E-04
Cm	1.003E-04	9.336E-05	8.694E-05	8.099E-05	6.797E-05	5.720E-05	5.404E-06
Bk	4.991E-13	1.026E-13	2.108E-14	4.333E-15	8.297E-17	1.589E-18	1.926E-26
Cf	1.786E-11	1.780E-11	1.752E-11	1.723E-11	1.662E-11	1.616E-11	2.591E-12
Total	9.538E-01	9.538E-01	9.538E-01	9.538E-01	9.538E-01	9.538E-01	9.538E-01

TABLE D.6.g. Actinide Inventory by Element at 50 MWd/kgM, g/gU

Element	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
He	2.884E-06	3.203E-06	3.512E-06	3.814E-06	4.536E-06	5.216E-06	4.311E-05
Pb	4.550E-11	8.420E-11	1.314E-10	1.841E-10	3.276E-10	4.743E-10	4.177E-09
Bi	5.065E-15	6.493E-15	7.659E-15	8.614E-15	1.043E-14	1.191E-14	2.350E-11
Ra	3.724E-13	5.053E-13	6.263E-13	7.408E-13	1.034E-12	1.387E-12	4.475E-09
Ac	4.387E-14	5.860E-14	7.264E-14	8.604E-14	1.169E-13	1.446E-13	2.064E-12
Th	3.709E-09	4.668E-09	5.656E-09	6.671E-09	9.336E-09	1.218E-08	1.376E-06
Pa	4.542E-10	4.596E-10	4.651E-10	4.706E-10	4.843E-10	4.981E-10	3.226E-09
U	9.363E-01	9.363E-01	9.363E-01	9.363E-01	9.363E-01	9.364E-01	9.371E-01
Np	7.076E-04	7.090E-04	7.107E-04	7.128E-04	7.193E-04	7.274E-04	2.090E-03
Pu	1.084E-02	1.072E-02	1.060E-02	1.050E-02	1.028E-02	1.010E-02	8.778E-03
Am	6.988E-04	8.269E-04	9.427E-04	1.047E-03	1.267E-03	1.436E-03	6.732E-04
Cm	1.575E-04	1.466E-04	1.366E-04	1.273E-04	1.070E-04	9.014E-05	9.243E-06
Bk	1.409E-12	2.896E-13	5.951E-14	1.223E-14	2.342E-16	4.485E-18	6.921E-26
Cf	5.081E-11	5.051E-11	4.962E-11	4.874E-11	4.696E-11	4.561E-11	7.381E-12
Total	9.487E-01	9.487E-01	9.487E-01	9.487E-01	9.487E-01	9.487E-01	9.487E-01

TABLE D.7.a. Fuel Activation Product Inventory by Isotope at 20 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-1	5.987E-09	5.987E-09	5.987E-09	5.987E-09	5.987E-09	5.987E-09	5.987E-09
H-2	3.011E-12	3.011E-12	3.011E-12	3.011E-12	3.011E-12	3.011E-12	3.011E-12
H-3	1.848E-15	1.652E-15	1.476E-15	1.319E-15	9.965E-16	7.527E-16	0.00
He-3	5.253E-16	7.215E-16	8.969E-16	1.054E-15	1.376E-15	1.620E-15	2.373E-15
He-4	1.330E-06	1.330E-06	1.330E-06	1.330E-06	1.330E-06	1.330E-06	1.330E-06
Li-6	1.092E-14	1.092E-14	1.092E-14	1.092E-14	1.092E-14	1.092E-14	1.092E-14
Be-9	8.502E-11	8.502E-11	8.502E-11	8.502E-11	8.502E-11	8.502E-11	8.502E-11
Be-10	2.124E-11	2.124E-11	2.124E-11	2.124E-11	2.124E-11	2.124E-11	2.123E-11
B-11	7.756E-09	7.756E-09	7.756E-09	7.756E-09	7.756E-09	7.756E-09	7.756E-09
C-12	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05
C-13	4.543E-06	4.543E-06	4.543E-06	4.543E-06	4.543E-06	4.543E-06	4.543E-06
C-14	8.197E-08	8.195E-08	8.193E-08	8.191E-08	8.186E-08	8.181E-08	7.266E-08
N-14	2.592E-05	2.592E-05	2.592E-05	2.592E-05	2.592E-05	2.592E-05	2.593E-05
N-15	1.068E-07	1.068E-07	1.068E-07	1.068E-07	1.068E-07	1.068E-07	1.068E-07
O-16	1.342E-01	1.342E-01	1.342E-01	1.342E-01	1.342E-01	1.342E-01	1.342E-01
O-17	5.431E-05	5.431E-05	5.431E-05	5.431E-05	5.431E-05	5.431E-05	5.431E-05
O-18	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04
F-19	5.700E-06	5.700E-06	5.700E-06	5.700E-06	5.700E-06	5.700E-06	5.700E-06
Ne-20	1.043E-10	1.043E-10	1.043E-10	1.043E-10	1.043E-10	1.043E-10	1.043E-10
Ne-21	2.965E-15	2.965E-15	2.965E-15	2.965E-15	2.965E-15	2.965E-15	2.965E-15
Ne-22	3.240E-15	3.240E-15	3.240E-15	3.240E-15	3.240E-15	3.240E-15	3.240E-15
Na-23	2.622E-16	2.622E-16	2.622E-16	2.622E-16	2.622E-16	2.622E-16	2.622E-16
Mg-24	9.280E-11	9.280E-11	9.280E-11	9.280E-11	9.280E-11	9.280E-11	9.280E-11
Mg-25	9.763E-11	9.763E-11	9.763E-11	9.763E-11	9.763E-11	9.763E-11	9.763E-11
Mg-26	4.460E-11	4.460E-11	4.460E-11	4.460E-11	4.460E-11	4.460E-11	4.460E-11
Al-27	3.629E-05	3.629E-05	3.629E-05	3.629E-05	3.629E-05	3.629E-05	3.629E-05
Si-28	3.335E-05	3.335E-05	3.335E-05	3.335E-05	3.335E-05	3.335E-05	3.335E-05
Si-29	1.756E-06	1.756E-06	1.756E-06	1.756E-06	1.756E-06	1.756E-06	1.756E-06
Si-30	1.201E-06	1.201E-06	1.201E-06	1.201E-06	1.201E-06	1.201E-06	1.201E-06
P-31	2.022E-10	2.022E-10	2.022E-10	2.022E-10	2.022E-10	2.022E-10	2.022E-10
S-32	1.028E-10	1.028E-10	1.028E-10	1.028E-10	1.028E-10	1.028E-10	1.028E-10
S-33	3.689E-14	3.689E-14	3.689E-14	3.689E-14	3.689E-14	3.689E-14	3.689E-14
S-34	7.045E-12	7.045E-12	7.045E-12	7.045E-12	7.045E-12	7.045E-12	7.045E-12
S-35	2.188E-15	6.931E-18	2.198E-20	6.875E-23	3.891E-29	2.202E-35	0.00
S-36	7.007E-14	9.095E-14	1.118E-13	1.327E-13	1.849E-13	2.371E-13	1.046E-11
Cl-35	4.026E-06	4.026E-06	4.026E-06	4.026E-06	4.026E-06	4.026E-06	4.026E-06
Cl-36	2.386E-07	2.386E-07	2.386E-07	2.386E-07	2.386E-07	2.386E-07	2.381E-07
Cl-37	1.442E-06	1.442E-06	1.442E-06	1.442E-06	1.442E-06	1.442E-06	1.442E-06
Ar-36	3.614E-12	4.692E-12	5.771E-12	6.849E-12	9.544E-12	1.224E-11	5.399E-10
Ar-38	9.042E-10	9.042E-10	9.042E-10	9.042E-10	9.042E-10	9.042E-10	9.042E-10
Ar-39	1.682E-11	1.673E-11	1.665E-11	1.656E-11	1.635E-11	1.614E-11	1.292E-12
Ar-40	3.064E-11	3.064E-11	3.064E-11	3.064E-11	3.064E-11	3.064E-11	3.064E-11
K-39	3.058E-13	3.923E-13	4.783E-13	5.638E-13	7.759E-13	9.851E-13	1.583E-11
K-40	7.142E-09	7.142E-09	7.142E-09	7.142E-09	7.142E-09	7.142E-09	7.142E-09
K-41	1.484E-10	1.487E-10	1.490E-10	1.494E-10	1.502E-10	1.510E-10	3.108E-10
Ca-40	3.506E-05	3.506E-05	3.506E-05	3.506E-05	3.506E-05	3.506E-05	3.506E-05

TABLE D.7.a. Fuel Activation Product Inventory by Isotope at 20 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Ca-41	1.914E-08	1.914E-08	1.914E-08	1.914E-08	1.914E-08	1.914E-08	1.898E-08
Ca-42	2.455E-07	2.455E-07	2.455E-07	2.455E-07	2.455E-07	2.455E-07	2.455E-07
Ca-43	5.033E-08	5.033E-08	5.033E-08	5.033E-08	5.033E-08	5.033E-08	5.033E-08
Ca-44	8.315E-07	8.315E-07	8.315E-07	8.315E-07	8.315E-07	8.315E-07	8.315E-07
Ca-45	2.896E-13	1.295E-14	5.794E-16	2.592E-17	1.097E-20	4.641E-24	0.00
Ca-46	1.455E-09	1.455E-09	1.455E-09	1.455E-09	1.455E-09	1.455E-09	1.455E-09
Ca-48	8.240E-08	8.240E-08	8.240E-08	8.240E-08	8.240E-08	8.240E-08	8.240E-08
Sc-45	1.149E-09	1.150E-09	1.150E-09	1.150E-09	1.150E-09	1.150E-09	1.150E-09
Ti-46	1.612E-11	1.612E-11	1.612E-11	1.612E-11	1.612E-11	1.612E-11	1.612E-11
Ti-47	1.400E-12	1.400E-12	1.400E-12	1.400E-12	1.400E-12	1.400E-12	1.400E-12
Ti-48	1.853E-15	1.853E-15	1.853E-15	1.853E-15	1.853E-15	1.853E-15	1.853E-15
Ti-49	1.231E-10	1.231E-10	1.231E-10	1.231E-10	1.231E-10	1.231E-10	1.231E-10
Ti-50	1.958E-13	1.958E-13	1.958E-13	1.958E-13	1.958E-13	1.958E-13	1.958E-13
V-51	2.865E-11	2.865E-11	2.865E-11	2.865E-11	2.865E-11	2.865E-11	2.865E-11
Cr-52	9.440E-14	9.440E-14	9.440E-14	9.440E-14	9.440E-14	9.440E-14	9.440E-14
Cr-53	5.599E-11	5.599E-11	5.599E-11	5.599E-11	5.599E-11	5.599E-11	5.599E-11
Cr-54	8.481E-10	8.541E-10	8.553E-10	8.555E-10	8.556E-10	8.556E-10	8.556E-10
Mn-54	7.490E-12	1.482E-12	2.931E-13	5.800E-14	1.010E-15	1.758E-17	0.00
Mn-55	7.551E-09	8.253E-09	8.665E-09	8.906E-09	9.159E-09	9.226E-09	9.249E-09
Fe-54	2.858E-06	2.858E-06	2.858E-06	2.858E-06	2.858E-06	2.858E-06	2.858E-06
Fe-55	1.698E-09	9.964E-10	5.846E-10	3.430E-10	9.045E-11	2.385E-11	0.00
Fe-56	4.678E-05	4.678E-05	4.678E-05	4.678E-05	4.678E-05	4.678E-05	4.678E-05
Fe-57	1.301E-06	1.301E-06	1.301E-06	1.301E-06	1.301E-06	1.301E-06	1.301E-06
Fe-58	1.623E-07	1.623E-07	1.623E-07	1.623E-07	1.623E-07	1.623E-07	1.623E-07
Co-58	1.575E-16	1.231E-19	9.620E-23	7.519E-26	1.284E-33	0.00	0.00
Co-59	1.416E-09	1.418E-09	1.421E-09	1.423E-09	1.428E-09	1.434E-09	2.494E-09
Co-60	5.206E-11	4.002E-11	3.076E-11	2.364E-11	1.225E-11	6.346E-12	0.00
Ni-58	1.900E-05	1.900E-05	1.900E-05	1.900E-05	1.900E-05	1.900E-05	1.900E-05
Ni-59	1.254E-07	1.254E-07	1.254E-07	1.254E-07	1.254E-07	1.254E-07	1.243E-07
Ni-60	7.551E-06	7.551E-06	7.551E-06	7.551E-06	7.551E-06	7.551E-06	7.551E-06
Ni-61	3.612E-07	3.612E-07	3.612E-07	3.612E-07	3.612E-07	3.612E-07	3.612E-07
Ni-62	1.057E-06	1.057E-06	1.057E-06	1.057E-06	1.057E-06	1.057E-06	1.057E-06
Ni-63	1.932E-08	1.904E-08	1.875E-08	1.847E-08	1.779E-08	1.713E-08	1.064E-11
Ni-64	2.812E-07	2.812E-07	2.812E-07	2.812E-07	2.812E-07	2.812E-07	2.812E-07
Cu-63	9.985E-10	1.288E-09	1.572E-09	1.853E-09	2.535E-09	3.193E-09	2.031E-08
Cu-65	6.092E-10	6.092E-10	6.092E-10	6.092E-10	6.092E-10	6.092E-10	6.092E-10
Zn-64	3.576E-13	3.576E-13	3.576E-13	3.576E-13	3.576E-13	3.576E-13	3.576E-13
Zn-66	1.052E-12	1.052E-12	1.052E-12	1.052E-12	1.052E-12	1.052E-12	1.052E-12
Zn-67	4.546E-16	4.546E-16	4.546E-16	4.546E-16	4.546E-16	4.546E-16	4.546E-16
Ru-104	7.845E-16	7.845E-16	7.845E-16	7.845E-16	7.845E-16	7.845E-16	7.845E-16
Pd-104	1.731E-13	1.731E-13	1.731E-13	1.731E-13	1.731E-13	1.731E-13	1.731E-13
Pd-105	8.177E-16	8.177E-16	8.177E-16	8.177E-16	8.177E-16	8.177E-16	8.177E-16
Pd-106	3.660E-12	3.660E-12	3.660E-12	3.660E-12	3.660E-12	3.660E-12	3.660E-12
Pd-107	1.710E-13	1.710E-13	1.710E-13	1.710E-13	1.710E-13	1.710E-13	1.710E-13
Pd-108	1.206E-09	1.238E-09	1.270E-09	1.302E-09	1.379E-09	1.454E-09	4.163E-09
Pd-110	6.863E-10	6.863E-10	6.863E-10	6.863E-10	6.863E-10	6.863E-10	6.863E-10

TABLE D.7.a. Fuel Activation Product Inventory by Isotope at 20 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Ag-107	5.130E-07	5.130E-07	5.130E-07	5.130E-07	5.130E-07	5.130E-07	5.130E-07
Ag-108m	3.252E-09	3.217E-09	3.182E-09	3.148E-09	3.063E-09	2.980E-09	1.417E-11
Ag-109	2.959E-07	2.959E-07	2.959E-07	2.959E-07	2.959E-07	2.959E-07	2.959E-07
Ag-110m	3.108E-11	4.097E-12	5.400E-13	7.118E-14	4.491E-16	2.834E-18	0.00
Cd-108	4.794E-08	4.795E-08	4.795E-08	4.795E-08	4.796E-08	4.797E-08	4.823E-08
Cd-109	4.150E-12	1.394E-12	4.680E-13	1.571E-13	1.027E-14	6.709E-16	0.00
Cd-110	2.361E-07	2.361E-07	2.361E-07	2.361E-07	2.361E-07	2.361E-07	2.361E-07
Cd-111	4.372E-09	4.372E-09	4.372E-09	4.372E-09	4.372E-09	4.372E-09	4.372E-09
Cd-112	8.062E-11	8.062E-11	8.062E-11	8.062E-11	8.062E-11	8.062E-11	8.062E-11
Cd-113	1.215E-14	1.215E-14	1.215E-14	1.215E-14	1.215E-14	1.215E-14	1.215E-14
Cd-114	1.837E-13	1.837E-13	1.837E-13	1.837E-13	1.837E-13	1.837E-13	1.837E-13
Total	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01

TABLE D.7.b. Fuel Activation Product Inventory by Isotope at 25 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-1	7.651E-09	7.651E-09	7.651E-09	7.651E-09	7.651E-09	7.651E-09	7.651E-09
H-2	4.923E-12	4.923E-12	4.923E-12	4.923E-12	4.923E-12	4.923E-12	4.923E-12
H-3	3.623E-15	3.238E-15	2.895E-15	2.587E-15	1.954E-15	1.476E-15	0.00
He-3	1.008E-15	1.393E-15	1.737E-15	2.044E-15	2.678E-15	3.156E-15	4.632E-15
He-4	1.701E-06	1.701E-06	1.701E-06	1.701E-06	1.701E-06	1.701E-06	1.701E-06
Li-6	1.634E-14	1.634E-14	1.634E-14	1.634E-14	1.634E-14	1.634E-14	1.634E-14
Be-9	1.087E-10	1.087E-10	1.087E-10	1.087E-10	1.087E-10	1.087E-10	1.087E-10
Be-10	3.395E-11	3.395E-11	3.395E-11	3.395E-11	3.395E-11	3.395E-11	3.394E-11
B-11	9.914E-09	9.914E-09	9.914E-09	9.914E-09	9.914E-09	9.914E-09	9.914E-09
C-12	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05
C-13	5.741E-06	5.741E-06	5.741E-06	5.741E-06	5.741E-06	5.741E-06	5.741E-06
C-14	1.048E-07	1.048E-07	1.047E-07	1.047E-07	1.046E-07	1.046E-07	9.289E-08
N-14	2.589E-05	2.589E-05	2.589E-05	2.589E-05	2.589E-05	2.590E-05	2.591E-05
N-15	1.081E-07	1.081E-07	1.081E-07	1.081E-07	1.081E-07	1.081E-07	1.081E-07
O-16	1.342E-01	1.342E-01	1.342E-01	1.342E-01	1.342E-01	1.342E-01	1.342E-01
O-17	5.432E-05	5.432E-05	5.432E-05	5.432E-05	5.432E-05	5.432E-05	5.432E-05
O-18	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04
F-19	5.700E-06	5.700E-06	5.700E-06	5.700E-06	5.700E-06	5.700E-06	5.700E-06
Ne-20	1.334E-10	1.334E-10	1.334E-10	1.334E-10	1.334E-10	1.334E-10	1.334E-10
Ne-21	4.847E-15	4.847E-15	4.847E-15	4.847E-15	4.847E-15	4.847E-15	4.847E-15
Ne-22	5.298E-15	5.298E-15	5.298E-15	5.298E-15	5.298E-15	5.298E-15	5.298E-15
Na-23	4.290E-16	4.290E-16	4.290E-16	4.290E-16	4.290E-16	4.290E-16	4.290E-16
Mg-24	1.187E-10	1.187E-10	1.187E-10	1.187E-10	1.187E-10	1.187E-10	1.187E-10
Mg-25	1.248E-10	1.248E-10	1.248E-10	1.248E-10	1.248E-10	1.248E-10	1.248E-10
Mg-26	5.707E-11	5.707E-11	5.707E-11	5.707E-11	5.707E-11	5.707E-11	5.707E-11
Al-27	3.628E-05	3.628E-05	3.628E-05	3.628E-05	3.628E-05	3.628E-05	3.628E-05
Si-28	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05
Si-29	1.758E-06	1.758E-06	1.758E-06	1.758E-06	1.758E-06	1.758E-06	1.758E-06
Si-30	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06
P-31	2.586E-10	2.586E-10	2.586E-10	2.586E-10	2.586E-10	2.586E-10	2.586E-10
S-32	1.305E-10	1.305E-10	1.305E-10	1.305E-10	1.305E-10	1.305E-10	1.305E-10
S-33	6.002E-14	6.002E-14	6.002E-14	6.002E-14	6.002E-14	6.002E-14	6.002E-14
S-34	9.011E-12	9.011E-12	9.011E-12	9.011E-12	9.011E-12	9.011E-12	9.011E-12
S-35	2.803E-15	8.885E-18	2.817E-20	8.836E-23	5.001E-29	2.830E-35	0.00
S-36	8.851E-14	1.150E-13	1.414E-13	1.678E-13	2.340E-13	3.001E-13	1.324E-11
Cl-35	3.963E-06	3.963E-06	3.963E-06	3.963E-06	3.963E-06	3.963E-06	3.963E-06
Cl-36	3.022E-07	3.022E-07	3.022E-07	3.022E-07	3.022E-07	3.022E-07	3.015E-07
Cl-37	1.443E-06	1.443E-06	1.443E-06	1.443E-06	1.443E-06	1.443E-06	1.443E-06
Ar-36	4.564E-12	5.930E-12	7.295E-12	8.661E-12	1.207E-11	1.549E-11	6.837E-10
Ar-38	1.156E-09	1.156E-09	1.156E-09	1.156E-09	1.156E-09	1.156E-09	1.156E-09
Ar-39	1.971E-11	1.961E-11	1.951E-11	1.941E-11	1.916E-11	1.892E-11	1.514E-12
Ar-40	4.858E-11	4.858E-11	4.858E-11	4.858E-11	4.858E-11	4.858E-11	4.858E-11
K-39	3.613E-13	4.626E-13	5.634E-13	6.637E-13	9.122E-13	1.157E-12	1.856E-11
K-40	9.074E-09	9.074E-09	9.074E-09	9.074E-09	9.074E-09	9.074E-09	9.074E-09
K-41	2.411E-10	2.416E-10	2.420E-10	2.424E-10	2.434E-10	2.445E-10	4.488E-10
Ca-40	3.505E-05	3.505E-05	3.505E-05	3.505E-05	3.505E-05	3.505E-05	3.505E-05

TABLE D.7.b. Fuel Activation Product Inventory by Isotope at 25 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Ca-41	2.447E-08	2.447E-08	2.447E-08	2.447E-08	2.447E-08	2.447E-08	2.426E-08
Ca-42	2.454E-07	2.454E-07	2.454E-07	2.454E-07	2.454E-07	2.454E-07	2.454E-07
Ca-43	5.026E-08	5.026E-08	5.026E-08	5.026E-08	5.026E-08	5.026E-08	5.026E-08
Ca-44	8.313E-07	8.313E-07	8.313E-07	8.313E-07	8.313E-07	8.313E-07	8.313E-07
Ca-45	3.769E-13	1.686E-14	7.542E-16	3.374E-17	1.428E-20	6.041E-24	0.00
Ca-46	1.455E-09	1.455E-09	1.455E-09	1.455E-09	1.455E-09	1.455E-09	1.455E-09
Ca-48	8.237E-08	8.237E-08	8.237E-08	8.237E-08	8.237E-08	8.237E-08	8.237E-08
Sc-45	1.464E-09	1.465E-09	1.465E-09	1.465E-09	1.465E-09	1.465E-09	1.465E-09
Ti-46	2.629E-11	2.629E-11	2.629E-11	2.629E-11	2.629E-11	2.629E-11	2.629E-11
Ti-47	1.800E-12	1.800E-12	1.800E-12	1.800E-12	1.800E-12	1.800E-12	1.800E-12
Ti-48	3.036E-15	3.036E-15	3.036E-15	3.036E-15	3.036E-15	3.036E-15	3.036E-15
Ti-49	1.573E-10	1.573E-10	1.573E-10	1.573E-10	1.573E-10	1.573E-10	1.573E-10
Ti-50	3.200E-13	3.200E-13	3.200E-13	3.200E-13	3.200E-13	3.200E-13	3.200E-13
V-51	3.659E-11	3.659E-11	3.659E-11	3.659E-11	3.659E-11	3.659E-11	3.659E-11
Cr-52	1.542E-13	1.542E-13	1.542E-13	1.542E-13	1.542E-13	1.542E-13	1.542E-13
Cr-53	7.132E-11	7.132E-11	7.132E-11	7.132E-11	7.132E-11	7.132E-11	7.132E-11
Cr-54	1.084E-09	1.092E-09	1.093E-09	1.093E-09	1.094E-09	1.094E-09	1.094E-09
Mn-54	9.711E-12	1.921E-12	3.801E-13	7.519E-14	1.309E-15	2.279E-17	0.00
Mn-55	9.626E-09	1.053E-08	1.106E-08	1.137E-08	1.169E-08	1.178E-08	1.181E-08
Fe-54	2.855E-06	2.855E-06	2.855E-06	2.855E-06	2.855E-06	2.855E-06	2.855E-06
Fe-55	2.185E-09	1.282E-09	7.521E-10	4.413E-10	1.164E-10	3.068E-11	0.00
Fe-56	4.673E-05	4.673E-05	4.673E-05	4.673E-05	4.673E-05	4.673E-05	4.673E-05
Fe-57	1.351E-06	1.351E-06	1.351E-06	1.351E-06	1.351E-06	1.351E-06	1.351E-06
Fe-58	1.644E-07	1.644E-07	1.644E-07	1.644E-07	1.644E-07	1.644E-07	1.644E-07
Co-58	1.921E-16	1.502E-19	1.174E-22	9.173E-26	1.566E-33	0.00	0.00
Co-59	2.097E-09	2.100E-09	2.103E-09	2.105E-09	2.112E-09	2.119E-09	3.442E-09
Co-60	8.137E-11	6.255E-11	4.808E-11	3.696E-11	1.915E-11	9.920E-12	0.00
Ni-58	1.896E-05	1.896E-05	1.896E-05	1.896E-05	1.896E-05	1.896E-05	1.896E-05
Ni-59	1.565E-07	1.565E-07	1.565E-07	1.565E-07	1.565E-07	1.565E-07	1.552E-07
Ni-60	7.549E-06	7.549E-06	7.549E-06	7.549E-06	7.549E-06	7.549E-06	7.549E-06
Ni-61	3.690E-07	3.690E-07	3.690E-07	3.690E-07	3.690E-07	3.690E-07	3.690E-07
Ni-62	1.052E-06	1.052E-06	1.052E-06	1.052E-06	1.052E-06	1.052E-06	1.052E-06
Ni-63	2.455E-08	2.418E-08	2.382E-08	2.347E-08	2.260E-08	2.176E-08	1.352E-11
Ni-64	2.813E-07	2.813E-07	2.813E-07	2.813E-07	2.813E-07	2.813E-07	2.813E-07
Cu-63	1.264E-09	1.631E-09	1.993E-09	2.349E-09	3.217E-09	4.052E-09	2.580E-08
Cu-65	7.786E-10	7.786E-10	7.786E-10	7.786E-10	7.786E-10	7.786E-10	7.786E-10
Zn-64	5.827E-13	5.827E-13	5.827E-13	5.827E-13	5.827E-13	5.827E-13	5.827E-13
Zn-66	1.720E-12	1.720E-12	1.720E-12	1.720E-12	1.720E-12	1.720E-12	1.720E-12
Zn-67	9.493E-16	9.493E-16	9.493E-16	9.493E-16	9.493E-16	9.493E-16	9.493E-16
Ru-104	9.895E-16	9.895E-16	9.895E-16	9.895E-16	9.895E-16	9.895E-16	9.895E-16
Pd-104	2.181E-13	2.181E-13	2.181E-13	2.181E-13	2.181E-13	2.181E-13	2.181E-13
Pd-105	1.317E-15	1.317E-15	1.317E-15	1.317E-15	1.317E-15	1.317E-15	1.317E-15
Pd-106	4.608E-12	4.608E-12	4.608E-12	4.608E-12	4.608E-12	4.608E-12	4.608E-12
Pd-107	2.172E-13	2.172E-13	2.172E-13	2.172E-13	2.172E-13	2.172E-13	2.172E-13
Pd-108	1.501E-09	1.542E-09	1.582E-09	1.622E-09	1.719E-09	1.814E-09	5.233E-09
Pd-110	8.150E-10	8.150E-10	8.150E-10	8.150E-10	8.150E-10	8.150E-10	8.150E-10

TABLE D.7.b. Fuel Activation Product Inventory by Isotope at 25 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Ag-107	4.993E-07	4.993E-07	4.993E-07	4.993E-07	4.993E-07	4.993E-07	4.993E-07
Ag-108m	4.105E-09	4.060E-09	4.016E-09	3.973E-09	3.866E-09	3.762E-09	1.789E-11
Ag-109	2.509E-07	2.509E-07	2.509E-07	2.509E-07	2.509E-07	2.509E-07	2.509E-07
Ag-110m	3.498E-11	4.611E-12	6.078E-13	8.012E-14	5.054E-16	3.188E-18	0.00
Cd-108	6.047E-08	6.048E-08	6.048E-08	6.048E-08	6.049E-08	6.050E-08	6.083E-08
Cd-109	6.491E-12	2.180E-12	7.319E-13	2.458E-13	1.606E-14	1.049E-15	0.00
Cd-110	2.789E-07	2.790E-07	2.790E-07	2.790E-07	2.790E-07	2.790E-07	2.790E-07
Cd-111	6.741E-09	6.741E-09	6.741E-09	6.741E-09	6.741E-09	6.741E-09	6.741E-09
Cd-112	1.611E-10	1.611E-10	1.611E-10	1.611E-10	1.611E-10	1.611E-10	1.611E-10
Cd-113	2.453E-14	2.453E-14	2.453E-14	2.453E-14	2.453E-14	2.453E-14	2.453E-14
Cd-114	4.798E-13	4.798E-13	4.798E-13	4.798E-13	4.798E-13	4.798E-13	4.798E-13
Total	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01

TABLE D.7.c. Fuel Activation Product Inventory by Isotope at 30 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-1	9.409E-09	9.409E-09	9.409E-09	9.409E-09	9.409E-09	9.409E-09	9.409E-09
H-2	7.449E-12	7.449E-12	7.449E-12	7.449E-12	7.449E-12	7.449E-12	7.449E-12
H-3	6.320E-15	5.649E-15	5.049E-15	4.513E-15	3.409E-15	2.574E-15	0.00
He-3	1.729E-15	2.400E-15	2.999E-15	3.536E-15	4.640E-15	5.474E-15	8.048E-15
He-4	2.093E-06	2.093E-06	2.093E-06	2.093E-06	2.093E-06	2.093E-06	2.093E-06
Li-6	2.264E-14	2.264E-14	2.264E-14	2.264E-14	2.264E-14	2.264E-14	2.264E-14
Be-9	1.337E-10	1.337E-10	1.337E-10	1.337E-10	1.337E-10	1.337E-10	1.337E-10
Be-10	5.061E-11	5.061E-11	5.061E-11	5.061E-11	5.061E-11	5.061E-11	5.059E-11
B-11	1.219E-08	1.219E-08	1.219E-08	1.219E-08	1.219E-08	1.219E-08	1.219E-08
C-12	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05
C-13	7.007E-06	7.007E-06	7.007E-06	7.007E-06	7.007E-06	7.007E-06	7.007E-06
C-14	1.289E-07	1.288E-07	1.288E-07	1.288E-07	1.287E-07	1.286E-07	1.142E-07
N-14	2.587E-05	2.587E-05	2.587E-05	2.587E-05	2.587E-05	2.587E-05	2.589E-05
N-15	1.094E-07	1.094E-07	1.094E-07	1.094E-07	1.094E-07	1.094E-07	1.094E-07
O-16	1.341E-01	1.341E-01	1.341E-01	1.341E-01	1.341E-01	1.341E-01	1.341E-01
O-17	5.432E-05	5.432E-05	5.432E-05	5.432E-05	5.432E-05	5.432E-05	5.432E-05
O-18	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04
F-19	5.699E-06	5.699E-06	5.699E-06	5.699E-06	5.699E-06	5.699E-06	5.699E-06
Ne-20	1.642E-10	1.642E-10	1.642E-10	1.642E-10	1.642E-10	1.642E-10	1.642E-10
Ne-21	7.335E-15	7.335E-15	7.335E-15	7.335E-15	7.335E-15	7.335E-15	7.335E-15
Ne-22	8.020E-15	8.020E-15	8.020E-15	8.020E-15	8.020E-15	8.020E-15	8.020E-15
Na-23	6.496E-16	6.496E-16	6.496E-16	6.496E-16	6.496E-16	6.496E-16	6.496E-16
Mg-24	1.460E-10	1.460E-10	1.460E-10	1.460E-10	1.460E-10	1.460E-10	1.460E-10
Mg-25	1.536E-10	1.536E-10	1.536E-10	1.536E-10	1.536E-10	1.536E-10	1.536E-10
Mg-26	7.026E-11	7.026E-11	7.026E-11	7.026E-11	7.026E-11	7.026E-11	7.026E-11
Al-27	3.628E-05	3.628E-05	3.628E-05	3.628E-05	3.628E-05	3.628E-05	3.628E-05
Si-28	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05
Si-29	1.760E-06	1.760E-06	1.760E-06	1.760E-06	1.760E-06	1.760E-06	1.760E-06
Si-30	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06
P-31	3.182E-10	3.182E-10	3.182E-10	3.182E-10	3.182E-10	3.182E-10	3.182E-10
S-32	1.592E-10	1.592E-10	1.592E-10	1.592E-10	1.592E-10	1.592E-10	1.592E-10
S-33	9.037E-14	9.037E-14	9.037E-14	9.037E-14	9.037E-14	9.037E-14	9.037E-14
S-34	1.109E-11	1.109E-11	1.109E-11	1.109E-11	1.109E-11	1.109E-11	1.109E-11
S-35	3.512E-15	1.114E-17	3.534E-20	1.108E-22	6.270E-29	3.548E-35	0.00
S-36	1.075E-13	1.397E-13	1.719E-13	2.041E-13	2.846E-13	3.651E-13	1.613E-11
Cl-35	3.898E-06	3.898E-06	3.898E-06	3.898E-06	3.898E-06	3.898E-06	3.898E-06
Cl-36	3.680E-07	3.680E-07	3.680E-07	3.680E-07	3.680E-07	3.680E-07	3.672E-07
Cl-37	1.444E-06	1.444E-06	1.444E-06	1.444E-06	1.444E-06	1.444E-06	1.444E-06
Ar-36	5.542E-12	7.204E-12	8.867E-12	1.053E-11	1.469E-11	1.884E-11	8.327E-10
Ar-38	1.423E-09	1.423E-09	1.423E-09	1.423E-09	1.423E-09	1.423E-09	1.423E-09
Ar-39	2.222E-11	2.210E-11	2.199E-11	2.188E-11	2.160E-11	2.132E-11	1.706E-12
Ar-40	7.159E-11	7.159E-11	7.159E-11	7.159E-11	7.159E-11	7.159E-11	7.159E-11
K-39	4.105E-13	5.247E-13	6.383E-13	7.514E-13	1.031E-12	1.308E-12	2.092E-11
K-40	1.109E-08	1.109E-08	1.109E-08	1.109E-08	1.109E-08	1.109E-08	1.109E-08
K-41	3.628E-10	3.634E-10	3.639E-10	3.644E-10	3.657E-10	3.670E-10	6.183E-10
Ca-40	3.504E-05	3.504E-05	3.504E-05	3.504E-05	3.504E-05	3.504E-05	3.504E-05

TABLE D.7.c. Fuel Activation Product Inventory by Isotope at 30 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Ca-41	3.010E-08	3.010E-08	3.010E-08	3.010E-08	3.010E-08	3.010E-08	2.985E-08
Ca-42	2.453E-07	2.453E-07	2.453E-07	2.453E-07	2.453E-07	2.453E-07	2.453E-07
Ca-43	5.019E-08	5.019E-08	5.019E-08	5.019E-08	5.019E-08	5.019E-08	5.019E-08
Ca-44	8.311E-07	8.311E-07	8.311E-07	8.311E-07	8.311E-07	8.311E-07	8.311E-07
Ca-45	4.762E-13	2.130E-14	9.528E-16	4.262E-17	1.803E-20	7.631E-24	0.00
Ca-46	1.455E-09	1.455E-09	1.455E-09	1.455E-09	1.455E-09	1.455E-09	1.455E-09
Ca-48	8.234E-08	8.234E-08	8.234E-08	8.234E-08	8.234E-08	8.234E-08	8.234E-08
Sc-45	1.794E-09	1.794E-09	1.794E-09	1.794E-09	1.794E-09	1.794E-09	1.794E-09
Ti-46	3.969E-11	3.969E-11	3.969E-11	3.969E-11	3.969E-11	3.969E-11	3.969E-11
Ti-47	2.231E-12	2.231E-12	2.231E-12	2.231E-12	2.231E-12	2.231E-12	2.231E-12
Ti-48	4.609E-15	4.609E-15	4.609E-15	4.609E-15	4.609E-15	4.609E-15	4.609E-15
Ti-49	1.934E-10	1.934E-10	1.934E-10	1.934E-10	1.934E-10	1.934E-10	1.934E-10
Ti-50	4.841E-13	4.841E-13	4.841E-13	4.841E-13	4.841E-13	4.841E-13	4.841E-13
V-51	4.495E-11	4.495E-11	4.495E-11	4.495E-11	4.495E-11	4.495E-11	4.495E-11
Cr-52	2.331E-13	2.331E-13	2.331E-13	2.331E-13	2.331E-13	2.331E-13	2.331E-13
Cr-53	8.739E-11	8.739E-11	8.739E-11	8.739E-11	8.739E-11	8.739E-11	8.739E-11
Cr-54	1.333E-09	1.342E-09	1.344E-09	1.345E-09	1.345E-09	1.345E-09	1.345E-09
Mn-54	1.215E-11	2.404E-12	4.756E-13	9.410E-14	1.638E-15	2.852E-17	0.00
Mn-55	1.180E-08	1.292E-08	1.358E-08	1.396E-08	1.436E-08	1.447E-08	1.451E-08
Fe-54	2.852E-06	2.852E-06	2.852E-06	2.852E-06	2.852E-06	2.852E-06	2.852E-06
Fe-55	2.706E-09	1.588E-09	9.315E-10	5.466E-10	1.441E-10	3.800E-11	0.00
Fe-56	4.668E-05	4.668E-05	4.668E-05	4.668E-05	4.668E-05	4.668E-05	4.668E-05
Fe-57	1.404E-06	1.404E-06	1.404E-06	1.404E-06	1.404E-06	1.404E-06	1.404E-06
Fe-58	1.667E-07	1.667E-07	1.667E-07	1.667E-07	1.667E-07	1.667E-07	1.667E-07
Co-58	2.292E-16	1.791E-19	1.400E-22	1.094E-25	1.868E-33	0.00	0.00
Co-59	2.903E-09	2.907E-09	2.910E-09	2.913E-09	2.921E-09	2.929E-09	4.516E-09
Co-60	1.218E-10	9.360E-11	7.195E-11	5.531E-11	2.865E-11	1.484E-11	0.00
Ni-58	1.892E-05	1.892E-05	1.892E-05	1.892E-05	1.892E-05	1.892E-05	1.892E-05
Ni-59	1.877E-07	1.877E-07	1.877E-07	1.877E-07	1.877E-07	1.877E-07	1.861E-07
Ni-60	7.549E-06	7.549E-06	7.549E-06	7.549E-06	7.549E-06	7.549E-06	7.549E-06
Ni-61	3.773E-07	3.773E-07	3.773E-07	3.773E-07	3.773E-07	3.773E-07	3.773E-07
Ni-62	1.046E-06	1.046E-06	1.046E-06	1.046E-06	1.046E-06	1.046E-06	1.046E-06
Ni-63	3.000E-08	2.955E-08	2.911E-08	2.867E-08	2.761E-08	2.659E-08	1.652E-11
Ni-64	2.813E-07	2.813E-07	2.813E-07	2.813E-07	2.813E-07	2.813E-07	2.813E-07
Cu-63	1.539E-09	1.988E-09	2.430E-09	2.865E-09	3.925E-09	4.946E-09	3.152E-08
Cu-65	9.575E-10	9.575E-10	9.575E-10	9.575E-10	9.575E-10	9.575E-10	9.575E-10
Zn-64	8.795E-13	8.795E-13	8.795E-13	8.795E-13	8.795E-13	8.795E-13	8.795E-13
Zn-66	2.602E-12	2.602E-12	2.602E-12	2.602E-12	2.602E-12	2.602E-12	2.602E-12
Zn-67	1.766E-15	1.766E-15	1.766E-15	1.766E-15	1.766E-15	1.766E-15	1.766E-15
Ru-104	1.200E-15	1.200E-15	1.200E-15	1.200E-15	1.200E-15	1.200E-15	1.200E-15
Pd-104	2.643E-13	2.643E-13	2.643E-13	2.643E-13	2.643E-13	2.643E-13	2.643E-13
Pd-105	1.963E-15	1.963E-15	1.963E-15	1.963E-15	1.963E-15	1.963E-15	1.963E-15
Pd-106	5.577E-12	5.577E-12	5.577E-12	5.577E-12	5.577E-12	5.577E-12	5.577E-12
Pd-107	2.654E-13	2.654E-13	2.654E-13	2.654E-13	2.654E-13	2.654E-13	2.653E-13
Pd-108	1.794E-09	1.844E-09	1.892E-09	1.941E-09	2.059E-09	2.175E-09	6.323E-09
Pd-110	9.294E-10	9.294E-10	9.294E-10	9.294E-10	9.294E-10	9.294E-10	9.294E-10

TABLE D.7.c. Fuel Activation Product Inventory by Isotope at 30 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Ag-107	4.853E-07	4.853E-07	4.853E-07	4.853E-07	4.853E-07	4.853E-07	4.853E-07
Ag-108m	4.981E-09	4.927E-09	4.873E-09	4.821E-09	4.691E-09	4.565E-09	2.171E-11
Ag-109	2.108E-07	2.108E-07	2.108E-07	2.108E-07	2.108E-07	2.108E-07	2.108E-07
Ag-110m	3.777E-11	4.979E-12	6.563E-13	8.651E-14	5.458E-16	3.443E-18	0.00
Cd-108	7.333E-08	7.333E-08	7.334E-08	7.334E-08	7.336E-08	7.337E-08	7.376E-08
Cd-109	9.400E-12	3.156E-12	1.060E-12	3.559E-13	2.326E-14	1.520E-15	0.00
Cd-110	3.163E-07	3.163E-07	3.163E-07	3.163E-07	3.163E-07	3.163E-07	3.163E-07
Cd-111	9.601E-09	9.601E-09	9.601E-09	9.601E-09	9.601E-09	9.601E-09	9.601E-09
Cd-112	2.861E-10	2.861E-10	2.861E-10	2.861E-10	2.861E-10	2.861E-10	2.861E-10
Cd-113	4.389E-14	4.389E-14	4.389E-14	4.389E-14	4.389E-14	4.389E-14	4.389E-14
Cd-114	1.074E-12	1.074E-12	1.074E-12	1.074E-12	1.074E-12	1.074E-12	1.074E-12
In-115	1.849E-16	1.849E-16	1.849E-16	1.849E-16	1.849E-16	1.849E-16	1.849E-16
Total	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01

TABLE D.7.d. Fuel Activation Product Inventory by Isotope at 35 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-1	1.127E-08	1.127E-08	1.127E-08	1.127E-08	1.127E-08	1.127E-08	1.127E-08
H-2	1.069E-11	1.069E-11	1.069E-11	1.069E-11	1.069E-11	1.069E-11	1.069E-11
H-3	1.017E-14	9.086E-15	8.122E-15	7.259E-15	5.483E-15	4.141E-15	0.00
He-3	2.745E-15	3.824E-15	4.789E-15	5.651E-15	7.428E-15	8.770E-15	1.291E-14
He-4	2.507E-06	2.507E-06	2.507E-06	2.507E-06	2.507E-06	2.507E-06	2.507E-06
Li-6	2.975E-14	2.975E-14	2.975E-14	2.975E-14	2.975E-14	2.975E-14	2.975E-14
Be-9	1.602E-10	1.602E-10	1.602E-10	1.602E-10	1.602E-10	1.602E-10	1.602E-10
Be-10	7.183E-11	7.183E-11	7.183E-11	7.183E-11	7.183E-11	7.183E-11	7.180E-11
B-10	1.590E-16	2.212E-16	2.835E-16	3.457E-16	5.013E-16	6.569E-16	3.115E-14
B-11	1.460E-08	1.460E-08	1.460E-08	1.460E-08	1.460E-08	1.460E-08	1.460E-08
C-12	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05
C-13	8.347E-06	8.347E-06	8.347E-06	8.347E-06	8.347E-06	8.347E-06	8.347E-06
C-14	1.543E-07	1.543E-07	1.543E-07	1.542E-07	1.541E-07	1.541E-07	1.368E-07
N-14	2.585E-05	2.585E-05	2.585E-05	2.585E-05	2.585E-05	2.585E-05	2.586E-05
N-15	1.108E-07	1.108E-07	1.108E-07	1.108E-07	1.108E-07	1.108E-07	1.108E-07
O-16	1.341E-01	1.341E-01	1.341E-01	1.341E-01	1.341E-01	1.341E-01	1.341E-01
O-17	5.433E-05	5.433E-05	5.433E-05	5.433E-05	5.433E-05	5.433E-05	5.433E-05
O-18	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04
F-19	5.699E-06	5.699E-06	5.699E-06	5.699E-06	5.699E-06	5.699E-06	5.699E-06
Ne-20	1.967E-10	1.967E-10	1.967E-10	1.967E-10	1.967E-10	1.967E-10	1.967E-10
Ne-21	1.053E-14	1.053E-14	1.053E-14	1.053E-14	1.053E-14	1.053E-14	1.053E-14
Ne-22	1.151E-14	1.151E-14	1.151E-14	1.151E-14	1.151E-14	1.151E-14	1.151E-14
Na-23	9.328E-16	9.328E-16	9.328E-16	9.328E-16	9.328E-16	9.328E-16	9.328E-16
Mg-24	1.749E-10	1.749E-10	1.749E-10	1.749E-10	1.749E-10	1.749E-10	1.749E-10
Mg-25	1.840E-10	1.840E-10	1.840E-10	1.840E-10	1.840E-10	1.840E-10	1.840E-10
Mg-26	8.424E-11	8.424E-11	8.424E-11	8.424E-11	8.424E-11	8.424E-11	8.424E-11
Al-27	3.628E-05	3.628E-05	3.628E-05	3.628E-05	3.628E-05	3.628E-05	3.628E-05
Si-28	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05
Si-29	1.762E-06	1.762E-06	1.762E-06	1.762E-06	1.762E-06	1.762E-06	1.762E-06
Si-30	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06
P-31	3.812E-10	3.812E-10	3.812E-10	3.812E-10	3.812E-10	3.812E-10	3.812E-10
S-32	1.891E-10	1.891E-10	1.891E-10	1.891E-10	1.891E-10	1.891E-10	1.891E-10
S-33	1.290E-13	1.290E-13	1.290E-13	1.290E-13	1.290E-13	1.290E-13	1.290E-13
S-34	1.329E-11	1.329E-11	1.329E-11	1.329E-11	1.329E-11	1.329E-11	1.329E-11
S-35	4.243E-15	1.345E-17	4.260E-20	1.334E-22	7.552E-29	4.274E-35	0.00
S-36	1.271E-13	1.652E-13	2.034E-13	2.416E-13	3.370E-13	4.324E-13	1.911E-11
Cl-35	3.830E-06	3.830E-06	3.830E-06	3.830E-06	3.830E-06	3.830E-06	3.830E-06
Cl-36	4.362E-07	4.362E-07	4.362E-07	4.362E-07	4.362E-07	4.362E-07	4.352E-07
Cl-37	1.446E-06	1.446E-06	1.446E-06	1.446E-06	1.446E-06	1.446E-06	1.446E-06
Ar-36	6.548E-12	8.519E-12	1.049E-11	1.246E-11	1.739E-11	2.231E-11	9.869E-10
Ar-38	1.705E-09	1.705E-09	1.705E-09	1.705E-09	1.705E-09	1.705E-09	1.705E-09
Ar-39	2.438E-11	2.426E-11	2.413E-11	2.401E-11	2.370E-11	2.340E-11	1.873E-12
Ar-40	1.003E-10	1.003E-10	1.003E-10	1.003E-10	1.003E-10	1.003E-10	1.003E-10
K-39	4.542E-13	5.795E-13	7.042E-13	8.283E-13	1.136E-12	1.439E-12	2.297E-11
K-40	1.319E-08	1.319E-08	1.319E-08	1.319E-08	1.319E-08	1.319E-08	1.319E-08
K-41	5.178E-10	5.184E-10	5.190E-10	5.196E-10	5.212E-10	5.227E-10	8.238E-10

TABLE D.7.d. Fuel Activation Product Inventory by Isotope at 35 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Ca-40	3.504E-05	3.504E-05	3.504E-05	3.504E-05	3.504E-05	3.504E-05	3.504E-05
Ca-41	3.606E-08	3.606E-08	3.606E-08	3.606E-08	3.606E-08	3.606E-08	3.576E-08
Ca-42	2.453E-07	2.453E-07	2.453E-07	2.453E-07	2.453E-07	2.453E-07	2.453E-07
Ca-43	5.011E-08	5.011E-08	5.011E-08	5.011E-08	5.011E-08	5.011E-08	5.011E-08
Ca-44	8.309E-07	8.309E-07	8.309E-07	8.309E-07	8.309E-07	8.309E-07	8.309E-07
Ca-45	5.835E-13	2.610E-14	1.167E-15	5.222E-17	2.210E-20	9.351E-24	0.00
Ca-46	1.454E-09	1.454E-09	1.454E-09	1.454E-09	1.454E-09	1.454E-09	1.454E-09
Ca-48	8.230E-08	8.230E-08	8.230E-08	8.230E-08	8.230E-08	8.230E-08	8.230E-08
Sc-45	2.140E-09	2.141E-09	2.141E-09	2.141E-09	2.141E-09	2.141E-09	2.141E-09
Ti-46	5.679E-11	5.679E-11	5.679E-11	5.679E-11	5.679E-11	5.679E-11	5.679E-11
Ti-47	2.699E-12	2.699E-12	2.699E-12	2.699E-12	2.699E-12	2.699E-12	2.699E-12
Ti-48	6.643E-15	6.643E-15	6.643E-15	6.643E-15	6.643E-15	6.643E-15	6.643E-15
Ti-49	2.315E-10	2.315E-10	2.315E-10	2.315E-10	2.315E-10	2.315E-10	2.315E-10
Ti-50	6.946E-13	6.946E-13	6.946E-13	6.946E-13	6.946E-13	6.946E-13	6.946E-13
V-51	5.377E-11	5.377E-11	5.377E-11	5.377E-11	5.377E-11	5.377E-11	5.377E-11
Cr-52	3.341E-13	3.341E-13	3.341E-13	3.341E-13	3.341E-13	3.341E-13	3.341E-13
Cr-53	1.042E-10	1.042E-10	1.042E-10	1.042E-10	1.042E-10	1.042E-10	1.042E-10
Cr-54	1.595E-09	1.607E-09	1.610E-09	1.610E-09	1.610E-09	1.610E-09	1.610E-09
Mn-54	1.479E-11	2.927E-12	5.790E-13	1.146E-13	1.994E-15	3.472E-17	0.00
Mn-55	1.409E-08	1.544E-08	1.623E-08	1.669E-08	1.718E-08	1.731E-08	1.735E-08
Fe-54	2.849E-06	2.849E-06	2.849E-06	2.849E-06	2.849E-06	2.849E-06	2.849E-06
Fe-55	3.263E-09	1.915E-09	1.123E-09	6.592E-10	1.738E-10	4.583E-11	0.00
Fe-56	4.662E-05	4.662E-05	4.662E-05	4.662E-05	4.662E-05	4.662E-05	4.662E-05
Fe-57	1.460E-06	1.460E-06	1.460E-06	1.460E-06	1.460E-06	1.460E-06	1.460E-06
Fe-58	1.690E-07	1.690E-07	1.690E-07	1.690E-07	1.690E-07	1.690E-07	1.690E-07
Co-58	2.627E-16	2.053E-19	1.605E-22	1.254E-25	2.142E-33	0.00	0.00
Co-59	3.835E-09	3.839E-09	3.843E-09	3.847E-09	3.856E-09	3.866E-09	5.716E-09
Co-60	1.759E-10	1.352E-10	1.040E-10	7.991E-11	4.140E-11	2.145E-11	0.00
Ni-58	1.888E-05	1.888E-05	1.888E-05	1.888E-05	1.888E-05	1.888E-05	1.888E-05
Ni-59	2.189E-07	2.189E-07	2.189E-07	2.189E-07	2.189E-07	2.189E-07	2.170E-07
Ni-60	7.550E-06	7.550E-06	7.550E-06	7.550E-06	7.550E-06	7.550E-06	7.550E-06
Ni-61	3.859E-07	3.859E-07	3.859E-07	3.859E-07	3.859E-07	3.859E-07	3.859E-07
Ni-62	1.040E-06	1.040E-06	1.040E-06	1.040E-06	1.040E-06	1.040E-06	1.040E-06
Ni-63	3.568E-08	3.514E-08	3.462E-08	3.410E-08	3.284E-08	3.163E-08	1.965E-11
Ni-64	2.815E-07	2.815E-07	2.815E-07	2.815E-07	2.815E-07	2.815E-07	2.815E-07
Cu-63	1.824E-09	2.358E-09	2.883E-09	3.401E-09	4.662E-09	5.876E-09	3.748E-08
Cu-65	1.147E-09	1.147E-09	1.147E-09	1.147E-09	1.147E-09	1.147E-09	1.147E-09
Zn-64	1.258E-12	1.258E-12	1.258E-12	1.258E-12	1.258E-12	1.258E-12	1.258E-12
Zn-66	3.733E-12	3.733E-12	3.733E-12	3.733E-12	3.733E-12	3.733E-12	3.733E-12
Zn-67	3.034E-15	3.034E-15	3.034E-15	3.034E-15	3.034E-15	3.034E-15	3.034E-15
Ru-104	1.416E-15	1.416E-15	1.416E-15	1.416E-15	1.416E-15	1.416E-15	1.416E-15
Pd-104	3.115E-13	3.115E-13	3.115E-13	3.115E-13	3.115E-13	3.115E-13	3.115E-13
Pd-105	2.772E-15	2.772E-15	2.772E-15	2.772E-15	2.772E-15	2.772E-15	2.772E-15
Pd-106	6.569E-12	6.569E-12	6.569E-12	6.569E-12	6.569E-12	6.569E-12	6.569E-12
Pd-107	3.156E-13	3.156E-13	3.156E-13	3.156E-13	3.156E-13	3.156E-13	3.155E-13
Pd-108	2.085E-09	2.144E-09	2.201E-09	2.258E-09	2.398E-09	2.534E-09	7.432E-09

TABLE D.7.d. Fuel Activation Product Inventory by Isotope at 35 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Pd-110	1.030E-09	1.030E-09	1.030E-09	1.030E-09	1.030E-09	1.030E-09	1.030E-09
Ag-107	4.709E-07	4.709E-07	4.709E-07	4.709E-07	4.709E-07	4.709E-07	4.709E-07
Ag-108m	5.881E-09	5.817E-09	5.754E-09	5.692E-09	5.539E-09	5.390E-09	2.563E-11
Ag-109	1.754E-07	1.754E-07	1.754E-07	1.754E-07	1.754E-07	1.754E-07	1.754E-07
Ag-110m	3.935E-11	5.187E-12	6.838E-13	9.014E-14	5.687E-16	3.588E-18	0.00
Cd-108	8.652E-08	8.653E-08	8.653E-08	8.654E-08	8.655E-08	8.657E-08	8.703E-08
Cd-109	1.287E-11	4.321E-12	1.451E-12	4.873E-13	3.184E-14	2.080E-15	0.00
Cd-110	3.485E-07	3.485E-07	3.485E-07	3.485E-07	3.485E-07	3.485E-07	3.485E-07
Cd-111	1.294E-08	1.294E-08	1.294E-08	1.294E-08	1.294E-08	1.294E-08	1.294E-08
Cd-112	4.684E-10	4.684E-10	4.684E-10	4.684E-10	4.684E-10	4.684E-10	4.684E-10
Cd-113	7.404E-14	7.404E-14	7.404E-14	7.404E-14	7.404E-14	7.404E-14	7.404E-14
Cd-114	2.161E-12	2.161E-12	2.161E-12	2.161E-12	2.161E-12	2.161E-12	2.161E-12
In-115	4.278E-16	4.278E-16	4.278E-16	4.278E-16	4.278E-16	4.278E-16	4.278E-16
Sn-116	2.732E-16	2.732E-16	2.732E-16	2.732E-16	2.732E-16	2.732E-16	2.732E-16
Total	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01

TABLE D.7.e. Fuel Activation Product Inventory by Isotope at 40 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-1	1.321E-08	1.321E-08	1.321E-08	1.321E-08	1.321E-08	1.321E-08	1.321E-08
H-2	1.470E-11	1.470E-11	1.470E-11	1.470E-11	1.470E-11	1.470E-11	1.470E-11
H-3	1.535E-14	1.372E-14	1.226E-14	1.096E-14	8.278E-15	6.253E-15	0.00
He-3	4.104E-15	5.734E-15	7.191E-15	8.493E-15	1.117E-14	1.320E-14	1.945E-14
He-4	2.942E-06	2.942E-06	2.942E-06	2.942E-06	2.942E-06	2.942E-06	2.942E-06
Li-6	3.753E-14	3.753E-14	3.753E-14	3.753E-14	3.753E-14	3.753E-14	3.753E-14
Li-7	1.602E-16	1.602E-16	1.602E-16	1.602E-16	1.602E-16	1.602E-16	1.602E-16
Be-9	1.878E-10	1.878E-10	1.878E-10	1.878E-10	1.878E-10	1.878E-10	1.878E-10
Be-10	9.803E-11	9.803E-11	9.803E-11	9.803E-11	9.803E-11	9.803E-11	9.799E-11
B-10	2.107E-16	2.956E-16	3.805E-16	4.655E-16	6.778E-16	8.902E-16	4.250E-14
B-11	1.712E-08	1.712E-08	1.712E-08	1.712E-08	1.712E-08	1.712E-08	1.712E-08
C-12	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05
C-13	9.750E-06	9.750E-06	9.750E-06	9.750E-06	9.750E-06	9.750E-06	9.750E-06
C-14	1.810E-07	1.810E-07	1.809E-07	1.809E-07	1.808E-07	1.807E-07	1.605E-07
N-14	2.582E-05	2.582E-05	2.582E-05	2.582E-05	2.582E-05	2.582E-05	2.584E-05
N-15	1.122E-07	1.122E-07	1.122E-07	1.122E-07	1.122E-07	1.122E-07	1.122E-07
O-16	1.341E-01	1.341E-01	1.341E-01	1.341E-01	1.341E-01	1.341E-01	1.341E-01
O-17	5.433E-05	5.433E-05	5.433E-05	5.433E-05	5.433E-05	5.433E-05	5.433E-05
O-18	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04
F-19	5.699E-06	5.699E-06	5.699E-06	5.699E-06	5.699E-06	5.699E-06	5.699E-06
Ne-20	2.307E-10	2.307E-10	2.307E-10	2.307E-10	2.307E-10	2.307E-10	2.307E-10
Ne-21	1.448E-14	1.448E-14	1.448E-14	1.448E-14	1.448E-14	1.448E-14	1.448E-14
Ne-22	1.585E-14	1.585E-14	1.585E-14	1.585E-14	1.585E-14	1.585E-14	1.585E-14
Na-23	1.284E-15	1.284E-15	1.284E-15	1.284E-15	1.284E-15	1.284E-15	1.284E-15
Mg-24	2.052E-10	2.052E-10	2.052E-10	2.052E-10	2.052E-10	2.052E-10	2.052E-10
Mg-25	2.159E-10	2.159E-10	2.159E-10	2.159E-10	2.159E-10	2.159E-10	2.159E-10
Mg-26	9.889E-11	9.889E-11	9.889E-11	9.889E-11	9.889E-11	9.889E-11	9.889E-11
Al-27	3.627E-05	3.627E-05	3.627E-05	3.627E-05	3.627E-05	3.627E-05	3.627E-05
Si-28	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05
Si-29	1.765E-06	1.765E-06	1.765E-06	1.765E-06	1.765E-06	1.765E-06	1.765E-06
Si-30	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06
P-31	4.472E-10	4.472E-10	4.472E-10	4.472E-10	4.472E-10	4.472E-10	4.472E-10
S-32	2.198E-10	2.198E-10	2.198E-10	2.198E-10	2.198E-10	2.198E-10	2.198E-10
S-33	1.765E-13	1.765E-13	1.765E-13	1.765E-13	1.765E-13	1.765E-13	1.765E-13
S-34	1.560E-11	1.560E-11	1.560E-11	1.560E-11	1.560E-11	1.560E-11	1.560E-11
S-35	4.982E-15	1.576E-17	5.001E-20	1.568E-22	8.874E-29	5.022E-35	0.00
S-36	1.471E-13	1.913E-13	2.356E-13	2.799E-13	3.906E-13	5.013E-13	2.217E-11
Cl-35	3.760E-06	3.760E-06	3.760E-06	3.760E-06	3.760E-06	3.760E-06	3.760E-06
Cl-36	5.060E-07	5.060E-07	5.060E-07	5.060E-07	5.060E-07	5.060E-07	5.048E-07
Cl-37	1.448E-06	1.448E-06	1.448E-06	1.448E-06	1.448E-06	1.448E-06	1.448E-06
Ar-36	7.577E-12	9.863E-12	1.215E-11	1.444E-11	2.015E-11	2.587E-11	1.145E-09
Ar-38	2.001E-09	2.001E-09	2.001E-09	2.001E-09	2.001E-09	2.001E-09	2.001E-09
Ar-39	2.623E-11	2.610E-11	2.596E-11	2.583E-11	2.550E-11	2.517E-11	2.015E-12
Ar-40	1.349E-10	1.349E-10	1.349E-10	1.349E-10	1.349E-10	1.349E-10	1.349E-10
K-39	4.927E-13	6.275E-13	7.617E-13	8.951E-13	1.226E-12	1.552E-12	2.471E-11
K-40	1.535E-08	1.535E-08	1.535E-08	1.535E-08	1.535E-08	1.535E-08	1.535E-08

TABLE D.7.e. Fuel Activation Product Inventory by Isotope at 40 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
K-41	7.084E-10	7.091E-10	7.098E-10	7.106E-10	7.124E-10	7.142E-10	1.067E-09
Ca-40	3.503E-05	3.503E-05	3.503E-05	3.503E-05	3.503E-05	3.503E-05	3.503E-05
Ca-41	4.230E-08	4.230E-08	4.230E-08	4.230E-08	4.230E-08	4.230E-08	4.194E-08
Ca-42	2.452E-07	2.452E-07	2.452E-07	2.452E-07	2.452E-07	2.452E-07	2.452E-07
Ca-43	5.003E-08	5.003E-08	5.003E-08	5.003E-08	5.003E-08	5.003E-08	5.003E-08
Ca-44	8.307E-07	8.307E-07	8.307E-07	8.307E-07	8.307E-07	8.307E-07	8.307E-07
Ca-45	6.963E-13	3.115E-14	1.393E-15	6.231E-17	2.637E-20	1.116E-23	0.00
Ca-46	1.454E-09	1.454E-09	1.454E-09	1.454E-09	1.454E-09	1.454E-09	1.454E-09
Ca-48	8.226E-08	8.226E-08	8.226E-08	8.226E-08	8.226E-08	8.226E-08	8.226E-08
Sc-45	2.499E-09	2.500E-09	2.500E-09	2.500E-09	2.500E-09	2.500E-09	2.500E-09
Ti-46	7.786E-11	7.786E-11	7.786E-11	7.786E-11	7.786E-11	7.786E-11	7.786E-11
Ti-47	3.205E-12	3.205E-12	3.205E-12	3.205E-12	3.205E-12	3.205E-12	3.205E-12
Ti-48	9.191E-15	9.191E-15	9.191E-15	9.191E-15	9.191E-15	9.191E-15	9.191E-15
Ti-49	2.714E-10	2.714E-10	2.714E-10	2.714E-10	2.714E-10	2.714E-10	2.714E-10
Ti-50	9.554E-13	9.554E-13	9.554E-13	9.554E-13	9.554E-13	9.554E-13	9.554E-13
V-51	6.298E-11	6.298E-11	6.298E-11	6.298E-11	6.298E-11	6.298E-11	6.298E-11
Cr-52	4.591E-13	4.591E-13	4.591E-13	4.591E-13	4.591E-13	4.591E-13	4.591E-13
Cr-53	1.217E-10	1.217E-10	1.217E-10	1.217E-10	1.217E-10	1.217E-10	1.217E-10
Cr-54	1.870E-09	1.884E-09	1.887E-09	1.888E-09	1.888E-09	1.888E-09	1.888E-09
Mn-54	1.757E-11	3.475E-12	6.875E-13	1.360E-13	2.368E-15	4.123E-17	0.00
Mn-55	1.648E-08	1.807E-08	1.900E-08	1.955E-08	2.012E-08	2.027E-08	2.032E-08
Fe-54	2.846E-06	2.846E-06	2.846E-06	2.846E-06	2.846E-06	2.846E-06	2.846E-06
Fe-55	3.849E-09	2.258E-09	1.325E-09	7.775E-10	2.050E-10	5.406E-11	0.00
Fe-56	4.656E-05	4.656E-05	4.656E-05	4.656E-05	4.656E-05	4.656E-05	4.656E-05
Fe-57	1.519E-06	1.519E-06	1.519E-06	1.519E-06	1.519E-06	1.519E-06	1.519E-06
Fe-58	1.714E-07	1.714E-07	1.714E-07	1.714E-07	1.714E-07	1.714E-07	1.714E-07
Co-58	2.933E-16	2.292E-19	1.791E-22	1.400E-25	2.391E-33	0.00	0.00
Co-59	4.880E-09	4.885E-09	4.889E-09	4.893E-09	4.904E-09	4.915E-09	7.027E-09
Co-60	2.461E-10	1.892E-10	1.454E-10	1.118E-10	5.791E-11	3.000E-11	0.00
Ni-58	1.883E-05	1.883E-05	1.883E-05	1.883E-05	1.883E-05	1.883E-05	1.883E-05
Ni-59	2.498E-07	2.498E-07	2.498E-07	2.498E-07	2.497E-07	2.497E-07	2.476E-07
Ni-60	7.553E-06	7.553E-06	7.553E-06	7.553E-06	7.553E-06	7.553E-06	7.553E-06
Ni-61	3.950E-07	3.950E-07	3.950E-07	3.950E-07	3.950E-07	3.950E-07	3.950E-07
Ni-62	1.034E-06	1.034E-06	1.034E-06	1.034E-06	1.034E-06	1.034E-06	1.034E-06
Ni-63	4.154E-08	4.091E-08	4.030E-08	3.970E-08	3.823E-08	3.682E-08	2.288E-11
Ni-64	2.817E-07	2.817E-07	2.817E-07	2.817E-07	2.817E-07	2.817E-07	2.817E-07
Cu-63	2.117E-09	2.739E-09	3.350E-09	3.953E-09	5.421E-09	6.834E-09	4.363E-08
Cu-65	1.345E-09	1.345E-09	1.345E-09	1.345E-09	1.345E-09	1.345E-09	1.345E-09
Zn-64	1.722E-12	1.722E-12	1.722E-12	1.722E-12	1.722E-12	1.722E-12	1.722E-12
Zn-66	5.135E-12	5.135E-12	5.135E-12	5.135E-12	5.135E-12	5.135E-12	5.135E-12
Zn-67	4.892E-15	4.892E-15	4.892E-15	4.892E-15	4.892E-15	4.892E-15	4.892E-15
Ru-104	1.635E-15	1.635E-15	1.635E-15	1.635E-15	1.635E-15	1.635E-15	1.635E-15
Pd-104	3.594E-13	3.594E-13	3.594E-13	3.594E-13	3.594E-13	3.594E-13	3.594E-13
Pd-105	3.749E-15	3.749E-15	3.749E-15	3.749E-15	3.749E-15	3.749E-15	3.749E-15
Pd-106	7.572E-12	7.572E-12	7.572E-12	7.572E-12	7.572E-12	7.572E-12	7.572E-12
Pd-107	3.673E-13	3.673E-13	3.673E-13	3.673E-13	3.673E-13	3.673E-13	3.673E-13

TABLE D.7.e. Fuel Activation Product Inventory by Isotope at 40 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Pd-108	2.370E-09	2.437E-09	2.504E-09	2.570E-09	2.731E-09	2.889E-09	8.548E-09
Pd-110	1.117E-09	1.117E-09	1.117E-09	1.117E-09	1.117E-09	1.117E-09	1.117E-09
Ag-107	4.563E-07	4.563E-07	4.563E-07	4.563E-07	4.563E-07	4.563E-07	4.563E-07
Ag-108m	6.796E-09	6.722E-09	6.649E-09	6.577E-09	6.400E-09	6.227E-09	2.961E-11
Ag-109	1.447E-07	1.447E-07	1.447E-07	1.447E-07	1.447E-07	1.447E-07	1.447E-07
Ag-110m	3.970E-11	5.233E-12	6.898E-13	9.093E-14	5.737E-16	3.621E-18	0.00
Cd-108	9.990E-08	9.991E-08	9.991E-08	9.992E-08	9.994E-08	9.995E-08	1.005E-07
Cd-109	1.682E-11	5.649E-12	1.897E-12	6.370E-13	4.162E-14	2.720E-15	0.00
Cd-110	3.754E-07	3.754E-07	3.755E-07	3.755E-07	3.755E-07	3.755E-07	3.755E-07
Cd-111	1.670E-08	1.670E-08	1.670E-08	1.670E-08	1.670E-08	1.670E-08	1.670E-08
Cd-112	7.191E-10	7.191E-10	7.191E-10	7.191E-10	7.191E-10	7.191E-10	7.191E-10
Cd-113	1.136E-13	1.136E-13	1.136E-13	1.136E-13	1.136E-13	1.136E-13	1.136E-13
Cd-114	3.937E-12	3.937E-12	3.937E-12	3.937E-12	3.937E-12	3.937E-12	3.937E-12
In-115	8.636E-16	8.636E-16	8.636E-16	8.636E-16	8.636E-16	8.636E-16	8.636E-16
Sn-116	6.387E-16	6.387E-16	6.387E-16	6.387E-16	6.387E-16	6.387E-16	6.387E-16
Total	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01

TABLE D.7.f. Fuel Activation Product Inventory by Isotope at 45 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-1	1.523E-08	1.523E-08	1.523E-08	1.523E-08	1.523E-08	1.523E-08	1.523E-08
H-2	1.956E-11	1.956E-11	1.956E-11	1.956E-11	1.956E-11	1.956E-11	1.956E-11
H-3	2.205E-14	1.971E-14	1.762E-14	1.574E-14	1.189E-14	8.982E-15	1.158E-38
He-3	5.851E-15	8.192E-15	1.028E-14	1.216E-14	1.601E-14	1.892E-14	2.790E-14
He-4	3.394E-06	3.394E-06	3.394E-06	3.394E-06	3.394E-06	3.394E-06	3.394E-06
Li-6	4.588E-14	4.588E-14	4.588E-14	4.588E-14	4.588E-14	4.588E-14	4.588E-14
Li-7	2.168E-16	2.168E-16	2.168E-16	2.168E-16	2.168E-16	2.168E-16	2.168E-16
Be-9	2.167E-10	2.167E-10	2.167E-10	2.167E-10	2.167E-10	2.167E-10	2.167E-10
Be-10	1.296E-10	1.296E-10	1.296E-10	1.296E-10	1.296E-10	1.296E-10	1.296E-10
B-10	2.719E-16	3.842E-16	4.966E-16	6.089E-16	8.897E-16	1.170E-15	5.619E-14
B-11	1.974E-08	1.974E-08	1.974E-08	1.974E-08	1.974E-08	1.974E-08	1.974E-08
C-12	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05
C-13	1.121E-05	1.121E-05	1.121E-05	1.121E-05	1.121E-05	1.121E-05	1.121E-05
C-14	2.087E-07	2.087E-07	2.086E-07	2.086E-07	2.085E-07	2.083E-07	1.850E-07
N-14	2.579E-05	2.579E-05	2.579E-05	2.579E-05	2.579E-05	2.579E-05	2.582E-05
N-15	1.138E-07	1.138E-07	1.138E-07	1.138E-07	1.138E-07	1.138E-07	1.138E-07
O-16	1.341E-01	1.341E-01	1.341E-01	1.341E-01	1.341E-01	1.341E-01	1.341E-01
O-17	5.434E-05	5.434E-05	5.434E-05	5.434E-05	5.434E-05	5.434E-05	5.434E-05
O-18	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04
F-19	5.699E-06	5.699E-06	5.699E-06	5.699E-06	5.699E-06	5.699E-06	5.699E-06
Ne-20	2.662E-10	2.662E-10	2.662E-10	2.662E-10	2.662E-10	2.662E-10	2.662E-10
Ne-21	1.927E-14	1.927E-14	1.927E-14	1.927E-14	1.927E-14	1.927E-14	1.927E-14
Ne-22	2.109E-14	2.109E-14	2.109E-14	2.109E-14	2.109E-14	2.109E-14	2.109E-14
Na-23	1.710E-15	1.710E-15	1.710E-15	1.710E-15	1.710E-15	1.710E-15	1.710E-15
Mg-24	2.367E-10	2.367E-10	2.367E-10	2.367E-10	2.367E-10	2.367E-10	2.367E-10
Mg-25	2.491E-10	2.491E-10	2.491E-10	2.491E-10	2.491E-10	2.491E-10	2.491E-10
Mg-26	1.142E-10	1.142E-10	1.142E-10	1.142E-10	1.142E-10	1.142E-10	1.142E-10
Al-27	3.627E-05	3.627E-05	3.627E-05	3.627E-05	3.627E-05	3.627E-05	3.627E-05
Si-28	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05
Si-29	1.767E-06	1.767E-06	1.767E-06	1.767E-06	1.767E-06	1.767E-06	1.767E-06
Si-30	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06
P-31	5.160E-10	5.160E-10	5.160E-10	5.160E-10	5.160E-10	5.160E-10	5.160E-10
S-32	2.512E-10	2.512E-10	2.512E-10	2.512E-10	2.512E-10	2.512E-10	2.512E-10
S-33	2.334E-13	2.334E-13	2.334E-13	2.334E-13	2.334E-13	2.334E-13	2.334E-13
S-34	1.801E-11	1.801E-11	1.801E-11	1.801E-11	1.801E-11	1.801E-11	1.801E-11
S-35	5.720E-15	1.813E-17	5.752E-20	1.805E-22	1.022E-28	5.782E-35	0.00
S-36	1.674E-13	2.179E-13	2.684E-13	3.189E-13	4.451E-13	5.713E-13	2.528E-11
Cl-35	3.689E-06	3.689E-06	3.689E-06	3.689E-06	3.689E-06	3.689E-06	3.689E-06
Cl-36	5.769E-07	5.769E-07	5.769E-07	5.769E-07	5.769E-07	5.769E-07	5.756E-07
Cl-37	1.451E-06	1.451E-06	1.451E-06	1.451E-06	1.451E-06	1.451E-06	1.451E-06
Ar-36	8.624E-12	1.123E-11	1.384E-11	1.644E-11	2.296E-11	2.948E-11	1.305E-09
Ar-38	2.310E-09	2.310E-09	2.310E-09	2.310E-09	2.310E-09	2.310E-09	2.310E-09
Ar-39	2.781E-11	2.767E-11	2.752E-11	2.738E-11	2.703E-11	2.669E-11	2.136E-12
Ar-40	1.758E-10	1.758E-10	1.758E-10	1.758E-10	1.758E-10	1.758E-10	1.758E-10
K-39	5.266E-13	6.695E-13	8.117E-13	9.532E-13	1.304E-12	1.650E-12	2.620E-11
K-40	1.758E-08	1.758E-08	1.758E-08	1.758E-08	1.758E-08	1.758E-08	1.758E-08

TABLE D.7.f. Fuel Activation Product Inventory by Isotope at 45 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
K-41	9.372E-10	9.381E-10	9.389E-10	9.397E-10	9.418E-10	9.439E-10	1.351E-09
Ca-40	3.502E-05	3.502E-05	3.502E-05	3.502E-05	3.502E-05	3.502E-05	3.502E-05
Ca-41	4.880E-08	4.879E-08	4.879E-08	4.879E-08	4.879E-08	4.879E-08	4.838E-08
Ca-42	2.451E-07	2.451E-07	2.451E-07	2.451E-07	2.451E-07	2.451E-07	2.451E-07
Ca-43	4.995E-08	4.995E-08	4.995E-08	4.995E-08	4.995E-08	4.995E-08	4.995E-08
Ca-44	8.304E-07	8.304E-07	8.304E-07	8.304E-07	8.304E-07	8.304E-07	8.304E-07
Ca-45	8.132E-13	3.637E-14	1.627E-15	7.278E-17	3.080E-20	1.303E-23	0.00
Ca-46	1.453E-09	1.453E-09	1.453E-09	1.453E-09	1.453E-09	1.453E-09	1.453E-09
Ca-48	8.222E-08	8.222E-08	8.222E-08	8.222E-08	8.222E-08	8.222E-08	8.222E-08
Sc-45	2.870E-09	2.870E-09	2.870E-09	2.870E-09	2.870E-09	2.870E-09	2.870E-09
Ti-46	1.032E-10	1.032E-10	1.032E-10	1.032E-10	1.032E-10	1.032E-10	1.032E-10
Ti-47	3.751E-12	3.751E-12	3.751E-12	3.751E-12	3.751E-12	3.751E-12	3.751E-12
Ti-48	1.231E-14	1.231E-14	1.231E-14	1.231E-14	1.231E-14	1.231E-14	1.231E-14
Ti-49	3.129E-10	3.129E-10	3.129E-10	3.129E-10	3.129E-10	3.129E-10	3.129E-10
Ti-50	1.271E-12	1.271E-12	1.271E-12	1.271E-12	1.271E-12	1.271E-12	1.271E-12
V-51	7.254E-11	7.254E-11	7.254E-11	7.254E-11	7.254E-11	7.254E-11	7.254E-11
Cr-52	6.100E-13	6.100E-13	6.100E-13	6.100E-13	6.100E-13	6.100E-13	6.100E-13
Cr-53	1.398E-10	1.398E-10	1.398E-10	1.398E-10	1.398E-10	1.398E-10	1.398E-10
Cr-54	2.156E-09	2.173E-09	2.176E-09	2.177E-09	2.177E-09	2.177E-09	2.177E-09
Mn-54	2.045E-11	4.045E-12	8.003E-13	1.583E-13	2.756E-15	4.798E-17	0.00
Mn-55	1.895E-08	2.079E-08	2.187E-08	2.251E-08	2.317E-08	2.334E-08	2.341E-08
Fe-54	2.843E-06	2.843E-06	2.843E-06	2.843E-06	2.843E-06	2.843E-06	2.843E-06
Fe-55	4.459E-09	2.617E-09	1.535E-09	9.007E-10	2.375E-10	6.263E-11	0.00
Fe-56	4.650E-05	4.650E-05	4.650E-05	4.650E-05	4.650E-05	4.650E-05	4.650E-05
Fe-57	1.580E-06	1.580E-06	1.580E-06	1.580E-06	1.580E-06	1.580E-06	1.580E-06
Fe-58	1.738E-07	1.738E-07	1.738E-07	1.738E-07	1.738E-07	1.738E-07	1.738E-07
Co-58	3.208E-16	2.507E-19	1.960E-22	1.532E-25	2.615E-33	0.00	0.00
Co-59	6.027E-09	6.031E-09	6.036E-09	6.041E-09	6.053E-09	6.065E-09	8.432E-09
Co-60	3.344E-10	2.571E-10	1.976E-10	1.519E-10	7.869E-11	4.077E-11	0.00
Ni-58	1.878E-05	1.878E-05	1.878E-05	1.878E-05	1.878E-05	1.878E-05	1.878E-05
Ni-59	2.800E-07	2.800E-07	2.800E-07	2.800E-07	2.800E-07	2.799E-07	2.776E-07
Ni-60	7.558E-06	7.558E-06	7.558E-06	7.558E-06	7.558E-06	7.558E-06	7.558E-06
Ni-61	4.045E-07	4.045E-07	4.045E-07	4.045E-07	4.045E-07	4.045E-07	4.045E-07
Ni-62	1.028E-06	1.028E-06	1.028E-06	1.028E-06	1.028E-06	1.028E-06	1.028E-06
Ni-63	4.753E-08	4.682E-08	4.612E-08	4.543E-08	4.375E-08	4.214E-08	2.618E-11
Ni-64	2.820E-07	2.820E-07	2.820E-07	2.820E-07	2.820E-07	2.820E-07	2.820E-07
Cu-63	2.417E-09	3.128E-09	3.829E-09	4.518E-09	6.198E-09	7.816E-09	4.993E-08
Cu-65	1.551E-09	1.551E-09	1.551E-09	1.551E-09	1.551E-09	1.551E-09	1.551E-09
Zn-64	2.278E-12	2.278E-12	2.278E-12	2.278E-12	2.278E-12	2.278E-12	2.278E-12
Zn-66	6.831E-12	6.831E-12	6.831E-12	6.831E-12	6.831E-12	6.831E-12	6.831E-12
Zn-67	7.498E-15	7.498E-15	7.498E-15	7.498E-15	7.498E-15	7.498E-15	7.498E-15
Ru-104	1.855E-15	1.855E-15	1.855E-15	1.855E-15	1.855E-15	1.855E-15	1.855E-15
Pd-104	4.074E-13	4.074E-13	4.074E-13	4.074E-13	4.074E-13	4.074E-13	4.074E-13
Pd-105	4.900E-15	4.900E-15	4.900E-15	4.900E-15	4.900E-15	4.900E-15	4.900E-15
Pd-106	8.580E-12	8.580E-12	8.580E-12	8.580E-12	8.580E-12	8.580E-12	8.580E-12
Pd-107	4.204E-13	4.204E-13	4.204E-13	4.204E-13	4.204E-13	4.204E-13	4.203E-13

TABLE D.7.f. Fuel Activation Product Inventory by Isotope at 45 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Pd-108	2.646E-09	2.722E-09	2.798E-09	2.873E-09	3.056E-09	3.235E-09	9.661E-09
Pd-110	1.192E-09	1.192E-09	1.192E-09	1.192E-09	1.192E-09	1.192E-09	1.192E-09
Ag-107	4.415E-07	4.415E-07	4.415E-07	4.415E-07	4.415E-07	4.415E-07	4.415E-07
Ag-108m	7.717E-09	7.634E-09	7.551E-09	7.469E-09	7.268E-09	7.072E-09	3.363E-11
Ag-109	1.185E-07	1.185E-07	1.185E-07	1.185E-07	1.185E-07	1.185E-07	1.185E-07
Ag-110m	3.901E-11	5.142E-12	6.778E-13	8.935E-14	5.638E-16	3.557E-18	0.00
Cd-108	1.134E-07	1.134E-07	1.134E-07	1.134E-07	1.134E-07	1.134E-07	1.140E-07
Cd-109	2.120E-11	7.119E-12	2.391E-12	8.028E-13	5.245E-14	3.427E-15	0.00
Cd-110	3.974E-07	3.975E-07	3.975E-07	3.975E-07	3.975E-07	3.975E-07	3.975E-07
Cd-111	2.082E-08	2.082E-08	2.082E-08	2.082E-08	2.082E-08	2.082E-08	2.082E-08
Cd-112	1.049E-09	1.049E-09	1.049E-09	1.049E-09	1.049E-09	1.049E-09	1.049E-09
Cd-113	1.658E-13	1.658E-13	1.658E-13	1.658E-13	1.658E-13	1.658E-13	1.658E-13
Cd-114	6.698E-12	6.698E-12	6.698E-12	6.698E-12	6.698E-12	6.698E-12	6.698E-12
In-115	1.606E-15	1.606E-15	1.606E-15	1.606E-15	1.606E-15	1.606E-15	1.606E-15
Sn-116	1.352E-15	1.352E-15	1.352E-15	1.352E-15	1.352E-15	1.352E-15	1.352E-15
Total	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01

TABLE D.7.g. Fuel Activation Product Inventory by Isotope at 50 MWd/kgM, g/gU

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-1	1.731E-08	1.731E-08	1.731E-08	1.731E-08	1.731E-08	1.731E-08	1.731E-08
H-2	2.531E-11	2.531E-11	2.531E-11	2.531E-11	2.531E-11	2.531E-11	2.531E-11
H-3	3.042E-14	2.719E-14	2.430E-14	2.172E-14	1.641E-14	1.239E-14	1.597E-38
He-3	8.023E-15	1.125E-14	1.414E-14	1.672E-14	2.204E-14	2.605E-14	3.844E-14
He-4	3.862E-06	3.862E-06	3.862E-06	3.862E-06	3.862E-06	3.862E-06	3.862E-06
Li-6	5.470E-14	5.470E-14	5.470E-14	5.470E-14	5.470E-14	5.470E-14	5.470E-14
Li-7	2.843E-16	2.843E-16	2.843E-16	2.843E-16	2.843E-16	2.843E-16	2.843E-16
Be-9	2.465E-10	2.465E-10	2.465E-10	2.465E-10	2.465E-10	2.465E-10	2.465E-10
Be-10	1.670E-10	1.670E-10	1.670E-10	1.670E-10	1.670E-10	1.669E-10	1.669E-10
B-10	3.434E-16	4.881E-16	6.327E-16	7.774E-16	1.139E-15	1.501E-15	7.237E-14
B-11	2.245E-08	2.245E-08	2.245E-08	2.245E-08	2.245E-08	2.245E-08	2.245E-08
C-12	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05	2.015E-05
C-13	1.272E-05	1.272E-05	1.272E-05	1.272E-05	1.272E-05	1.272E-05	1.272E-05
C-14	2.374E-07	2.373E-07	2.373E-07	2.372E-07	2.371E-07	2.369E-07	2.105E-07
N-14	2.576E-05	2.576E-05	2.576E-05	2.576E-05	2.577E-05	2.577E-05	2.579E-05
N-15	1.153E-07	1.153E-07	1.153E-07	1.153E-07	1.153E-07	1.153E-07	1.153E-07
O-16	1.341E-01	1.341E-01	1.341E-01	1.341E-01	1.341E-01	1.341E-01	1.341E-01
O-17	5.435E-05	5.435E-05	5.435E-05	5.435E-05	5.435E-05	5.435E-05	5.435E-05
O-18	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04	3.086E-04
F-19	5.699E-06	5.699E-06	5.699E-06	5.699E-06	5.699E-06	5.699E-06	5.699E-06
Ne-20	3.029E-10	3.029E-10	3.029E-10	3.029E-10	3.029E-10	3.029E-10	3.029E-10
Ne-21	2.494E-14	2.494E-14	2.494E-14	2.494E-14	2.494E-14	2.494E-14	2.494E-14
Ne-22	2.731E-14	2.731E-14	2.731E-14	2.731E-14	2.731E-14	2.731E-14	2.731E-14
Na-23	2.215E-15	2.215E-15	2.215E-15	2.215E-15	2.215E-15	2.215E-15	2.215E-15
Mg-24	2.693E-10	2.693E-10	2.693E-10	2.693E-10	2.693E-10	2.693E-10	2.693E-10
Mg-25	2.834E-10	2.834E-10	2.834E-10	2.834E-10	2.834E-10	2.834E-10	2.834E-10
Mg-26	1.300E-10	1.300E-10	1.300E-10	1.300E-10	1.300E-10	1.300E-10	1.300E-10
Al-27	3.626E-05	3.626E-05	3.626E-05	3.626E-05	3.626E-05	3.626E-05	3.626E-05
Si-28	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05	3.336E-05
Si-29	1.770E-06	1.770E-06	1.770E-06	1.770E-06	1.770E-06	1.770E-06	1.770E-06
Si-30	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06	1.202E-06
P-31	5.871E-10	5.871E-10	5.871E-10	5.871E-10	5.871E-10	5.871E-10	5.871E-10
S-32	2.831E-10	2.831E-10	2.831E-10	2.831E-10	2.831E-10	2.831E-10	2.831E-10
S-33	3.002E-13	3.002E-13	3.002E-13	3.002E-13	3.002E-13	3.002E-13	3.002E-13
S-34	2.050E-11	2.050E-11	2.050E-11	2.050E-11	2.050E-11	2.050E-11	2.050E-11
S-35	6.447E-15	2.045E-17	6.490E-20	2.034E-22	1.151E-28	6.515E-35	0.00
S-36	1.881E-13	2.448E-13	3.016E-13	3.583E-13	5.002E-13	6.421E-13	2.842E-11
Cl-35	3.616E-06	3.616E-06	3.616E-06	3.616E-06	3.616E-06	3.616E-06	3.616E-06
Cl-36	6.485E-07	6.485E-07	6.485E-07	6.485E-07	6.485E-07	6.485E-07	6.471E-07
Cl-37	1.454E-06	1.454E-06	1.454E-06	1.454E-06	1.454E-06	1.454E-06	1.454E-06
Ar-36	9.682E-12	1.261E-11	1.554E-11	1.847E-11	2.580E-11	3.312E-11	1.467E-09
Ar-38	2.630E-09	2.630E-09	2.630E-09	2.630E-09	2.630E-09	2.630E-09	2.630E-09
Ar-39	2.915E-11	2.900E-11	2.885E-11	2.870E-11	2.834E-11	2.797E-11	2.239E-12
Ar-40	2.232E-10	2.232E-10	2.232E-10	2.232E-10	2.232E-10	2.232E-10	2.232E-10
K-39	5.565E-13	7.063E-13	8.554E-13	1.004E-12	1.371E-12	1.734E-12	2.747E-11
K-40	1.984E-08	1.984E-08	1.984E-08	1.984E-08	1.984E-08	1.984E-08	1.984E-08

TABLE D.7.g. Fuel Activation Product Inventory by Isotope at 50 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
K-41	1.206E-09	1.207E-09	1.208E-09	1.209E-09	1.211E-09	1.214E-09	1.677E-09
Ca-40	3.501E-05	3.501E-05	3.501E-05	3.501E-05	3.501E-05	3.501E-05	3.501E-05
Ca-41	5.551E-08	5.551E-08	5.551E-08	5.551E-08	5.551E-08	5.551E-08	5.504E-08
Ca-42	2.450E-07	2.450E-07	2.450E-07	2.450E-07	2.450E-07	2.450E-07	2.450E-07
Ca-43	4.986E-08	4.986E-08	4.986E-08	4.986E-08	4.986E-08	4.986E-08	4.986E-08
Ca-44	8.302E-07	8.302E-07	8.302E-07	8.302E-07	8.302E-07	8.302E-07	8.302E-07
Ca-45	9.337E-13	4.176E-14	1.868E-15	8.356E-17	3.536E-20	1.496E-23	0.00
Ca-46	1.453E-09	1.453E-09	1.453E-09	1.453E-09	1.453E-09	1.453E-09	1.453E-09
Ca-48	8.217E-08	8.217E-08	8.217E-08	8.217E-08	8.217E-08	8.217E-08	8.217E-08
Sc-45	3.249E-09	3.250E-09	3.250E-09	3.250E-09	3.250E-09	3.250E-09	3.250E-09
Ti-46	1.330E-10	1.330E-10	1.330E-10	1.330E-10	1.330E-10	1.330E-10	1.330E-10
Ti-47	4.340E-12	4.340E-12	4.340E-12	4.340E-12	4.340E-12	4.340E-12	4.340E-12
Ti-48	1.607E-14	1.607E-14	1.607E-14	1.607E-14	1.607E-14	1.607E-14	1.607E-14
Ti-49	3.558E-10	3.558E-10	3.558E-10	3.558E-10	3.558E-10	3.558E-10	3.558E-10
Ti-50	1.645E-12	1.645E-12	1.645E-12	1.645E-12	1.645E-12	1.645E-12	1.645E-12
V-51	8.240E-11	8.240E-11	8.240E-11	8.240E-11	8.240E-11	8.240E-11	8.240E-11
Cr-52	7.885E-13	7.885E-13	7.885E-13	7.885E-13	7.885E-13	7.885E-13	7.885E-13
Cr-53	1.583E-10	1.583E-10	1.583E-10	1.583E-10	1.583E-10	1.583E-10	1.583E-10
Cr-54	2.452E-09	2.471E-09	2.474E-09	2.475E-09	2.475E-09	2.475E-09	2.475E-09
Mn-54	2.341E-11	4.631E-12	9.162E-13	1.813E-13	3.156E-15	5.494E-17	0.00
Mn-55	2.149E-08	2.360E-08	2.483E-08	2.556E-08	2.631E-08	2.651E-08	2.658E-08
Fe-54	2.840E-06	2.840E-06	2.840E-06	2.840E-06	2.840E-06	2.840E-06	2.840E-06
Fe-55	5.091E-09	2.987E-09	1.752E-09	1.028E-09	2.711E-10	7.150E-11	0.00
Fe-56	4.644E-05	4.644E-05	4.644E-05	4.644E-05	4.644E-05	4.644E-05	4.644E-05
Fe-57	1.642E-06	1.642E-06	1.642E-06	1.642E-06	1.642E-06	1.642E-06	1.642E-06
Fe-58	1.764E-07	1.764E-07	1.764E-07	1.764E-07	1.764E-07	1.764E-07	1.764E-07
Co-58	3.455E-16	2.700E-19	2.110E-22	1.649E-25	2.817E-33	0.00	0.00
Co-59	7.258E-09	7.263E-09	7.269E-09	7.274E-09	7.288E-09	7.301E-09	9.916E-09
Co-60	4.427E-10	3.403E-10	2.616E-10	2.011E-10	1.042E-10	5.397E-11	0.00
Ni-58	1.873E-05	1.873E-05	1.873E-05	1.873E-05	1.873E-05	1.873E-05	1.873E-05
Ni-59	3.093E-07	3.093E-07	3.093E-07	3.093E-07	3.093E-07	3.093E-07	3.067E-07
Ni-60	7.564E-06	7.564E-06	7.564E-06	7.564E-06	7.564E-06	7.565E-06	7.565E-06
Ni-61	4.143E-07	4.143E-07	4.143E-07	4.143E-07	4.143E-07	4.143E-07	4.143E-07
Ni-62	1.022E-06	1.022E-06	1.022E-06	1.022E-06	1.022E-06	1.022E-06	1.022E-06
Ni-63	5.364E-08	5.283E-08	5.204E-08	5.127E-08	4.937E-08	4.755E-08	2.955E-11
Ni-64	2.823E-07	2.823E-07	2.823E-07	2.823E-07	2.823E-07	2.823E-07	2.823E-07
Cu-63	2.723E-09	3.525E-09	4.315E-09	5.094E-09	6.989E-09	8.814E-09	5.633E-08
Cu-65	1.764E-09	1.764E-09	1.764E-09	1.764E-09	1.764E-09	1.764E-09	1.764E-09
Zn-64	2.929E-12	2.929E-12	2.929E-12	2.929E-12	2.929E-12	2.929E-12	2.929E-12
Zn-66	8.840E-12	8.840E-12	8.840E-12	8.840E-12	8.840E-12	8.840E-12	8.840E-12
Zn-67	1.103E-14	1.103E-14	1.103E-14	1.103E-14	1.103E-14	1.103E-14	1.103E-14
Ru-104	2.075E-15	2.075E-15	2.075E-15	2.075E-15	2.075E-15	2.075E-15	2.075E-15
Pd-104	4.553E-13	4.553E-13	4.553E-13	4.553E-13	4.553E-13	4.553E-13	4.553E-13
Pd-105	6.227E-15	6.227E-15	6.227E-15	6.227E-15	6.227E-15	6.227E-15	6.227E-15
Pd-106	9.584E-12	9.584E-12	9.584E-12	9.584E-12	9.584E-12	9.584E-12	9.584E-12
Pd-107	4.743E-13	4.743E-13	4.743E-13	4.743E-13	4.743E-13	4.743E-13	4.743E-13

TABLE D.7.g. Fuel Activation Product Inventory by Isotope at 50 MWd/kgM, g/gU (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Pd-108	2.910E-09	2.995E-09	3.080E-09	3.164E-09	3.369E-09	3.569E-09	1.076E-08
Pd-110	1.254E-09	1.254E-09	1.254E-09	1.254E-09	1.254E-09	1.254E-09	1.254E-09
Ag-107	4.268E-07	4.268E-07	4.268E-07	4.268E-07	4.268E-07	4.268E-07	4.268E-07
Ag-108m	8.640E-09	8.546E-09	8.453E-09	8.361E-09	8.136E-09	7.917E-09	3.765E-11
Ag-109	9.638E-08	9.639E-08	9.640E-08	9.640E-08	9.640E-08	9.640E-08	9.640E-08
Ag-110m	3.750E-11	4.944E-12	6.517E-13	8.591E-14	5.419E-16	3.418E-18	0.00
Cd-108	1.268E-07	1.268E-07	1.268E-07	1.268E-07	1.269E-07	1.269E-07	1.276E-07
Cd-109	2.593E-11	8.708E-12	2.924E-12	9.819E-13	6.416E-14	4.192E-15	0.00
Cd-110	4.150E-07	4.150E-07	4.150E-07	4.150E-07	4.150E-07	4.150E-07	4.150E-07
Cd-111	2.523E-08	2.523E-08	2.523E-08	2.523E-08	2.523E-08	2.523E-08	2.523E-08
Cd-112	1.467E-09	1.467E-09	1.467E-09	1.467E-09	1.467E-09	1.467E-09	1.467E-09
Cd-113	2.319E-13	2.319E-13	2.319E-13	2.319E-13	2.319E-13	2.319E-13	2.319E-13
Cd-114	1.078E-11	1.078E-11	1.078E-11	1.078E-11	1.078E-11	1.078E-11	1.078E-11
In-115	2.795E-15	2.795E-15	2.795E-15	2.795E-15	2.795E-15	2.795E-15	2.795E-15
Sn-116	2.645E-15	2.645E-15	2.645E-15	2.645E-15	2.645E-15	2.645E-15	2.645E-15
Total	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01	1.348E-01

TABLE D.8.a. Cladding Activation Product Inventory by Isotope at 20 MWd/kgM, g/gZr

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-1	1.402E-05	1.402E-05	1.402E-05	1.402E-05	1.402E-05	1.402E-05	1.402E-05
H-2	1.828E-08	1.828E-08	1.828E-08	1.828E-08	1.828E-08	1.828E-08	1.828E-08
H-3	1.955E-14	1.748E-14	1.562E-14	1.396E-14	1.055E-14	7.965E-15	1.027E-38
He-3	5.600E-15	7.676E-15	9.532E-15	1.119E-14	1.461E-14	1.719E-14	2.515E-14
He-4	5.018E-08	5.018E-08	5.018E-08	5.018E-08	5.018E-08	5.018E-08	5.018E-08
Li-6	6.156E-14	6.156E-14	6.156E-14	6.156E-14	6.156E-14	6.156E-14	6.156E-14
Be-9	4.793E-10	4.793E-10	4.793E-10	4.793E-10	4.793E-10	4.793E-10	4.793E-10
Be-10	1.243E-11	1.243E-11	1.243E-11	1.243E-11	1.243E-11	1.243E-11	1.242E-11
B-11	7.429E-09	7.429E-09	7.429E-09	7.429E-09	7.429E-09	7.429E-09	7.429E-09
C-12	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04
C-13	1.419E-06	1.419E-06	1.419E-06	1.419E-06	1.419E-06	1.419E-06	1.419E-06
C-14	6.526E-08	6.525E-08	6.523E-08	6.522E-08	6.518E-08	6.514E-08	5.786E-08
N-14	2.482E-05	2.482E-05	2.482E-05	2.482E-05	2.482E-05	2.483E-05	2.483E-05
N-15	1.007E-07	1.007E-07	1.007E-07	1.007E-07	1.007E-07	1.007E-07	1.007E-07
O-16	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03
O-17	4.704E-07	4.704E-07	4.704E-07	4.704E-07	4.704E-07	4.704E-07	4.704E-07
O-18	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06
F-19	1.342E-12	1.342E-12	1.342E-12	1.342E-12	1.342E-12	1.342E-12	1.342E-12
Ne-22	7.137E-15	7.137E-15	7.137E-15	7.137E-15	7.137E-15	7.137E-15	7.137E-15
Mg-24	1.023E-10	1.023E-10	1.023E-10	1.023E-10	1.023E-10	1.023E-10	1.023E-10
Mg-25	2.151E-10	2.151E-10	2.151E-10	2.151E-10	2.151E-10	2.151E-10	2.151E-10
Mg-26	9.829E-11	9.829E-11	9.829E-11	9.829E-11	9.829E-11	9.829E-11	9.829E-11
Al-27	3.999E-05	3.999E-05	3.999E-05	3.999E-05	3.999E-05	3.999E-05	3.999E-05
Si-28	7.350E-05	7.350E-05	7.350E-05	7.350E-05	7.350E-05	7.350E-05	7.350E-05
Si-29	3.870E-06	3.870E-06	3.870E-06	3.870E-06	3.870E-06	3.870E-06	3.870E-06
Si-30	2.648E-06	2.648E-06	2.648E-06	2.648E-06	2.648E-06	2.648E-06	2.648E-06
P-31	4.457E-10	4.457E-10	4.457E-10	4.457E-10	4.457E-10	4.457E-10	4.457E-10
S-32	5.500E-14	5.500E-14	5.500E-14	5.500E-14	5.500E-14	5.500E-14	5.502E-14
Ca-44	1.282E-15	1.282E-15	1.282E-15	1.282E-15	1.282E-15	1.282E-15	1.282E-15
Ti-47	1.119E-10	1.119E-10	1.119E-10	1.119E-10	1.119E-10	1.119E-10	1.119E-10
Ti-48	1.567E-13	1.567E-13	1.567E-13	1.567E-13	1.567E-13	1.567E-13	1.567E-13
Ti-49	3.051E-10	3.051E-10	3.051E-10	3.051E-10	3.051E-10	3.051E-10	3.051E-10
Ti-50	1.226E-09	1.226E-09	1.226E-09	1.226E-09	1.226E-09	1.226E-09	1.226E-09
V 50	4.410E-09	4.410E-09	4.410E-09	4.410E-09	4.410E-09	4.410E-09	4.410E-09
V-51	8.976E-07	8.976E-07	8.976E-07	8.976E-07	8.976E-07	8.976E-07	8.976E-07
Cr-50	4.090E-05	4.090E-05	4.090E-05	4.090E-05	4.090E-05	4.090E-05	4.090E-05
Cr-52	8.330E-04	8.330E-04	8.330E-04	8.330E-04	8.330E-04	8.330E-04	8.330E-04
Cr-53	9.846E-05	9.846E-05	9.846E-05	9.846E-05	9.846E-05	9.846E-05	9.846E-05
Cr-54	2.693E-05	2.693E-05	2.693E-05	2.693E-05	2.693E-05	2.693E-05	2.693E-05
Mn-54	2.931E-10	5.799E-11	1.147E-11	2.270E-12	3.952E-14	6.880E-16	0.00
Mn-55	2.967E-07	3.231E-07	3.386E-07	3.477E-07	3.572E-07	3.597E-07	3.606E-07
Fe-54	1.119E-04	1.119E-04	1.119E-04	1.119E-04	1.119E-04	1.119E-04	1.119E-04
Fe-55	6.390E-08	3.749E-08	2.200E-08	1.291E-08	3.403E-09	8.974E-10	0.00
Fe-56	1.831E-03	1.831E-03	1.831E-03	1.831E-03	1.831E-03	1.831E-03	1.831E-03
Fe-57	5.093E-05	5.093E-05	5.093E-05	5.093E-05	5.093E-05	5.093E-05	5.093E-05
Fe-58	6.168E-06	6.168E-06	6.168E-06	6.168E-06	6.168E-06	6.168E-06	6.168E-06

TABLE D.8.a. Cladding Activation Product Inventory by Isotope at 20 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Co-59	1.061E-08	1.061E-08	1.061E-08	1.061E-08	1.061E-08	1.061E-08	1.061E-08
Co-60	1.682E-10	1.293E-10	9.938E-11	7.639E-11	3.958E-11	2.050E-11	0.00
Ni-60	1.852E-10	2.241E-10	2.540E-10	2.770E-10	3.138E-10	3.329E-10	3.534E-10
Ni-61	4.452E-13	4.452E-13	4.452E-13	4.452E-13	4.452E-13	4.452E-13	4.452E-13
Sr-87	7.477E-09	7.477E-09	7.477E-09	7.477E-09	7.477E-09	7.477E-09	7.477E-09
Sr-88	7.040E-07	7.040E-07	7.040E-07	7.040E-07	7.040E-07	7.040E-07	7.040E-07
Sr-90	1.388E-11	1.323E-11	1.262E-11	1.203E-11	1.068E-11	9.483E-12	7.024E-22
Y-89	5.359E-08	5.359E-08	5.359E-08	5.359E-08	5.359E-08	5.359E-08	5.359E-08
Y-90	3.480E-15	3.319E-15	3.164E-15	3.017E-15	2.679E-15	2.378E-15	1.762E-25
Zr-90	4.975E-01	4.975E-01	4.975E-01	4.975E-01	4.975E-01	4.975E-01	4.975E-01
Zr-91	1.092E-01	1.092E-01	1.092E-01	1.092E-01	1.092E-01	1.092E-01	1.092E-01
Zr-92	1.692E-01	1.692E-01	1.692E-01	1.692E-01	1.692E-01	1.692E-01	1.692E-01
Zr-93	1.334E-04	1.334E-04	1.334E-04	1.334E-04	1.334E-04	1.334E-04	1.333E-04
Zr-94	1.756E-01	1.756E-01	1.756E-01	1.756E-01	1.756E-01	1.756E-01	1.756E-01
Zr-95	3.395E-13	1.241E-16	4.538E-20	1.659E-23	4.241E-32	0.00	0.00
Zr-96	2.879E-02	2.879E-02	2.879E-02	2.879E-02	2.879E-02	2.879E-02	2.879E-02
Nb-93	8.116E-11	1.241E-10	1.747E-10	2.320E-10	4.010E-10	6.000E-10	5.945E-08
Nb-93m	3.228E-10	4.007E-10	4.710E-10	5.345E-10	6.677E-10	7.708E-10	1.126E-09
Nb-94	3.496E-14	3.496E-14	3.495E-14	3.495E-14	3.495E-14	3.494E-14	3.379E-14
Nb-95	4.141E-13	1.514E-16	5.535E-20	2.024E-23	3.836E-34	0.00	0.00
Mo-95	4.861E-05	4.861E-05	4.861E-05	4.861E-05	4.861E-05	4.861E-05	4.861E-05
Mo-96	1.300E-06	1.300E-06	1.300E-06	1.300E-06	1.300E-06	1.300E-06	1.300E-06
Mo-97	7.415E-05	7.415E-05	7.415E-05	7.415E-05	7.415E-05	7.415E-05	7.415E-05
Mo-98	3.759E-07	3.759E-07	3.759E-07	3.759E-07	3.759E-07	3.759E-07	3.759E-07
Mo-100	1.480E-14	1.480E-14	1.480E-14	1.480E-14	1.480E-14	1.480E-14	1.480E-14
Tc-99	5.257E-11	5.257E-11	5.257E-11	5.257E-11	5.257E-11	5.257E-11	5.240E-11
Ru-100	1.757E-12	1.757E-12	1.757E-12	1.757E-12	1.757E-12	1.757E-12	1.757E-12
Ru-101	4.004E-15	4.004E-15	4.004E-15	4.004E-15	4.004E-15	4.004E-15	4.004E-15
Cd-111	7.771E-12	7.771E-12	7.771E-12	7.771E-12	7.771E-12	7.771E-12	7.771E-12
Cd-112	6.674E-11	6.674E-11	6.674E-11	6.674E-11	6.674E-11	6.674E-11	6.674E-11
Cd-113	3.393E-13	3.393E-13	3.393E-13	3.393E-13	3.393E-13	3.393E-13	3.393E-13
Cd-114	6.252E-09	6.252E-09	6.252E-09	6.252E-09	6.252E-09	6.252E-09	6.252E-09
Cd-116	4.878E-11	4.878E-11	4.878E-11	4.878E-11	4.878E-11	4.878E-11	4.878E-11
In-113	1.440E-06	1.440E-06	1.440E-06	1.440E-06	1.440E-06	1.440E-06	1.440E-06
In-113m	8.760E-15	1.077E-16	1.323E-18	1.626E-20	2.723E-25	4.559E-30	0.00
In-115	2.686E-11	2.686E-11	2.686E-11	2.686E-11	2.686E-11	2.686E-11	2.686E-11
Sn-112	1.399E-04	1.399E-04	1.399E-04	1.399E-04	1.399E-04	1.399E-04	1.399E-04
Sn-113	1.459E-11	1.793E-13	2.203E-15	2.708E-17	4.534E-22	7.591E-27	0.00
Sn-114	9.651E-05	9.651E-05	9.651E-05	9.651E-05	9.651E-05	9.651E-05	9.651E-05
Sn-115	5.172E-05	5.172E-05	5.172E-05	5.172E-05	5.172E-05	5.172E-05	5.172E-05
Sn-116	2.138E-03	2.138E-03	2.138E-03	2.138E-03	2.138E-03	2.138E-03	2.138E-03
Sn-117	1.152E-03	1.152E-03	1.152E-03	1.152E-03	1.152E-03	1.152E-03	1.152E-03
Sn-118	3.613E-03	3.613E-03	3.613E-03	3.613E-03	3.613E-03	3.613E-03	3.613E-03
Sn-119	1.308E-03	1.308E-03	1.308E-03	1.308E-03	1.308E-03	1.308E-03	1.308E-03
Sn-119m	2.678E-08	3.391E-09	4.293E-10	5.437E-11	3.102E-13	1.770E-15	0.00
Sn-120	4.911E-03	4.911E-03	4.911E-03	4.911E-03	4.911E-03	4.911E-03	4.911E-03

TABLE D.8.a. Cladding Activation Product Inventory by Isotope at 20 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Sn-121m	2.241E-08	2.179E-08	2.120E-08	2.062E-08	1.924E-08	1.795E-08	2.241E-14
Sn-122	7.082E-04	7.082E-04	7.082E-04	7.082E-04	7.082E-04	7.082E-04	7.082E-04
Sn-123	1.714E-11	3.401E-13	6.748E-15	1.339E-16	7.422E-21	4.115E-25	0.00
Sn-124	8.719E-04	8.719E-04	8.719E-04	8.719E-04	8.719E-04	8.719E-04	8.719E-04
Sb-121	4.048E-06	4.048E-06	4.049E-06	4.049E-06	4.051E-06	4.052E-06	4.070E-06
Sb-123	4.294E-07	4.294E-07	4.294E-07	4.294E-07	4.294E-07	4.294E-07	4.294E-07
Sb-125	1.022E-06	6.196E-07	3.756E-07	2.277E-07	6.516E-08	1.864E-08	0.00
Te-122	1.579E-07	1.579E-07	1.579E-07	1.579E-07	1.579E-07	1.579E-07	1.579E-07
Te-123	1.569E-09	1.569E-09	1.569E-09	1.569E-09	1.569E-09	1.569E-09	1.569E-09
Te-123m	3.268E-14	4.752E-16	6.909E-18	1.004E-19	2.560E-24	6.523E-29	0.00
Te-124	9.590E-09	9.590E-09	9.590E-09	9.590E-09	9.590E-09	9.590E-09	9.590E-09
Te-125	3.999E-06	4.408E-06	4.655E-06	4.805E-06	4.970E-06	5.017E-06	5.036E-06
Te-125m	1.429E-08	8.668E-09	5.255E-09	3.186E-09	9.113E-10	2.608E-10	0.00
Te-126	2.922E-08	2.922E-08	2.922E-08	2.922E-08	2.922E-08	2.922E-08	2.922E-08
Te-128	6.453E-14	6.453E-14	6.453E-14	6.453E-14	6.453E-14	6.453E-14	6.453E-14
I-127	6.351E-11	6.351E-11	6.351E-11	6.351E-11	6.351E-11	6.351E-11	6.351E-11
Xe-128	1.009E-12	1.009E-12	1.009E-12	1.009E-12	1.009E-12	1.009E-12	1.009E-12
Xe-129	1.990E-15	1.990E-15	1.990E-15	1.990E-15	1.990E-15	1.990E-15	1.990E-15
Yb-172	1.414E-15	1.414E-15	1.414E-15	1.414E-15	1.414E-15	1.414E-15	1.414E-15
Lu-175	3.383E-08	3.383E-08	3.383E-08	3.383E-08	3.383E-08	3.383E-08	3.383E-08
Lu-176	8.435E-10	8.435E-10	8.435E-10	8.435E-10	8.435E-10	8.435E-10	8.435E-10
Lu-177m	1.204E-15	4.591E-17	1.751E-18	6.675E-20	1.895E-23	5.380E-27	0.00
Hf-174	4.604E-08	4.604E-08	4.604E-08	4.604E-08	4.604E-08	4.604E-08	4.604E-08
Hf-176	2.106E-06	2.106E-06	2.106E-06	2.106E-06	2.106E-06	2.106E-06	2.106E-06
Hf-177	7.131E-07	7.131E-07	7.131E-07	7.131E-07	7.131E-07	7.131E-07	7.131E-07
Hf-178	1.266E-05	1.266E-05	1.266E-05	1.266E-05	1.266E-05	1.266E-05	1.266E-05
Hf-179	1.670E-05	1.670E-05	1.670E-05	1.670E-05	1.670E-05	1.670E-05	1.670E-05
Hf-180	2.227E-05	2.227E-05	2.227E-05	2.227E-05	2.227E-05	2.227E-05	2.227E-05
Hf-182	1.122E-09	1.122E-09	1.122E-09	1.122E-09	1.122E-09	1.122E-09	1.122E-09
Ta-181	5.519E-07	5.519E-07	5.519E-07	5.519E-07	5.519E-07	5.519E-07	5.519E-07
Ta-182	1.006E-12	1.235E-14	1.899E-16	4.109E-17	3.924E-17	3.924E-17	3.924E-17
W-182	3.984E-08	3.984E-08	3.984E-08	3.984E-08	3.984E-08	3.984E-08	3.984E-08
W-183	3.293E-08	3.293E-08	3.293E-08	3.293E-08	3.293E-08	3.293E-08	3.293E-08
W-184	1.375E-09	1.375E-09	1.375E-09	1.375E-09	1.375E-09	1.375E-09	1.375E-09
W-186	1.398E-14	1.398E-14	1.398E-14	1.398E-14	1.398E-14	1.398E-14	1.398E-14
Re-185	2.074E-12	2.074E-12	2.074E-12	2.074E-12	2.074E-12	2.074E-12	2.074E-12
Os-186	2.078E-13	2.078E-13	2.078E-13	2.078E-13	2.078E-13	2.078E-13	2.078E-13
Total	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00

TABLE D.8.b. Cladding Activation Product Inventory by Isotope at 25 MWd/kgM, g/gZr

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-1	1.403E-05	1.403E-05	1.403E-05	1.403E-05	1.403E-05	1.403E-05	1.403E-05
H-2	2.221E-08	2.221E-08	2.221E-08	2.221E-08	2.221E-08	2.221E-08	2.221E-08
H-3	3.423E-14	3.059E-14	2.735E-14	2.444E-14	1.846E-14	1.394E-14	1.799E-38
He-3	9.563E-15	1.320E-14	1.645E-14	1.935E-14	2.533E-14	2.985E-14	4.379E-14
He-4	6.416E-08	6.416E-08	6.416E-08	6.416E-08	6.416E-08	6.416E-08	6.416E-08
Li-6	9.211E-14	9.211E-14	9.211E-14	9.211E-14	9.211E-14	9.211E-14	9.211E-14
Be-9	6.128E-10	6.128E-10	6.128E-10	6.128E-10	6.128E-10	6.128E-10	6.128E-10
Be-10	1.595E-11	1.595E-11	1.595E-11	1.595E-11	1.595E-11	1.595E-11	1.594E-11
B-11	9.496E-09	9.496E-09	9.496E-09	9.496E-09	9.496E-09	9.496E-09	9.496E-09
C-12	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04
C-13	1.430E-06	1.430E-06	1.430E-06	1.430E-06	1.430E-06	1.430E-06	1.430E-06
C-14	8.342E-08	8.340E-08	8.338E-08	8.336E-08	8.331E-08	8.326E-08	7.395E-08
N-14	2.480E-05	2.480E-05	2.480E-05	2.480E-05	2.480E-05	2.480E-05	2.481E-05
N-15	1.014E-07	1.014E-07	1.014E-07	1.014E-07	1.014E-07	1.014E-07	1.014E-07
O-16	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03
O-17	4.704E-07	4.704E-07	4.704E-07	4.704E-07	4.704E-07	4.704E-07	4.704E-07
O-18	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06
F-19	1.716E-12	1.716E-12	1.716E-12	1.716E-12	1.716E-12	1.716E-12	1.716E-12
Ne-22	1.167E-14	1.167E-14	1.167E-14	1.167E-14	1.167E-14	1.167E-14	1.167E-14
Mg-24	1.308E-10	1.308E-10	1.308E-10	1.308E-10	1.308E-10	1.308E-10	1.308E-10
Mg-25	2.751E-10	2.751E-10	2.751E-10	2.751E-10	2.751E-10	2.751E-10	2.751E-10
Mg-26	1.258E-10	1.258E-10	1.258E-10	1.258E-10	1.258E-10	1.258E-10	1.258E-10
Al-27	3.998E-05	3.998E-05	3.998E-05	3.998E-05	3.998E-05	3.998E-05	3.998E-05
Si-28	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05
Si-29	3.875E-06	3.875E-06	3.875E-06	3.875E-06	3.875E-06	3.875E-06	3.875E-06
Si-30	2.648E-06	2.648E-06	2.648E-06	2.648E-06	2.648E-06	2.648E-06	2.648E-06
P-31	5.700E-10	5.700E-10	5.700E-10	5.700E-10	5.700E-10	5.700E-10	5.700E-10
S-32	8.994E-14	8.994E-14	8.994E-14	8.994E-14	8.994E-14	8.994E-14	8.998E-14
Ca-44	2.092E-15	2.092E-15	2.092E-15	2.092E-15	2.092E-15	2.092E-15	2.092E-15
Ti-47	1.426E-10	1.426E-10	1.426E-10	1.426E-10	1.426E-10	1.426E-10	1.426E-10
Ti-48	2.554E-13	2.554E-13	2.554E-13	2.554E-13	2.554E-13	2.554E-13	2.554E-13
Ti-49	3.898E-10	3.898E-10	3.898E-10	3.898E-10	3.898E-10	3.898E-10	3.898E-10
Ti-50	1.572E-09	1.572E-09	1.572E-09	1.572E-09	1.572E-09	1.572E-09	1.572E-09
V-50	5.541E-09	5.541E-09	5.541E-09	5.541E-09	5.541E-09	5.541E-09	5.541E-09
V-51	1.143E-06	1.143E-06	1.143E-06	1.143E-06	1.143E-06	1.143E-06	1.143E-06
Cr-50	4.065E-05	4.065E-05	4.065E-05	4.065E-05	4.065E-05	4.065E-05	4.065E-05
Cr-52	8.318E-04	8.318E-04	8.318E-04	8.318E-04	8.318E-04	8.318E-04	8.318E-04
Cr-53	9.893E-05	9.893E-05	9.893E-05	9.893E-05	9.893E-05	9.893E-05	9.893E-05
Cr-54	2.763E-05	2.763E-05	2.763E-05	2.763E-05	2.763E-05	2.763E-05	2.763E-05
Mn-54	3.801E-10	7.519E-11	1.488E-11	2.943E-12	5.124E-14	8.920E-16	0.00
Mn-55	3.784E-07	4.124E-07	4.324E-07	4.440E-07	4.563E-07	4.595E-07	4.607E-07
Fe-54	1.117E-04	1.117E-04	1.117E-04	1.117E-04	1.117E-04	1.117E-04	1.117E-04
Fe-55	8.221E-08	4.824E-08	2.830E-08	1.661E-08	4.379E-09	1.155E-09	0.00
Fe-56	1.829E-03	1.829E-03	1.829E-03	1.829E-03	1.829E-03	1.829E-03	1.829E-03
Fe-57	5.289E-05	5.289E-05	5.289E-05	5.289E-05	5.289E-05	5.289E-05	5.289E-05
Fe-58	6.215E-06	6.215E-06	6.215E-06	6.215E-06	6.215E-06	6.215E-06	6.215E-06

TABLE D.8.b. Cladding Activation Product Inventory by Isotope at 25 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Co-59	1.350E-08	1.350E-08	1.350E-08	1.350E-08	1.350E-08	1.350E-08	1.350E-08
Co-60	2.747E-10	2.111E-10	1.623E-10	1.248E-10	6.463E-11	3.348E-11	0.00
Ni-60	3.008E-10	3.643E-10	4.131E-10	4.507E-10	5.108E-10	5.420E-10	5.754E-10
Ni-61	9.292E-13	9.292E-13	9.292E-13	9.292E-13	9.292E-13	9.292E-13	9.292E-13
Ni-62	1.012E-15	1.012E-15	1.012E-15	1.012E-15	1.012E-15	1.012E-15	1.012E-15
Sr-87	9.479E-09	9.479E-09	9.479E-09	9.479E-09	9.479E-09	9.479E-09	9.479E-09
Sr-88	9.001E-07	9.001E-07	9.001E-07	9.001E-07	9.001E-07	9.001E-07	9.001E-07
Sr-90	2.268E-11	2.163E-11	2.062E-11	1.966E-11	1.746E-11	1.550E-11	1.148E-21
Y-89	6.853E-08	6.853E-08	6.853E-08	6.853E-08	6.853E-08	6.853E-08	6.853E-08
Y-90	5.687E-15	5.423E-15	5.171E-15	4.930E-15	4.377E-15	3.886E-15	2.879E-25
Zr-90	4.974E-01	4.974E-01	4.974E-01	4.974E-01	4.974E-01	4.974E-01	4.974E-01
Zr-91	1.091E-01	1.091E-01	1.091E-01	1.091E-01	1.091E-01	1.091E-01	1.091E-01
Zr-92	1.693E-01	1.693E-01	1.693E-01	1.693E-01	1.693E-01	1.693E-01	1.693E-01
Zr-93	1.702E-04	1.702E-04	1.702E-04	1.702E-04	1.702E-04	1.702E-04	1.702E-04
Zr-94	1.756E-01	1.756E-01	1.756E-01	1.756E-01	1.756E-01	1.756E-01	1.756E-01
Zr-95	4.406E-13	1.611E-16	5.890E-20	2.154E-23	5.505E-32	0.00	0.00
Zr-96	2.877E-02	2.877E-02	2.877E-02	2.877E-02	2.877E-02	2.877E-02	2.877E-02
Nb-93	1.030E-10	1.577E-10	2.221E-10	2.952E-10	5.107E-10	7.645E-10	7.588E-08
Nb-93m	4.108E-10	5.103E-10	6.002E-10	6.814E-10	8.515E-10	9.834E-10	1.437E-09
Nb-94	5.690E-14	5.690E-14	5.689E-14	5.689E-14	5.688E-14	5.687E-14	5.500E-14
Nb-95	5.374E-13	1.965E-16	7.184E-20	2.627E-23	4.979E-34	0.00	0.00
Mo-95	6.171E-05	6.171E-05	6.171E-05	6.171E-05	6.171E-05	6.171E-05	6.171E-05
Mo-96	2.114E-06	2.114E-06	2.114E-06	2.114E-06	2.114E-06	2.114E-06	2.114E-06
Mo-97	9.465E-05	9.465E-05	9.465E-05	9.465E-05	9.465E-05	9.465E-05	9.465E-05
Mo-98	6.138E-07	6.138E-07	6.138E-07	6.138E-07	6.138E-07	6.138E-07	6.138E-07
Mo-100	4.002E-14	4.002E-14	4.002E-14	4.002E-14	4.002E-14	4.002E-14	4.002E-14
Tc-99	1.088E-10	1.088E-10	1.088E-10	1.088E-10	1.088E-10	1.088E-10	1.085E-10
Ru-99	1.880E-15	2.588E-15	3.296E-15	4.005E-15	5.775E-15	7.546E-15	3.541E-13
Ru-100	4.658E-12	4.658E-12	4.658E-12	4.658E-12	4.658E-12	4.658E-12	4.658E-12
Ru-101	1.357E-14	1.357E-14	1.357E-14	1.357E-14	1.357E-14	1.357E-14	1.357E-14
Cd-111	9.869E-12	9.869E-12	9.869E-12	9.869E-12	9.869E-12	9.869E-12	9.869E-12
Cd-112	8.449E-11	8.449E-11	8.449E-11	8.449E-11	8.449E-11	8.449E-11	8.449E-11
Cd-113	3.414E-13	3.414E-13	3.414E-13	3.414E-13	3.414E-13	3.414E-13	3.414E-13
Cd-114	9.959E-09	9.959E-09	9.959E-09	9.959E-09	9.959E-09	9.959E-09	9.959E-09
Cd-116	6.245E-11	6.245E-11	6.245E-11	6.245E-11	6.245E-11	6.245E-11	6.245E-11
In-113	1.800E-06	1.800E-06	1.800E-06	1.800E-06	1.800E-06	1.800E-06	1.800E-06
In-113m	1.135E-14	1.395E-16	1.715E-18	2.107E-20	3.529E-25	5.908E-30	0.00
In-115	2.848E-11	2.848E-11	2.848E-11	2.848E-11	2.848E-11	2.848E-11	2.848E-11
Sn-112	1.395E-04	1.395E-04	1.395E-04	1.395E-04	1.395E-04	1.395E-04	1.395E-04
Sn-113	1.890E-11	2.323E-13	2.855E-15	3.509E-17	5.875E-22	9.837E-27	0.00
Sn-114	9.656E-05	9.656E-05	9.656E-05	9.656E-05	9.656E-05	9.656E-05	9.656E-05
Sn-115	5.079E-05	5.079E-05	5.079E-05	5.079E-05	5.079E-05	5.079E-05	5.079E-05
Sn-116	2.133E-03	2.133E-03	2.133E-03	2.133E-03	2.133E-03	2.133E-03	2.133E-03
Sn-117	1.153E-03	1.153E-03	1.153E-03	1.153E-03	1.153E-03	1.153E-03	1.153E-03
Sn-118	3.610E-03	3.610E-03	3.610E-03	3.610E-03	3.610E-03	3.610E-03	3.610E-03
Sn-119	1.312E-03	1.312E-03	1.312E-03	1.312E-03	1.312E-03	1.312E-03	1.312E-03

TABLE D.8.b. Cladding Activation Product Inventory by Isotope at 25 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Sn-119m	3.481E-08	4.407E-09	5.581E-10	7.067E-11	4.032E-13	2.301E-15	0.00
Sn-120	4.912E-03	4.912E-03	4.912E-03	4.912E-03	4.912E-03	4.912E-03	4.912E-03
Sn-121m	2.866E-08	2.788E-08	2.712E-08	2.638E-08	2.461E-08	2.296E-08	2.867E-14
Sn-122	7.081E-04	7.081E-04	7.081E-04	7.081E-04	7.081E-04	7.081E-04	7.081E-04
Sn-123	2.232E-11	4.428E-13	8.786E-15	1.743E-16	9.664E-21	5.357E-25	0.00
Sn-124	8.705E-04	8.705E-04	8.705E-04	8.705E-04	8.705E-04	8.705E-04	8.705E-04
Sb-121	5.120E-06	5.121E-06	5.122E-06	5.123E-06	5.124E-06	5.126E-06	5.149E-06
Sb-123	5.460E-07	5.461E-07	5.461E-07	5.461E-07	5.461E-07	5.461E-07	5.461E-07
Sb-125	1.312E-06	7.955E-07	4.823E-07	2.924E-07	8.366E-08	2.394E-08	0.00
Te-122	2.552E-07	2.552E-07	2.552E-07	2.552E-07	2.552E-07	2.552E-07	2.552E-07
Te-123	2.929E-09	2.929E-09	2.929E-09	2.929E-09	2.929E-09	2.929E-09	2.929E-09
Te-123m	6.850E-14	9.960E-16	1.448E-17	2.105E-19	5.365E-24	1.367E-28	0.00
Te-124	1.636E-08	1.636E-08	1.636E-08	1.636E-08	1.636E-08	1.636E-08	1.636E-08
Te-125	5.094E-06	5.618E-06	5.935E-06	6.128E-06	6.339E-06	6.400E-06	6.424E-06
Te-125m	1.836E-08	1.113E-08	6.748E-09	4.091E-09	1.170E-09	3.349E-10	0.00
Te-126	4.768E-08	4.768E-08	4.768E-08	4.768E-08	4.768E-08	4.768E-08	4.768E-08
Te-128	1.717E-13	1.717E-13	1.717E-13	1.717E-13	1.717E-13	1.717E-13	1.717E-13
I-127	1.320E-10	1.320E-10	1.320E-10	1.320E-10	1.320E-10	1.320E-10	1.320E-10
Xe-128	2.685E-12	2.685E-12	2.685E-12	2.685E-12	2.685E-12	2.685E-12	2.685E-12
Xe-129	6.744E-15	6.744E-15	6.744E-15	6.744E-15	6.744E-15	6.744E-15	6.744E-15
Yb-172	2.131E-15	2.131E-15	2.131E-15	2.131E-15	2.131E-15	2.131E-15	2.131E-15
Yb-173	1.486E-15	1.486E-15	1.486E-15	1.486E-15	1.486E-15	1.486E-15	1.486E-15
Lu-175	3.808E-08	3.808E-08	3.808E-08	3.808E-08	3.808E-08	3.808E-08	3.808E-08
Lu-176	1.060E-09	1.060E-09	1.060E-09	1.060E-09	1.060E-09	1.060E-09	1.060E-09
Lu-177m	2.009E-15	7.661E-17	2.921E-18	1.114E-19	3.162E-23	8.979E-27	0.00
Hf-174	3.871E-08	3.871E-08	3.871E-08	3.871E-08	3.871E-08	3.871E-08	3.871E-08
Hf-176	1.942E-06	1.942E-06	1.942E-06	1.942E-06	1.942E-06	1.942E-06	1.942E-06
Hf-177	4.205E-07	4.205E-07	4.205E-07	4.205E-07	4.205E-07	4.205E-07	4.205E-07
Hf-178	1.056E-05	1.056E-05	1.056E-05	1.056E-05	1.056E-05	1.056E-05	1.056E-05
Hf-179	1.799E-05	1.799E-05	1.799E-05	1.799E-05	1.799E-05	1.799E-05	1.799E-05
Hf-180	2.337E-05	2.337E-05	2.337E-05	2.337E-05	2.337E-05	2.337E-05	2.337E-05
Hf-182	1.867E-09	1.867E-09	1.867E-09	1.867E-09	1.867E-09	1.867E-09	1.867E-09
Ta-181	6.986E-07	6.986E-07	6.986E-07	6.986E-07	6.986E-07	6.986E-07	6.986E-07
Ta-182	1.452E-12	1.784E-14	2.829E-16	6.799E-17	6.533E-17	6.533E-17	6.532E-17
W-182	5.644E-08	5.644E-08	5.644E-08	5.644E-08	5.644E-08	5.644E-08	5.644E-08
W-183	6.080E-08	6.080E-08	6.080E-08	6.080E-08	6.080E-08	6.080E-08	6.080E-08
W-184	3.262E-09	3.262E-09	3.262E-09	3.262E-09	3.262E-09	3.262E-09	3.262E-09
W-186	5.249E-14	5.249E-14	5.249E-14	5.249E-14	5.249E-14	5.249E-14	5.249E-14
Re-185	6.158E-12	6.158E-12	6.158E-12	6.158E-12	6.158E-12	6.158E-12	6.158E-12
Re-187	2.224E-15	2.224E-15	2.224E-15	2.224E-15	2.224E-15	2.224E-15	2.224E-15
Os-186	7.878E-13	7.878E-13	7.878E-13	7.878E-13	7.878E-13	7.878E-13	7.878E-13
Total	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00

TABLE D.8.c. Cladding Activation Product Inventory by Isotope at 30 MWd/kgM, g/gZr

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-1	1.403E-05	1.403E-05	1.403E-05	1.403E-05	1.403E-05	1.403E-05	1.403E-05
H-2	2.637E-08	2.637E-08	2.637E-08	2.637E-08	2.637E-08	2.637E-08	2.637E-08
H-3	5.536E-14	4.948E-14	4.423E-14	3.953E-14	2.986E-14	2.255E-14	2.908E-38
He-3	1.517E-14	2.105E-14	2.631E-14	3.100E-14	4.068E-14	4.799E-14	7.054E-14
He-4	7.894E-08	7.894E-08	7.894E-08	7.894E-08	7.894E-08	7.894E-08	7.894E-08
Li-6	1.276E-13	1.276E-13	1.276E-13	1.276E-13	1.276E-13	1.276E-13	1.276E-13
Be-9	7.538E-10	7.538E-10	7.538E-10	7.538E-10	7.538E-10	7.538E-10	7.538E-10
Be-10	1.970E-11	1.970E-11	1.970E-11	1.970E-11	1.970E-11	1.970E-11	1.970E-11
B-11	1.168E-08	1.168E-08	1.168E-08	1.168E-08	1.168E-08	1.168E-08	1.168E-08
C-12	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04
C-13	1.441E-06	1.441E-06	1.441E-06	1.441E-06	1.441E-06	1.441E-06	1.441E-06
C-14	1.026E-07	1.026E-07	1.025E-07	1.025E-07	1.025E-07	1.024E-07	9.095E-08
N-14	2.478E-05	2.478E-05	2.478E-05	2.478E-05	2.478E-05	2.478E-05	2.479E-05
N-15	1.022E-07	1.022E-07	1.022E-07	1.022E-07	1.022E-07	1.022E-07	1.022E-07
O-16	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03
O-17	4.705E-07	4.705E-07	4.705E-07	4.705E-07	4.705E-07	4.705E-07	4.705E-07
O-18	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06
F-19	2.111E-12	2.111E-12	2.111E-12	2.111E-12	2.111E-12	2.111E-12	2.111E-12
Ne-22	1.767E-14	1.767E-14	1.767E-14	1.767E-14	1.767E-14	1.767E-14	1.767E-14
Na-23	1.432E-15	1.432E-15	1.432E-15	1.432E-15	1.432E-15	1.432E-15	1.432E-15
Mg-24	1.609E-10	1.609E-10	1.609E-10	1.609E-10	1.609E-10	1.609E-10	1.609E-10
Mg-25	3.385E-10	3.385E-10	3.385E-10	3.385E-10	3.385E-10	3.385E-10	3.385E-10
Mg-26	1.548E-10	1.548E-10	1.548E-10	1.548E-10	1.548E-10	1.548E-10	1.548E-10
Al-27	3.998E-05	3.998E-05	3.998E-05	3.998E-05	3.998E-05	3.998E-05	3.998E-05
Si-28	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05
Si-29	3.879E-06	3.879E-06	3.879E-06	3.879E-06	3.879E-06	3.879E-06	3.879E-06
Si-30	2.649E-06	2.649E-06	2.649E-06	2.649E-06	2.649E-06	2.649E-06	2.649E-06
P-31	7.013E-10	7.013E-10	7.013E-10	7.013E-10	7.013E-10	7.013E-10	7.013E-10
S-32	1.361E-13	1.361E-13	1.361E-13	1.361E-13	1.361E-13	1.361E-13	1.362E-13
Ca-44	3.158E-15	3.158E-15	3.158E-15	3.158E-15	3.158E-15	3.158E-15	3.158E-15
Ca-46	1.270E-15	1.270E-15	1.270E-15	1.270E-15	1.270E-15	1.270E-15	1.270E-15
Ti-47	1.748E-10	1.748E-10	1.748E-10	1.748E-10	1.748E-10	1.748E-10	1.748E-10
Ti-48	3.853E-13	3.853E-13	3.853E-13	3.853E-13	3.853E-13	3.853E-13	3.853E-13
Ti-49	4.790E-10	4.790E-10	4.790E-10	4.790E-10	4.790E-10	4.790E-10	4.790E-10
Ti-50	1.939E-09	1.939E-09	1.939E-09	1.939E-09	1.939E-09	1.939E-09	1.939E-09
V-50	6.692E-09	6.692E-09	6.692E-09	6.692E-09	6.692E-09	6.692E-09	6.692E-09
V-51	1.401E-06	1.401E-06	1.401E-06	1.401E-06	1.401E-06	1.401E-06	1.401E-06
Cr-50	4.040E-05	4.040E-05	4.040E-05	4.040E-05	4.040E-05	4.040E-05	4.040E-05
Cr-52	8.307E-04	8.307E-04	8.307E-04	8.307E-04	8.307E-04	8.307E-04	8.307E-04
Cr-53	9.943E-05	9.943E-05	9.943E-05	9.943E-05	9.943E-05	9.943E-05	9.943E-05
Cr-54	2.836E-05	2.836E-05	2.836E-05	2.836E-05	2.836E-05	2.836E-05	2.836E-05
Mn-54	4.756E-10	9.410E-11	1.862E-11	3.683E-12	6.412E-14	1.116E-15	0.00
Mn-55	4.643E-07	5.064E-07	5.311E-07	5.456E-07	5.607E-07	5.647E-07	5.661E-07
Fe-54	1.116E-04	1.116E-04	1.116E-04	1.116E-04	1.116E-04	1.116E-04	1.116E-04
Fe-55	1.018E-07	5.974E-08	3.505E-08	2.057E-08	5.423E-09	1.430E-09	0.00
Fe-56	1.827E-03	1.827E-03	1.827E-03	1.827E-03	1.827E-03	1.827E-03	1.827E-03

TABLE D.8.c. Cladding Activation Product Inventory by Isotope at 30 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Fe-57	5.497E-05	5.497E-05	5.497E-05	5.497E-05	5.497E-05	5.497E-05	5.497E-05
Fe-58	6.266E-06	6.266E-06	6.266E-06	6.266E-06	6.266E-06	6.266E-06	6.266E-06
Co-59	1.651E-08	1.651E-08	1.651E-08	1.651E-08	1.651E-08	1.651E-08	1.651E-08
Co-60	4.153E-10	3.192E-10	2.454E-10	1.886E-10	9.772E-11	5.063E-11	0.00
Ni-60	4.520E-10	5.481E-10	6.219E-10	6.787E-10	7.696E-10	8.167E-10	8.673E-10
Ni-61	1.727E-12	1.727E-12	1.727E-12	1.727E-12	1.727E-12	1.727E-12	1.727E-12
Ni-62	2.316E-15	2.316E-15	2.316E-15	2.316E-15	2.316E-15	2.316E-15	2.316E-15
Sr-87	1.156E-08	1.156E-08	1.156E-08	1.156E-08	1.156E-08	1.156E-08	1.156E-08
Sr-88	1.107E-06	1.107E-06	1.107E-06	1.107E-06	1.107E-06	1.107E-06	1.107E-06
Sr-90	3.430E-11	3.271E-11	3.119E-11	2.974E-11	2.640E-11	2.344E-11	1.736E-21
Y-89	8.432E-08	8.432E-08	8.432E-08	8.432E-08	8.432E-08	8.432E-08	8.432E-08
Y-90	8.602E-15	8.202E-15	7.821E-15	7.457E-15	6.621E-15	5.878E-15	4.354E-25
Zr-90	4.974E-01	4.974E-01	4.974E-01	4.974E-01	4.974E-01	4.974E-01	4.974E-01
Zr-91	1.090E-01	1.090E-01	1.090E-01	1.090E-01	1.090E-01	1.090E-01	1.090E-01
Zr-92	1.694E-01	1.694E-01	1.694E-01	1.694E-01	1.694E-01	1.694E-01	1.694E-01
Zr-93	2.091E-04	2.091E-04	2.091E-04	2.091E-04	2.091E-04	2.091E-04	2.090E-04
Zr-94	1.755E-01	1.755E-01	1.755E-01	1.755E-01	1.755E-01	1.755E-01	1.755E-01
Zr-95	5.625E-13	2.056E-16	7.519E-20	2.749E-23	7.027E-32	0.00	0.00
Zr-96	2.875E-02	2.875E-02	2.875E-02	2.875E-02	2.875E-02	2.875E-02	2.875E-02
Nb-93	1.256E-10	1.927E-10	2.716E-10	3.613E-10	6.256E-10	9.371E-10	9.318E-08
Nb-93m	5.028E-10	6.252E-10	7.357E-10	8.355E-10	1.045E-09	1.207E-09	1.765E-09
Nb-94	8.580E-14	8.580E-14	8.579E-14	8.578E-14	8.577E-14	8.575E-14	8.293E-14
Nb-95	6.860E-13	2.508E-16	9.171E-20	3.353E-23	6.355E-34	0.00	0.00
Mo-95	7.533E-05	7.533E-05	7.533E-05	7.533E-05	7.533E-05	7.533E-05	7.533E-05
Mo-96	3.180E-06	3.180E-06	3.180E-06	3.180E-06	3.180E-06	3.180E-06	3.180E-06
Mo-97	1.162E-04	1.162E-04	1.162E-04	1.162E-04	1.162E-04	1.162E-04	1.162E-04
Mo-98	9.277E-07	9.277E-07	9.277E-07	9.277E-07	9.277E-07	9.277E-07	9.277E-07
Mo-100	9.289E-14	9.289E-14	9.289E-14	9.289E-14	9.289E-14	9.289E-14	9.289E-14
Tc-99	2.006E-10	2.006E-10	2.006E-10	2.006E-10	2.006E-10	2.006E-10	1.999E-10
Ru-99	3.445E-15	4.750E-15	6.056E-15	7.361E-15	1.062E-14	1.389E-14	6.525E-13
Ru-100	1.057E-11	1.057E-11	1.057E-11	1.057E-11	1.057E-11	1.057E-11	1.057E-11
Ru-101	3.787E-14	3.787E-14	3.787E-14	3.787E-14	3.787E-14	3.787E-14	3.787E-14
Cd-111	1.205E-11	1.205E-11	1.205E-11	1.205E-11	1.205E-11	1.205E-11	1.205E-11
Cd-112	1.029E-10	1.029E-10	1.029E-10	1.029E-10	1.029E-10	1.029E-10	1.029E-10
Cd-113	3.436E-13	3.436E-13	3.436E-13	3.436E-13	3.436E-13	3.436E-13	3.436E-13
Cd-114	1.472E-08	1.472E-08	1.472E-08	1.472E-08	1.472E-08	1.472E-08	1.472E-08
Cd-116	7.693E-11	7.693E-11	7.693E-11	7.693E-11	7.693E-11	7.693E-11	7.693E-11
In-113	2.162E-06	2.162E-06	2.162E-06	2.162E-06	2.162E-06	2.162E-06	2.162E-06
In-113m	1.434E-14	1.754E-16	2.156E-18	2.650E-20	4.436E-25	7.428E-30	0.00
In-115	2.985E-11	2.985E-11	2.985E-11	2.985E-11	2.985E-11	2.985E-11	2.985E-11
Sn-112	1.390E-04	1.390E-04	1.390E-04	1.390E-04	1.390E-04	1.390E-04	1.390E-04
Sn-113	2.377E-11	2.921E-13	3.589E-15	4.412E-17	7.387E-22	1.237E-26	0.00
Sn-114	9.663E-05	9.663E-05	9.663E-05	9.663E-05	9.663E-05	9.663E-05	9.663E-05
Sn-115	4.983E-05	4.983E-05	4.983E-05	4.983E-05	4.983E-05	4.983E-05	4.983E-05
Sn-116	2.129E-03	2.129E-03	2.129E-03	2.129E-03	2.129E-03	2.129E-03	2.129E-03
Sn-117	1.155E-03	1.155E-03	1.155E-03	1.155E-03	1.155E-03	1.155E-03	1.155E-03

TABLE D.8.c. Cladding Activation Product Inventory by Isotope at 30 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Sn-118	3.608E-03	3.608E-03	3.608E-03	3.608E-03	3.608E-03	3.608E-03	3.608E-03
Sn-119	1.317E-03	1.317E-03	1.317E-03	1.317E-03	1.317E-03	1.317E-03	1.317E-03
Sn-119m	4.374E-08	5.538E-09	7.013E-10	8.880E-11	5.066E-13	2.891E-15	0.00
Sn-120	4.912E-03	4.912E-03	4.912E-03	4.912E-03	4.912E-03	4.912E-03	4.912E-03
Sn-121m	3.528E-08	3.432E-08	3.338E-08	3.246E-08	3.029E-08	2.826E-08	3.529E-14
Sn-122	7.080E-04	7.080E-04	7.080E-04	7.080E-04	7.080E-04	7.080E-04	7.080E-04
Sn-123	2.820E-11	5.594E-13	1.110E-14	2.202E-16	1.221E-20	6.768E-25	0.00
Sn-124	8.690E-04	8.690E-04	8.690E-04	8.690E-04	8.690E-04	8.690E-04	8.690E-04
Sb-121	6.228E-06	6.229E-06	6.230E-06	6.231E-06	6.233E-06	6.235E-06	6.263E-06
Sb-123	6.678E-07	6.679E-07	6.679E-07	6.679E-07	6.679E-07	6.679E-07	6.679E-07
Sb-125	1.622E-06	9.833E-07	5.961E-07	3.614E-07	1.034E-07	2.959E-08	0.00
Te-122	3.815E-07	3.815E-07	3.815E-07	3.815E-07	3.815E-07	3.815E-07	3.815E-07
Te-123	4.892E-09	4.892E-09	4.892E-09	4.892E-09	4.892E-09	4.892E-09	4.892E-09
Te-123m	1.296E-13	1.885E-15	2.740E-17	3.983E-19	1.015E-23	2.587E-28	0.00
Te-124	2.595E-08	2.595E-08	2.595E-08	2.595E-08	2.595E-08	2.595E-08	2.595E-08
Te-125	6.239E-06	6.887E-06	7.279E-06	7.517E-06	7.779E-06	7.854E-06	7.884E-06
Te-125m	2.269E-08	1.376E-08	8.340E-09	5.056E-09	1.446E-09	4.139E-10	0.00
Te-126	7.200E-08	7.200E-08	7.200E-08	7.200E-08	7.200E-08	7.200E-08	7.200E-08
Te-128	3.915E-13	3.915E-13	3.915E-13	3.915E-13	3.915E-13	3.915E-13	3.915E-13
I-127	2.443E-10	2.443E-10	2.443E-10	2.443E-10	2.443E-10	2.443E-10	2.443E-10
Xe-128	6.118E-12	6.118E-12	6.118E-12	6.118E-12	6.118E-12	6.118E-12	6.118E-12
Xe-129	1.883E-14	1.883E-14	1.883E-14	1.883E-14	1.883E-14	1.883E-14	1.883E-14
Yb-172	2.964E-15	2.964E-15	2.964E-15	2.964E-15	2.964E-15	2.964E-15	2.964E-15
Yb-173	2.246E-15	2.246E-15	2.246E-15	2.246E-15	2.246E-15	2.246E-15	2.246E-15
Lu-175	4.098E-08	4.098E-08	4.098E-08	4.098E-08	4.098E-08	4.098E-08	4.098E-08
Lu-176	1.231E-09	1.231E-09	1.231E-09	1.231E-09	1.231E-09	1.231E-09	1.231E-09
Lu-177m	3.012E-15	1.148E-16	4.379E-18	1.670E-19	4.741E-23	1.346E-26	0.00
Hf-174	3.223E-08	3.223E-08	3.223E-08	3.223E-08	3.223E-08	3.223E-08	3.223E-08
Hf-175	1.024E-15	7.394E-19	5.338E-22	3.854E-25	5.399E-33	0.00	0.00
Hf-176	1.784E-06	1.784E-06	1.784E-06	1.784E-06	1.784E-06	1.784E-06	1.784E-06
Hf-177	2.806E-07	2.806E-07	2.806E-07	2.806E-07	2.806E-07	2.806E-07	2.806E-07
Hf-178	8.621E-06	8.621E-06	8.621E-06	8.621E-06	8.621E-06	8.621E-06	8.621E-06
Hf-179	1.880E-05	1.880E-05	1.880E-05	1.880E-05	1.880E-05	1.880E-05	1.880E-05
Hf-180	2.462E-05	2.462E-05	2.462E-05	2.462E-05	2.462E-05	2.462E-05	2.462E-05
Hf-182	2.885E-09	2.885E-09	2.885E-09	2.885E-09	2.885E-09	2.885E-09	2.885E-09
Ta-181	8.528E-07	8.528E-07	8.528E-07	8.528E-07	8.528E-07	8.528E-07	8.528E-07
Ta-182	1.973E-12	2.425E-14	3.966E-16	1.045E-16	1.009E-16	1.009E-16	1.009E-16
W-182	7.437E-08	7.438E-08	7.438E-08	7.438E-08	7.438E-08	7.438E-08	7.438E-08
W-183	1.004E-07	1.004E-07	1.004E-07	1.004E-07	1.004E-07	1.004E-07	1.004E-07
W-184	6.660E-09	6.660E-09	6.660E-09	6.660E-09	6.660E-09	6.660E-09	6.660E-09
W-186	1.568E-13	1.568E-13	1.568E-13	1.568E-13	1.568E-13	1.568E-13	1.568E-13
Re-185	1.514E-11	1.514E-11	1.514E-11	1.514E-11	1.514E-11	1.514E-11	1.514E-11
Re-187	8.202E-15	8.202E-15	8.202E-15	8.202E-15	8.202E-15	8.202E-15	8.202E-15
Os-186	2.377E-12	2.377E-12	2.377E-12	2.377E-12	2.377E-12	2.377E-12	2.377E-12
Total	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00

TABLE D.8.d. Cladding Activation Product Inventory by Isotope at 35 MWd/kgM, g/gZr

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-1	1.404E-05	1.404E-05	1.404E-05	1.404E-05	1.404E-05	1.404E-05	1.404E-05
H-2	3.077E-08	3.077E-08	3.077E-08	3.077E-08	3.077E-08	3.077E-08	3.077E-08
H-3	8.444E-14	7.547E-14	6.746E-14	6.029E-14	4.554E-14	3.439E-14	4.432E-38
He-3	2.282E-14	3.179E-14	3.980E-14	4.697E-14	6.172E-14	7.286E-14	1.073E-13
He-4	9.457E-08	9.457E-08	9.457E-08	9.457E-08	9.457E-08	9.457E-08	9.457E-08
Li-6	1.677E-13	1.677E-13	1.677E-13	1.677E-13	1.677E-13	1.677E-13	1.677E-13
Be-9	9.029E-10	9.029E-10	9.029E-10	9.029E-10	9.029E-10	9.029E-10	9.029E-10
Be-10	2.371E-11	2.371E-11	2.371E-11	2.371E-11	2.371E-11	2.371E-11	2.370E-11
B-11	1.398E-08	1.398E-08	1.398E-08	1.398E-08	1.398E-08	1.398E-08	1.398E-08
C-12	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04
C-13	1.453E-06	1.453E-06	1.453E-06	1.453E-06	1.453E-06	1.453E-06	1.453E-06
C-14	1.229E-07	1.228E-07	1.228E-07	1.228E-07	1.227E-07	1.226E-07	1.089E-07
N-14	2.476E-05	2.476E-05	2.476E-05	2.476E-05	2.476E-05	2.476E-05	2.477E-05
N-15	1.030E-07	1.030E-07	1.030E-07	1.030E-07	1.030E-07	1.030E-07	1.030E-07
O-16	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03
O-17	4.705E-07	4.705E-07	4.705E-07	4.705E-07	4.705E-07	4.705E-07	4.705E-07
O-18	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06
F-19	2.529E-12	2.529E-12	2.529E-12	2.529E-12	2.529E-12	2.529E-12	2.529E-12
Ne-21	1.056E-15	1.056E-15	1.056E-15	1.056E-15	1.056E-15	1.056E-15	1.056E-15
Ne-22	2.536E-14	2.536E-14	2.536E-14	2.536E-14	2.536E-14	2.536E-14	2.536E-14
Na-23	2.056E-15	2.056E-15	2.056E-15	2.056E-15	2.056E-15	2.056E-15	2.056E-15
Mg-24	1.927E-10	1.927E-10	1.927E-10	1.927E-10	1.927E-10	1.927E-10	1.927E-10
Mg-25	4.055E-10	4.055E-10	4.055E-10	4.055E-10	4.055E-10	4.055E-10	4.055E-10
Mg-26	1.856E-10	1.856E-10	1.856E-10	1.856E-10	1.856E-10	1.856E-10	1.856E-10
Al-27	3.997E-05	3.997E-05	3.997E-05	3.997E-05	3.997E-05	3.997E-05	3.997E-05
Si-28	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05
Si-29	3.884E-06	3.884E-06	3.884E-06	3.884E-06	3.884E-06	3.884E-06	3.884E-06
Si-30	2.649E-06	2.649E-06	2.649E-06	2.649E-06	2.649E-06	2.649E-06	2.649E-06
P-31	8.402E-10	8.402E-10	8.402E-10	8.402E-10	8.402E-10	8.402E-10	8.402E-10
S-32	1.954E-13	1.954E-13	1.954E-13	1.954E-13	1.954E-13	1.954E-13	1.955E-13
Ca-44	4.521E-15	4.521E-15	4.521E-15	4.521E-15	4.521E-15	4.521E-15	4.521E-15
Ca-46	1.822E-15	1.822E-15	1.822E-15	1.822E-15	1.822E-15	1.822E-15	1.822E-15
Ti-47	2.086E-10	2.086E-10	2.086E-10	2.086E-10	2.086E-10	2.086E-10	2.086E-10
Ti-48	5.511E-13	5.511E-13	5.511E-13	5.511E-13	5.511E-13	5.511E-13	5.511E-13
Ti-49	5.731E-10	5.731E-10	5.731E-10	5.731E-10	5.731E-10	5.731E-10	5.731E-10
Ti-50	2.329E-09	2.329E-09	2.329E-09	2.329E-09	2.329E-09	2.329E-09	2.329E-09
V-50	7.863E-09	7.863E-09	7.863E-09	7.863E-09	7.863E-09	7.863E-09	7.863E-09
V-51	1.672E-06	1.672E-06	1.672E-06	1.672E-06	1.672E-06	1.672E-06	1.672E-06
Cr-50	4.013E-05	4.013E-05	4.013E-05	4.013E-05	4.013E-05	4.013E-05	4.013E-05
Cr-52	8.294E-04	8.294E-04	8.294E-04	8.294E-04	8.294E-04	8.294E-04	8.294E-04
Cr-53	9.995E-05	9.995E-05	9.995E-05	9.995E-05	9.995E-05	9.995E-05	9.995E-05
Cr-54	2.914E-05	2.914E-05	2.914E-05	2.914E-05	2.914E-05	2.914E-05	2.914E-05
Mn-54	5.790E-10	1.146E-10	2.266E-11	4.484E-12	7.806E-14	1.359E-15	0.00
Mn-55	5.547E-07	6.054E-07	6.352E-07	6.527E-07	6.709E-07	6.758E-07	6.775E-07
Fe-54	1.115E-04	1.115E-04	1.115E-04	1.115E-04	1.115E-04	1.115E-04	1.115E-04
Fe-55	1.228E-07	7.205E-08	4.228E-08	2.480E-08	6.541E-09	1.725E-09	0.00

TABLE D.8.d. Cladding Activation Product Inventory by Isotope at 35 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Fe-56	1.825E-03	1.825E-03	1.825E-03	1.825E-03	1.825E-03	1.825E-03	1.825E-03
Fe-57	5.716E-05	5.716E-05	5.716E-05	5.716E-05	5.716E-05	5.716E-05	5.716E-05
Fe-58	6.322E-06	6.322E-06	6.322E-06	6.322E-06	6.322E-06	6.322E-06	6.322E-06
Co-59	1.967E-08	1.967E-08	1.967E-08	1.967E-08	1.967E-08	1.967E-08	1.967E-08
Co-60	5.952E-10	4.576E-10	3.517E-10	2.704E-10	1.401E-10	7.256E-11	0.00
Ni-60	6.440E-10	7.817E-10	8.875E-10	9.689E-10	1.099E-09	1.167E-09	1.239E-09
Ni-61	2.962E-12	2.962E-12	2.962E-12	2.962E-12	2.962E-12	2.962E-12	2.962E-12
Ni-62	4.765E-15	4.765E-15	4.765E-15	4.765E-15	4.765E-15	4.765E-15	4.765E-15
Sr-87	1.371E-08	1.371E-08	1.371E-08	1.371E-08	1.371E-08	1.371E-08	1.371E-08
Sr-88	1.326E-06	1.326E-06	1.326E-06	1.326E-06	1.326E-06	1.326E-06	1.326E-06
Sr-90	4.920E-11	4.691E-11	4.473E-11	4.265E-11	3.787E-11	3.362E-11	2.490E-21
Y-89	1.010E-07	1.010E-07	1.010E-07	1.010E-07	1.010E-07	1.010E-07	1.010E-07
Y-90	1.234E-14	1.176E-14	1.122E-14	1.070E-14	9.495E-15	8.430E-15	6.244E-25
Zr-90	4.973E-01	4.973E-01	4.973E-01	4.973E-01	4.973E-01	4.973E-01	4.973E-01
Zr-91	1.090E-01	1.090E-01	1.090E-01	1.090E-01	1.090E-01	1.090E-01	1.090E-01
Zr-92	1.695E-01	1.695E-01	1.695E-01	1.695E-01	1.695E-01	1.695E-01	1.695E-01
Zr-93	2.500E-04	2.500E-04	2.500E-04	2.500E-04	2.500E-04	2.500E-04	2.499E-04
Zr-94	1.755E-01	1.755E-01	1.755E-01	1.755E-01	1.755E-01	1.755E-01	1.755E-01
Zr-95	6.905E-13	2.524E-16	9.230E-20	3.375E-23	8.626E-32	0.00	0.00
Zr-96	2.872E-02	2.872E-02	2.872E-02	2.872E-02	2.872E-02	2.872E-02	2.872E-02
Nb-93	1.493E-10	2.292E-10	3.234E-10	4.304E-10	7.462E-10	1.118E-09	1.114E-07
Nb-93m	5.992E-10	7.457E-10	8.780E-10	9.975E-10	1.248E-09	1.442E-09	2.110E-09
Nb-94	1.225E-13	1.225E-13	1.225E-13	1.225E-13	1.225E-13	1.225E-13	1.184E-13
Nb-95	8.422E-13	3.079E-16	1.126E-19	4.116E-23	7.802E-34	0.00	0.00
Mo-95	8.952E-05	8.952E-05	8.952E-05	8.952E-05	8.952E-05	8.952E-05	8.952E-05
Mo-96	4.535E-06	4.535E-06	4.535E-06	4.535E-06	4.535E-06	4.535E-06	4.535E-06
Mo-97	1.390E-04	1.390E-04	1.390E-04	1.390E-04	1.390E-04	1.390E-04	1.390E-04
Mo-98	1.329E-06	1.329E-06	1.329E-06	1.329E-06	1.329E-06	1.329E-06	1.329E-06
Mo-100	1.937E-13	1.937E-13	1.937E-13	1.937E-13	1.937E-13	1.937E-13	1.937E-13
Tc-98	1.425E-15	1.425E-15	1.425E-15	1.425E-15	1.425E-15	1.425E-15	1.424E-15
Tc-99	3.411E-10	3.411E-10	3.411E-10	3.411E-10	3.411E-10	3.411E-10	3.400E-10
Ru-99	5.828E-15	8.048E-15	1.027E-14	1.249E-14	1.804E-14	2.359E-14	1.110E-12
Ru-100	2.157E-11	2.157E-11	2.157E-11	2.157E-11	2.157E-11	2.157E-11	2.157E-11
Ru-101	9.253E-14	9.253E-14	9.253E-14	9.253E-14	9.253E-14	9.253E-14	9.253E-14
Ru-102	1.263E-15	1.263E-15	1.263E-15	1.263E-15	1.263E-15	1.263E-15	1.263E-15
Cd-111	1.433E-11	1.433E-11	1.433E-11	1.433E-11	1.433E-11	1.433E-11	1.433E-11
Cd-112	1.219E-10	1.219E-10	1.219E-10	1.219E-10	1.219E-10	1.219E-10	1.219E-10
Cd-113	3.462E-13	3.462E-13	3.462E-13	3.462E-13	3.462E-13	3.462E-13	3.462E-13
Cd-114	2.064E-08	2.064E-08	2.064E-08	2.064E-08	2.064E-08	2.064E-08	2.064E-08
Cd-116	9.229E-11	9.229E-11	9.229E-11	9.229E-11	9.229E-11	9.229E-11	9.229E-11
In-113	2.527E-06	2.527E-06	2.527E-06	2.527E-06	2.527E-06	2.527E-06	2.527E-06
In-113m	1.755E-14	2.150E-16	2.642E-18	3.247E-20	5.436E-25	9.102E-30	0.00
In-115	3.135E-11	3.135E-11	3.135E-11	3.135E-11	3.135E-11	3.135E-11	3.135E-11
Sn-112	1.385E-04	1.385E-04	1.385E-04	1.385E-04	1.385E-04	1.385E-04	1.385E-04
Sn-113	2.912E-11	3.579E-13	4.399E-15	5.406E-17	9.052E-22	1.516E-26	0.00
Sn-114	9.673E-05	9.673E-05	9.673E-05	9.673E-05	9.673E-05	9.673E-05	9.673E-05

TABLE D.8.d. Cladding Activation Product Inventory by Isotope at 35 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Sn-115	4.883E-05	4.883E-05	4.883E-05	4.883E-05	4.883E-05	4.883E-05	4.883E-05
Sn-116	2.124E-03	2.124E-03	2.124E-03	2.124E-03	2.124E-03	2.124E-03	2.124E-03
Sn-117	1.157E-03	1.157E-03	1.157E-03	1.157E-03	1.157E-03	1.157E-03	1.157E-03
Sn-118	3.606E-03	3.606E-03	3.606E-03	3.606E-03	3.606E-03	3.606E-03	3.606E-03
Sn-119	1.321E-03	1.321E-03	1.321E-03	1.321E-03	1.321E-03	1.321E-03	1.321E-03
Sn-119m	5.343E-08	6.766E-09	8.568E-10	1.085E-10	6.191E-13	3.533E-15	0.00
Sn-120	4.913E-03	4.913E-03	4.913E-03	4.913E-03	4.913E-03	4.913E-03	4.913E-03
Sn-121m	4.229E-08	4.113E-08	4.001E-08	3.891E-08	3.631E-08	3.387E-08	4.230E-14
Sn-122	7.079E-04	7.079E-04	7.079E-04	7.079E-04	7.079E-04	7.079E-04	7.079E-04
Sn-123	3.462E-11	6.869E-13	1.363E-14	2.704E-16	1.499E-20	8.310E-25	0.00
Sn-124	8.674E-04	8.674E-04	8.674E-04	8.674E-04	8.674E-04	8.674E-04	8.674E-04
Sb-121	7.373E-06	7.374E-06	7.375E-06	7.376E-06	7.379E-06	7.381E-06	7.415E-06
Sb-123	7.952E-07	7.952E-07	7.952E-07	7.952E-07	7.952E-07	7.952E-07	7.952E-07
Sb-125	1.952E-06	1.183E-06	7.173E-07	4.349E-07	1.244E-07	3.561E-08	0.00
Te-122	5.406E-07	5.406E-07	5.406E-07	5.406E-07	5.406E-07	5.406E-07	5.406E-07
Te-123	7.580E-09	7.581E-09	7.581E-09	7.581E-09	7.581E-09	7.581E-09	7.581E-09
Te-123m	2.250E-13	3.272E-15	4.756E-17	6.915E-19	1.762E-23	4.491E-28	0.00
Te-124	3.912E-08	3.912E-08	3.912E-08	3.912E-08	3.912E-08	3.912E-08	3.912E-08
Te-125	7.441E-06	8.220E-06	8.693E-06	8.979E-06	9.294E-06	9.384E-06	9.420E-06
Te-125m	2.730E-08	1.655E-08	1.004E-08	6.084E-09	1.740E-09	4.980E-10	0.00
Te-126	1.031E-07	1.031E-07	1.031E-07	1.031E-07	1.031E-07	1.031E-07	1.031E-07
Te-128	8.023E-13	8.023E-13	8.023E-13	8.023E-13	8.023E-13	8.023E-13	8.023E-13
I-127	4.172E-10	4.172E-10	4.172E-10	4.172E-10	4.172E-10	4.172E-10	4.172E-10
Xe-128	1.253E-11	1.253E-11	1.253E-11	1.253E-11	1.253E-11	1.253E-11	1.253E-11
Xe-129	4.600E-14	4.600E-14	4.600E-14	4.600E-14	4.600E-14	4.600E-14	4.600E-14
Xe-130	1.766E-15	1.766E-15	1.766E-15	1.766E-15	1.766E-15	1.766E-15	1.766E-15
Yb-172	3.895E-15	3.895E-15	3.895E-15	3.895E-15	3.895E-15	3.895E-15	3.895E-15
Yb-173	3.130E-15	3.130E-15	3.130E-15	3.130E-15	3.130E-15	3.130E-15	3.130E-15
Lu-175	4.263E-08	4.263E-08	4.263E-08	4.263E-08	4.263E-08	4.263E-08	4.263E-08
Lu-176	1.354E-09	1.354E-09	1.354E-09	1.354E-09	1.354E-09	1.354E-09	1.354E-09
Lu-177m	4.148E-15	1.582E-16	6.031E-18	2.300E-19	6.530E-23	1.854E-26	0.00
Hf-174	2.655E-08	2.655E-08	2.655E-08	2.655E-08	2.655E-08	2.655E-08	2.655E-08
Hf-175	1.050E-15	7.579E-19	5.472E-22	3.951E-25	5.534E-33	0.00	0.00
Hf-176	1.631E-06	1.631E-06	1.631E-06	1.631E-06	1.631E-06	1.631E-06	1.631E-06
Hf-177	2.117E-07	2.117E-07	2.117E-07	2.117E-07	2.117E-07	2.117E-07	2.117E-07
Hf-178	6.930E-06	6.930E-06	6.930E-06	6.930E-06	6.930E-06	6.930E-06	6.930E-06
Hf-179	1.915E-05	1.915E-05	1.915E-05	1.915E-05	1.915E-05	1.915E-05	1.915E-05
Hf-180	2.596E-05	2.596E-05	2.596E-05	2.596E-05	2.596E-05	2.596E-05	2.596E-05
Hf-182	4.241E-09	4.241E-09	4.241E-09	4.241E-09	4.241E-09	4.241E-09	4.241E-09
Ta-181	1.015E-06	1.015E-06	1.015E-06	1.015E-06	1.015E-06	1.015E-06	1.015E-06
Ta-182	2.547E-12	3.132E-14	5.299E-16	1.530E-16	1.484E-16	1.484E-16	1.484E-16
W-182	9.322E-08	9.323E-08	9.323E-08	9.323E-08	9.323E-08	9.323E-08	9.323E-08
W-183	1.537E-07	1.537E-07	1.537E-07	1.537E-07	1.537E-07	1.537E-07	1.537E-07
W-184	1.228E-08	1.228E-08	1.228E-08	1.228E-08	1.228E-08	1.228E-08	1.228E-08
W-186	3.996E-13	3.996E-13	3.996E-13	3.996E-13	3.996E-13	3.996E-13	3.996E-13
Re-185	3.269E-11	3.269E-11	3.269E-11	3.269E-11	3.269E-11	3.269E-11	3.269E-11

TABLE D.8.d. Cladding Activation Product Inventory by Isotope at 35 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Re-187	2.514E-14	2.514E-14	2.514E-14	2.514E-14	2.514E-14	2.514E-14	2.514E-14
Os-186	6.124E-12	6.124E-12	6.124E-12	6.124E-12	6.124E-12	6.124E-12	6.124E-12
Os-188	1.267E-15	1.267E-15	1.267E-15	1.267E-15	1.267E-15	1.267E-15	1.267E-15
Total	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00

TABLE D.8.e. Cladding Activation Product Inventory by Isotope at 40 MWd/kgM, g/gZr

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-1	1.405E-05	1.405E-05	1.405E-05	1.405E-05	1.405E-05	1.405E-05	1.405E-05
H-2	3.538E-08	3.538E-08	3.538E-08	3.538E-08	3.538E-08	3.538E-08	3.538E-08
H-3	1.226E-13	1.096E-13	9.796E-14	8.756E-14	6.613E-14	4.995E-14	6.445E-38
He-3	3.281E-14	4.583E-14	5.747E-14	6.787E-14	8.930E-14	1.055E-13	1.554E-13
He-4	1.109E-07	1.109E-07	1.109E-07	1.109E-07	1.109E-07	1.109E-07	1.109E-07
Li-6	2.116E-13	2.116E-13	2.116E-13	2.116E-13	2.116E-13	2.116E-13	2.116E-13
Be-9	1.059E-09	1.059E-09	1.059E-09	1.059E-09	1.059E-09	1.059E-09	1.059E-09
Be-10	2.794E-11	2.794E-11	2.794E-11	2.794E-11	2.794E-11	2.794E-11	2.792E-11
B-11	1.640E-08	1.640E-08	1.640E-08	1.640E-08	1.640E-08	1.640E-08	1.640E-08
C-12	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04
C-13	1.465E-06	1.465E-06	1.465E-06	1.465E-06	1.465E-06	1.465E-06	1.465E-06
C-14	1.441E-07	1.440E-07	1.440E-07	1.440E-07	1.439E-07	1.438E-07	1.277E-07
N-14	2.473E-05	2.473E-05	2.473E-05	2.473E-05	2.473E-05	2.473E-05	2.475E-05
N-15	1.039E-07	1.039E-07	1.039E-07	1.039E-07	1.039E-07	1.039E-07	1.039E-07
O-16	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03
O-17	4.706E-07	4.706E-07	4.706E-07	4.706E-07	4.706E-07	4.706E-07	4.706E-07
O-18	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06
F-19	2.967E-12	2.967E-12	2.967E-12	2.967E-12	2.967E-12	2.967E-12	2.967E-12
Ne-21	1.453E-15	1.453E-15	1.453E-15	1.453E-15	1.453E-15	1.453E-15	1.453E-15
Ne-22	3.490E-14	3.490E-14	3.490E-14	3.490E-14	3.490E-14	3.490E-14	3.490E-14
Na-23	2.831E-15	2.831E-15	2.831E-15	2.831E-15	2.831E-15	2.831E-15	2.831E-15
Mg-24	2.261E-10	2.261E-10	2.261E-10	2.261E-10	2.261E-10	2.261E-10	2.261E-10
Mg-25	4.757E-10	4.757E-10	4.757E-10	4.757E-10	4.757E-10	4.757E-10	4.757E-10
Mg-26	2.180E-10	2.180E-10	2.180E-10	2.180E-10	2.180E-10	2.180E-10	2.180E-10
Al-27	3.997E-05	3.997E-05	3.997E-05	3.997E-05	3.997E-05	3.997E-05	3.997E-05
Si-28	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05
Si-29	3.889E-06	3.889E-06	3.889E-06	3.889E-06	3.889E-06	3.889E-06	3.889E-06
Si-30	2.649E-06	2.649E-06	2.649E-06	2.649E-06	2.649E-06	2.649E-06	2.649E-06
P-31	9.857E-10	9.857E-10	9.857E-10	9.857E-10	9.857E-10	9.857E-10	9.857E-10
S-32	2.689E-13	2.689E-13	2.689E-13	2.689E-13	2.689E-13	2.689E-13	2.690E-13
Ca-44	6.206E-15	6.206E-15	6.206E-15	6.206E-15	6.206E-15	6.206E-15	6.206E-15
Ca-46	2.505E-15	2.505E-15	2.505E-15	2.505E-15	2.505E-15	2.505E-15	2.505E-15
Ti-47	2.438E-10	2.438E-10	2.438E-10	2.438E-10	2.438E-10	2.438E-10	2.438E-10
Ti-48	7.556E-13	7.556E-13	7.556E-13	7.556E-13	7.556E-13	7.556E-13	7.556E-13
Ti-49	6.715E-10	6.715E-10	6.715E-10	6.715E-10	6.715E-10	6.715E-10	6.715E-10
Ti-50	2.740E-09	2.740E-09	2.740E-09	2.740E-09	2.740E-09	2.740E-09	2.740E-09
V-50	9.039E-09	9.039E-09	9.039E-09	9.039E-09	9.039E-09	9.039E-09	9.039E-09
V-51	1.952E-06	1.952E-06	1.952E-06	1.952E-06	1.952E-06	1.952E-06	1.952E-06
Cr-50	3.985E-05	3.985E-05	3.985E-05	3.985E-05	3.985E-05	3.985E-05	3.985E-05
Cr-52	8.281E-04	8.281E-04	8.281E-04	8.281E-04	8.281E-04	8.281E-04	8.281E-04
Cr-53	1.005E-04	1.005E-04	1.005E-04	1.005E-04	1.005E-04	1.005E-04	1.005E-04
Cr-54	2.996E-05	2.996E-05	2.996E-05	2.996E-05	2.996E-05	2.996E-05	2.996E-05
Mn-54	6.875E-10	1.360E-10	2.691E-11	5.324E-12	9.269E-14	1.614E-15	0.00
Mn-55	6.490E-07	7.089E-07	7.440E-07	7.646E-07	7.861E-07	7.918E-07	7.938E-07
Fe-54	1.114E-04	1.114E-04	1.114E-04	1.114E-04	1.114E-04	1.114E-04	1.114E-04
Fe-55	1.448E-07	8.499E-08	4.986E-08	2.926E-08	7.715E-09	2.034E-09	0.00

TABLE D.8.e. Cladding Activation Product Inventory by Isotope at 40 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Fe-56	1.822E-03	1.822E-03	1.822E-03	1.822E-03	1.822E-03	1.822E-03	1.822E-03
Fe-57	5.944E-05	5.944E-05	5.944E-05	5.944E-05	5.944E-05	5.944E-05	5.944E-05
Fe-58	6.384E-06	6.384E-06	6.384E-06	6.384E-06	6.384E-06	6.384E-06	6.384E-06
Co-59	2.295E-08	2.295E-08	2.295E-08	2.295E-08	2.295E-08	2.295E-08	2.295E-08
Co-60	8.173E-10	6.283E-10	4.829E-10	3.712E-10	1.923E-10	9.963E-11	0.00
Ni-60	8.800E-10	1.069E-09	1.214E-09	1.326E-09	1.505E-09	1.598E-09	1.697E-09
Ni-61	4.769E-12	4.769E-12	4.769E-12	4.769E-12	4.769E-12	4.769E-12	4.769E-12
Ni-62	9.006E-15	9.006E-15	9.006E-15	9.006E-15	9.006E-15	9.006E-15	9.006E-15
Sr-87	1.593E-08	1.593E-08	1.593E-08	1.593E-08	1.593E-08	1.593E-08	1.593E-08
Sr-88	1.555E-06	1.555E-06	1.555E-06	1.555E-06	1.555E-06	1.555E-06	1.555E-06
Sr-90	6.765E-11	6.451E-11	6.151E-11	5.865E-11	5.207E-11	4.623E-11	3.424E-21
Y-89	1.185E-07	1.185E-07	1.185E-07	1.185E-07	1.185E-07	1.185E-07	1.185E-07
Y-90	1.697E-14	1.618E-14	1.542E-14	1.471E-14	1.306E-14	1.159E-14	8.586E-25
Zr-90	4.973E-01	4.973E-01	4.973E-01	4.973E-01	4.973E-01	4.973E-01	4.973E-01
Zr-91	1.089E-01	1.089E-01	1.089E-01	1.089E-01	1.089E-01	1.089E-01	1.089E-01
Zr-92	1.696E-01	1.696E-01	1.696E-01	1.696E-01	1.696E-01	1.696E-01	1.696E-01
Zr-93	2.926E-04	2.926E-04	2.926E-04	2.926E-04	2.926E-04	2.926E-04	2.925E-04
Zr-94	1.755E-01	1.755E-01	1.755E-01	1.755E-01	1.755E-01	1.755E-01	1.755E-01
Zr-95	8.244E-13	3.014E-16	1.102E-19	4.029E-23	1.030E-31	0.00	0.00
Zr-96	2.870E-02	2.870E-02	2.870E-02	2.870E-02	2.870E-02	2.870E-02	2.870E-02
Nb-93	1.737E-10	2.672E-10	3.773E-10	5.024E-10	8.717E-10	1.307E-09	1.304E-07
Nb-93m	6.994E-10	8.711E-10	1.026E-09	1.166E-09	1.460E-09	1.687E-09	2.470E-09
Nb-94	1.674E-13	1.674E-13	1.674E-13	1.674E-13	1.674E-13	1.673E-13	1.618E-13
Nb-95	1.006E-12	3.677E-16	1.344E-19	4.915E-23	9.315E-34	0.00	0.00
Mo-95	1.041E-04	1.041E-04	1.041E-04	1.041E-04	1.041E-04	1.041E-04	1.041E-04
Mo-96	6.197E-06	6.197E-06	6.197E-06	6.197E-06	6.197E-06	6.197E-06	6.197E-06
Mo-97	1.628E-04	1.628E-04	1.628E-04	1.628E-04	1.628E-04	1.628E-04	1.628E-04
Mo-98	1.827E-06	1.827E-06	1.827E-06	1.827E-06	1.827E-06	1.827E-06	1.827E-06
Mo-100	3.712E-13	3.712E-13	3.712E-13	3.712E-13	3.712E-13	3.712E-13	3.712E-13
Tc-98	2.673E-15	2.673E-15	2.673E-15	2.673E-15	2.673E-15	2.673E-15	2.673E-15
Tc-99	5.444E-10	5.444E-10	5.444E-10	5.444E-10	5.444E-10	5.444E-10	5.426E-10
Ru-99	9.262E-15	1.280E-14	1.635E-14	1.989E-14	2.875E-14	3.761E-14	1.771E-12
Ru-100	4.045E-11	4.045E-11	4.045E-11	4.045E-11	4.045E-11	4.045E-11	4.045E-11
Ru-101	2.034E-13	2.034E-13	2.034E-13	2.034E-13	2.034E-13	2.034E-13	2.034E-13
Ru-102	3.262E-15	3.262E-15	3.262E-15	3.262E-15	3.262E-15	3.262E-15	3.262E-15
Cd-111	1.668E-11	1.668E-11	1.668E-11	1.668E-11	1.668E-11	1.668E-11	1.668E-11
Cd-112	1.413E-10	1.413E-10	1.413E-10	1.413E-10	1.413E-10	1.413E-10	1.413E-10
Cd-113	3.484E-13	3.484E-13	3.484E-13	3.484E-13	3.484E-13	3.484E-13	3.484E-13
Cd-114	2.776E-08	2.776E-08	2.776E-08	2.776E-08	2.776E-08	2.776E-08	2.776E-08
Cd-116	1.084E-10	1.084E-10	1.084E-10	1.084E-10	1.084E-10	1.084E-10	1.084E-10
In-113	2.889E-06	2.889E-06	2.889E-06	2.889E-06	2.889E-06	2.889E-06	2.889E-06
In-113m	2.089E-14	2.559E-16	3.145E-18	3.866E-20	6.472E-25	1.084E-29	0.00
In-115	3.319E-11	3.319E-11	3.319E-11	3.319E-11	3.319E-11	3.319E-11	3.319E-11
Sn-112	1.380E-04	1.380E-04	1.380E-04	1.380E-04	1.380E-04	1.380E-04	1.380E-04
Sn-113	3.468E-11	4.262E-13	5.238E-15	6.437E-17	1.078E-21	1.804E-26	0.00
Sn-114	9.684E-05	9.684E-05	9.684E-05	9.684E-05	9.684E-05	9.684E-05	9.684E-05

TABLE D.8.e. Cladding Activation Product Inventory by Isotope at 40 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Sn-115	4.781E-05	4.781E-05	4.781E-05	4.781E-05	4.781E-05	4.781E-05	4.781E-05
Sn-116	2.119E-03	2.119E-03	2.119E-03	2.119E-03	2.119E-03	2.119E-03	2.119E-03
Sn-117	1.159E-03	1.159E-03	1.159E-03	1.159E-03	1.159E-03	1.159E-03	1.159E-03
Sn-118	3.603E-03	3.603E-03	3.603E-03	3.603E-03	3.603E-03	3.603E-03	3.603E-03
Sn-119	1.326E-03	1.326E-03	1.326E-03	1.326E-03	1.326E-03	1.326E-03	1.326E-03
Sn-119m	6.362E-08	8.056E-09	1.020E-09	1.292E-10	7.371E-13	4.207E-15	0.00
Sn-120	4.913E-03	4.913E-03	4.913E-03	4.913E-03	4.913E-03	4.913E-03	4.913E-03
Sn-121m	4.963E-08	4.827E-08	4.695E-08	4.567E-08	4.261E-08	3.975E-08	4.965E-14
Sn-122	7.077E-04	7.077E-04	7.077E-04	7.077E-04	7.077E-04	7.077E-04	7.077E-04
Sn-123	4.132E-11	8.198E-13	1.626E-14	3.227E-16	1.789E-20	9.918E-25	0.00
Sn-124	8.658E-04	8.658E-04	8.658E-04	8.658E-04	8.658E-04	8.658E-04	8.658E-04
Sb-121	8.542E-06	8.543E-06	8.544E-06	8.546E-06	8.549E-06	8.552E-06	8.591E-06
Sb-123	9.268E-07	9.268E-07	9.268E-07	9.268E-07	9.268E-07	9.268E-07	9.268E-07
Sb-125	2.297E-06	1.393E-06	8.442E-07	5.118E-07	1.464E-07	4.191E-08	0.00
Te-122	7.340E-07	7.340E-07	7.340E-07	7.340E-07	7.340E-07	7.340E-07	7.340E-07
Te-123	1.108E-08	1.108E-08	1.108E-08	1.108E-08	1.108E-08	1.108E-08	1.108E-08
Te-123m	3.643E-13	5.297E-15	7.701E-17	1.120E-18	2.853E-23	7.272E-28	0.00
Te-124	5.660E-08	5.660E-08	5.660E-08	5.660E-08	5.660E-08	5.660E-08	5.660E-08
Te-125	8.691E-06	9.608E-06	1.016E-05	1.050E-05	1.087E-05	1.098E-05	1.102E-05
Te-125m	3.213E-08	1.948E-08	1.181E-08	7.160E-09	2.048E-09	5.861E-10	0.00
Te-126	1.415E-07	1.415E-07	1.415E-07	1.415E-07	1.415E-07	1.415E-07	1.415E-07
Te-127m	1.387E-15	1.333E-17	1.281E-19	1.235E-21	1.117E-26	1.011E-31	0.00
Te-128	1.511E-12	1.511E-12	1.511E-12	1.511E-12	1.511E-12	1.511E-12	1.511E-12
I-127	6.688E-10	6.688E-10	6.688E-10	6.688E-10	6.688E-10	6.688E-10	6.688E-10
I-129	1.111E-15	1.111E-15	1.111E-15	1.111E-15	1.111E-15	1.111E-15	1.111E-15
Xe-128	2.358E-11	2.358E-11	2.358E-11	2.358E-11	2.358E-11	2.358E-11	2.358E-11
Xe-129	1.011E-13	1.011E-13	1.011E-13	1.011E-13	1.011E-13	1.011E-13	1.011E-13
Xe-130	4.559E-15	4.559E-15	4.559E-15	4.559E-15	4.559E-15	4.559E-15	4.559E-15
Yb-172	4.894E-15	4.894E-15	4.894E-15	4.894E-15	4.894E-15	4.894E-15	4.894E-15
Yb-173	4.092E-15	4.092E-15	4.092E-15	4.092E-15	4.092E-15	4.092E-15	4.092E-15
Lu-175	4.316E-08	4.316E-08	4.316E-08	4.316E-08	4.316E-08	4.316E-08	4.316E-08
Lu-176	1.429E-09	1.429E-09	1.429E-09	1.429E-09	1.429E-09	1.429E-09	1.429E-09
Lu-177m	5.337E-15	2.035E-16	7.759E-18	2.959E-19	8.400E-23	2.385E-26	0.00
Hf-174	2.167E-08	2.167E-08	2.167E-08	2.167E-08	2.167E-08	2.167E-08	2.167E-08
Hf-175	1.038E-15	7.493E-19	5.410E-22	3.906E-25	5.471E-33	0.00	0.00
Hf-176	1.485E-06	1.485E-06	1.485E-06	1.485E-06	1.485E-06	1.485E-06	1.485E-06
Hf-177	1.749E-07	1.749E-07	1.749E-07	1.749E-07	1.749E-07	1.749E-07	1.749E-07
Hf-178	5.512E-06	5.512E-06	5.512E-06	5.512E-06	5.512E-06	5.512E-06	5.512E-06
Hf-179	1.910E-05	1.910E-05	1.910E-05	1.910E-05	1.910E-05	1.910E-05	1.910E-05
Hf-180	2.738E-05	2.738E-05	2.738E-05	2.738E-05	2.738E-05	2.738E-05	2.738E-05
Hf-182	5.997E-09	5.997E-09	5.997E-09	5.997E-09	5.997E-09	5.997E-09	5.997E-09
Ta-181	1.186E-06	1.186E-06	1.186E-06	1.186E-06	1.186E-06	1.186E-06	1.186E-06
Ta-182	3.150E-12	3.877E-14	6.819E-16	2.156E-16	2.098E-16	2.098E-16	2.098E-16
W-182	1.126E-07	1.126E-07	1.126E-07	1.126E-07	1.126E-07	1.126E-07	1.126E-07
W-183	2.218E-07	2.218E-07	2.218E-07	2.218E-07	2.218E-07	2.218E-07	2.218E-07
W-184	2.090E-08	2.090E-08	2.090E-08	2.090E-08	2.090E-08	2.090E-08	2.090E-08

TABLE D.8.e. Cladding Activation Product Inventory by Isotope at 40 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
W-186	9.013E-13	9.013E-13	9.013E-13	9.013E-13	9.013E-13	9.013E-13	9.013E-13
Re-185	6.382E-11	6.382E-11	6.382E-11	6.382E-11	6.382E-11	6.382E-11	6.382E-11
Re-187	6.663E-14	6.663E-14	6.663E-14	6.663E-14	6.663E-14	6.663E-14	6.663E-14
Os-186	1.397E-11	1.397E-11	1.397E-11	1.397E-11	1.397E-11	1.397E-11	1.397E-11
Os-188	3.975E-15	3.975E-15	3.975E-15	3.975E-15	3.975E-15	3.975E-15	3.975E-15
Total	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00

TABLE D.8.f. Cladding Activation Product Inventory by Isotope at 45 MWd/kgM, g/gZr

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-1	1.406E-05	1.406E-05	1.406E-05	1.406E-05	1.406E-05	1.406E-05	1.406E-05
H-2	4.018E-08	4.018E-08	4.018E-08	4.018E-08	4.018E-08	4.018E-08	4.018E-08
H-3	1.711E-13	1.529E-13	1.367E-13	1.221E-13	9.226E-14	6.968E-14	8.989E-38
He-3	4.541E-14	6.357E-14	7.981E-14	9.432E-14	1.242E-13	1.468E-13	2.165E-13
He-4	1.280E-07	1.280E-07	1.280E-07	1.280E-07	1.280E-07	1.280E-07	1.280E-07
Li-6	2.587E-13	2.587E-13	2.587E-13	2.587E-13	2.587E-13	2.587E-13	2.587E-13
Be-9	1.221E-09	1.221E-09	1.221E-09	1.221E-09	1.221E-09	1.221E-09	1.221E-09
Be-10	3.238E-11	3.238E-11	3.238E-11	3.238E-11	3.238E-11	3.238E-11	3.236E-11
B-11	1.891E-08	1.891E-08	1.891E-08	1.891E-08	1.891E-08	1.891E-08	1.891E-08
C-12	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04
C-13	1.478E-06	1.478E-06	1.478E-06	1.478E-06	1.478E-06	1.478E-06	1.478E-06
C-14	1.661E-07	1.661E-07	1.660E-07	1.660E-07	1.659E-07	1.658E-07	1.473E-07
N-14	2.471E-05	2.471E-05	2.471E-05	2.471E-05	2.471E-05	2.471E-05	2.472E-05
N-15	1.048E-07	1.048E-07	1.048E-07	1.048E-07	1.048E-07	1.048E-07	1.048E-07
O-16	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03
O-17	4.706E-07	4.706E-07	4.706E-07	4.706E-07	4.706E-07	4.706E-07	4.706E-07
O-18	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06
F-19	3.423E-12	3.423E-12	3.423E-12	3.423E-12	3.423E-12	3.423E-12	3.423E-12
Ne-21	1.933E-15	1.933E-15	1.933E-15	1.933E-15	1.933E-15	1.933E-15	1.933E-15
Ne-22	4.645E-14	4.645E-14	4.645E-14	4.645E-14	4.645E-14	4.645E-14	4.645E-14
Na-23	3.769E-15	3.769E-15	3.769E-15	3.769E-15	3.769E-15	3.769E-15	3.769E-15
Mg-24	2.608E-10	2.608E-10	2.608E-10	2.608E-10	2.608E-10	2.608E-10	2.608E-10
Mg-25	5.487E-10	5.487E-10	5.487E-10	5.487E-10	5.487E-10	5.487E-10	5.487E-10
Mg-26	2.516E-10	2.516E-10	2.516E-10	2.516E-10	2.516E-10	2.516E-10	2.516E-10
Al-27	3.997E-05	3.997E-05	3.997E-05	3.997E-05	3.997E-05	3.997E-05	3.997E-05
Si-28	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05
Si-29	3.895E-06	3.895E-06	3.895E-06	3.895E-06	3.895E-06	3.895E-06	3.895E-06
Si-30	2.650E-06	2.650E-06	2.650E-06	2.650E-06	2.650E-06	2.650E-06	2.650E-06
P-31	1.137E-09	1.137E-09	1.137E-09	1.137E-09	1.137E-09	1.137E-09	1.137E-09
S-32	3.579E-13	3.579E-13	3.579E-13	3.579E-13	3.579E-13	3.579E-13	3.580E-13
Ca-44	8.236E-15	8.236E-15	8.236E-15	8.236E-15	8.236E-15	8.236E-15	8.236E-15
Ca-46	3.331E-15	3.331E-15	3.331E-15	3.331E-15	3.331E-15	3.331E-15	3.331E-15
Ti-47	2.801E-10	2.801E-10	2.801E-10	2.801E-10	2.801E-10	2.801E-10	2.801E-10
Ti-48	1.002E-12	1.002E-12	1.002E-12	1.002E-12	1.002E-12	1.002E-12	1.002E-12
Ti-49	7.736E-10	7.736E-10	7.736E-10	7.736E-10	7.736E-10	7.736E-10	7.736E-10
Ti-50	3.171E-09	3.171E-09	3.171E-09	3.171E-09	3.171E-09	3.171E-09	3.171E-09
V-50	1.021E-08	1.021E-08	1.021E-08	1.021E-08	1.021E-08	1.021E-08	1.021E-08
V-51	2.242E-06	2.242E-06	2.242E-06	2.242E-06	2.242E-06	2.242E-06	2.242E-06
Cr-50	3.956E-05	3.956E-05	3.956E-05	3.956E-05	3.956E-05	3.956E-05	3.956E-05
Cr-52	8.267E-04	8.267E-04	8.267E-04	8.267E-04	8.267E-04	8.267E-04	8.267E-04
Cr-53	1.010E-04	1.010E-04	1.010E-04	1.010E-04	1.010E-04	1.010E-04	1.010E-04
Cr-54	3.082E-05	3.082E-05	3.082E-05	3.082E-05	3.082E-05	3.082E-05	3.082E-05
Mn-54	8.002E-10	1.583E-10	3.132E-11	6.197E-12	1.079E-13	1.878E-15	0.00
Mn-55	7.469E-07	8.162E-07	8.569E-07	8.808E-07	9.058E-07	9.123E-07	9.147E-07
Fe-54	1.113E-04	1.113E-04	1.113E-04	1.113E-04	1.113E-04	1.113E-04	1.113E-04
Fe-55	1.678E-07	9.847E-08	5.777E-08	3.390E-08	8.939E-09	2.357E-09	0.00

TABLE D.8.f. Cladding Activation Product Inventory by Isotope at 45 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Fe-56	1.820E-03	1.820E-03	1.820E-03	1.820E-03	1.820E-03	1.820E-03	1.820E-03
Fe-57	6.182E-05	6.182E-05	6.182E-05	6.182E-05	6.182E-05	6.182E-05	6.182E-05
Fe-58	6.450E-06	6.450E-06	6.450E-06	6.450E-06	6.450E-06	6.450E-06	6.450E-06
Co-59	2.632E-08	2.632E-08	2.632E-08	2.632E-08	2.632E-08	2.632E-08	2.632E-08
Co-60	1.084E-09	8.336E-10	6.408E-10	4.926E-10	2.552E-10	1.322E-10	0.00
Ni-60	1.163E-09	1.414E-09	1.607E-09	1.755E-09	1.993E-09	2.116E-09	2.248E-09
Ni-61	7.300E-12	7.300E-12	7.300E-12	7.300E-12	7.300E-12	7.300E-12	7.300E-12
Ni-62	1.591E-14	1.591E-14	1.591E-14	1.591E-14	1.591E-14	1.591E-14	1.591E-14
Sr-87	1.819E-08	1.819E-08	1.819E-08	1.819E-08	1.819E-08	1.819E-08	1.819E-08
Sr-88	1.794E-06	1.794E-06	1.794E-06	1.794E-06	1.794E-06	1.794E-06	1.794E-06
Sr-90	8.995E-11	8.577E-11	8.178E-11	7.798E-11	6.923E-11	6.147E-11	4.553E-21
Y-89	1.367E-07	1.367E-07	1.367E-07	1.367E-07	1.367E-07	1.367E-07	1.367E-07
Y-90	2.256E-14	2.151E-14	2.051E-14	1.956E-14	1.736E-14	1.541E-14	1.142E-24
Zr-90	4.972E-01	4.972E-01	4.972E-01	4.972E-01	4.972E-01	4.972E-01	4.972E-01
Zr-91	1.088E-01	1.088E-01	1.088E-01	1.088E-01	1.088E-01	1.088E-01	1.088E-01
Zr-92	1.697E-01	1.697E-01	1.697E-01	1.697E-01	1.697E-01	1.697E-01	1.697E-01
Zr-93	3.368E-04	3.368E-04	3.368E-04	3.368E-04	3.368E-04	3.368E-04	3.367E-04
Zr-94	1.755E-01	1.755E-01	1.755E-01	1.755E-01	1.755E-01	1.755E-01	1.755E-01
Zr-95	9.632E-13	3.521E-16	1.288E-19	4.707E-23	1.203E-31	0.00	0.00
Zr-96	2.867E-02	2.867E-02	2.867E-02	2.867E-02	2.867E-02	2.867E-02	2.867E-02
Nb-93	1.990E-10	3.064E-10	4.330E-10	5.769E-10	1.002E-09	1.503E-09	1.501E-07
Nb-93m	8.032E-10	1.001E-09	1.180E-09	1.341E-09	1.679E-09	1.941E-09	2.844E-09
Nb-94	2.209E-13	2.208E-13	2.208E-13	2.208E-13	2.208E-13	2.207E-13	2.135E-13
Nb-95	1.175E-12	4.295E-16	1.570E-19	5.742E-23	1.088E-33	0.00	0.00
Mo-95	1.191E-04	1.191E-04	1.191E-04	1.191E-04	1.191E-04	1.191E-04	1.191E-04
Mo-96	8.186E-06	8.186E-06	8.186E-06	8.186E-06	8.186E-06	8.186E-06	8.186E-06
Mo-97	1.874E-04	1.874E-04	1.874E-04	1.874E-04	1.874E-04	1.874E-04	1.874E-04
Mo-98	2.427E-06	2.427E-06	2.427E-06	2.427E-06	2.427E-06	2.427E-06	2.427E-06
Mo-100	6.631E-13	6.631E-13	6.631E-13	6.631E-13	6.631E-13	6.631E-13	6.631E-13
Tc-98	4.690E-15	4.690E-15	4.690E-15	4.690E-15	4.690E-15	4.690E-15	4.689E-15
Tc-99	8.259E-10	8.259E-10	8.259E-10	8.259E-10	8.259E-10	8.259E-10	8.233E-10
Ru-99	1.400E-14	1.938E-14	2.475E-14	3.013E-14	4.357E-14	5.700E-14	2.687E-12
Ru-100	7.091E-11	7.091E-11	7.091E-11	7.091E-11	7.091E-11	7.091E-11	7.091E-11
Ru-101	4.110E-13	4.110E-13	4.110E-13	4.110E-13	4.110E-13	4.110E-13	4.110E-13
Ru-102	7.615E-15	7.615E-15	7.615E-15	7.615E-15	7.615E-15	7.615E-15	7.615E-15
Cd-111	1.909E-11	1.909E-11	1.909E-11	1.909E-11	1.909E-11	1.909E-11	1.909E-11
Cd-112	1.611E-10	1.611E-10	1.611E-10	1.611E-10	1.611E-10	1.611E-10	1.611E-10
Cd-113	3.507E-13	3.507E-13	3.507E-13	3.507E-13	3.507E-13	3.507E-13	3.507E-13
Cd-114	3.611E-08	3.611E-08	3.611E-08	3.611E-08	3.611E-08	3.611E-08	3.611E-08
Cd-116	1.252E-10	1.252E-10	1.252E-10	1.252E-10	1.252E-10	1.252E-10	1.252E-10
In-113	3.246E-06	3.246E-06	3.246E-06	3.246E-06	3.246E-06	3.246E-06	3.246E-06
In-113m	2.433E-14	2.976E-16	3.657E-18	4.494E-20	7.525E-25	1.260E-29	0.00
In-115	3.552E-11	3.552E-11	3.552E-11	3.552E-11	3.552E-11	3.552E-11	3.552E-11
Sn-112	1.375E-04	1.375E-04	1.375E-04	1.375E-04	1.375E-04	1.375E-04	1.375E-04
Sn-113	4.032E-11	4.955E-13	6.089E-15	7.483E-17	1.253E-21	2.098E-26	0.00
Sn-114	9.698E-05	9.698E-05	9.698E-05	9.698E-05	9.698E-05	9.698E-05	9.698E-05

TABLE D.8.f. Cladding Activation Product Inventory by Isotope at 45 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Sn-115	4.677E-05	4.677E-05	4.677E-05	4.677E-05	4.677E-05	4.677E-05	4.677E-05
Sn-116	2.113E-03	2.113E-03	2.113E-03	2.113E-03	2.113E-03	2.113E-03	2.113E-03
Sn-117	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03
Sn-118	3.600E-03	3.600E-03	3.600E-03	3.600E-03	3.600E-03	3.600E-03	3.600E-03
Sn-119	1.331E-03	1.332E-03	1.332E-03	1.332E-03	1.332E-03	1.332E-03	1.332E-03
Sn-119m	7.422E-08	9.399E-09	1.190E-09	1.507E-10	8.595E-13	4.905E-15	0.00
Sn-120	4.914E-03	4.914E-03	4.914E-03	4.914E-03	4.914E-03	4.914E-03	4.914E-03
Sn-121m	5.728E-08	5.571E-08	5.419E-08	5.270E-08	4.917E-08	4.588E-08	5.730E-14
Sn-122	7.076E-04	7.076E-04	7.076E-04	7.076E-04	7.076E-04	7.076E-04	7.076E-04
Sn-123	4.827E-11	9.577E-13	1.900E-14	3.770E-16	2.090E-20	1.159E-24	0.00
Sn-124	8.641E-04	8.641E-04	8.641E-04	8.641E-04	8.641E-04	8.641E-04	8.641E-04
Sb-121	9.727E-06	9.729E-06	9.730E-06	9.732E-06	9.735E-06	9.738E-06	9.784E-06
Sb-123	1.062E-06	1.062E-06	1.062E-06	1.062E-06	1.062E-06	1.062E-06	1.062E-06
Sb-125	2.655E-06	1.610E-06	9.759E-07	5.916E-07	1.693E-07	4.844E-08	0.00
Te-122	9.632E-07	9.632E-07	9.632E-07	9.632E-07	9.632E-07	9.632E-07	9.632E-07
Te-123	1.549E-08	1.549E-08	1.549E-08	1.549E-08	1.549E-08	1.549E-08	1.549E-08
Te-123m	5.572E-13	8.101E-15	1.178E-16	1.712E-18	4.364E-23	1.112E-27	0.00
Te-124	7.921E-08	7.921E-08	7.921E-08	7.921E-08	7.921E-08	7.921E-08	7.921E-08
Te-125	9.984E-06	1.104E-05	1.169E-05	1.208E-05	1.251E-05	1.263E-05	1.268E-05
Te-125m	3.714E-08	2.252E-08	1.365E-08	8.277E-09	2.368E-09	6.776E-10	0.00
Te-126	1.878E-07	1.878E-07	1.878E-07	1.878E-07	1.878E-07	1.878E-07	1.878E-07
Te-127m	2.145E-15	2.061E-17	1.980E-19	1.909E-21	1.727E-26	1.563E-31	0.00
Te-128	2.660E-12	2.660E-12	2.660E-12	2.660E-12	2.660E-12	2.660E-12	2.660E-12
I-127	1.019E-09	1.019E-09	1.019E-09	1.019E-09	1.019E-09	1.019E-09	1.019E-09
I-129	2.250E-15	2.250E-15	2.250E-15	2.250E-15	2.250E-15	2.250E-15	2.250E-15
Xe-128	4.149E-11	4.149E-11	4.149E-11	4.149E-11	4.149E-11	4.149E-11	4.149E-11
Xe-129	2.041E-13	2.041E-13	2.041E-13	2.041E-13	2.041E-13	2.041E-13	2.041E-13
Xe-130	1.064E-14	1.064E-14	1.064E-14	1.064E-14	1.064E-14	1.064E-14	1.064E-14
Yb-172	5.933E-15	5.933E-15	5.933E-15	5.933E-15	5.933E-15	5.933E-15	5.933E-15
Yb-173	5.092E-15	5.092E-15	5.092E-15	5.092E-15	5.092E-15	5.092E-15	5.092E-15
Lu-175	4.275E-08	4.275E-08	4.275E-08	4.275E-08	4.275E-08	4.275E-08	4.275E-08
Lu-176	1.462E-09	1.462E-09	1.462E-09	1.462E-09	1.462E-09	1.462E-09	1.462E-09
Lu-177m	6.517E-15	2.485E-16	9.476E-18	3.613E-19	1.026E-22	2.913E-26	0.00
Hf-174	1.754E-08	1.754E-08	1.754E-08	1.754E-08	1.754E-08	1.754E-08	1.754E-08
Hf-176	1.347E-06	1.347E-06	1.347E-06	1.347E-06	1.347E-06	1.347E-06	1.347E-06
Hf-177	1.519E-07	1.519E-07	1.519E-07	1.519E-07	1.519E-07	1.519E-07	1.519E-07
Hf-178	4.353E-06	4.353E-06	4.353E-06	4.353E-06	4.353E-06	4.353E-06	4.353E-06
Hf-179	1.872E-05	1.872E-05	1.872E-05	1.872E-05	1.872E-05	1.872E-05	1.872E-05
Hf-180	2.881E-05	2.881E-05	2.881E-05	2.881E-05	2.881E-05	2.881E-05	2.881E-05
Hf-182	8.217E-09	8.217E-09	8.217E-09	8.217E-09	8.217E-09	8.217E-09	8.216E-09
Ta-181	1.362E-06	1.362E-06	1.362E-06	1.362E-06	1.362E-06	1.362E-06	1.362E-06
Ta-182	3.783E-12	4.659E-14	8.542E-16	2.944E-16	2.875E-16	2.875E-16	2.874E-16
W-182	1.322E-07	1.322E-07	1.322E-07	1.322E-07	1.322E-07	1.322E-07	1.322E-07
W-183	3.055E-07	3.055E-07	3.055E-07	3.055E-07	3.055E-07	3.055E-07	3.055E-07
W-184	3.340E-08	3.340E-08	3.340E-08	3.340E-08	3.340E-08	3.340E-08	3.340E-08
W-186	1.845E-12	1.845E-12	1.845E-12	1.845E-12	1.845E-12	1.845E-12	1.845E-12

TABLE D.8.f. Cladding Activation Product Inventory by Isotope at 45 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Re-185	1.150E-10	1.150E-10	1.150E-10	1.150E-10	1.150E-10	1.150E-10	1.150E-10
Re-187	1.575E-13	1.575E-13	1.575E-13	1.575E-13	1.575E-13	1.575E-13	1.575E-13
Os-186	2.895E-11	2.895E-11	2.895E-11	2.895E-11	2.895E-11	2.895E-11	2.895E-11
Os-188	1.092E-14	1.092E-14	1.092E-14	1.092E-14	1.092E-14	1.092E-14	1.092E-14
Total	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00

TABLE D.8.g. Cladding Activation Product Inventory by Isotope at 50 MWd/kgM, g/gZr

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
H-1	1.407E-05	1.407E-05	1.407E-05	1.407E-05	1.407E-05	1.407E-05	1.407E-05
H-2	4.515E-08	4.515E-08	4.515E-08	4.515E-08	4.515E-08	4.515E-08	4.515E-08
H-3	2.307E-13	2.062E-13	1.843E-13	1.647E-13	1.244E-13	9.398E-14	1.212E-37
He-3	6.087E-14	8.537E-14	1.073E-13	1.268E-13	1.672E-13	1.976E-13	2.916E-13
He-4	1.456E-07	1.456E-07	1.456E-07	1.456E-07	1.456E-07	1.456E-07	1.456E-07
Li-6	3.084E-13	3.084E-13	3.084E-13	3.084E-13	3.084E-13	3.084E-13	3.084E-13
Be-9	1.389E-09	1.389E-09	1.389E-09	1.389E-09	1.389E-09	1.389E-09	1.389E-09
Be-10	3.701E-11	3.701E-11	3.701E-11	3.701E-11	3.701E-11	3.701E-11	3.700E-11
B-11	2.150E-08	2.150E-08	2.150E-08	2.150E-08	2.150E-08	2.150E-08	2.150E-08
C-12	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04	1.136E-04
C-13	1.491E-06	1.491E-06	1.491E-06	1.491E-06	1.491E-06	1.491E-06	1.491E-06
C-14	1.889E-07	1.889E-07	1.888E-07	1.888E-07	1.887E-07	1.885E-07	1.675E-07
N-14	2.468E-05	2.468E-05	2.468E-05	2.468E-05	2.468E-05	2.468E-05	2.470E-05
N-15	1.058E-07	1.058E-07	1.058E-07	1.058E-07	1.058E-07	1.058E-07	1.058E-07
O-16	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03	1.162E-03
O-17	4.707E-07	4.707E-07	4.707E-07	4.707E-07	4.707E-07	4.707E-07	4.707E-07
O-18	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06	2.673E-06
F-19	3.895E-12	3.895E-12	3.895E-12	3.895E-12	3.895E-12	3.895E-12	3.895E-12
Ne-21	2.501E-15	2.501E-15	2.501E-15	2.501E-15	2.501E-15	2.501E-15	2.501E-15
Ne-22	6.013E-14	6.013E-14	6.013E-14	6.013E-14	6.013E-14	6.013E-14	6.013E-14
Na-23	4.883E-15	4.883E-15	4.883E-15	4.883E-15	4.883E-15	4.883E-15	4.883E-15
Mg-24	2.967E-10	2.967E-10	2.967E-10	2.967E-10	2.967E-10	2.967E-10	2.967E-10
Mg-25	6.244E-10	6.244E-10	6.244E-10	6.244E-10	6.244E-10	6.244E-10	6.244E-10
Mg-26	2.866E-10	2.866E-10	2.866E-10	2.866E-10	2.866E-10	2.866E-10	2.866E-10
Al-27	3.996E-05	3.996E-05	3.996E-05	3.996E-05	3.996E-05	3.996E-05	3.996E-05
Si-28	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05	7.349E-05
Si-29	3.900E-06	3.900E-06	3.900E-06	3.900E-06	3.900E-06	3.900E-06	3.900E-06
Si-30	2.650E-06	2.650E-06	2.650E-06	2.650E-06	2.650E-06	2.650E-06	2.650E-06
P-31	1.294E-09	1.294E-09	1.294E-09	1.294E-09	1.294E-09	1.294E-09	1.294E-09
S-32	4.633E-13	4.633E-13	4.633E-13	4.633E-13	4.633E-13	4.633E-13	4.635E-13
Ca-44	1.063E-14	1.063E-14	1.063E-14	1.063E-14	1.063E-14	1.063E-14	1.063E-14
Ca-46	4.308E-15	4.308E-15	4.308E-15	4.308E-15	4.308E-15	4.308E-15	4.308E-15
Ti-47	3.174E-10	3.174E-10	3.174E-10	3.174E-10	3.174E-10	3.174E-10	3.174E-10
Ti-48	1.292E-12	1.292E-12	1.292E-12	1.292E-12	1.292E-12	1.292E-12	1.292E-12
Ti-49	8.791E-10	8.791E-10	8.791E-10	8.791E-10	8.791E-10	8.791E-10	8.791E-10
Ti-50	3.619E-09	3.619E-09	3.619E-09	3.619E-09	3.619E-09	3.619E-09	3.619E-09
V-50	1.137E-08	1.137E-08	1.137E-08	1.137E-08	1.137E-08	1.137E-08	1.137E-08
V-51	2.539E-06	2.539E-06	2.539E-06	2.539E-06	2.539E-06	2.539E-06	2.539E-06
Cr-50	3.926E-05	3.926E-05	3.926E-05	3.926E-05	3.926E-05	3.926E-05	3.926E-05
Cr-52	8.253E-04	8.253E-04	8.253E-04	8.253E-04	8.253E-04	8.253E-04	8.253E-04
Cr-53	1.016E-04	1.016E-04	1.016E-04	1.016E-04	1.016E-04	1.016E-04	1.016E-04
Cr-54	3.171E-05	3.171E-05	3.171E-05	3.171E-05	3.171E-05	3.171E-05	3.171E-05
Mn-54	9.162E-10	1.813E-10	3.586E-11	7.095E-12	1.235E-13	2.150E-15	0.00
Mn-55	8.479E-07	9.271E-07	9.735E-07	1.001E-06	1.029E-06	1.037E-06	1.039E-06
Fe-54	1.111E-04	1.111E-04	1.111E-04	1.111E-04	1.111E-04	1.111E-04	1.111E-04
Fe-55	1.916E-07	1.124E-07	6.595E-08	3.870E-08	1.020E-08	2.691E-09	0.00

TABLE D.8.g. Cladding Activation Product Inventory by Isotope at 50 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Fe-56	1.817E-03	1.817E-03	1.817E-03	1.817E-03	1.817E-03	1.817E-03	1.817E-03
Fe-57	6.427E-05	6.427E-05	6.427E-05	6.427E-05	6.427E-05	6.427E-05	6.427E-05
Fe-58	6.522E-06	6.522E-06	6.522E-06	6.522E-06	6.522E-06	6.522E-06	6.522E-06
Co-59	2.978E-08	2.978E-08	2.978E-08	2.978E-08	2.978E-08	2.978E-08	2.978E-08
Co-60	1.399E-09	1.075E-09	8.267E-10	6.354E-10	3.292E-10	1.705E-10	0.00
Ni-60	1.496E-09	1.820E-09	2.069E-09	2.260E-09	2.566E-09	2.725E-09	2.895E-09
Ni-61	1.072E-11	1.072E-11	1.072E-11	1.072E-11	1.072E-11	1.072E-11	1.072E-11
Ni-62	2.658E-14	2.658E-14	2.658E-14	2.658E-14	2.658E-14	2.658E-14	2.658E-14
Sr-87	2.047E-08	2.047E-08	2.047E-08	2.047E-08	2.047E-08	2.047E-08	2.047E-08
Sr-88	2.040E-06	2.040E-06	2.040E-06	2.040E-06	2.040E-06	2.040E-06	2.040E-06
Sr-90	1.163E-10	1.109E-10	1.058E-10	1.009E-10	8.954E-11	7.949E-11	5.888E-21
Y-89	1.556E-07	1.556E-07	1.556E-07	1.556E-07	1.556E-07	1.556E-07	1.556E-07
Y-90	2.917E-14	2.782E-14	2.652E-14	2.529E-14	2.245E-14	1.993E-14	1.477E-24
Zr-90	4.971E-01	4.971E-01	4.971E-01	4.971E-01	4.971E-01	4.971E-01	4.971E-01
Zr-91	1.087E-01	1.087E-01	1.087E-01	1.087E-01	1.087E-01	1.087E-01	1.087E-01
Zr-92	1.698E-01	1.698E-01	1.698E-01	1.698E-01	1.698E-01	1.698E-01	1.698E-01
Zr-93	3.824E-04	3.824E-04	3.824E-04	3.824E-04	3.824E-04	3.824E-04	3.822E-04
Zr-94	1.755E-01	1.755E-01	1.755E-01	1.755E-01	1.755E-01	1.755E-01	1.755E-01
Zr-95	1.105E-12	4.041E-16	1.478E-19	5.402E-23	1.381E-31	0.00	0.00
Zr-96	2.865E-02	2.865E-02	2.865E-02	2.865E-02	2.865E-02	2.865E-02	2.865E-02
Nb-93	2.251E-10	3.468E-10	4.903E-10	6.535E-10	1.136E-09	1.704E-09	1.704E-07
Nb-93m	9.101E-10	1.135E-09	1.338E-09	1.521E-09	1.905E-09	2.203E-09	3.228E-09
Nb-94	2.831E-13	2.831E-13	2.831E-13	2.831E-13	2.830E-13	2.830E-13	2.737E-13
Nb-95	1.348E-12	4.929E-16	1.802E-19	6.589E-23	1.249E-33	0.00	0.00
Mo-95	1.343E-04	1.343E-04	1.343E-04	1.343E-04	1.343E-04	1.343E-04	1.343E-04
Mo-96	1.052E-05	1.052E-05	1.052E-05	1.052E-05	1.052E-05	1.052E-05	1.052E-05
Mo-97	2.128E-04	2.128E-04	2.128E-04	2.128E-04	2.128E-04	2.128E-04	2.128E-04
Mo-98	3.136E-06	3.136E-06	3.136E-06	3.136E-06	3.136E-06	3.136E-06	3.136E-06
Mo-100	1.119E-12	1.119E-12	1.119E-12	1.119E-12	1.119E-12	1.119E-12	1.119E-12
Tc-98	7.783E-15	7.783E-15	7.783E-15	7.783E-15	7.783E-15	7.783E-15	7.781E-15
Tc-99	1.202E-09	1.202E-09	1.202E-09	1.202E-09	1.202E-09	1.202E-09	1.198E-09
Ru-99	2.032E-14	2.814E-14	3.596E-14	4.378E-14	6.333E-14	8.289E-14	3.909E-12
Ru-100	1.176E-10	1.176E-10	1.176E-10	1.176E-10	1.176E-10	1.176E-10	1.176E-10
Ru-101	7.750E-13	7.750E-13	7.750E-13	7.750E-13	7.750E-13	7.750E-13	7.750E-13
Ru-102	1.636E-14	1.636E-14	1.636E-14	1.636E-14	1.636E-14	1.636E-14	1.636E-14
Cd-111	2.154E-11	2.154E-11	2.154E-11	2.154E-11	2.154E-11	2.154E-11	2.154E-11
Cd-112	1.810E-10	1.810E-10	1.810E-10	1.810E-10	1.810E-10	1.810E-10	1.810E-10
Cd-113	3.530E-13	3.530E-13	3.530E-13	3.530E-13	3.530E-13	3.530E-13	3.530E-13
Cd-114	4.569E-08	4.569E-08	4.569E-08	4.569E-08	4.569E-08	4.569E-08	4.569E-08
Cd-116	1.427E-10	1.427E-10	1.427E-10	1.427E-10	1.427E-10	1.427E-10	1.427E-10
In-113	3.594E-06	3.594E-06	3.594E-06	3.594E-06	3.594E-06	3.594E-06	3.594E-06
In-113m	2.783E-14	3.416E-16	4.198E-18	5.159E-20	8.638E-25	1.446E-29	0.00
In-115	3.844E-11	3.844E-11	3.844E-11	3.844E-11	3.844E-11	3.844E-11	3.844E-11
Sn-112	1.370E-04	1.370E-04	1.370E-04	1.370E-04	1.370E-04	1.370E-04	1.370E-04
Sn-113	4.628E-11	5.688E-13	6.990E-15	8.591E-17	1.438E-21	2.408E-26	0.00
Sn-114	9.714E-05	9.714E-05	9.714E-05	9.714E-05	9.714E-05	9.714E-05	9.714E-05

TABLE D.8.g. Cladding Activation Product Inventory by Isotope at 50 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Sn-115	4.572E-05	4.572E-05	4.572E-05	4.572E-05	4.572E-05	4.572E-05	4.572E-05
Sn-116	2.108E-03	2.108E-03	2.108E-03	2.108E-03	2.108E-03	2.108E-03	2.108E-03
Sn-117	1.164E-03	1.164E-03	1.164E-03	1.164E-03	1.164E-03	1.164E-03	1.164E-03
Sn-118	3.597E-03	3.597E-03	3.597E-03	3.597E-03	3.597E-03	3.597E-03	3.597E-03
Sn-119	1.337E-03	1.337E-03	1.337E-03	1.337E-03	1.337E-03	1.337E-03	1.337E-03
Sn-119m	8.515E-08	1.078E-08	1.365E-09	1.729E-10	9.863E-13	5.626E-15	0.00
Sn-120	4.914E-03	4.914E-03	4.914E-03	4.914E-03	4.914E-03	4.914E-03	4.914E-03
Sn-121m	6.519E-08	6.341E-08	6.167E-08	5.999E-08	5.597E-08	5.222E-08	6.521E-14
Sn-122	7.075E-04	7.075E-04	7.075E-04	7.075E-04	7.075E-04	7.075E-04	7.075E-04
Sn-123	5.548E-11	1.101E-12	2.184E-14	4.333E-16	2.402E-20	1.332E-24	0.00
Sn-124	8.624E-04	8.624E-04	8.624E-04	8.624E-04	8.624E-04	8.624E-04	8.624E-04
Sb-121	1.092E-05	1.092E-05	1.092E-05	1.093E-05	1.093E-05	1.093E-05	1.099E-05
Sb-123	1.200E-06	1.200E-06	1.200E-06	1.200E-06	1.200E-06	1.200E-06	1.200E-06
Sb-125	3.025E-06	1.834E-06	1.112E-06	6.739E-07	1.928E-07	5.518E-08	0.00
Te-122	1.229E-06	1.229E-06	1.229E-06	1.229E-06	1.229E-06	1.229E-06	1.229E-06
Te-123	2.086E-08	2.086E-08	2.086E-08	2.086E-08	2.086E-08	2.086E-08	2.086E-08
Te-123m	8.159E-13	1.186E-14	1.725E-16	2.507E-18	6.390E-23	1.628E-27	0.00
Te-124	1.077E-07	1.077E-07	1.077E-07	1.077E-07	1.077E-07	1.077E-07	1.077E-07
Te-125	1.131E-05	1.252E-05	1.325E-05	1.370E-05	1.419E-05	1.432E-05	1.438E-05
Te-125m	4.231E-08	2.565E-08	1.555E-08	9.428E-09	2.697E-09	7.718E-10	0.00
Te-126	2.424E-07	2.424E-07	2.424E-07	2.424E-07	2.424E-07	2.424E-07	2.424E-07
Te-127m	3.171E-15	3.047E-17	2.927E-19	2.822E-21	2.553E-26	2.311E-31	0.00
Te-128	4.429E-12	4.429E-12	4.429E-12	4.429E-12	4.429E-12	4.429E-12	4.429E-12
I-127	1.489E-09	1.489E-09	1.489E-09	1.489E-09	1.489E-09	1.489E-09	1.489E-09
I-129	4.252E-15	4.252E-15	4.252E-15	4.252E-15	4.252E-15	4.252E-15	4.252E-15
Xe-128	6.906E-11	6.906E-11	6.906E-11	6.906E-11	6.906E-11	6.906E-11	6.906E-11
Xe-129	3.845E-13	3.845E-13	3.845E-13	3.845E-13	3.845E-13	3.845E-13	3.845E-13
Xe-130	2.285E-14	2.285E-14	2.285E-14	2.285E-14	2.285E-14	2.285E-14	2.285E-14
Yb-172	6.987E-15	6.987E-15	6.987E-15	6.987E-15	6.987E-15	6.987E-15	6.987E-15
Yb-173	6.089E-15	6.089E-15	6.089E-15	6.089E-15	6.089E-15	6.089E-15	6.089E-15
Lu-175	4.158E-08	4.158E-08	4.158E-08	4.158E-08	4.158E-08	4.158E-08	4.158E-08
Lu-176	1.457E-09	1.457E-09	1.457E-09	1.457E-09	1.457E-09	1.457E-09	1.457E-09
Lu-177m	7.629E-15	2.909E-16	1.109E-17	4.230E-19	1.201E-22	3.410E-26	0.00
Hf-174	1.409E-08	1.409E-08	1.409E-08	1.409E-08	1.409E-08	1.409E-08	1.409E-08
Hf-176	1.218E-06	1.218E-06	1.218E-06	1.218E-06	1.218E-06	1.218E-06	1.218E-06
Hf-177	1.350E-07	1.350E-07	1.350E-07	1.350E-07	1.350E-07	1.350E-07	1.350E-07
Hf-178	3.424E-06	3.424E-06	3.424E-06	3.424E-06	3.424E-06	3.424E-06	3.424E-06
Hf-179	1.808E-05	1.808E-05	1.808E-05	1.808E-05	1.808E-05	1.808E-05	1.808E-05
Hf-180	3.024E-05	3.024E-05	3.024E-05	3.024E-05	3.024E-05	3.024E-05	3.024E-05
Hf-182	1.096E-08	1.096E-08	1.096E-08	1.096E-08	1.096E-08	1.096E-08	1.096E-08
Ta-181	1.545E-06	1.545E-06	1.545E-06	1.545E-06	1.545E-06	1.545E-06	1.545E-06
Ta-182	4.433E-12	5.464E-14	1.048E-15	3.915E-16	3.834E-16	3.834E-16	3.833E-16
W-182	1.519E-07	1.519E-07	1.519E-07	1.519E-07	1.519E-07	1.519E-07	1.519E-07
W-183	4.052E-07	4.052E-07	4.052E-07	4.052E-07	4.052E-07	4.052E-07	4.052E-07
W-184	5.073E-08	5.073E-08	5.073E-08	5.073E-08	5.073E-08	5.073E-08	5.073E-08
W-186	3.491E-12	3.491E-12	3.491E-12	3.491E-12	3.491E-12	3.491E-12	3.491E-12

TABLE D.8.g. Cladding Activation Product Inventory by Isotope at 50 MWd/kgM, g/gZr (cont'd)

Isotope	4 Years	6 Years	8 Years	10 Years	15 Years	20 Years	1000 Years
Re-185	1.943E-10	1.943E-10	1.943E-10	1.943E-10	1.943E-10	1.943E-10	1.943E-10
Re-187	3.389E-13	3.389E-13	3.389E-13	3.389E-13	3.389E-13	3.389E-13	3.389E-13
Os-186	5.544E-11	5.544E-11	5.544E-11	5.544E-11	5.544E-11	5.544E-11	5.544E-11
Os-188	2.695E-14	2.695E-14	2.695E-14	2.695E-14	2.695E-14	2.695E-14	2.695E-14
Total	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00

APPENDIX E

DETAILS OF CERAMOGRAPHY/METALLOGRAPHY

APPENDIX E

DETAILS OF CERAMOGRAPHY/METALLOGRAPHY

This appendix includes the results of all ceramographic and metallographic examinations conducted to date on ATM-104 fuel. Photographs presented in the text are presented here for completeness. Table E.1 gives a summary of fuel sample locations. Refer to Figure 4.3 and Appendix C (Sectioning Diagrams) for further details.

The organization of the Figures in Appendix E is given below:

Figure E.1.a - E.1.e	Photomacrographs of Polished Transverse Samples
Figure E.1.f - E.1.h	Photomacrographs of Polished Longitudinal Samples
Figure E.2.a - E.2.h	Photomicrographs of Polished Transverse Samples
Figure E.2.i - E.2.k	Photomicrographs of Polished Longitudinal Samples
Figure E.3.a - E.3.e	Photomicrographs of Argon Ion-Etched Transverse Samples
Figure E.3.f - E.3.h	Photomicrographs of Argon Ion-Etched Longitudinal Samples
Figure E.4.a - E.4.j	Exterior/Interior Cladding Surfaces of Polished Samples
Figure E.5.a - E.5.e	Etched Cladding of Transverse Samples
Figure E.5.f - E.5.h	Etched Cladding of Longitudinal Samples
Figure E.6.a - E.6.j	Alpha and Beta/Gamma Autoradiographs of Transverse Samples
Figure E.6.k - E.6.p	Alpha and Beta/Gamma Autoradiographs of Longitudinal Samples.

TABLE E.1. Summary of Ceramographic/Metallographic Sections

Sample ID	Distance from Top[a] cm (inches)	Type
104-MKP109-C	43.39-44.58 (17.08-17.55)	Transverse Fuel Sample
104-MKP109-H	121.92-123.19 (48.00-48.50)	Transverse Fuel Sample
104-MKP109-N	205.35-207.26 (80.85-81.60)	Longitudinal Fuel Sample
104-MKP109-O	207.32-208.59 (81.62-82.12)	Transverse Fuel Sample
104-MKP109-AA	341.99-343.92 (134.64-135.40)	Lontitudinal Fuel Sample
104-MKP109-BB	343.98-345.27 (135.43-135.93)	Transverse Fuel Sample
104-MIP109-JJ	356.70-358.62 (140.43-141.19)	Longitudinal Fuel Sample
104-MKP109-KK	358.68-359.97 (141.21-141.72)	Transverse Fuel Sample

(a) Rod distance referenced from top end of rod.

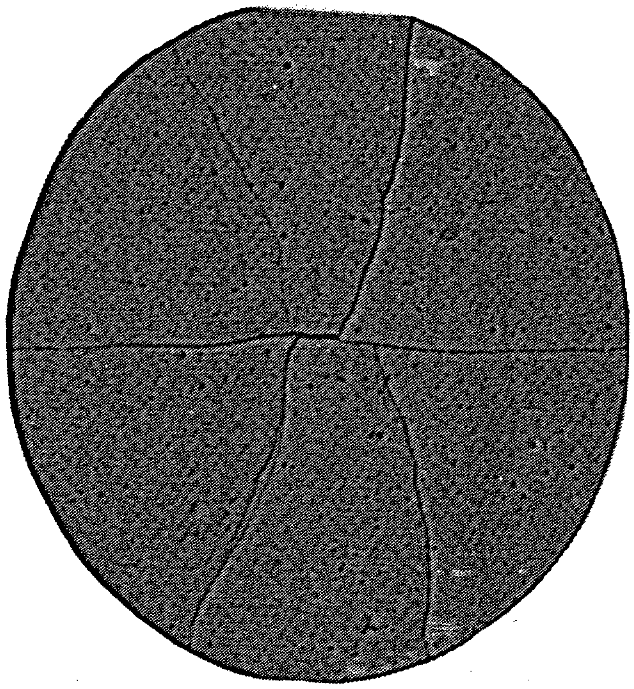


FIGURE E.1.a. Photomacrograph of Polished Transverse Sample 104-MKP109-C (~9x)(Neg. No. 8704494-14)

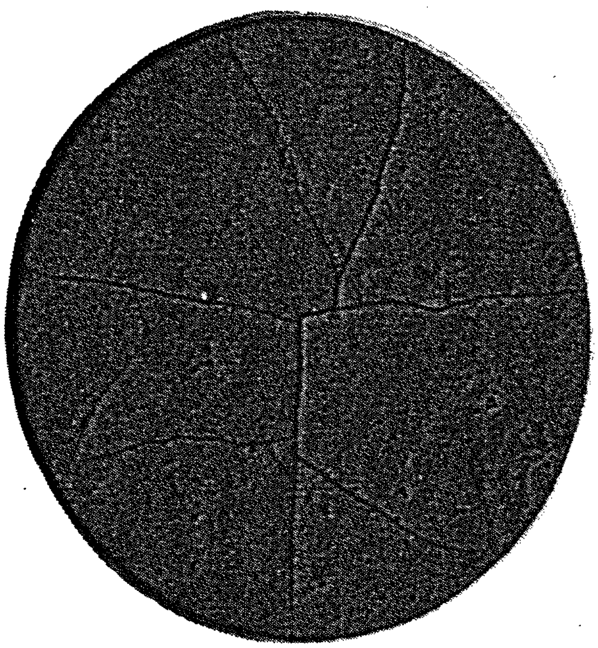


FIGURE E.1.b. Photomacrograph of Polished Transverse Sample 106-MKP109-H (~8x) (Neg. No. 8704675-5)

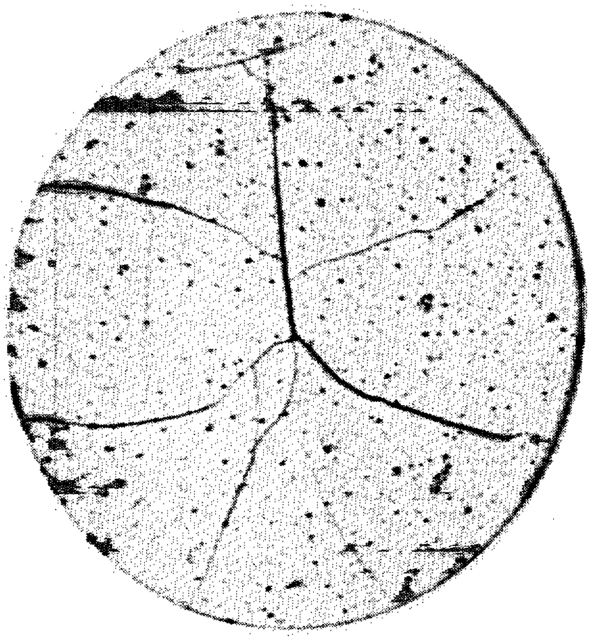


FIGURE E.1.c. Photomacrograph of Polished Transverse Sample 104-MKP109-0 (~8x) (Neg. No. 8704675-13)

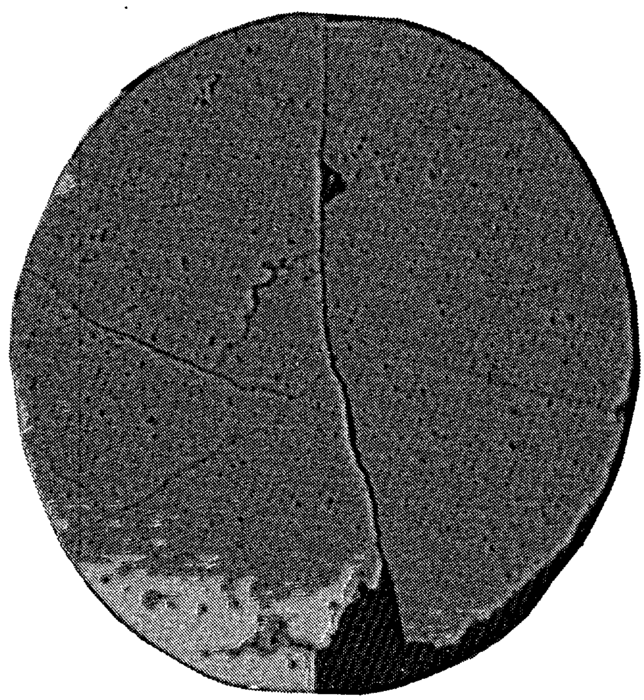


FIGURE E.1.d. Photomacrograph of Polished Transverse Sample 104-MKP109-BB (~9x) (Neg. No. 8704494-22)

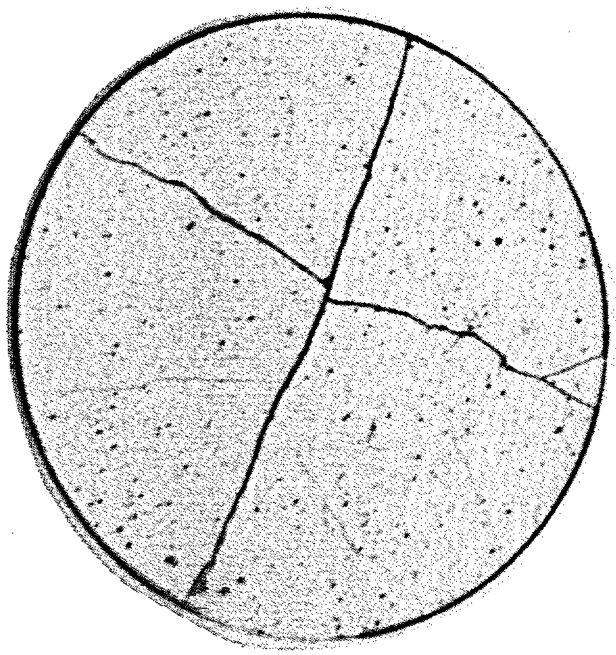


FIGURE E.1.e. Photomacrograph of Polished Transverse Sample 104-MKP109-KK (~8x) (Neg. No. 8704675-22)

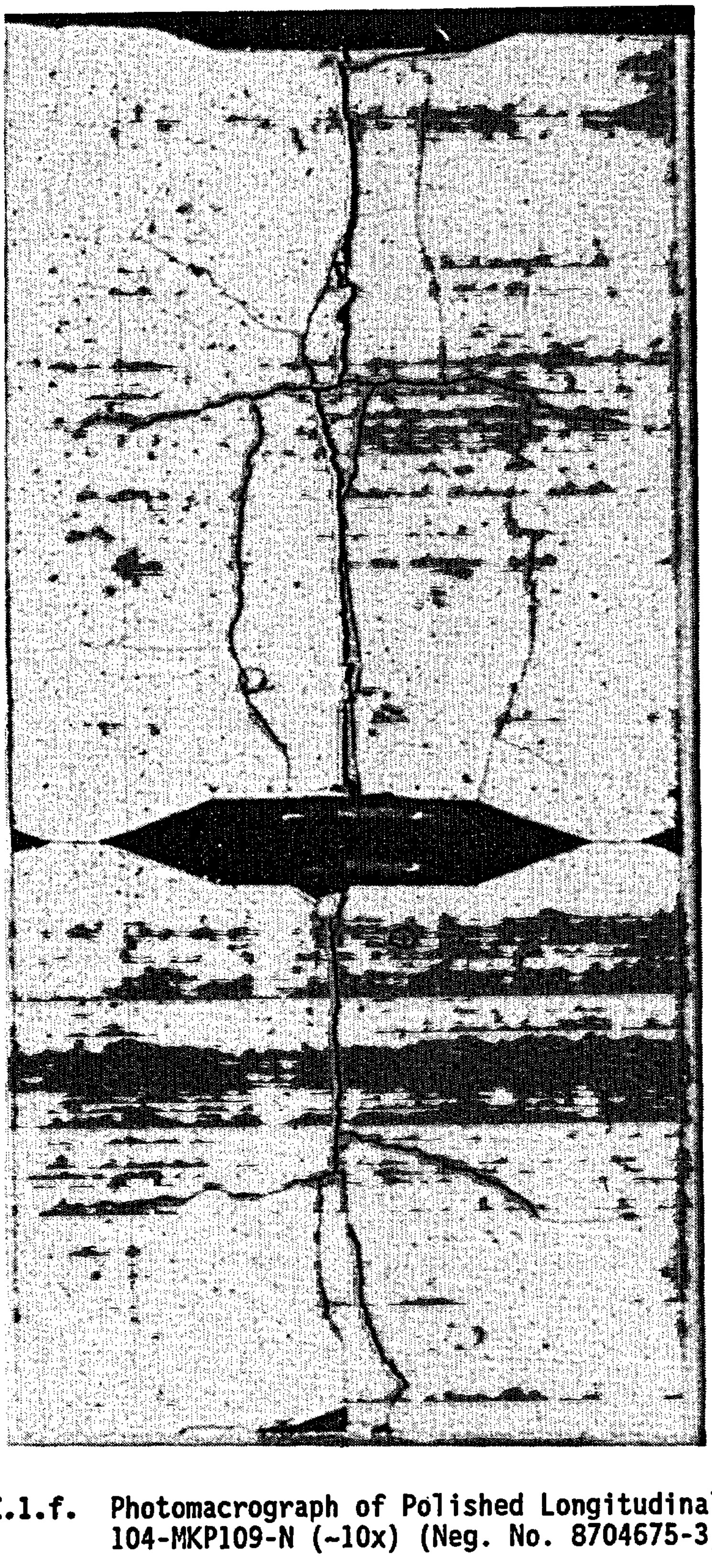


FIGURE E.1.f. Photomacrograph of Polished Longitudinal Sample 104-MKP109-N (~10x) (Neg. No. 8704675-3)

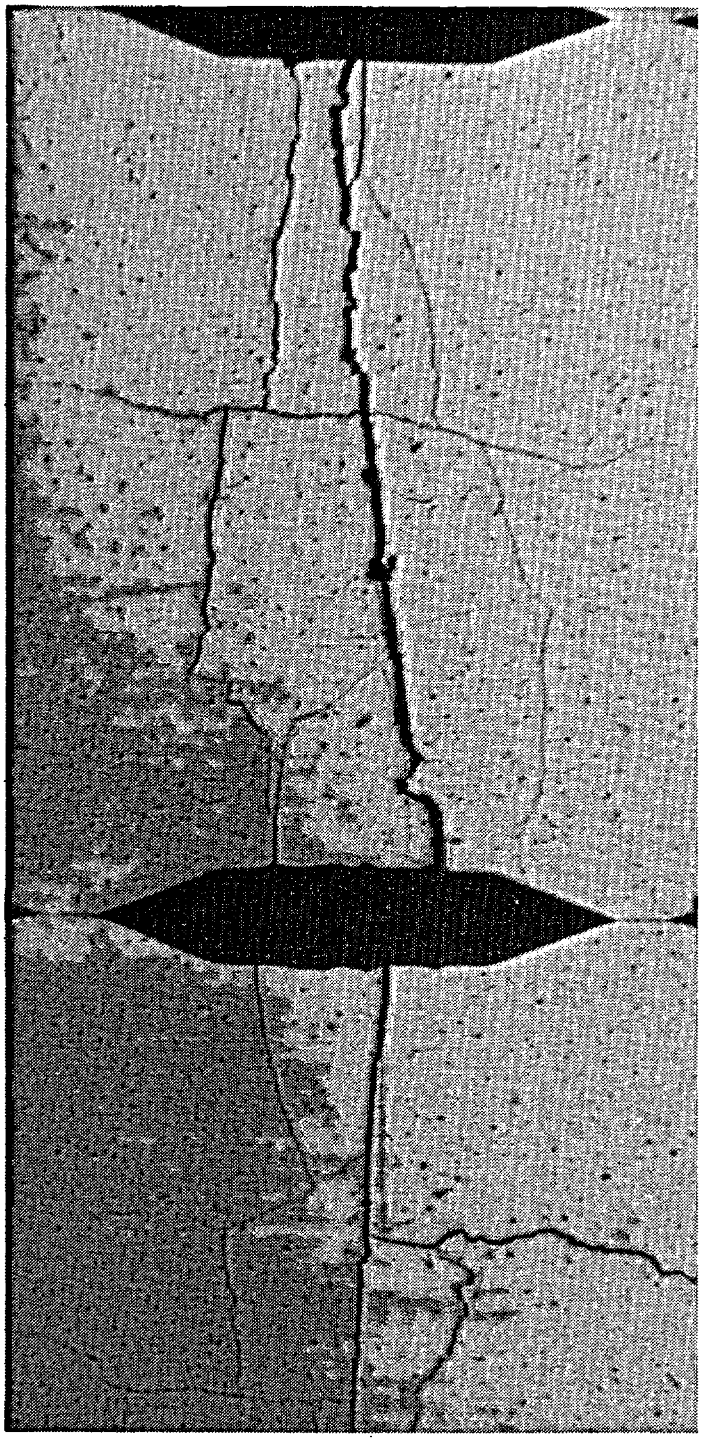


FIGURE E.1.g. Photomacrograph of Argon Ion-Etched Longitudinal Sample 104-MKP109-AA (~10x) (Neg. No. 8704494-6)

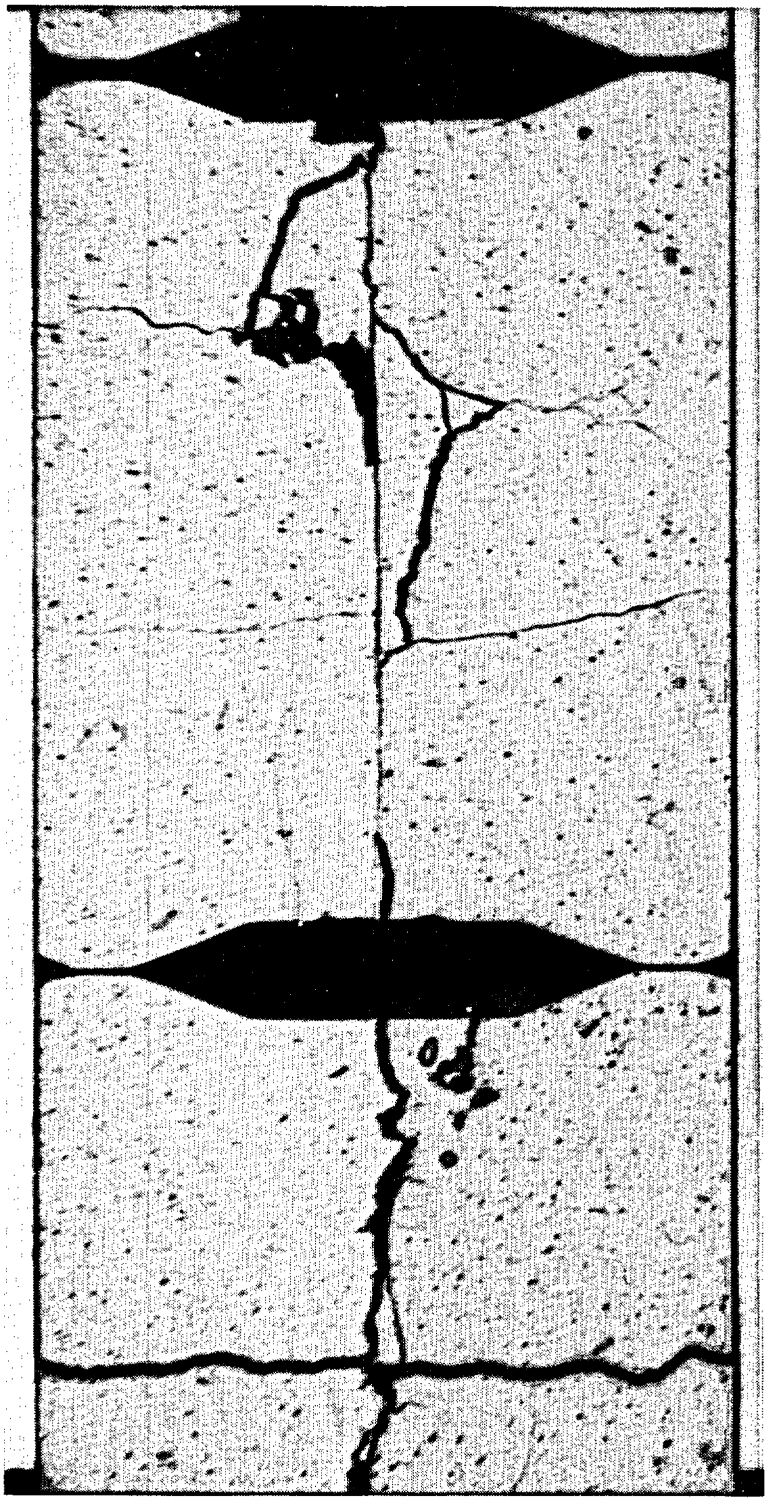
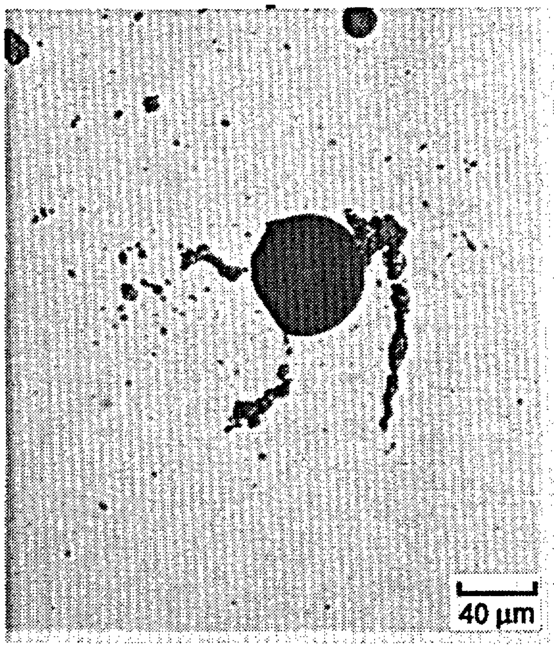
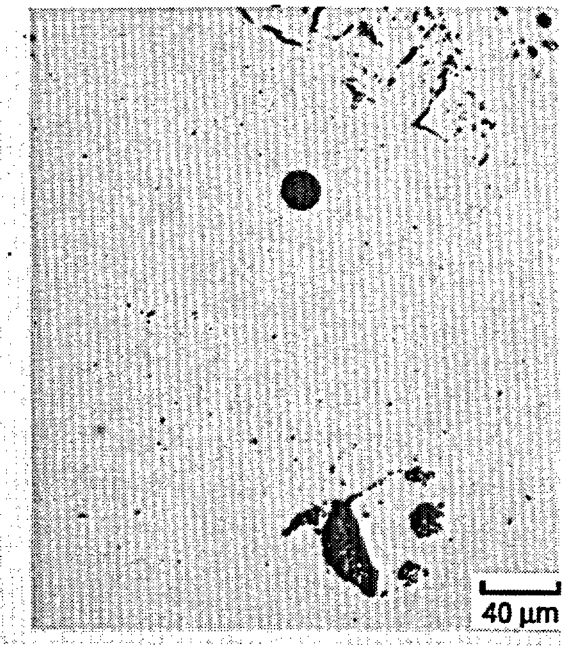


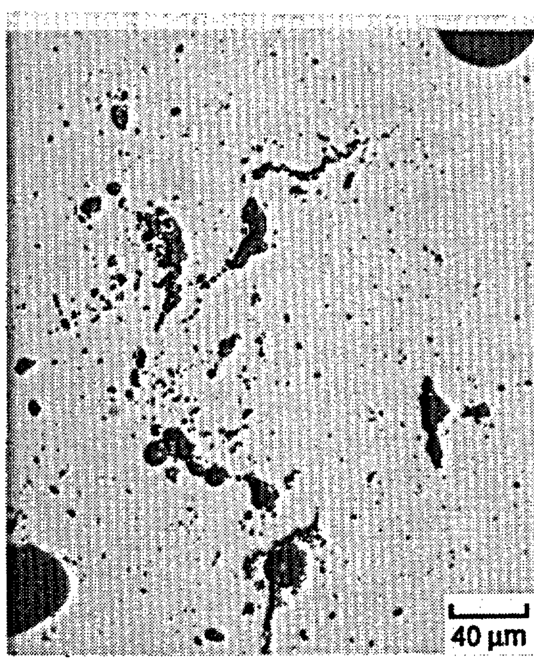
FIGURE E.1.h. Photomacrograph of Polished Longitudinal Sample 104-MKP109-JJ (~10x) (Neg. No. 8704675-18)



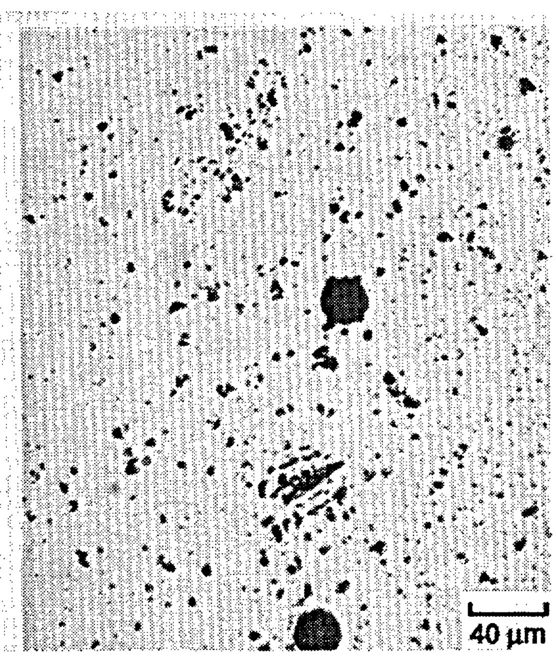
a) Center (Neg. No. P-3030)



b) 1/3 Radius (Neg. No. P-3029)



c) 2/3 Radius (Neg. No. P-3028)



d) Edge (Neg. No. P-3026)

FIGURE E.2.a. Photomicrographs of Polished Transverse Sample 104-MKP109-C

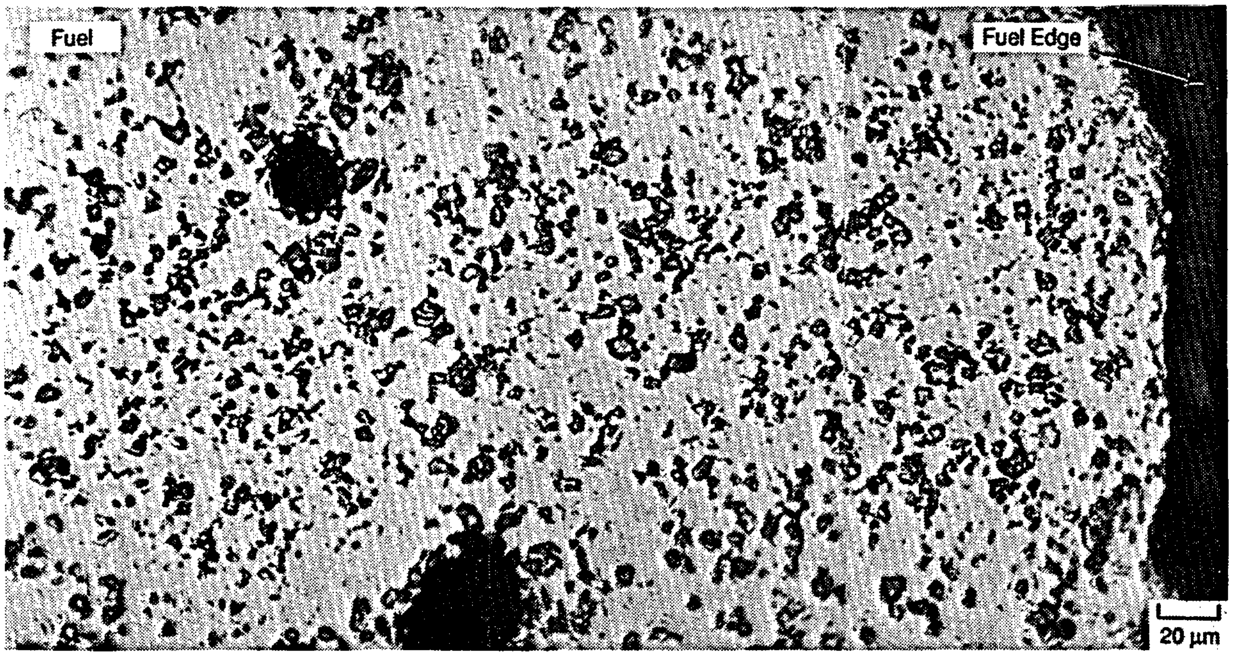
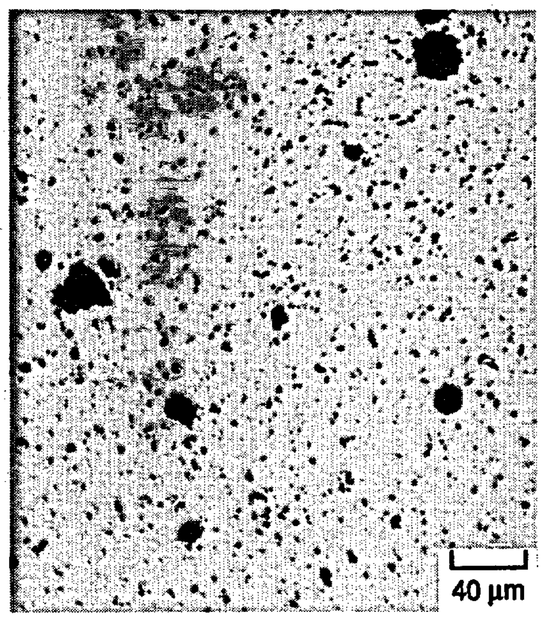
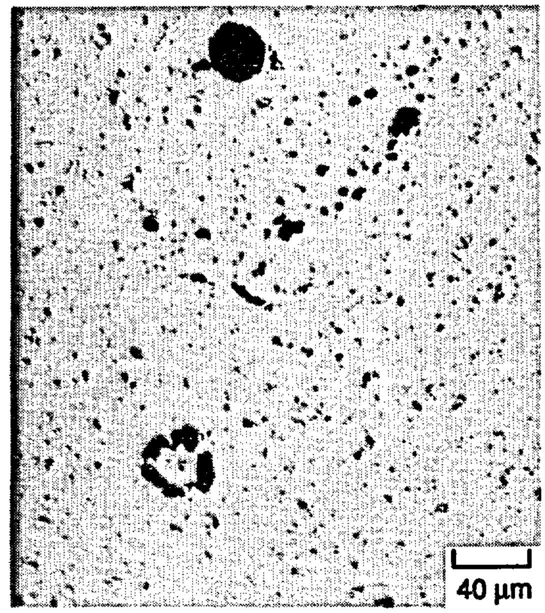


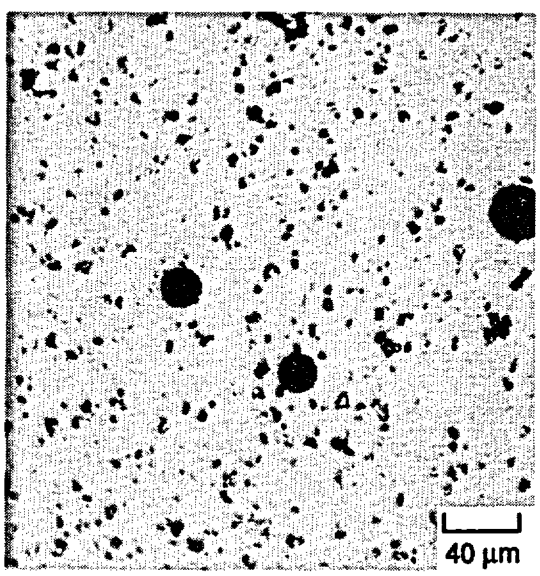
FIGURE E.2.b. Mosaic of Polished Transverse Sample 104-MKP109-C Near Fuel Edge (Neg Nos. 6545, 6546, 6547)



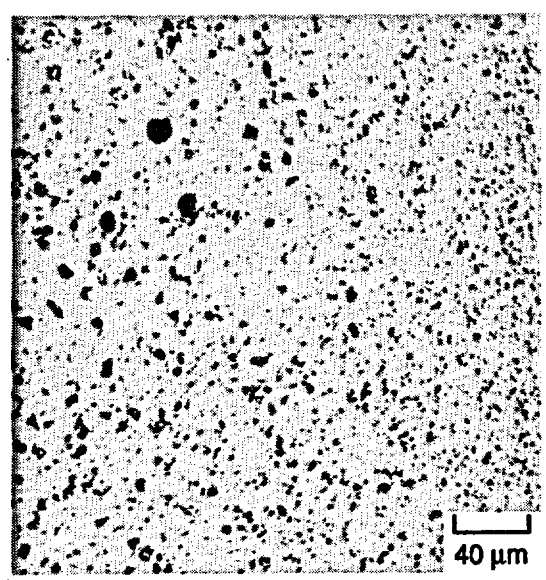
a) Centerline (Neg. No. P-2778)



b) 1/3 Radius (Neg. No. P-2777)



c) 2/3 Radius (Neg. No. P-2776)



d) Edge (Neg. No. P-2775)

FIGURE E.2.c. Photomicrographs of Polished Transverse Sample 104-MKP109-H

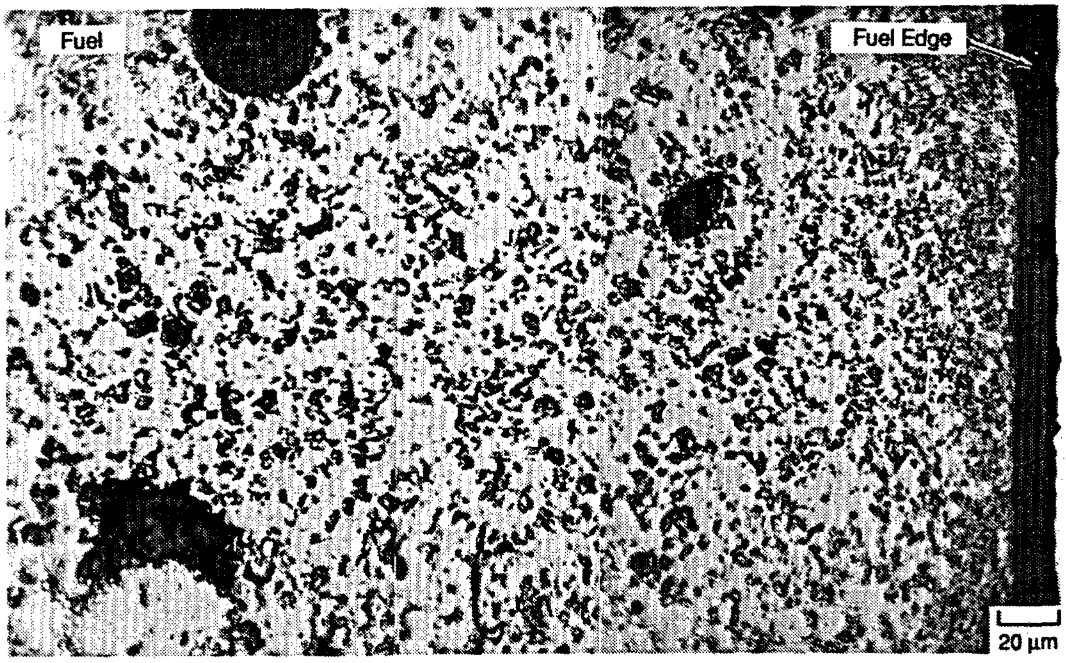
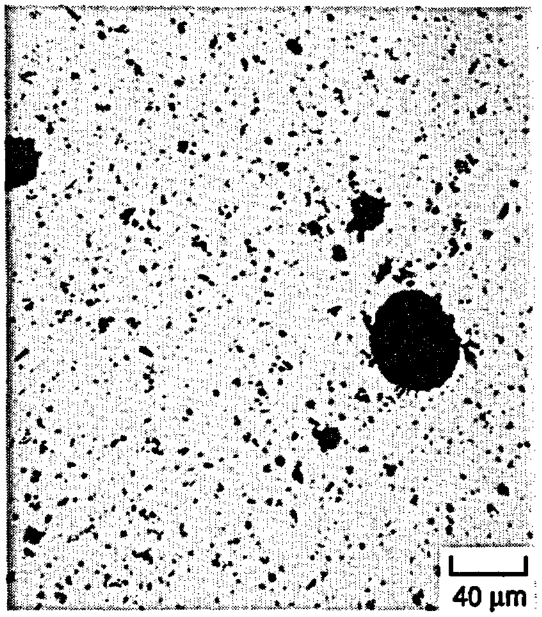
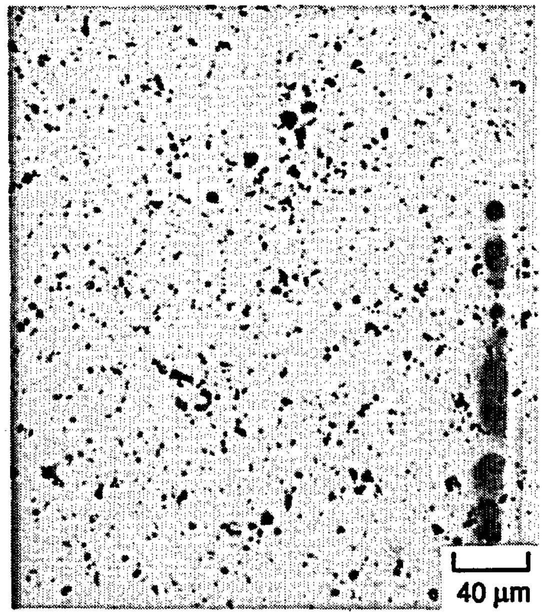


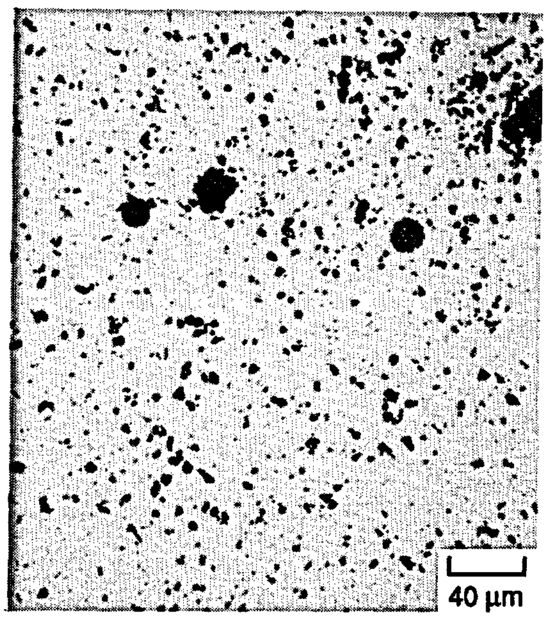
FIGURE E.2.d. Mosaic of Polished Transverse Sample 104-MKP109-H Near Fuel Edge (Neg Nos. 6534, 6535, 6536)



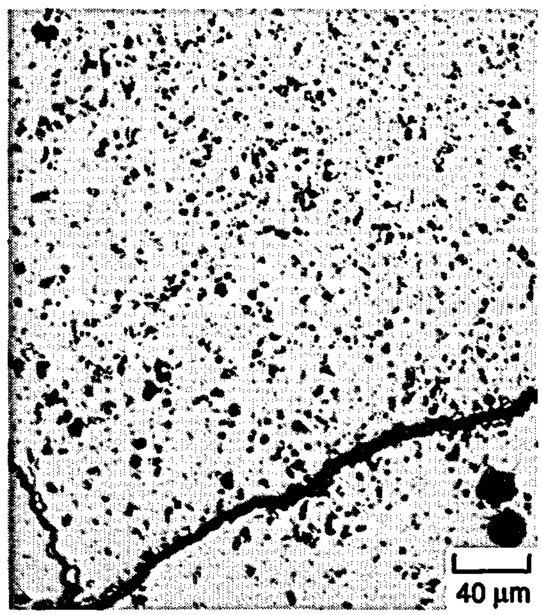
a) Centerline (Neg. No. P-2681)



b) 1/3 Radius (Neg. No. P-2680)



c) 2/3 Radius (Neg. No. P-2679)



d) Edge (Neg. No. P-2678)

FIGURE E.2.e. Photomicrographs of Polished Transverse Sample 104-MKP109-0

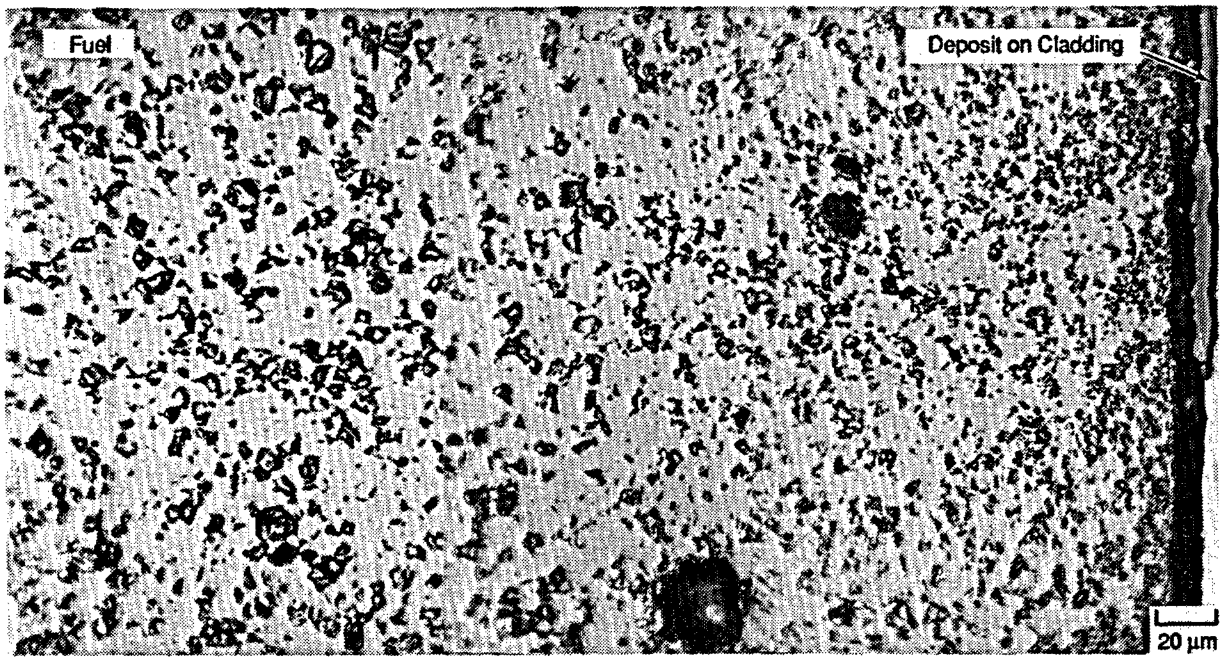
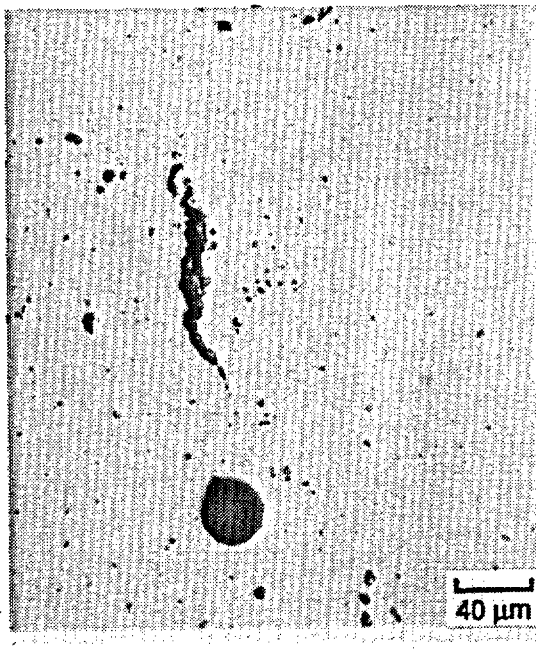
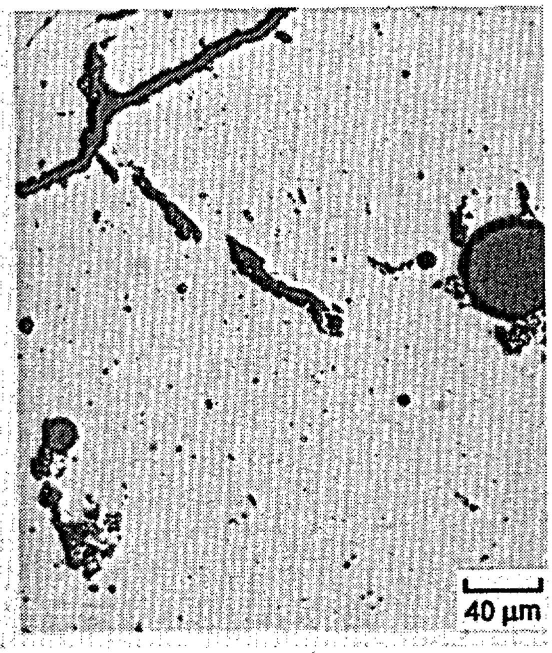


FIGURE E.2.f. Mosaic of Polished Transverse Sample 104-MKP109-0 Near Fuel Edge (Neg. Nos. 6523, 6524, 6525)

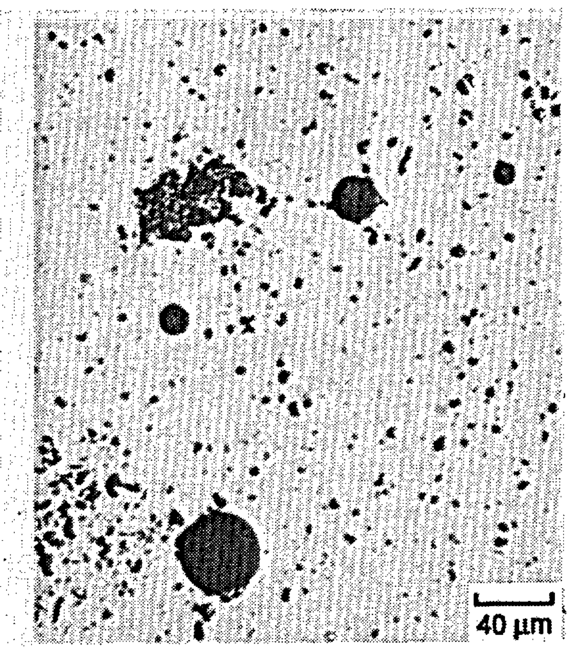


a) Center (Neg. No. P-3062)



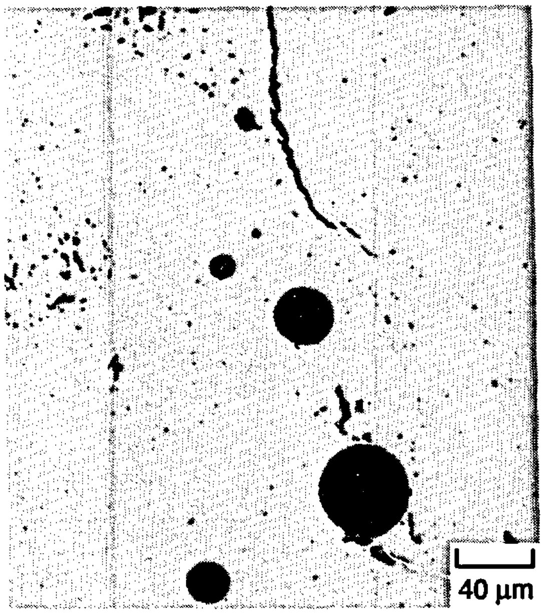
b) 1/3 Radius (Neg. No. P-3061)

c) 2/3 Radius (Neg. No. P-3060)



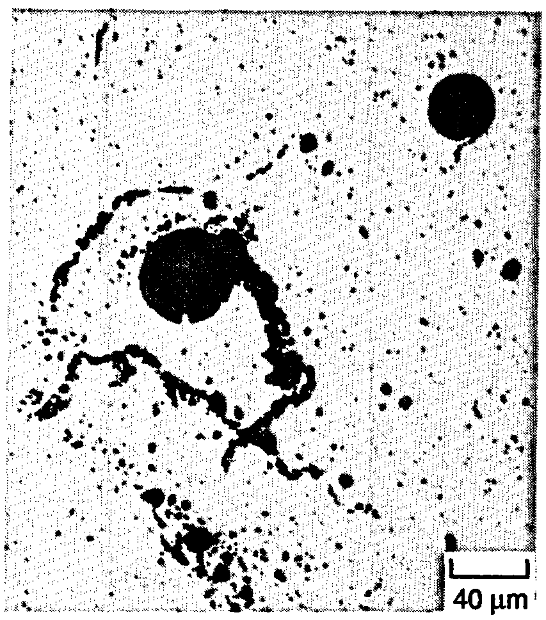
d) Edge (Neg. No. P-3059)

FIGURE E.2.g. Photomicrographs of Polished Transverse Sample 104-MKP109-BB

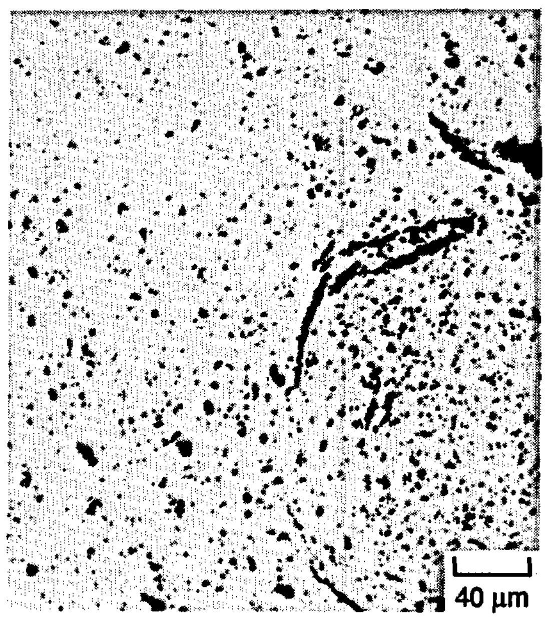


a) Centerline (Neg. No. P-2773)

b) 1/3 Radius (Neg. No. P-2772)

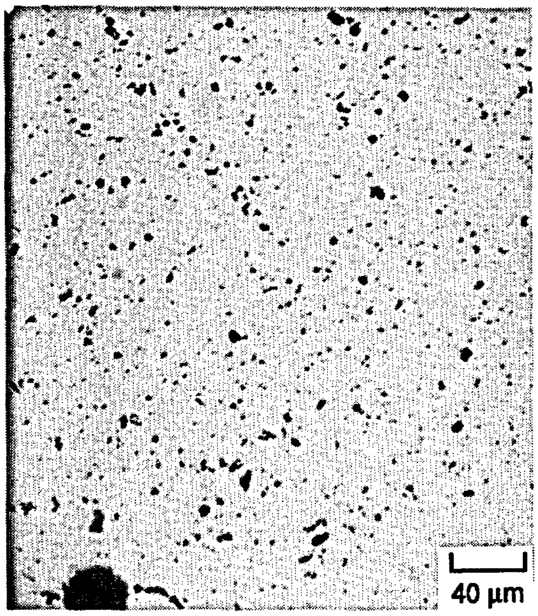


c) 2/3 Radius (Neg. No. P-2771)

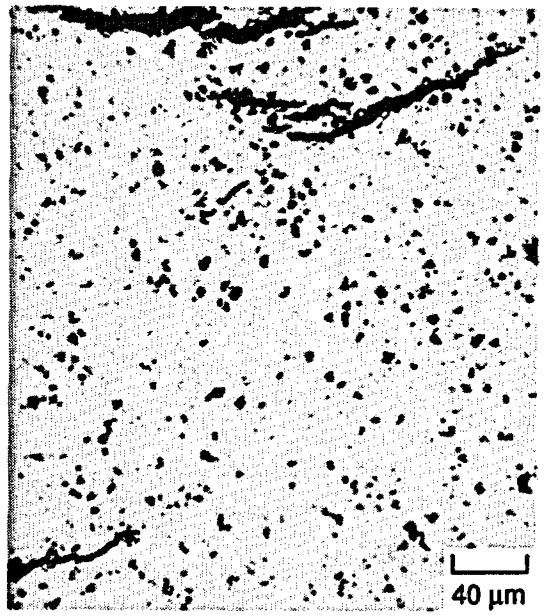


d) Edge (Neg. No. P-2770)

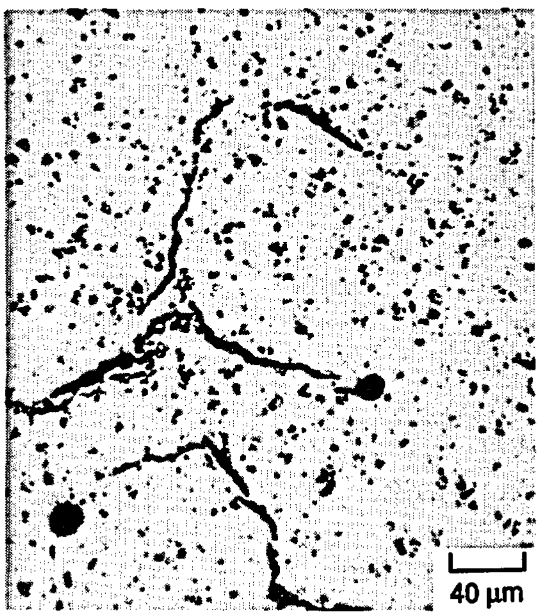
FIGURE E.2.h. Photomicrographs of Polished Transverse Sample 104-MKP109-KK



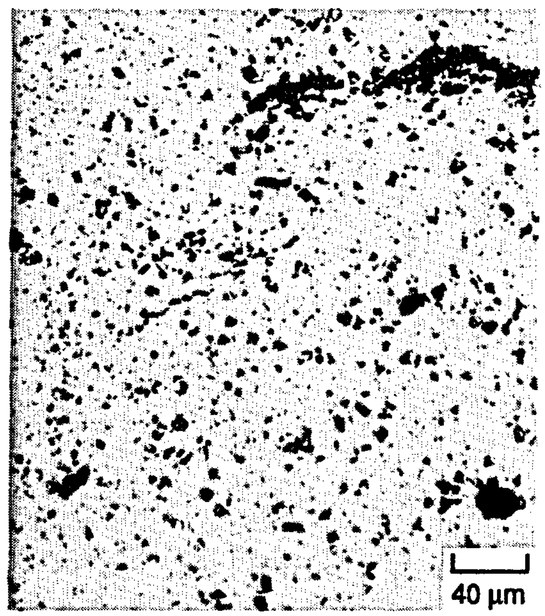
a) Centerline (Neg. No. P-2686)



b) 1/3 Radius (Neg. No. P-2685)

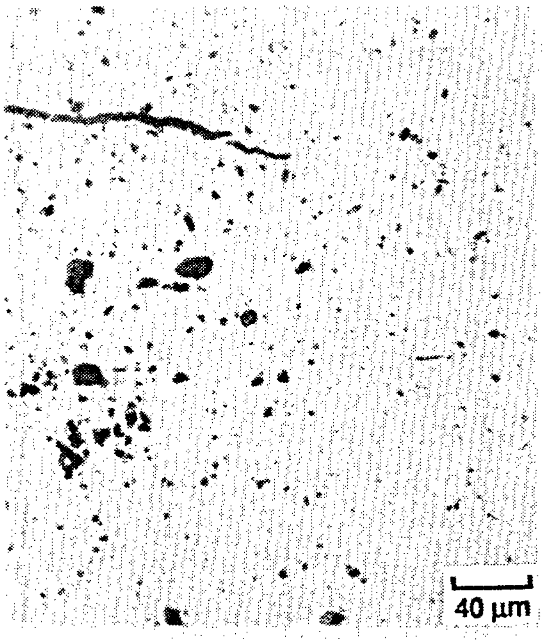


c) 2/3 Radius (Neg. No. P-2684)

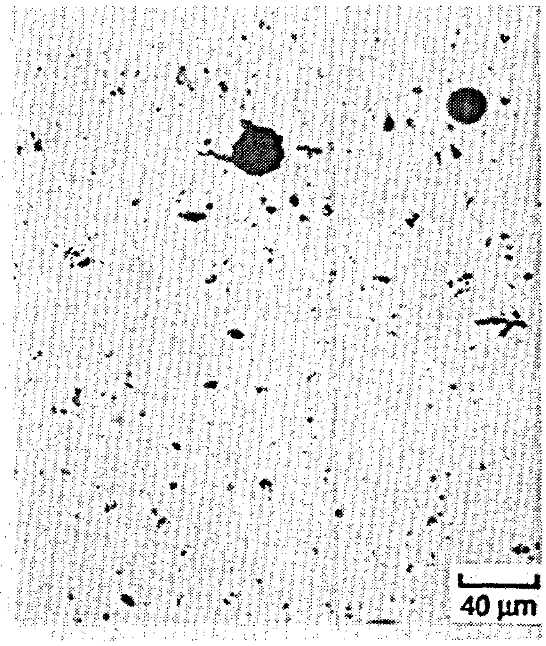


d) Edge (Neg. No. P-2683)

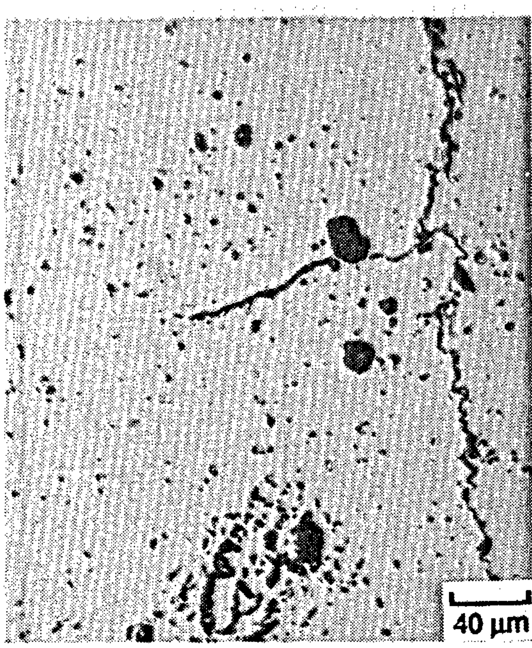
FIGURE E.2.i. Photomicrographs of Polished Longitudinal Sample 104-MKP109-N



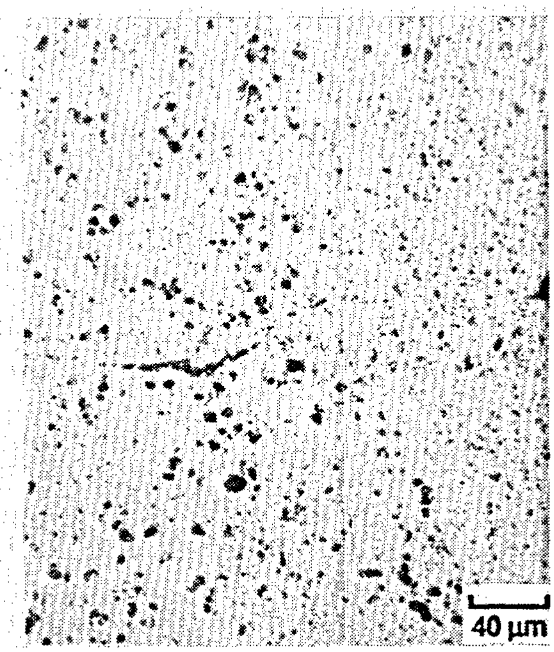
a) Center (Neg. No. P-2992)



b) 1/3 Radius (Neg. No. P-2991)

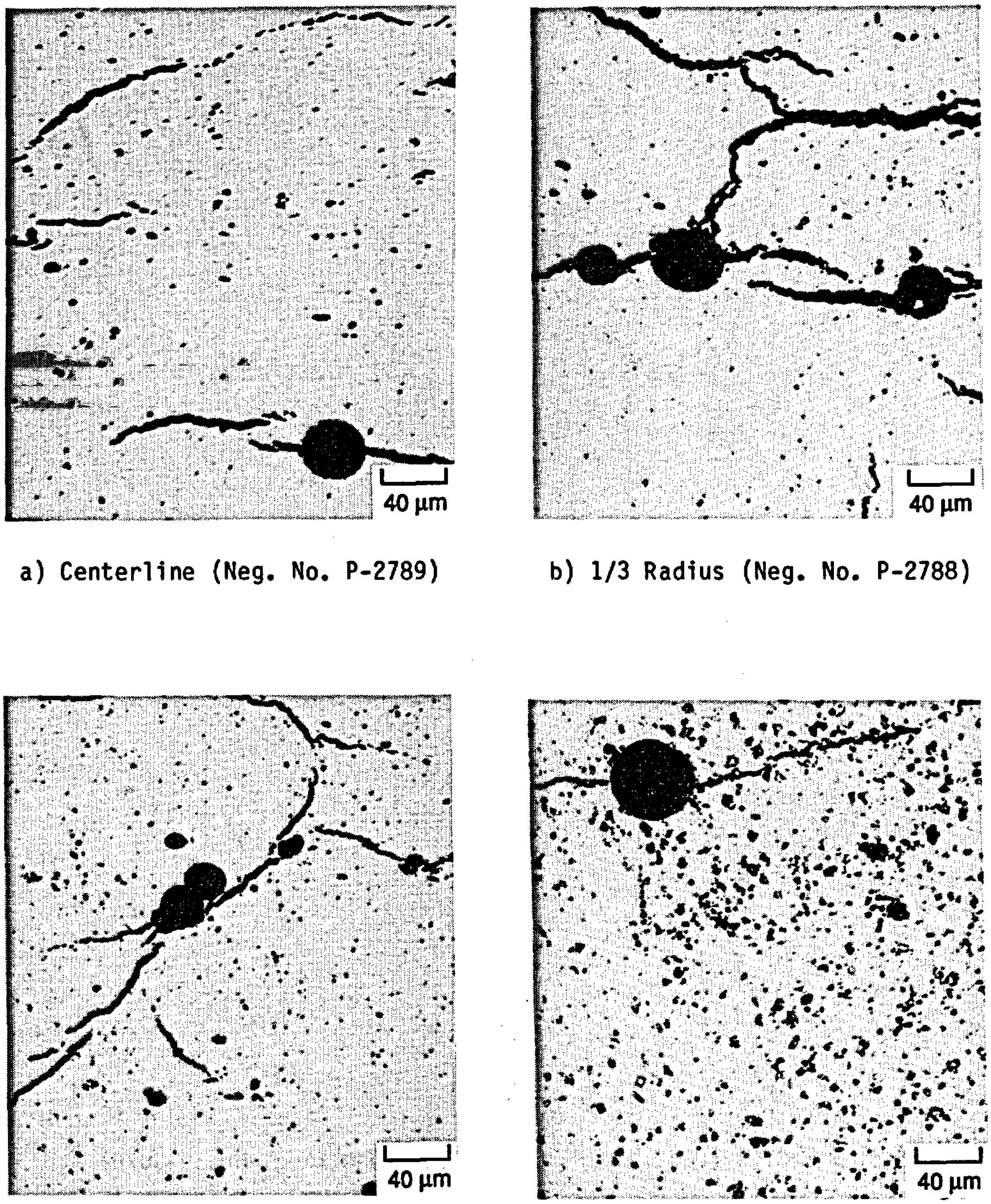


c) 2/3 Radius (Neg. No. P-2990)



d) Edge (Neg. No. P-2989)

FIGURE E.2.j. Photomicrographs of Polished Longitudinal Sample 104-MKP109-AA



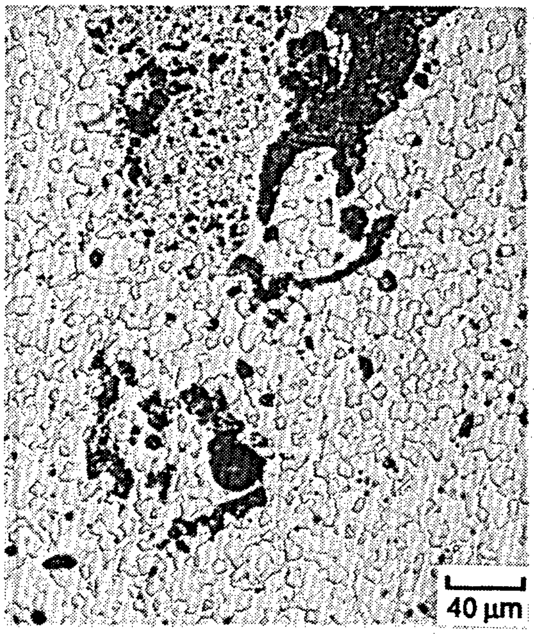
a) Centerline (Neg. No. P-2789)

b) 1/3 Radius (Neg. No. P-2788)

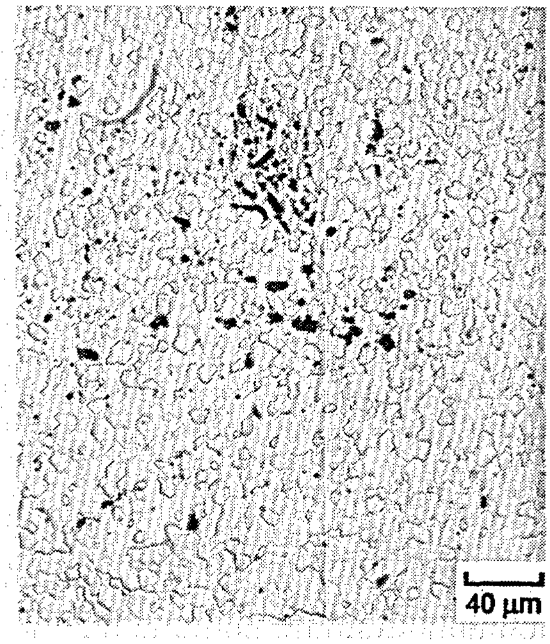
c) 2/3 Radius (Neg. No. P-2787)

d) Edge (Neg. No. P-2786)

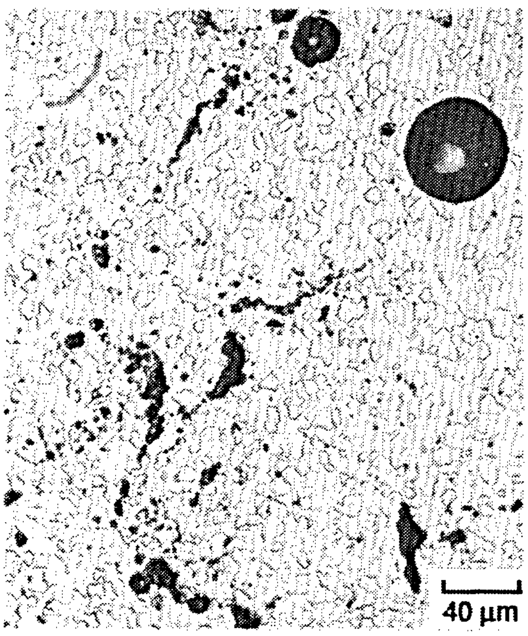
FIGURE E.2.k. Photomicrographs of Polished Longitudinal Sample 104-MKP109-JJ



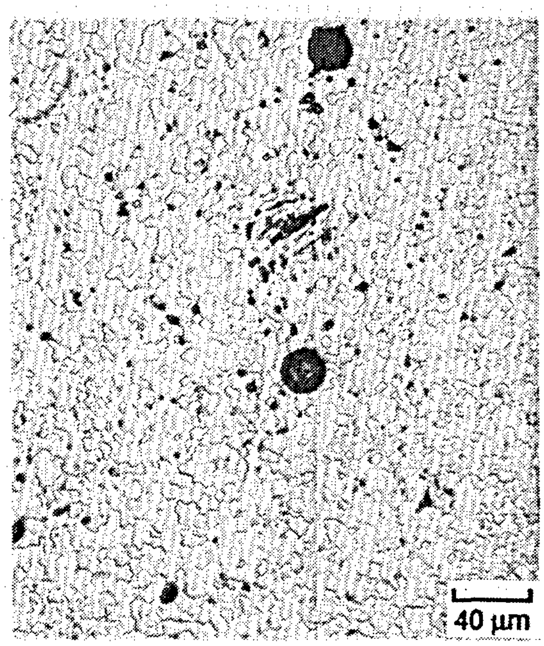
a) Center (Neg. No. P-3079)



b) 1/3 Radius (Neg. No. P-3078)

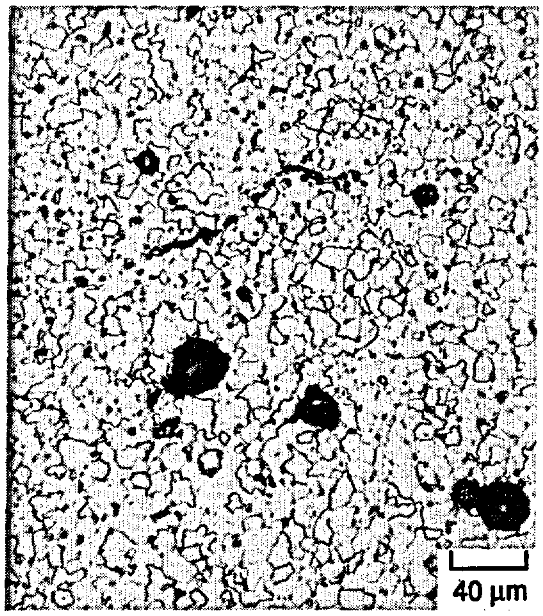


c) 2/3 Radius (Neg. No. P-3077)

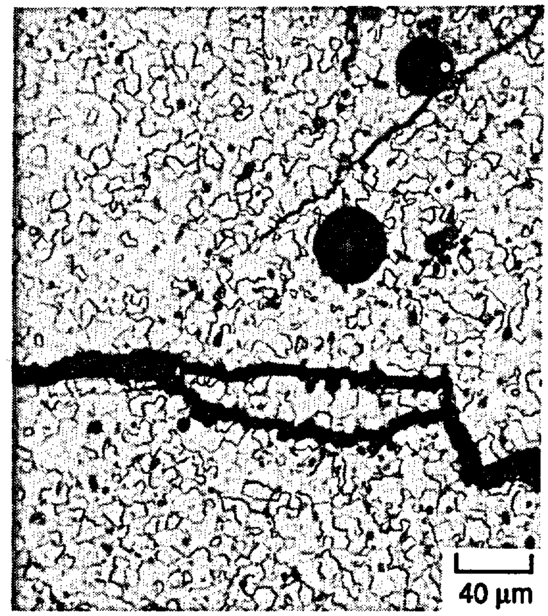


d) Edge (Neg. No. P-3076)

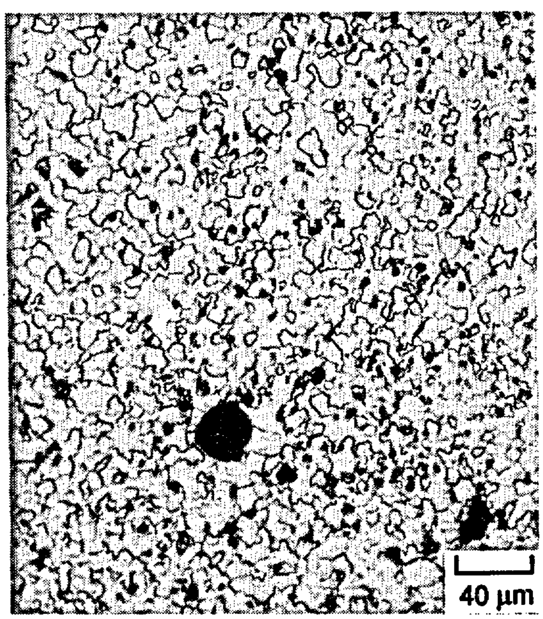
FIGURE E.3.a. Photomicrographs of Argon Ion-etched Transverse Sample 104-MKP109-C



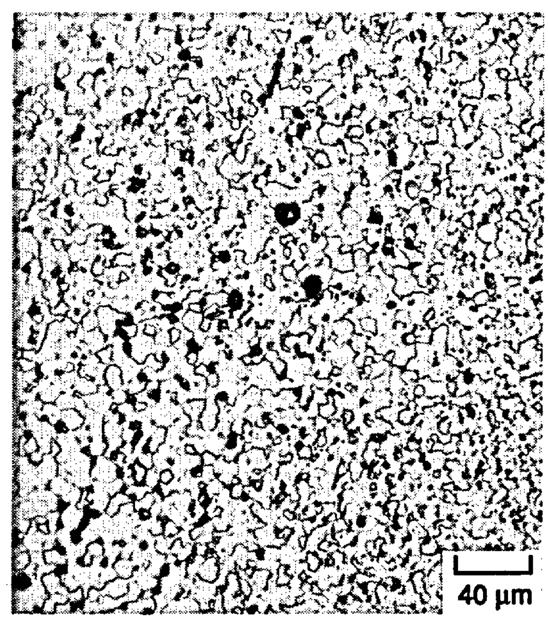
a) Centerline (Neg. No. P-2908)



b) 1/3 Radius (Neg. No. P-2907)

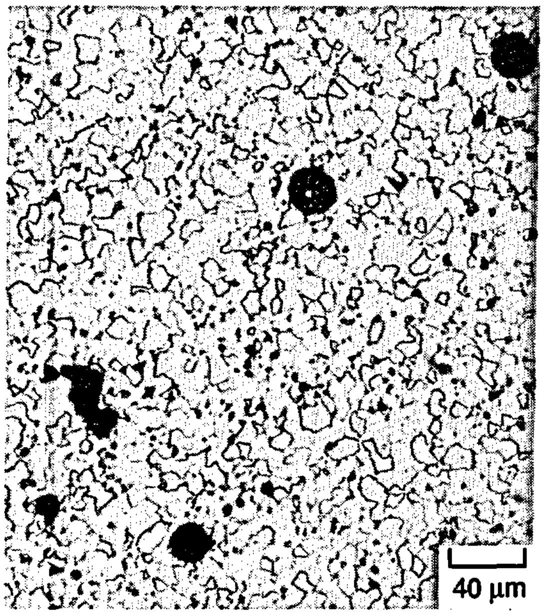


c) 2/3 Radius (Neg. No. P-2906)

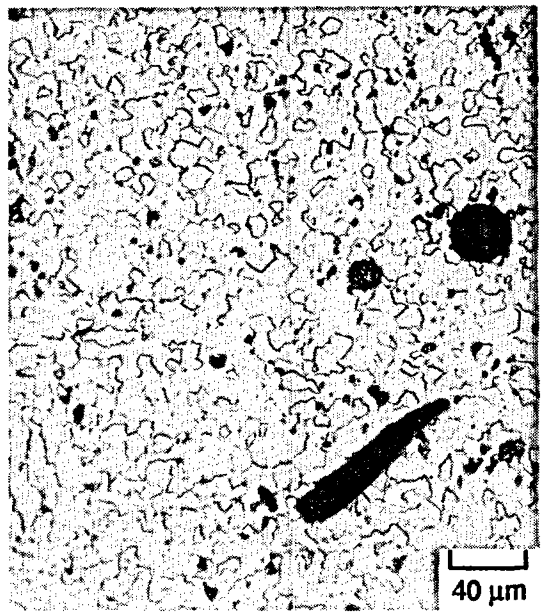


d) Edge (Neg. No. P-2905)

FIGURE E.3.b. Photomicrographs of Argon Ion-etched Transverse Sample 104-MKP109-H

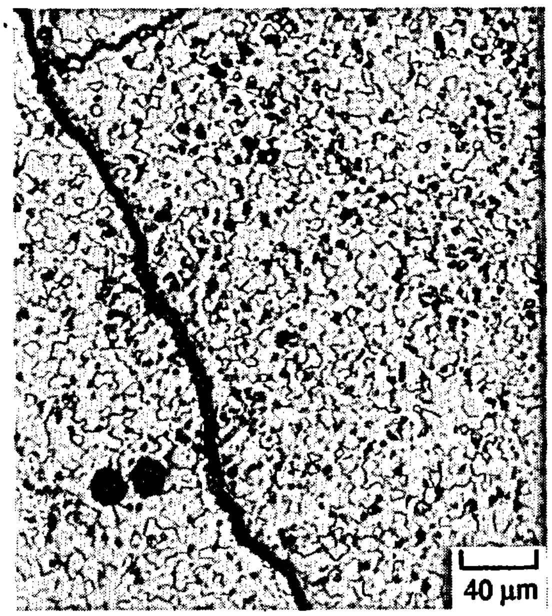


a) Centerline (Neg. No. P-2928)



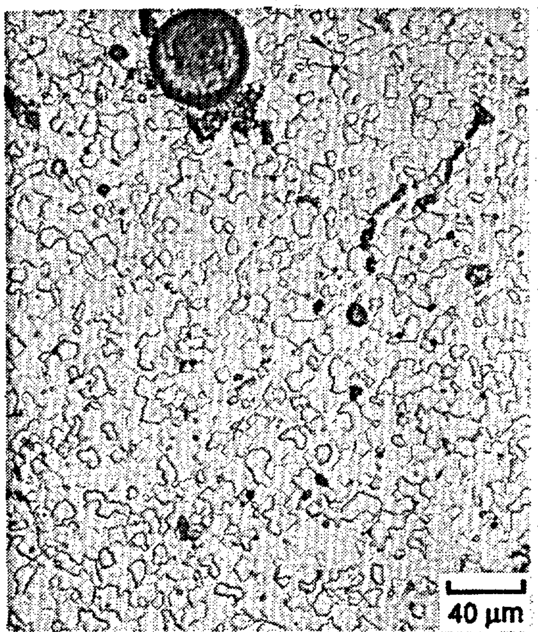
b) 1/3 Radius (Neg. No. P-2927)

c) 2/3 Radius (Neg. No. P-2926)

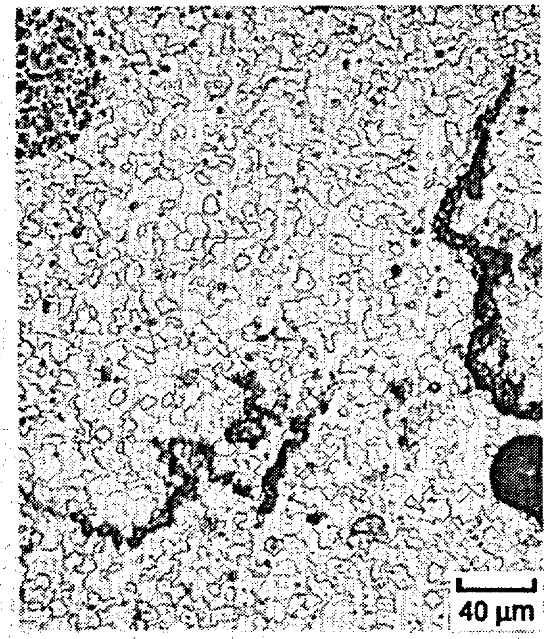


d) Edge (Neg. No. P-2925)

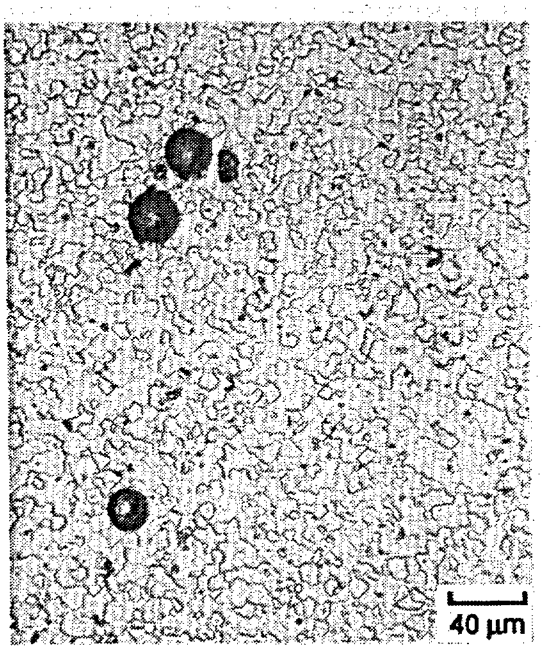
FIGURE E.3.c. Photomicrographs of Argon Ion-etched Transverse Sample 104-MKP109-O



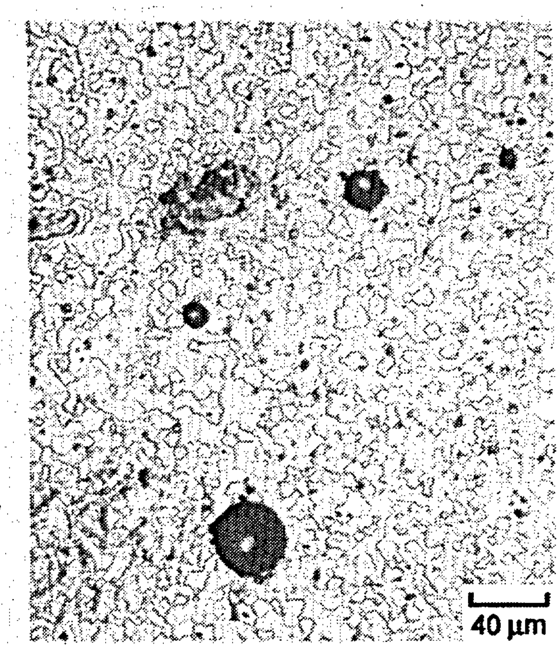
a) Center (Neg. No. P-3168)



b) 1/3 Radius (Neg. No. P-3167)



c) 2/3 Radius (Neg. No. P-3166)

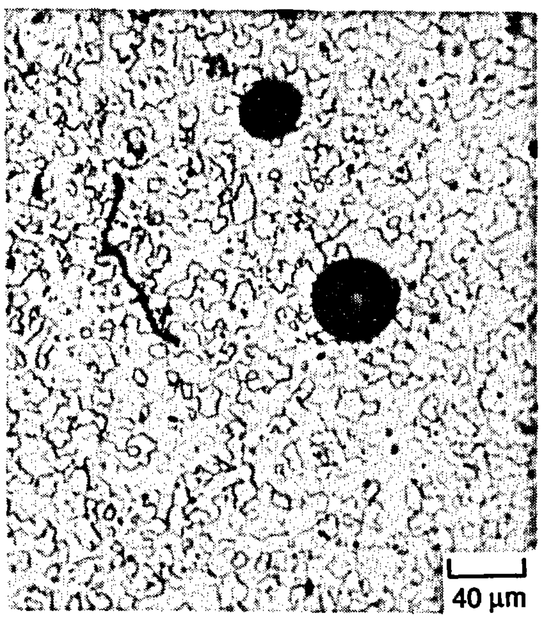


d) Edge (Neg. No. P-3165)

FIGURE E.3.d. Photomicrographs of Argon Ion-etched Transverse Sample 104-MKP109-BB

a) Centerline (Neg. No. P-2920)

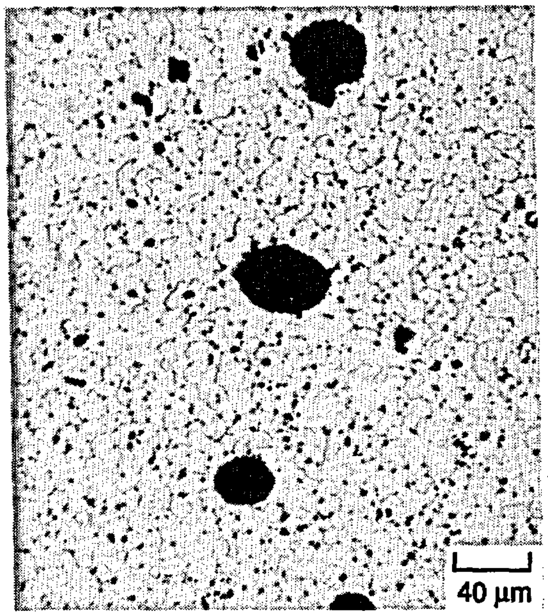
b) 1/3 Radius (Neg. No. P-2919)



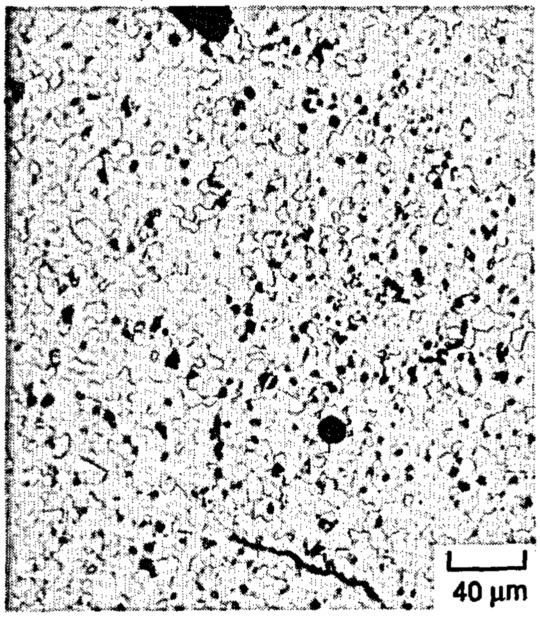
c) 2/3 Radius (Neg. No. P-2918)

d) Edge (Neg. No. P-2917)

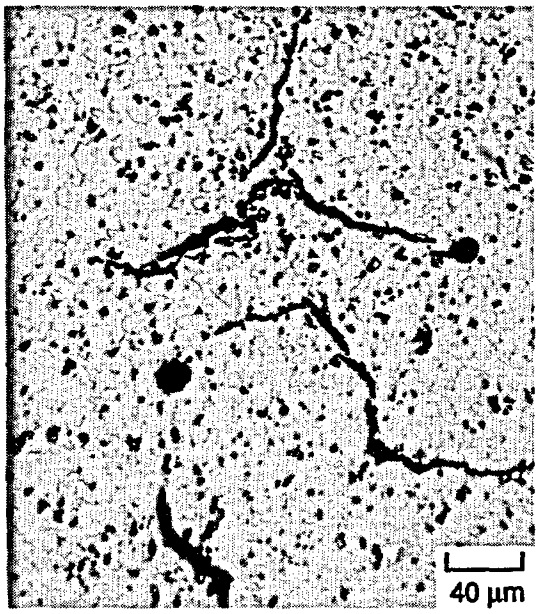
FIGURE E.3.e. Photomicrographs of Argon Ion-etched Transverse Sample 104-MKP109-KK



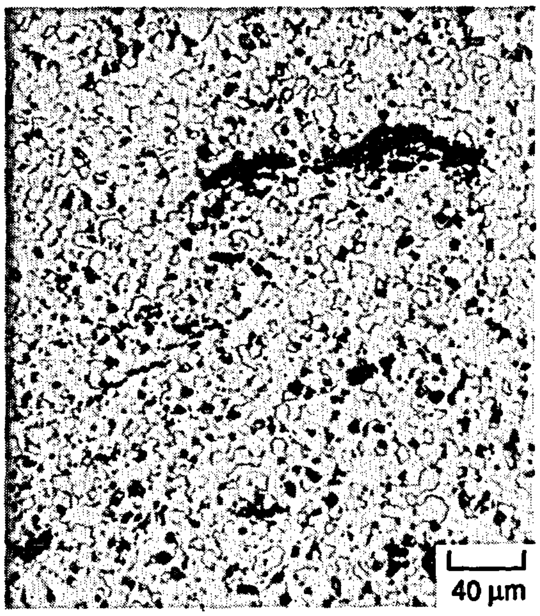
a) Centerline (Neg. No. P-2912)



b) 1/3 Radius (Neg. No. P-2911)



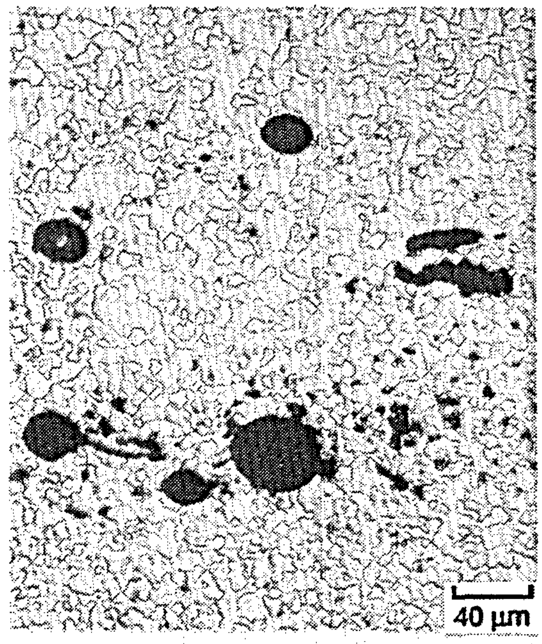
c) 2/3 Radius (Neg. No. P-2910)



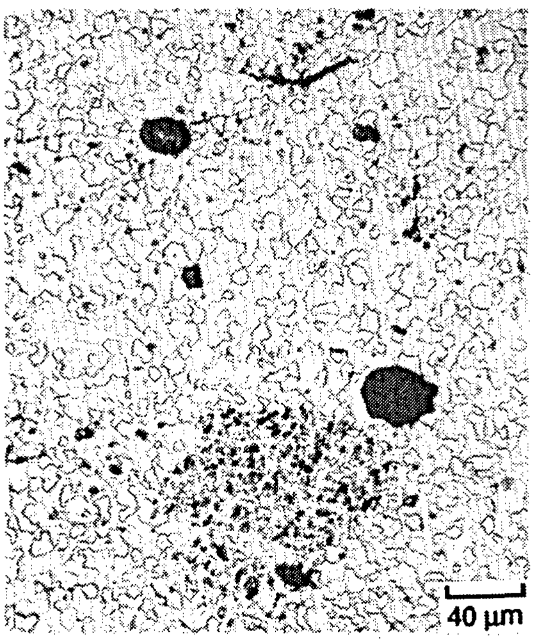
d) Edge (Neg. No. P-2909)

FIGURE E.3.f. Photomicrographs of Argon Ion-Etched Longitudinal Sample 104-MKP109-N

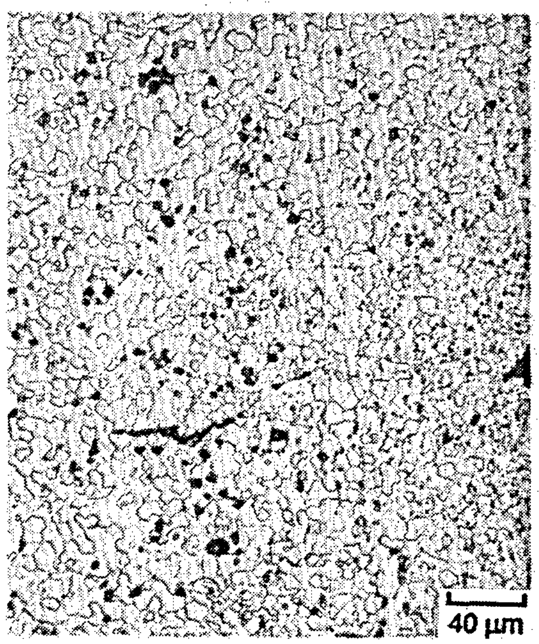
a) Center (Neg. No. P-3184)



b) 1/3 Radius (Neg. No. P-3183)

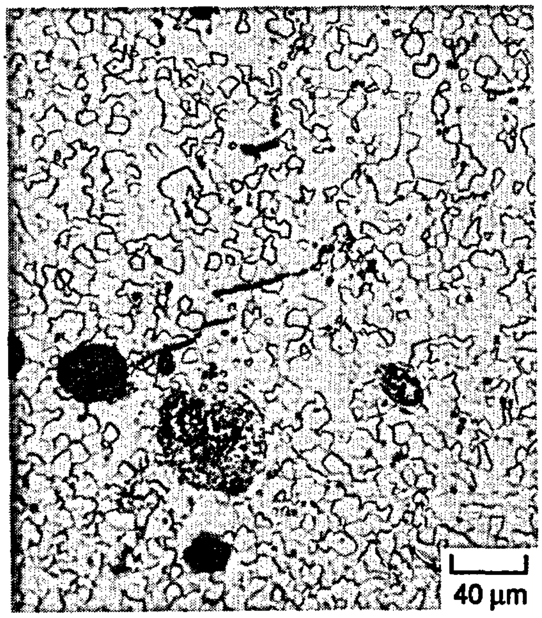


c) 2/3 Radius (Neg. No. P-3182)

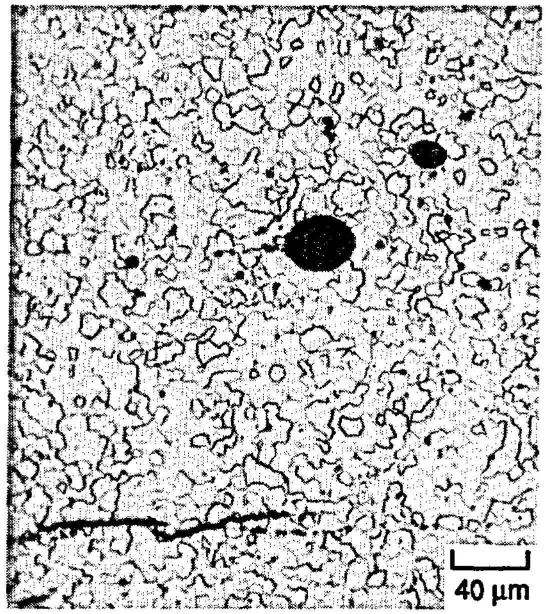


d) Edge (Neg. No. P-3181)

FIGURE E.3.g. Photomicrographs of Argon Ion-etched Longitudinal Sample 104-MKP109-AA

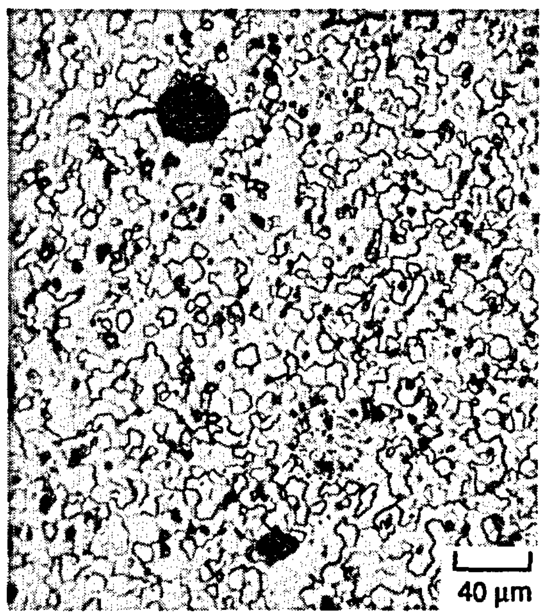


a) Centerline (Neg. No. P-2916)



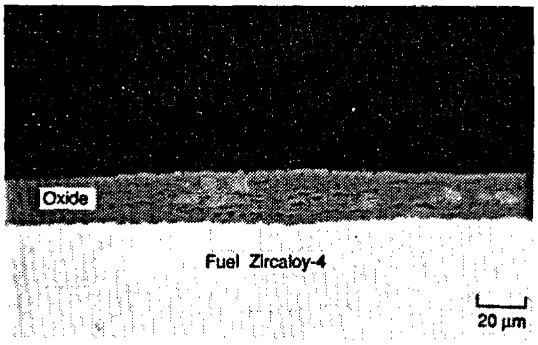
b) 1/3 Radius (Neg. No. P-2915)

c) 2/3 Radius (Neg. No. P-2914)

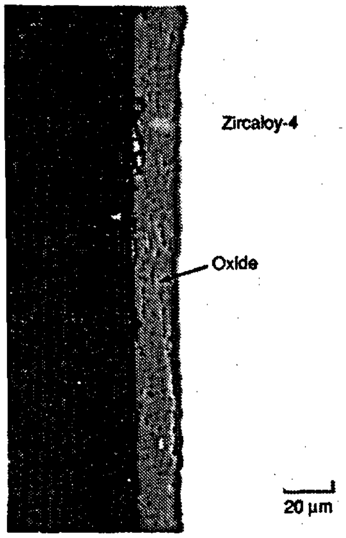


d) Edge (Neg. No. P-2913)

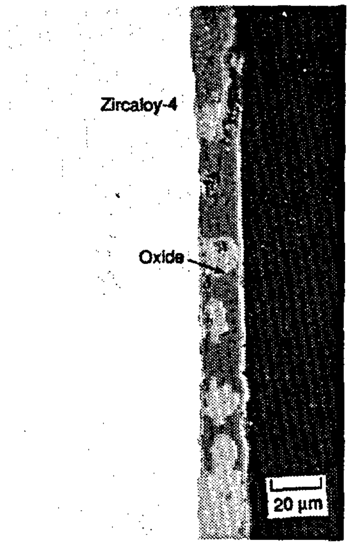
FIGURE E.3.h. Photomicrographs of Argon Ion-Etched Longitudinal Sample 104-MKP109-JJ



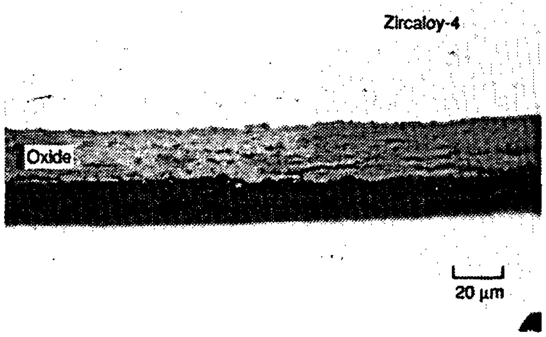
a) 0° Clockwise from Reference Notch (Neg. No. P-6538)



b) 270° Clockwise from Reference Notch (Neg. No. P-6544)

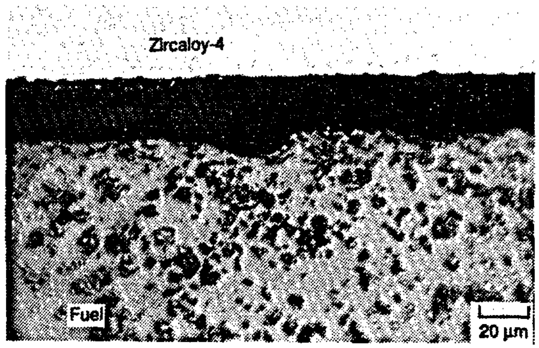


c) 90° Clockwise from Reference Notch (Neg. No. P-6540)

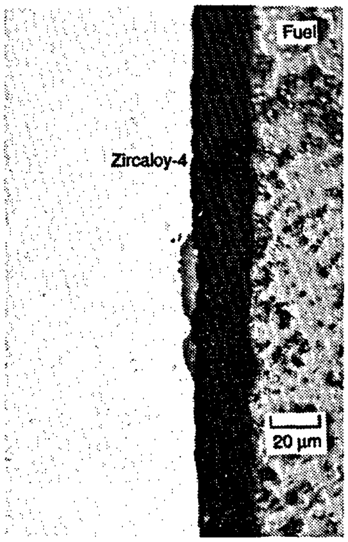


d) 180° Clockwise from Reference Notch (Neg. No. P-6542)

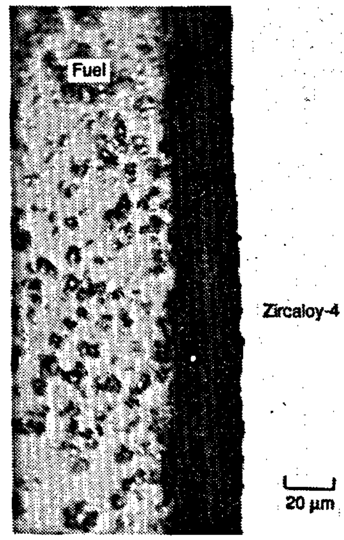
FIGURE E.4.a. Exterior Cladding Surface at Four Circumferential Locations on Polished Sample 104-MKP109-C



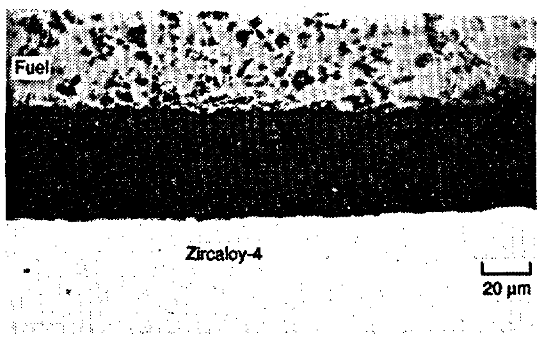
a) 0° Clockwise from Reference Notch (Neg. No. P-6537)



b) 270° Clockwise from Reference Notch (Neg. No. P-6543)

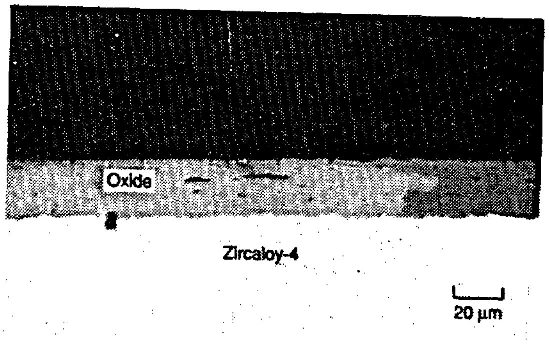


c) 90° Clockwise from Reference Notch (Neg. No. P-6539)

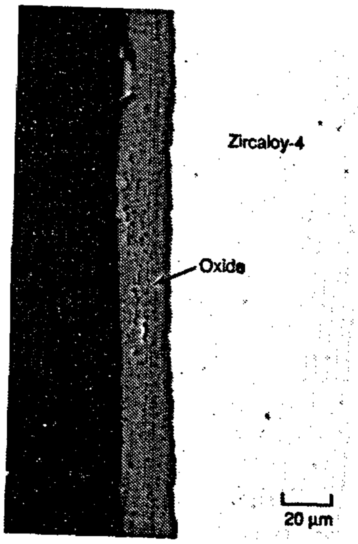


d) 180° Clockwise from Reference Notch (Neg. No. P-6541)

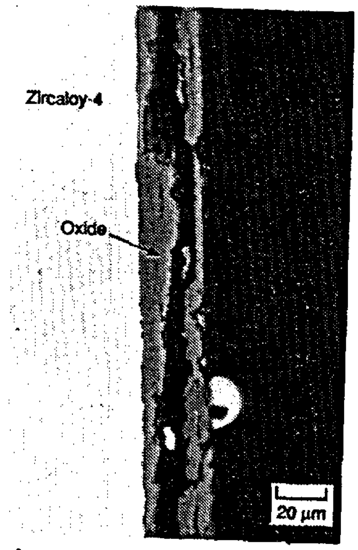
FIGURE E.4.b. Interior Cladding Surface at Four Circumferential Locations on Polished Sample 104-MKP109-C



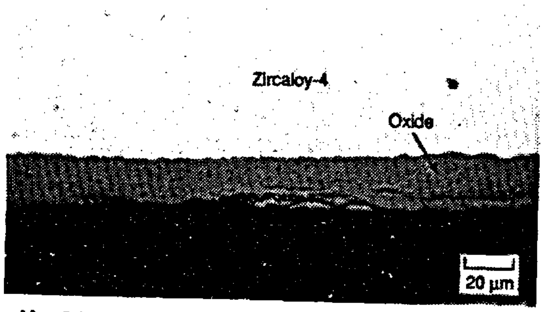
a) 0° Clockwise from Reference Notch (Neg. No. P-6527)



b) 270° Clockwise from Reference Notch (Neg. No. P-6533)

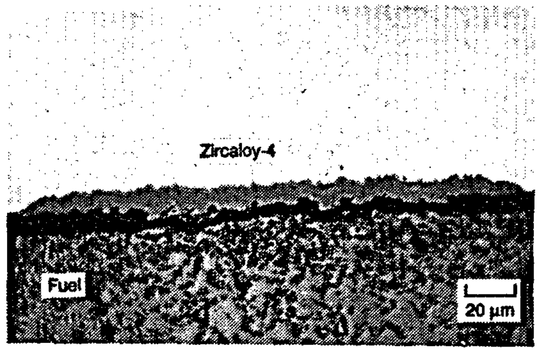


c) 90° Clockwise from Reference Notch (Neg. No. P-6529)

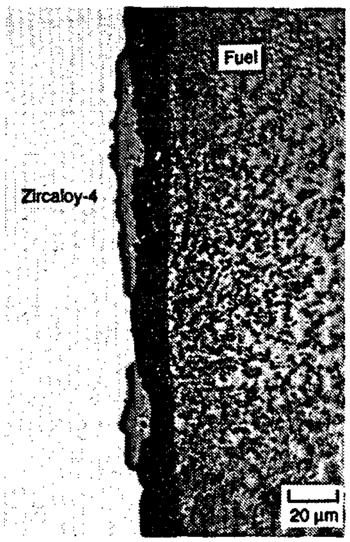


d) 180° Clockwise from Reference Notch (Neg. No. P-6531)

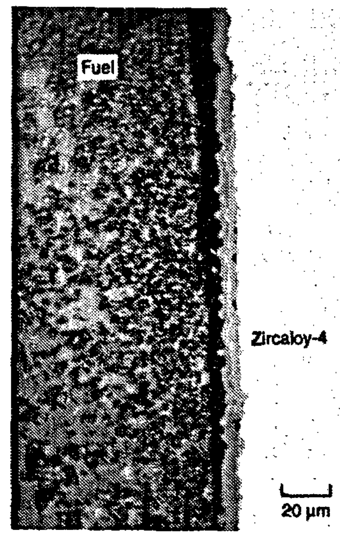
FIGURE E.4.c. Exterior Cladding Surface at Four Circumferential Locations on Polished Sample 104-MKP109-H



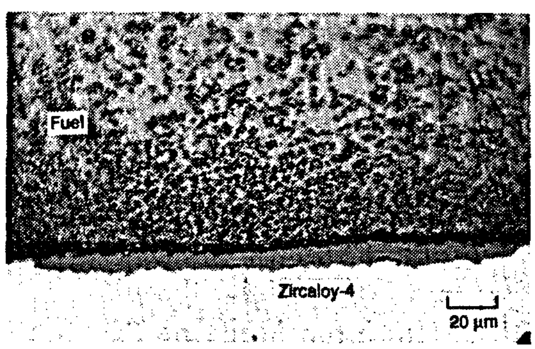
a) 0° Clockwise from Reference Notch (Neg. No. P-6526)



b) 270° Clockwise from Reference Notch (Neg. No. P-6532)

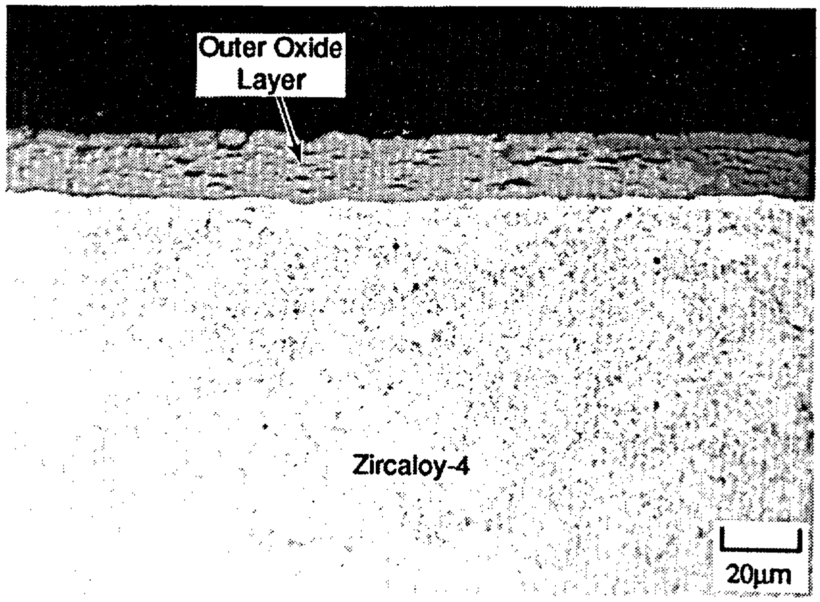


c) 90° Clockwise from Reference Notch (Neg. No. P-6528)

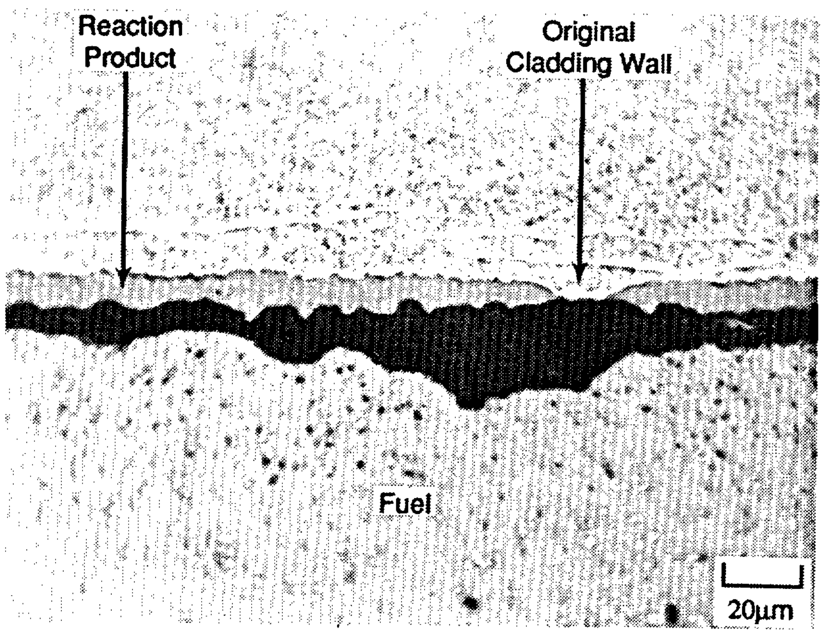


d) 180° Clockwise from Reference Notch (Neg. No. P-6530)

FIGURE E.4.d. Interior Cladding Surface at Four Circumferential Locations on Polished Sample 104-MKP109-H

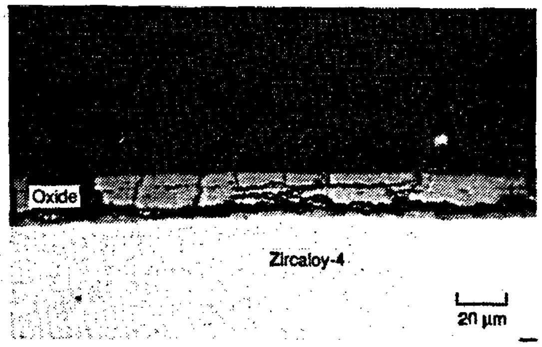


a) Exterior Surface (Neg. No. P-2687)

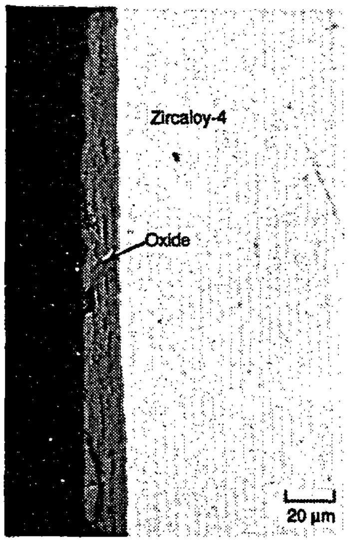


b) Interior Surface (Neg. No. P-2688)

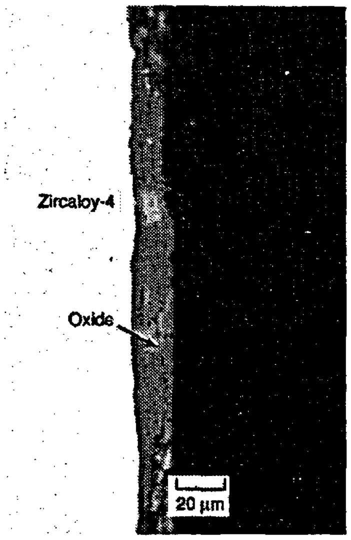
FIGURE E.4.e. Exterior/Interior Cladding Surface of Polished Sample 104-MKP109-N



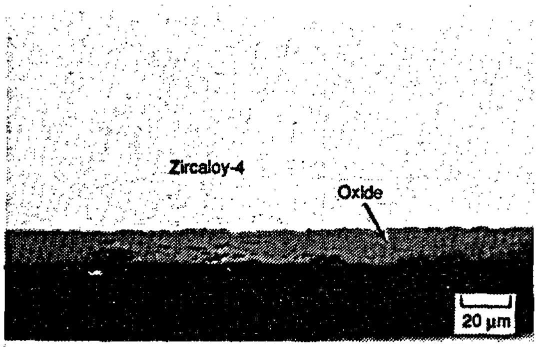
a) 0° Clockwise from Reference Notch (Neg. No. P-6516)



b) 270° Clockwise from Reference Notch (Neg. No. P-6522)

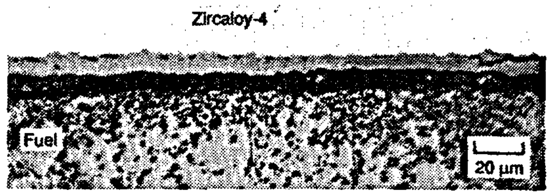


c) 90° Clockwise from Reference Notch (Neg. No. P-6518)

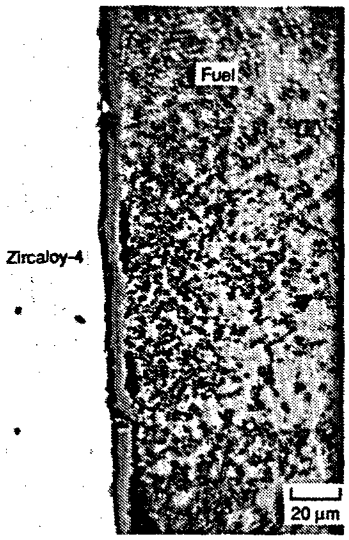


d) 180° Clockwise from Reference Notch (Neg. No. P-6520)

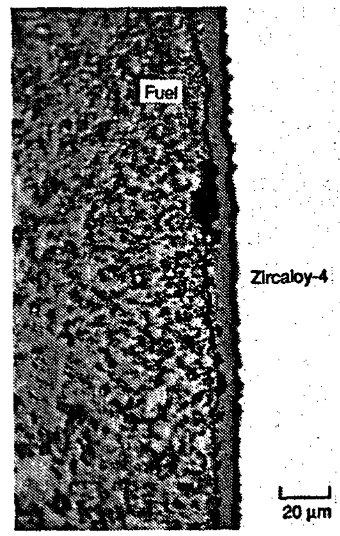
FIGURE E.4.f. Exterior Cladding Surface at Four Circumferential Locations on Polished Sample 104-MKP109-0



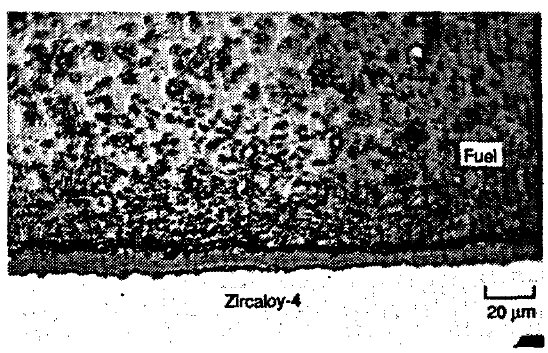
a) 0° Clockwise from Reference Notch (Neg. No. P-6515)



b) 270° Clockwise from Reference Notch (Neg. No. P-6521)

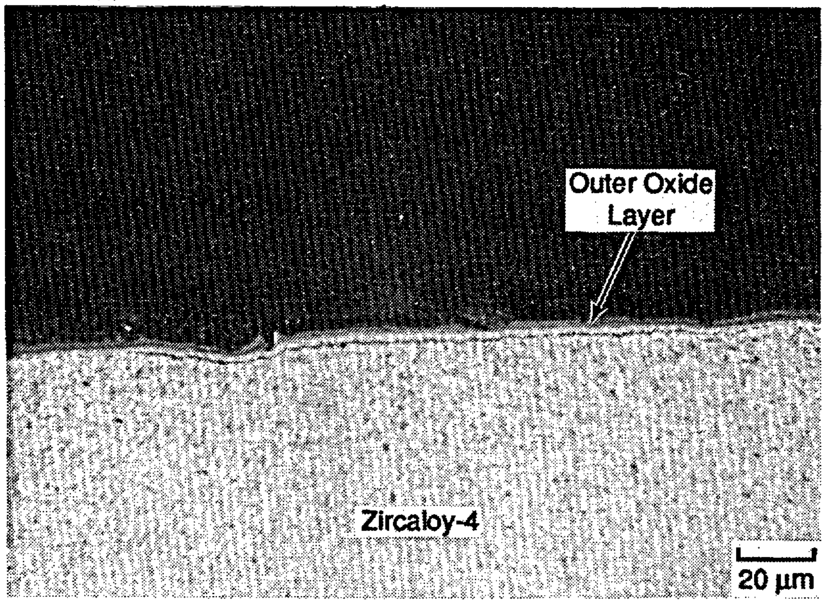


c) 90° Clockwise from Reference Notch (Neg. No. P-6517)

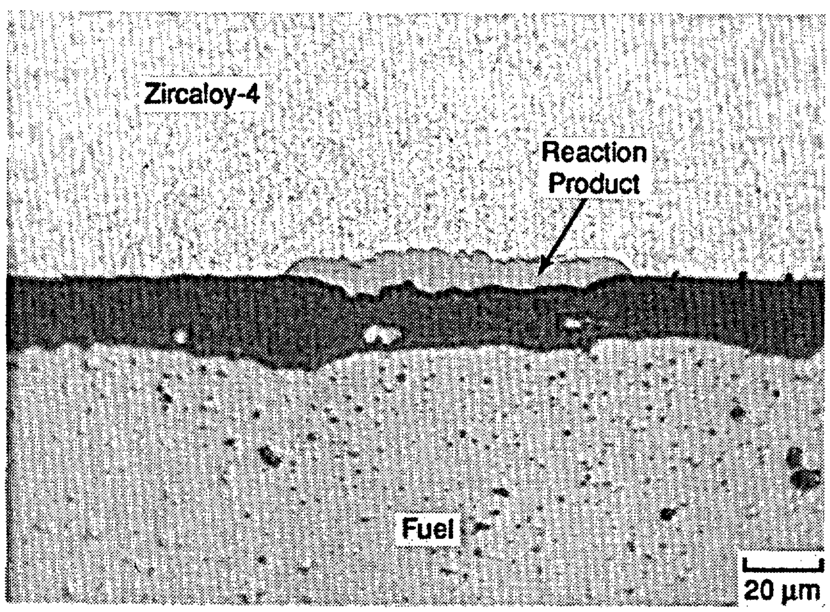


d) 180° Clockwise from Reference Notch (Neg. No. P-6519)

FIGURE E.4.g. Interior Cladding Surface at Four Circumferential Locations on Polished Sample 104-MKP109-0

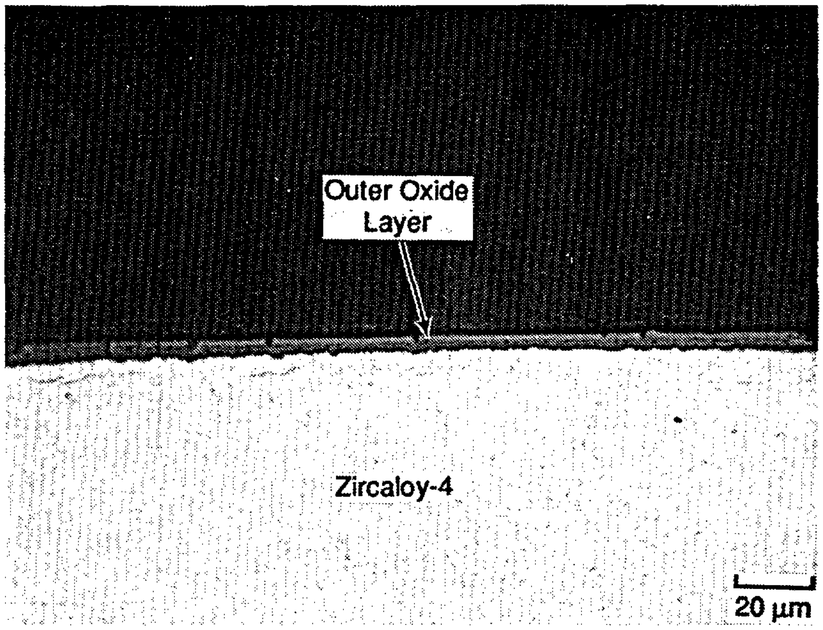


a) Exterior Surface (Neg. No. P-2993)



b) Interior Surface (Neg. No. P-2994)

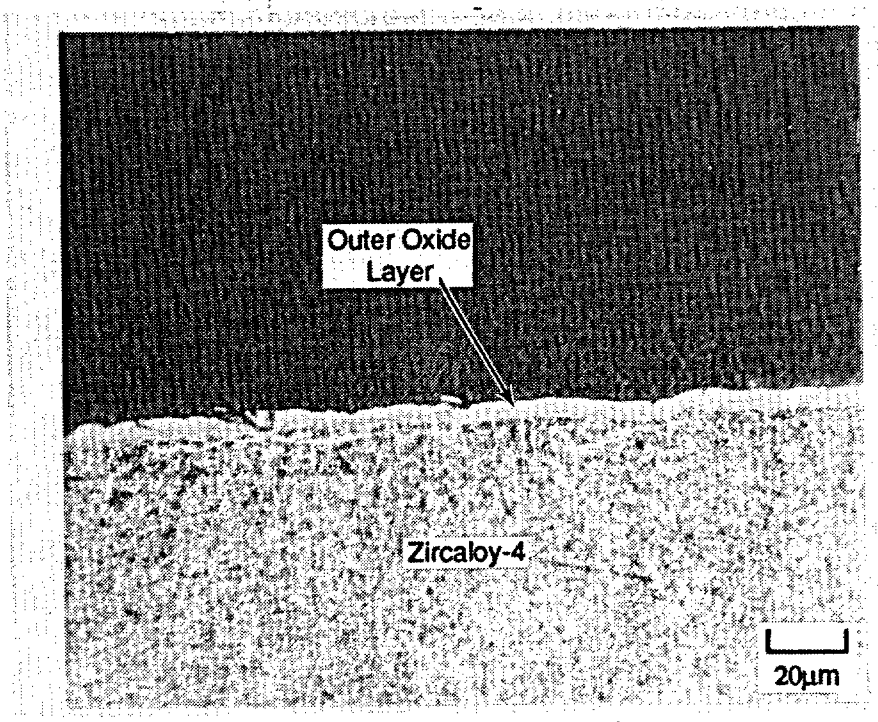
FIGURE E.4.h. Exterior/Interior Cladding Surface of Polished Sample 104-MKP109-AA



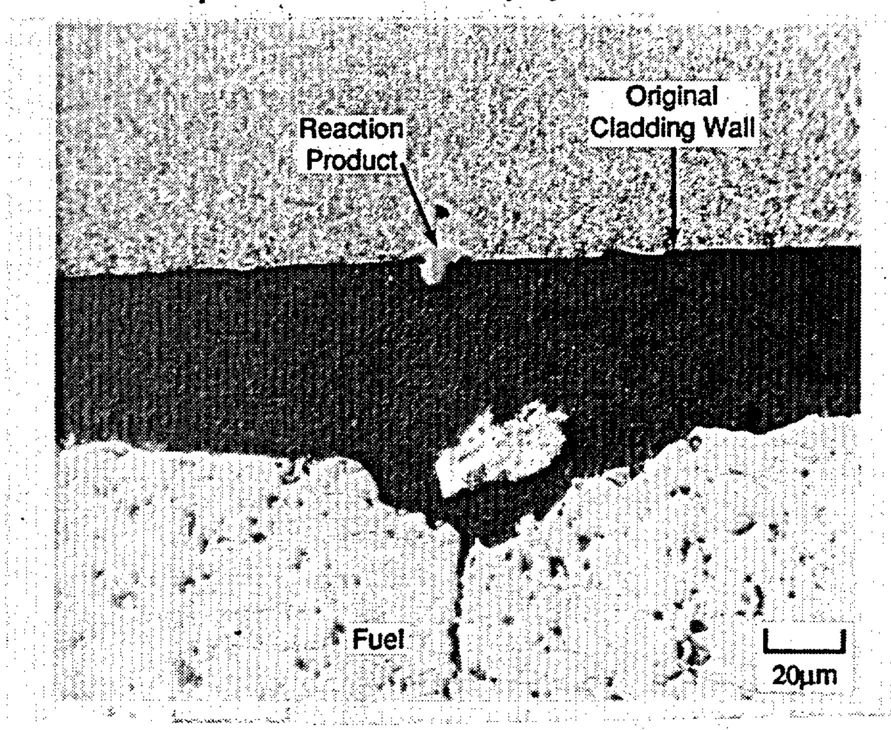
a) Exterior Surface (Neg. No. P-3063)

b) (Note: No interior surface examination was performed for Sample 104-MKP109-BB)

FIGURE E.4.i. Exterior Cladding Surface of Polished Sample 104-MKP109-BB



a) Exterior Surface (Neg. No. P-2790)



b) Interior Surface (Neg. No. P-2791)

FIGURE E.4.j. Exterior/Interior Cladding Surface of Polished Sample 104-MKP109-JJ

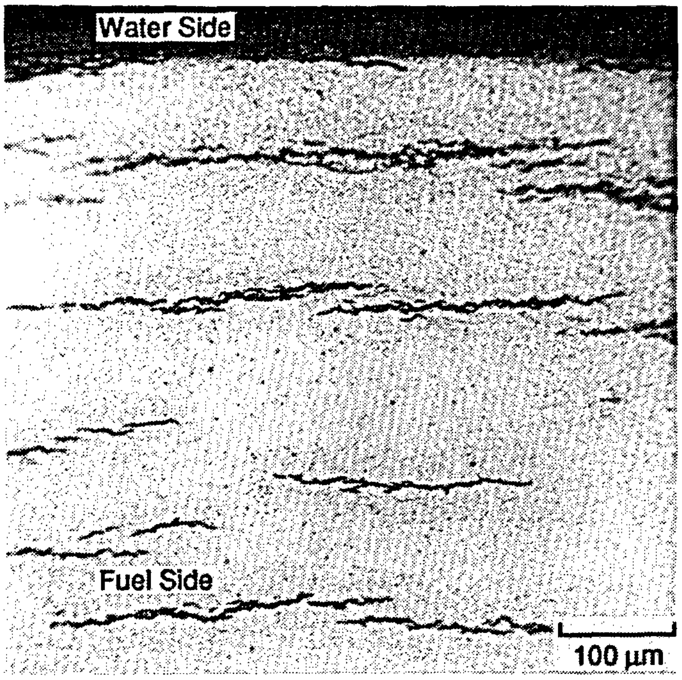


FIGURE E.5.a. Etched Cladding of Transverse Sample 104-MKP109-C (Neg. No. P-3314)

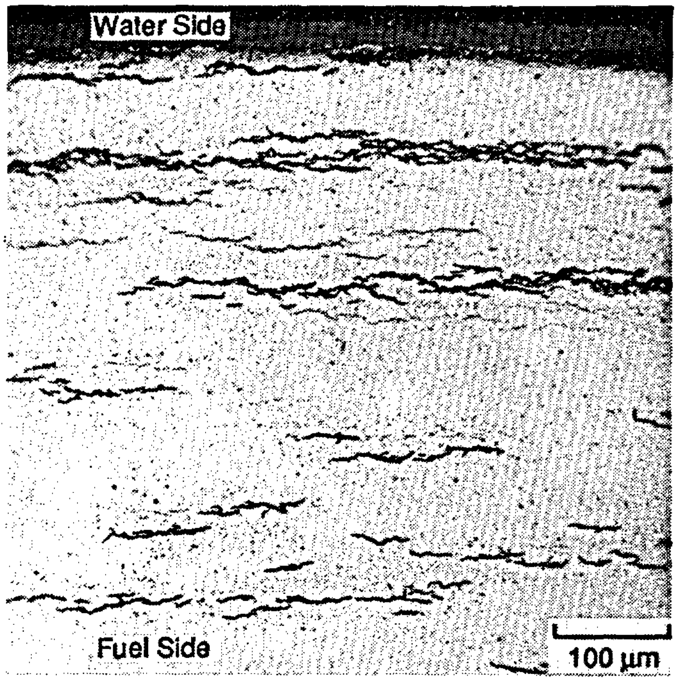


FIGURE E.5.b. Etched Cladding of Transverse Sample 104-MKP109-H (Neg. No. P-3276)

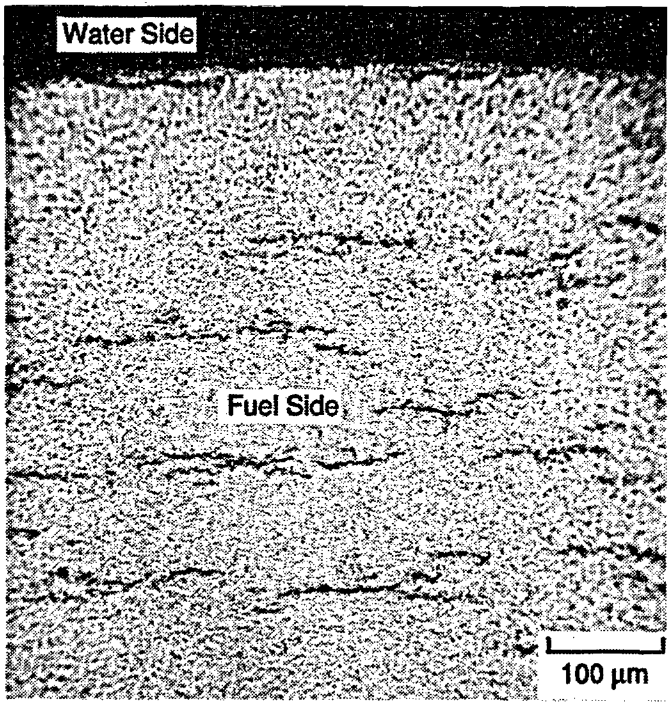


FIGURE E.5.c. Etched Cladding of Transverse Sample 104-MKP109-O (Neg. No. P-3297)

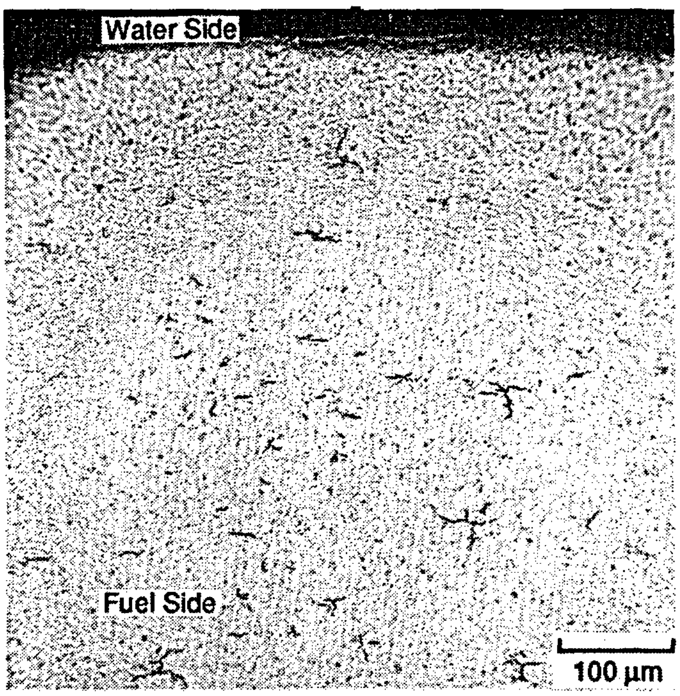


FIGURE E.5.d. Etched Cladding of Transverse Sample 104-MKP109-BB (Neg. No. P-3313)

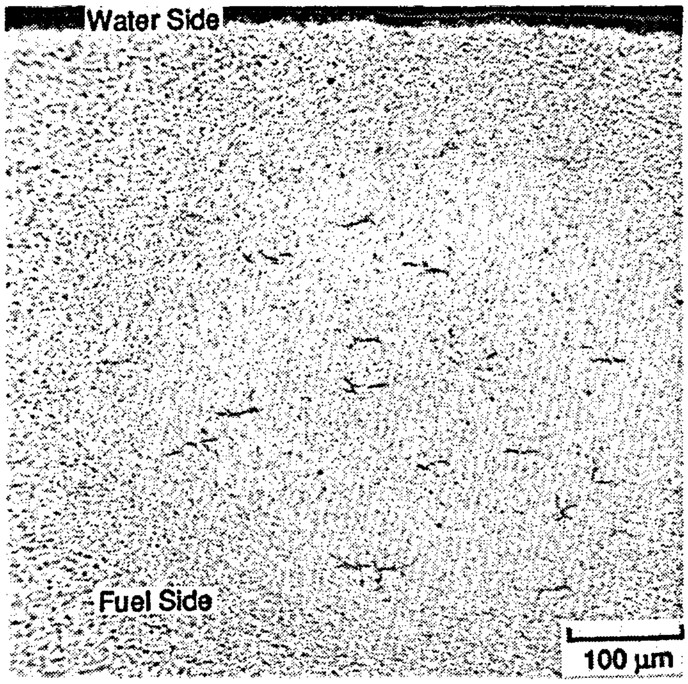


FIGURE E.5.e. Etched Cladding of Transverse Sample 104-MKP109-KK (Neg. No. P-3248)

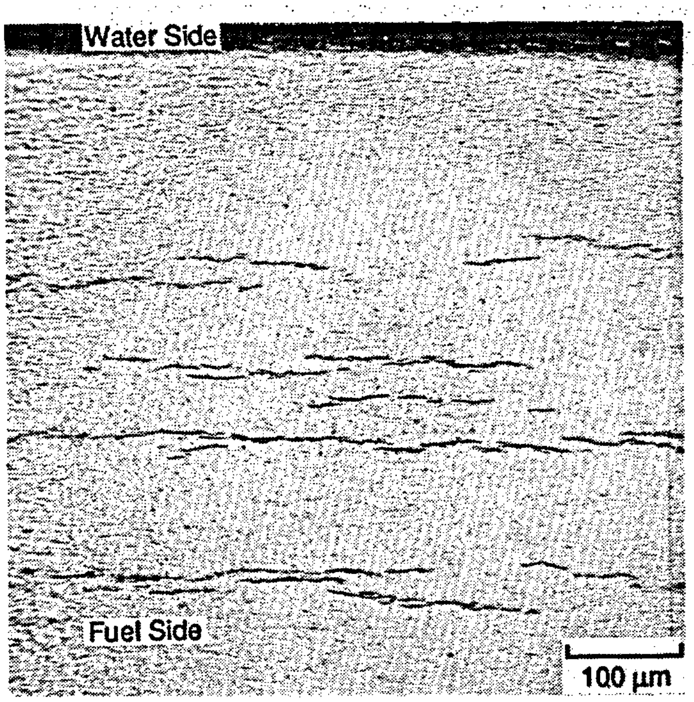


FIGURE E.5.f. Etched Cladding of Longitudinal Sample 104-MKP109-N (Neg. No. P-3272)

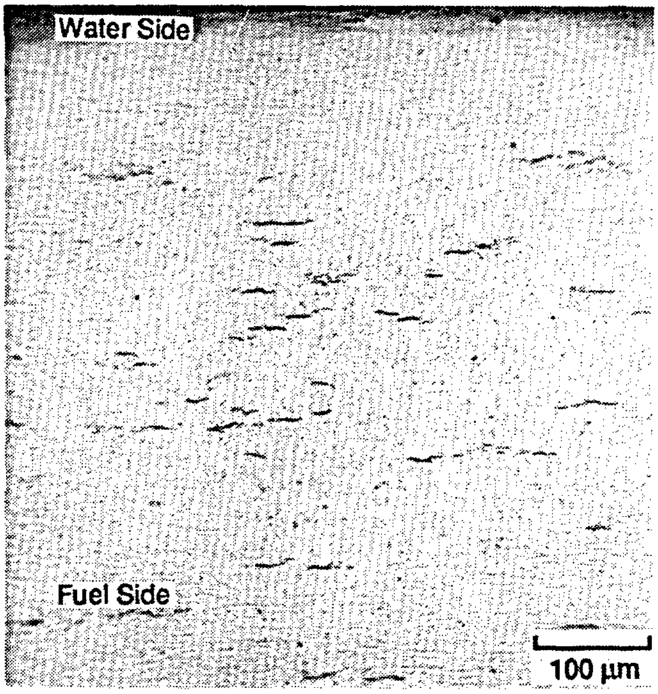


FIGURE E.5.g. Etched Cladding of Longitudinal Sample 104-MKP109-AA (Neg. No. P-3317)

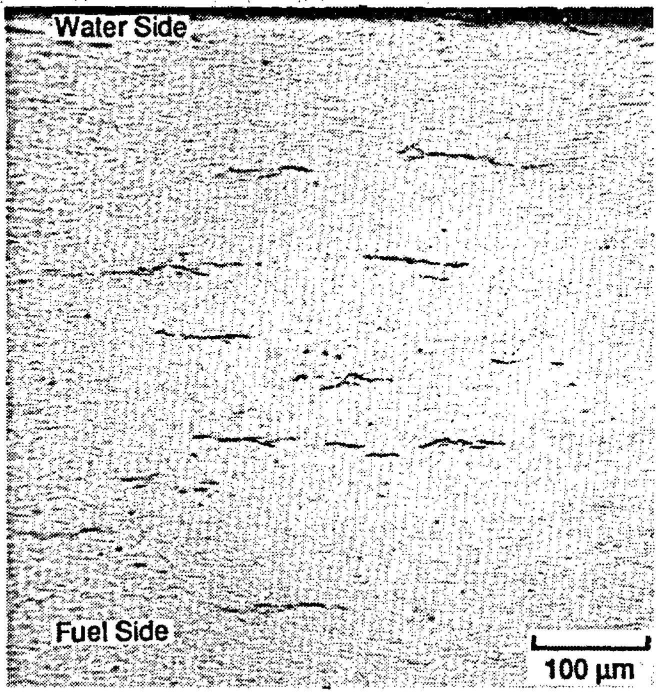


FIGURE E.5.h. Etched Cladding of Longitudinal Sample 104-MKP109-JJ (Neg. No. P-3275)

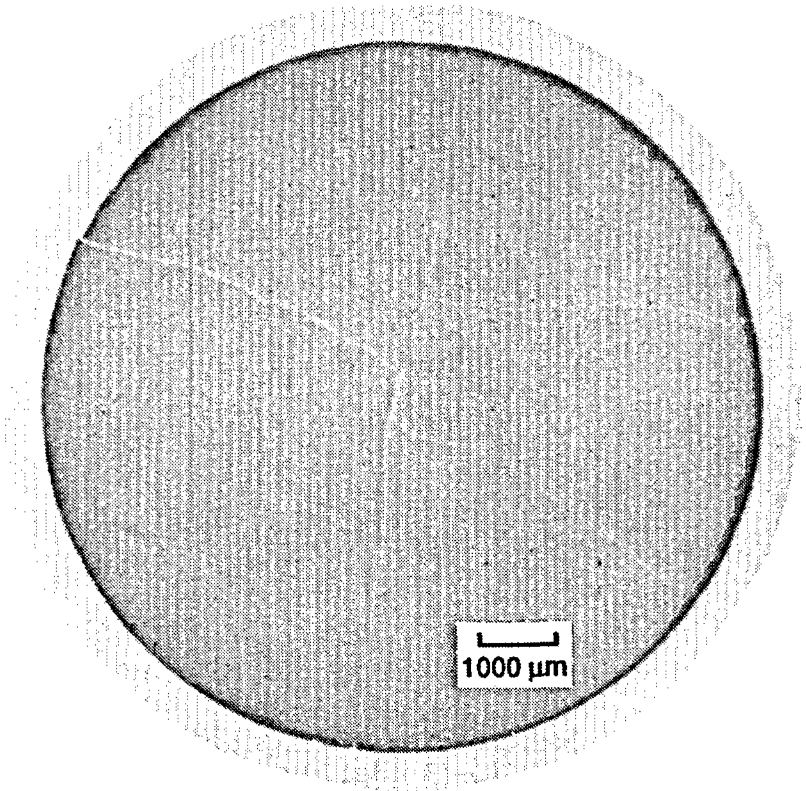


FIGURE E.6.a. Alpha Autoradiograph of Transverse Sample 104-MKP109-C (Neg. No. 5458)

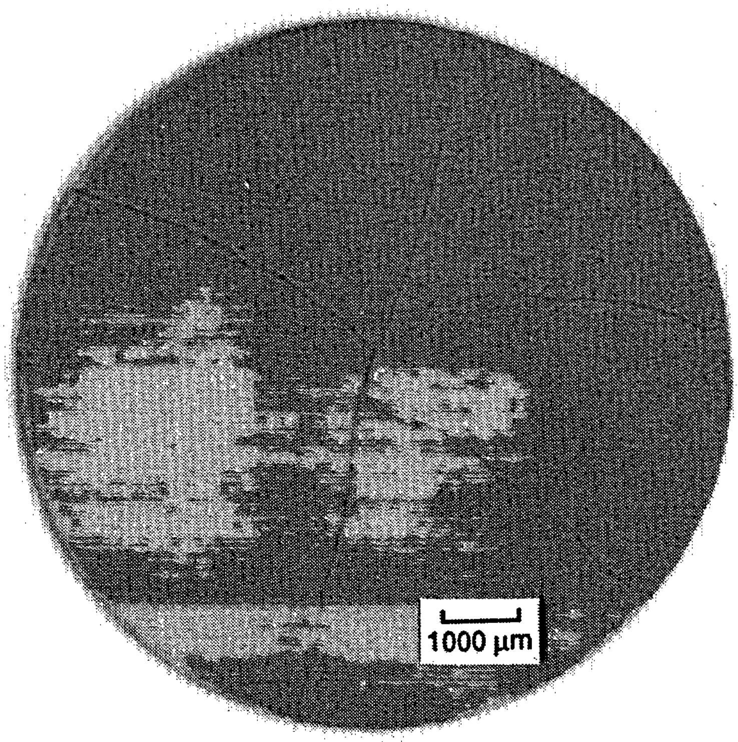


FIGURE E.6.b. Beta/Gamma Autoradiograph of Transverse Sample 104-MKP109-C (Neg. No. 5459)

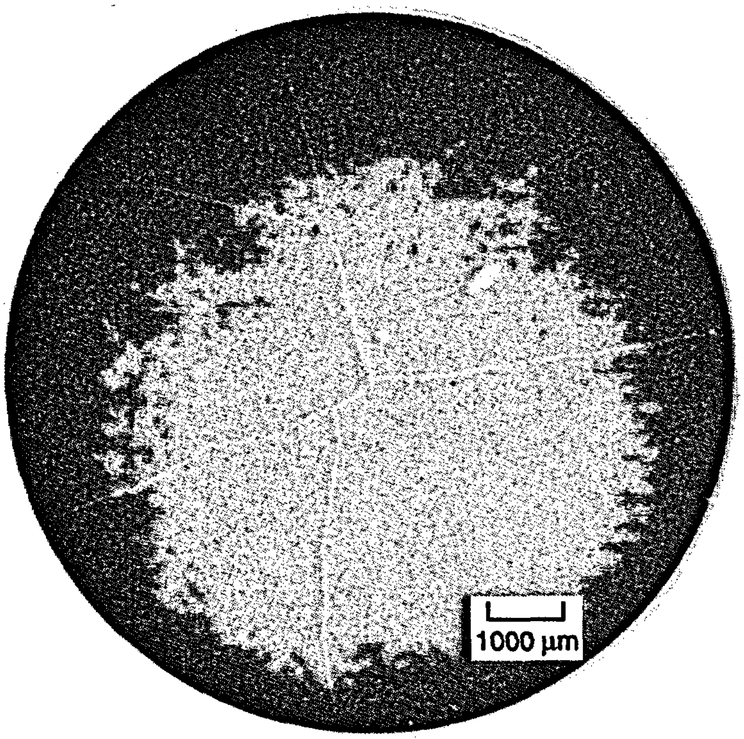


FIGURE E.6.c. Alpha Autoradiograph of Transverse Sample 104-MKP109-H (Neg. No. 5420)

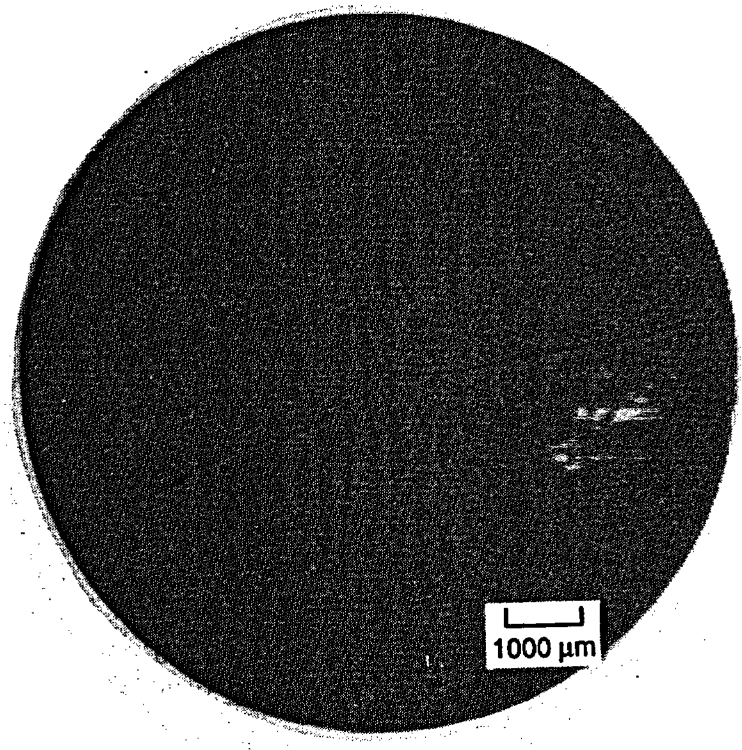


FIGURE E.6.d. Beta/Gamma Autoradiograph of Transverse Sample 104-MKP109-H (Neg. No. 5421)

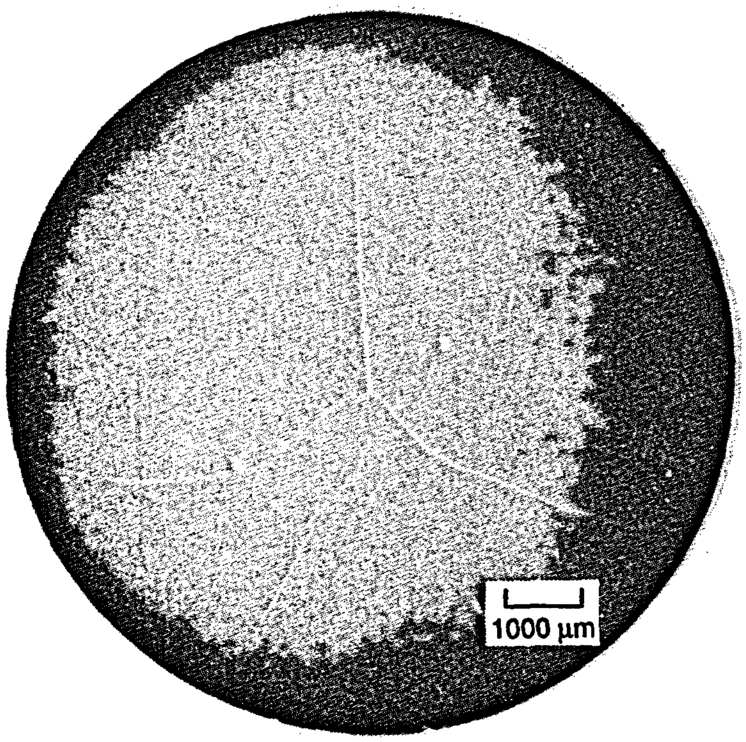


FIGURE E.6.e. Alpha Autoradiograph of Transverse Sample 104-MKP109-0 (Neg. No. 5416)

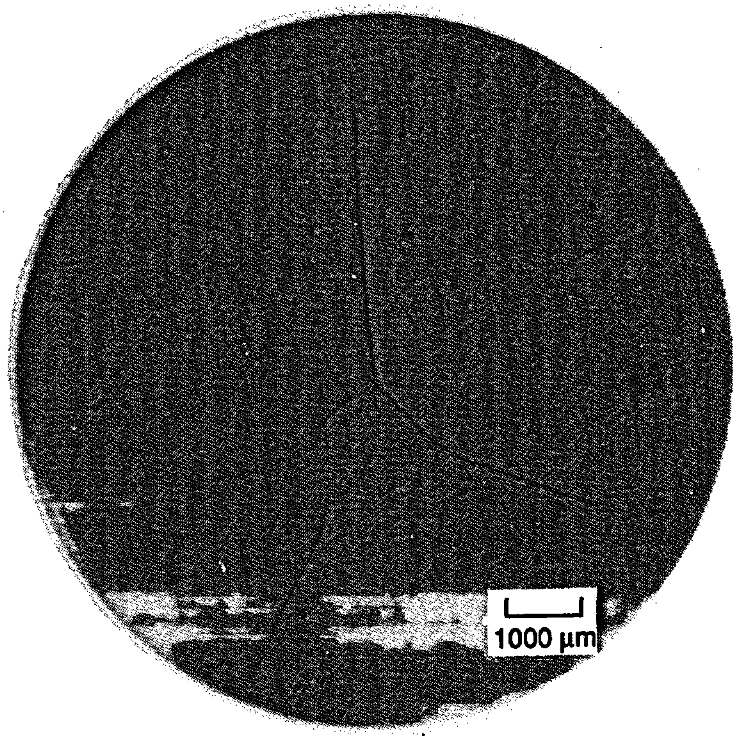


FIGURE E.6.f. Beta/Gamma Autoradiograph of Transverse Sample 104-MKP109-O (Neg. No. 5417)

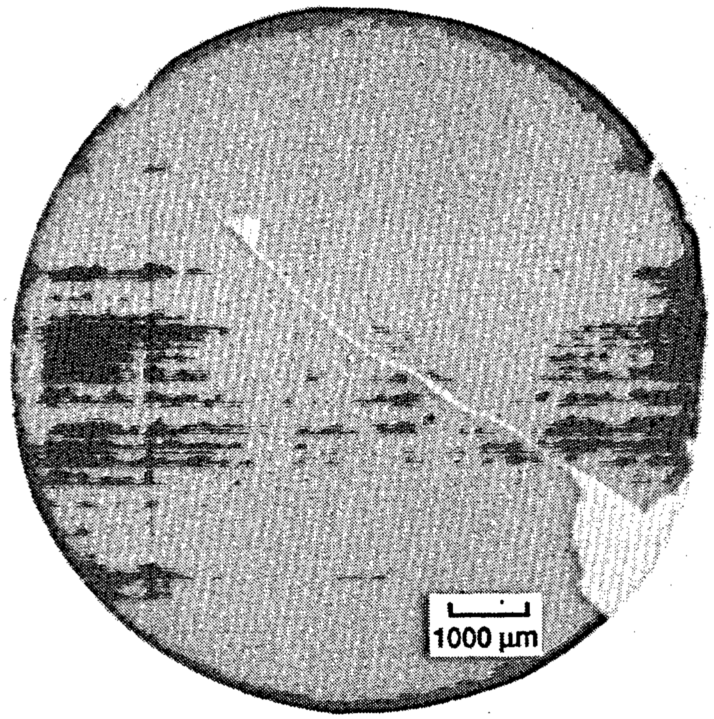


FIGURE E.6.g. Alpha Autoradiograph of Transverse Sample 104-MKP109-BB (Neg. No. 5450)

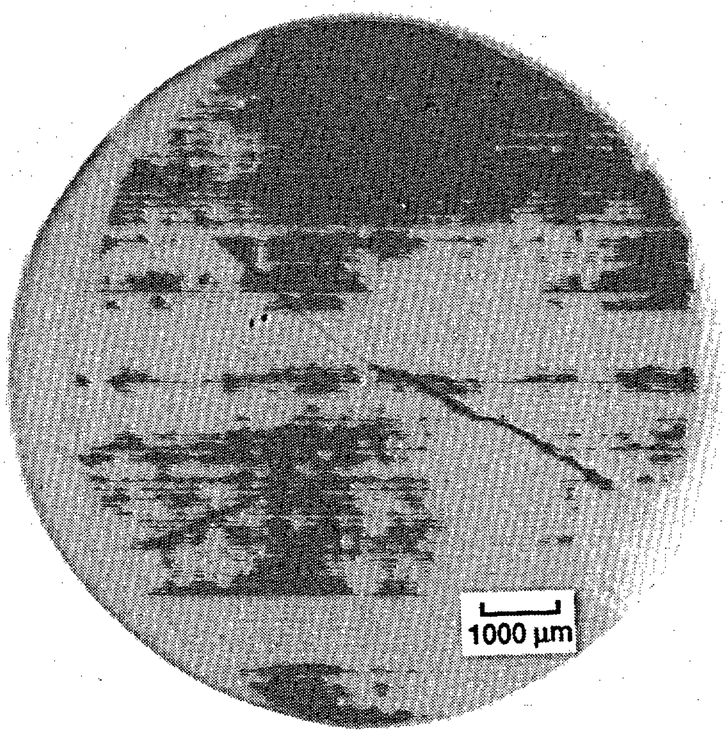


FIGURE E.6.h. Beta/Gamma Autoradiograph of Transverse Sample 104-MKP109-BB (Neg. No. 5451)

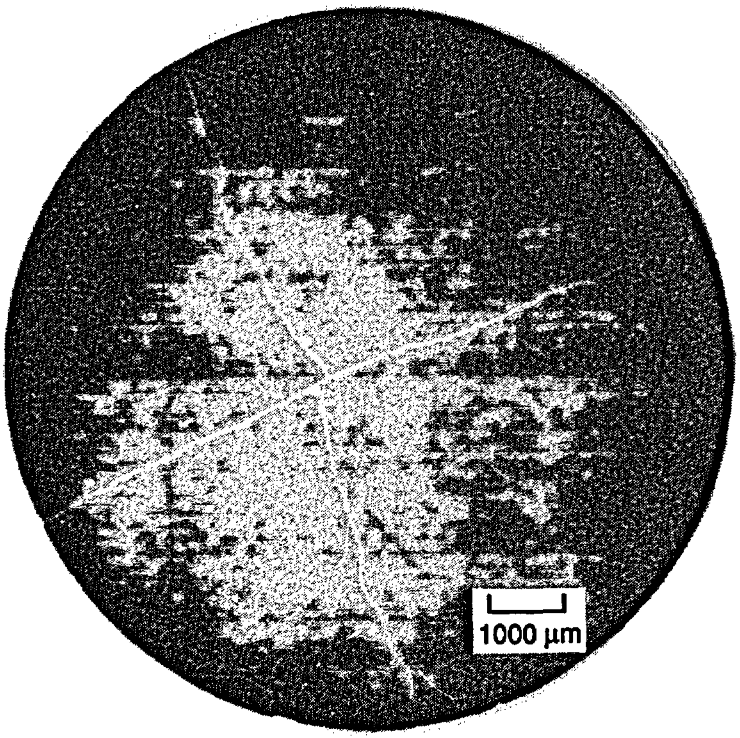


FIGURE E.6.i. Alpha Autoradiograph of Transverse Sample 104-MKP109-KK (Neg. No. 5428)

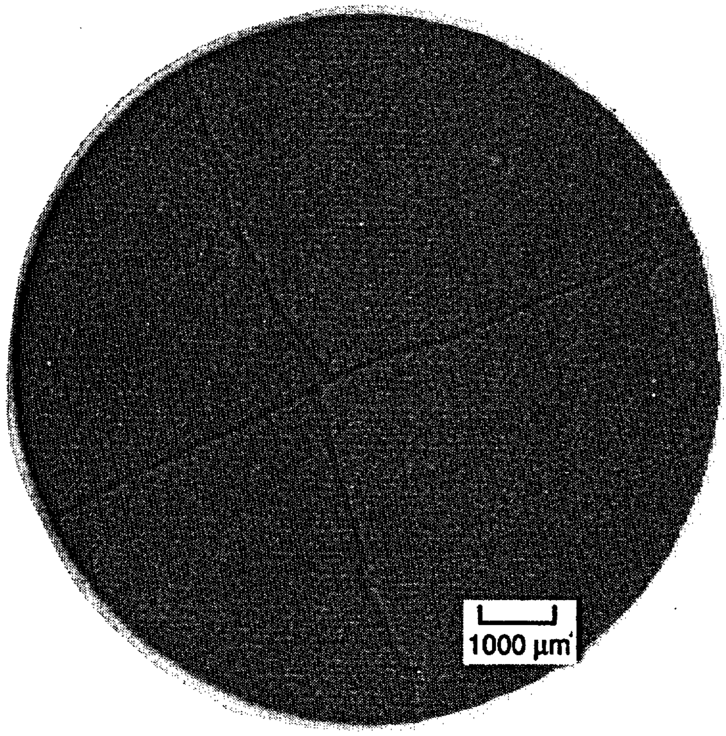


FIGURE E.6.j. Beta/Gamma Autoradiograph of Transverse Sample 104-MKP109-KK (Neg. No. 5429)

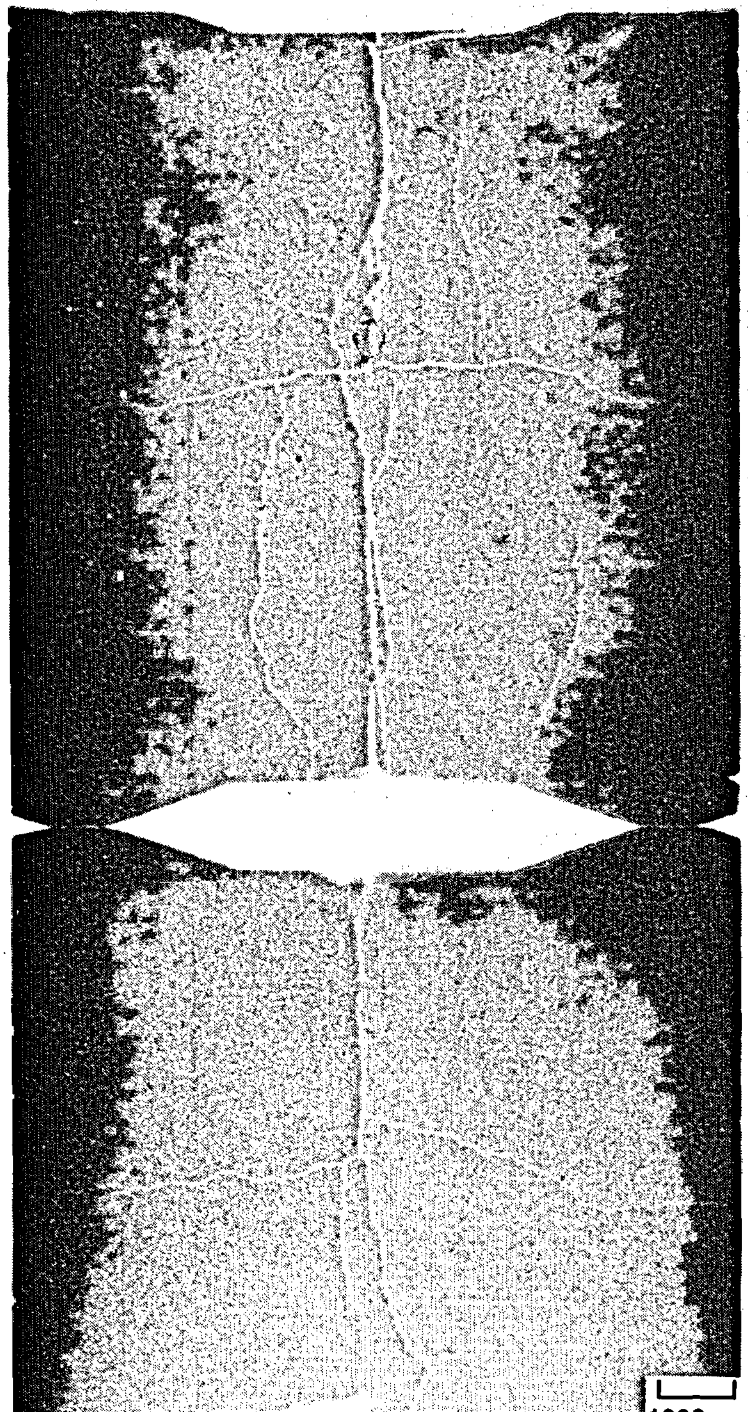


FIGURE E.6.k. Alpha Autoradiograph of Longitudinal Sample 104-MKP109-N (Neg.No. 5422)

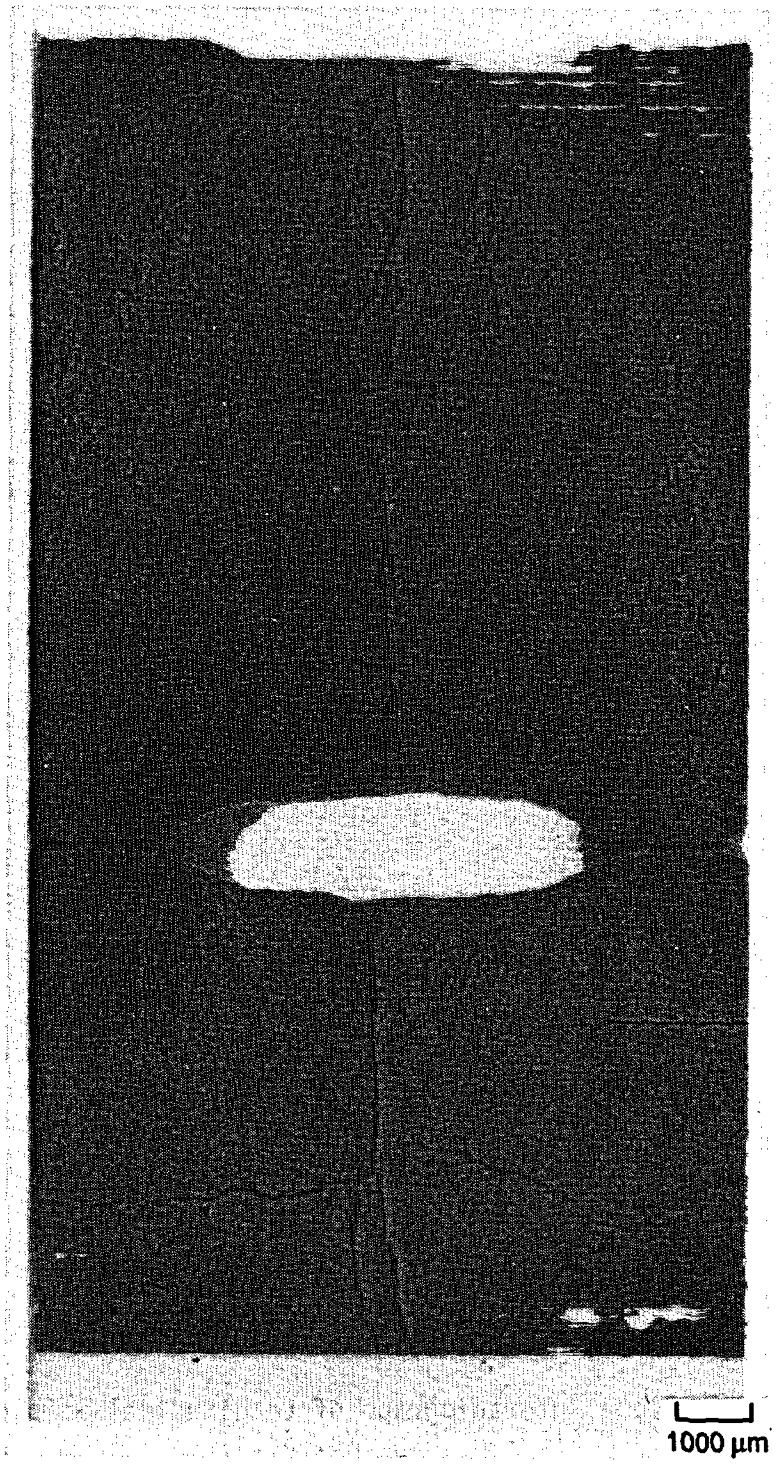


FIGURE E.6.1. Beta/Gamma Autoradiograph of Longitudinal Sample 104-MKP109-N (Neg. No. 5415)

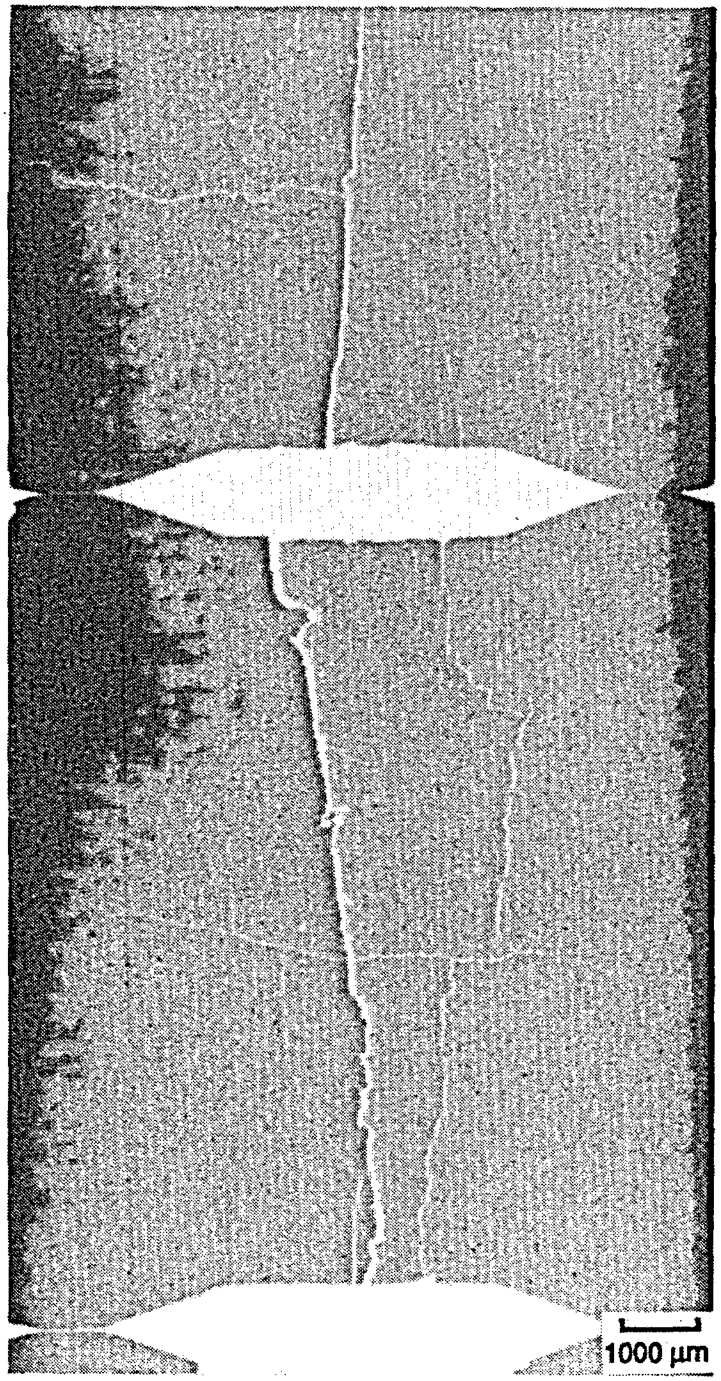


FIGURE E.6.m. Alpha Autoradiograph of Longitudinal Sample 104-MKP109-AA (Neg. No. 5454)

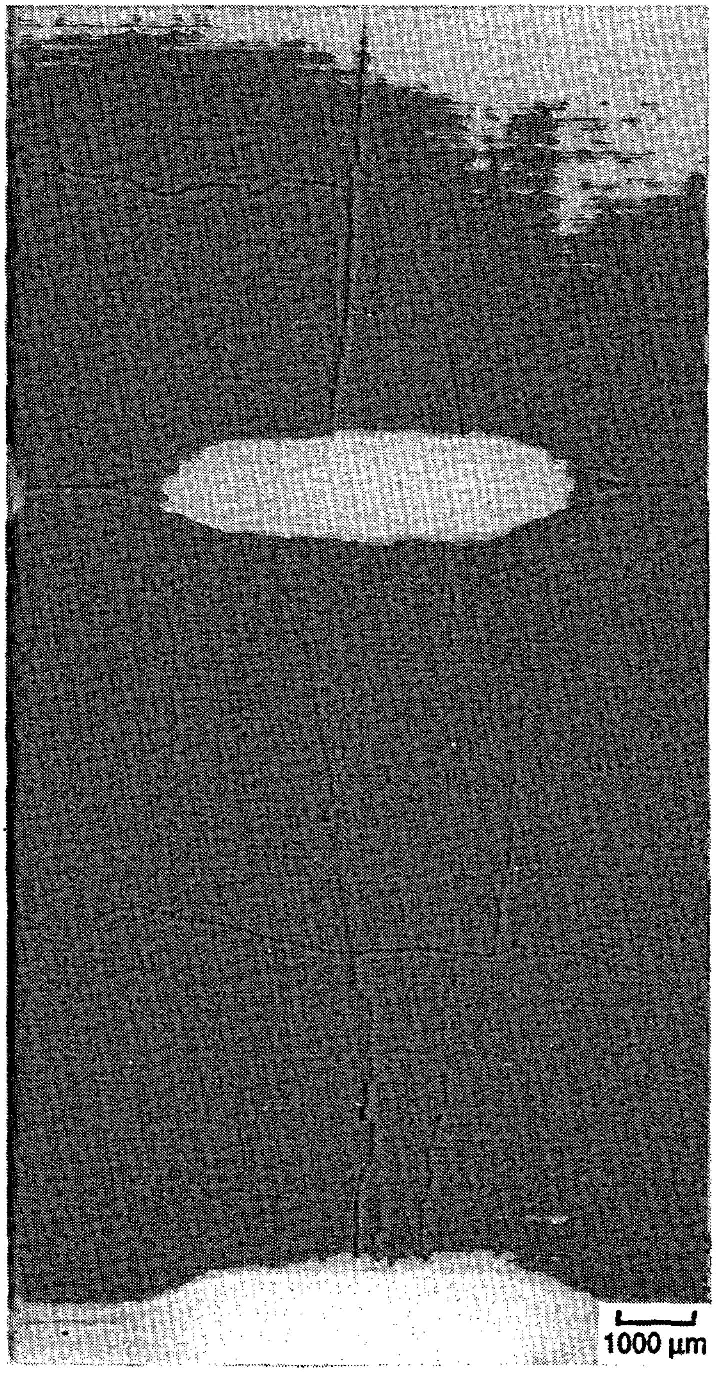


FIGURE E.6.n. Beta/Gamma Autoradiograph of Longitudinal Sample 104-MKP109-AA (Neg. No. 5455)

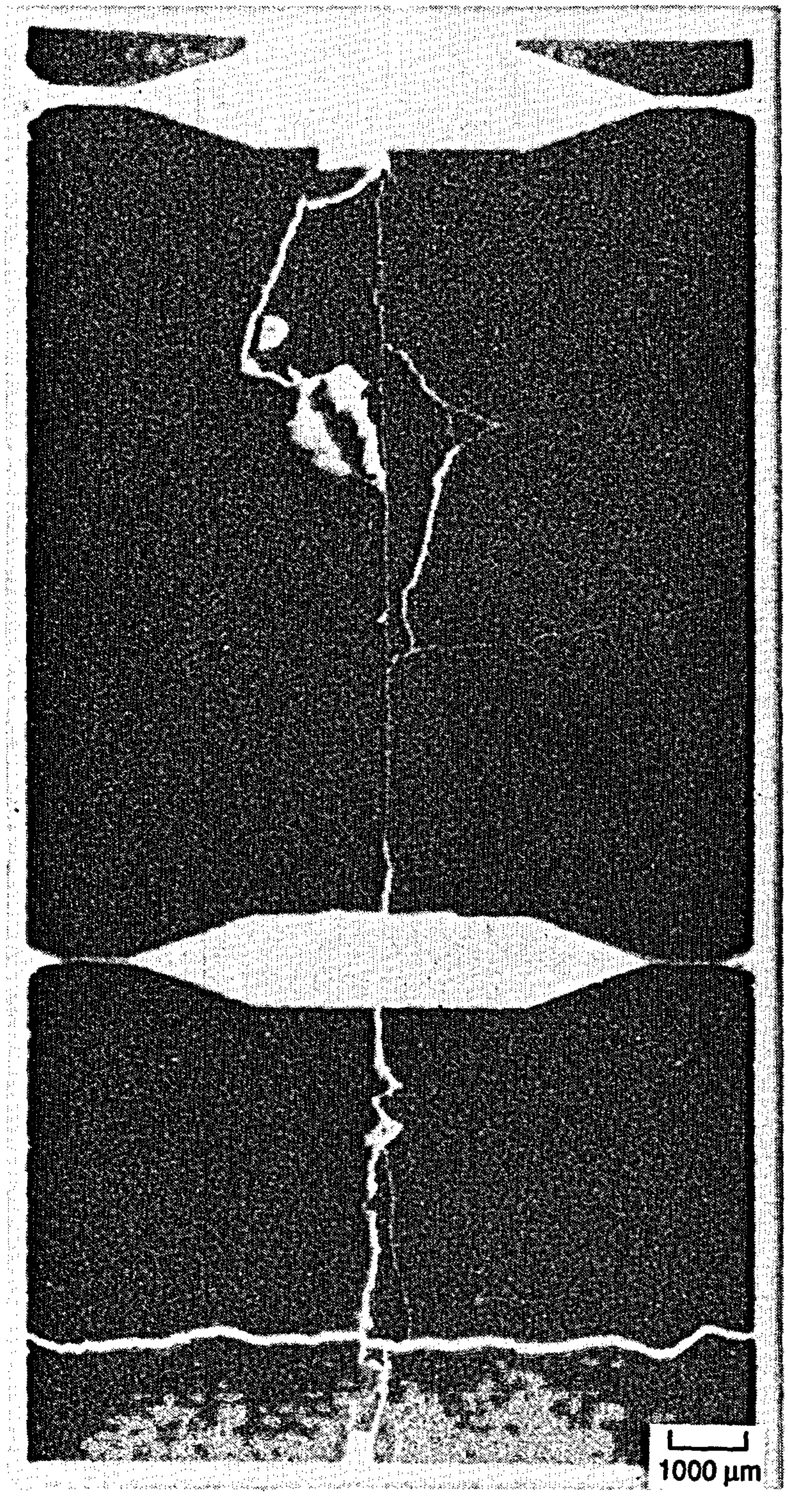


FIGURE E.6.o. Alpha Autoradiograph of Longitudinal Sample 104-MKP109-JJ (Neg. No. 5426)

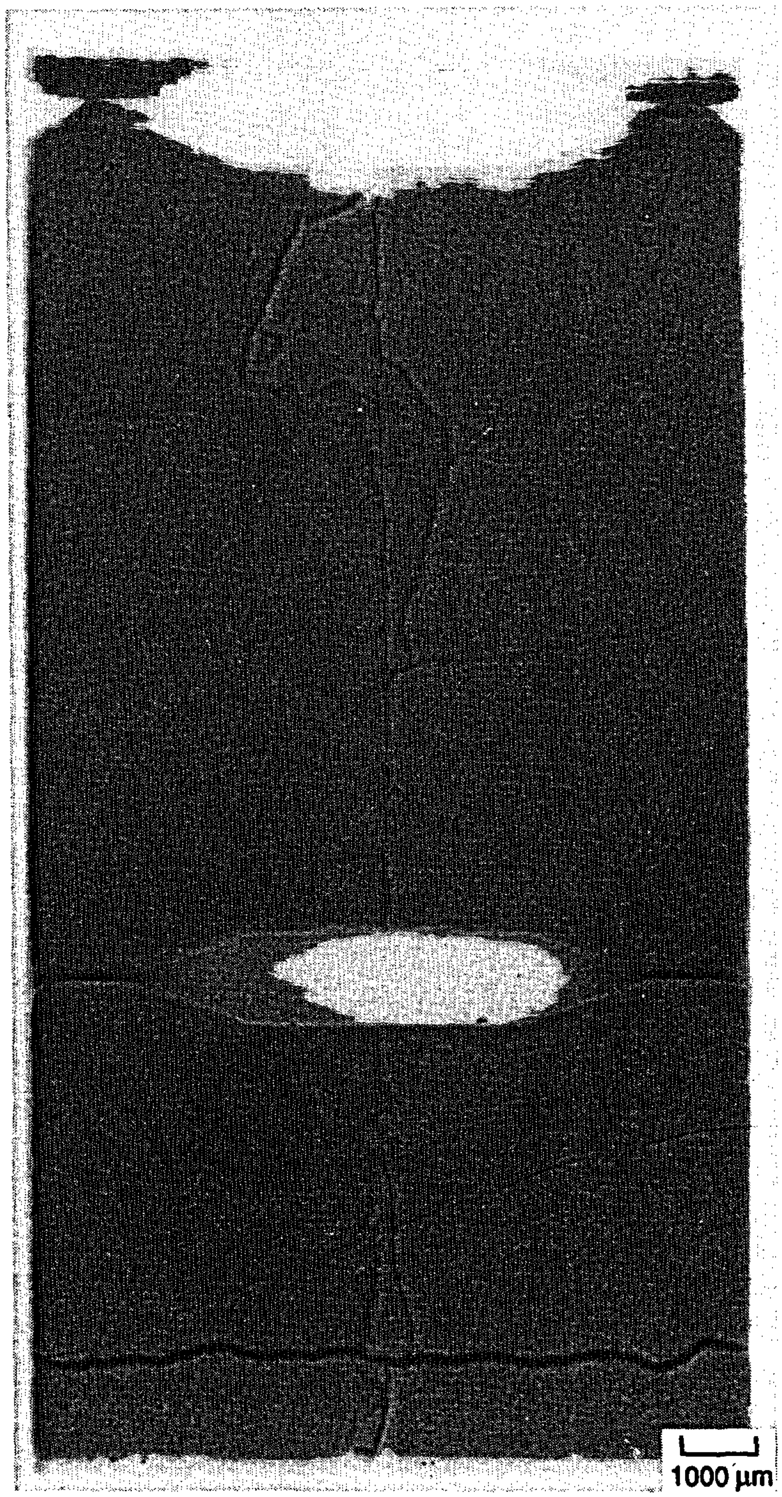


FIGURE E.6.p. Beta/Gamma Autoradiograph of Longitudinal Sample 104-MKP109-JJ (Neg. No. 5427)

APPENDIX F

DETAILS OF ELECTRON MICROPROBE ANALYSES

APPENDIX F

DETAILS OF ELECTRON MICROPROBE ANALYSES

Electron probe microanalyses (EPMA) were conducted on Sample 104-MKP109-H as discussed in Section 7.3.2 to determine the radial variation of several fission products and actinides of interest. This appendix provides information on the EPMA procedure and details on the results obtained for the concentrations of neodymium, cesium, xenon, plutonium, uranium, americium, technetium, and ruthenium in the ATM-104 fuel sample. The radial variation in fuel burnup is also provided based on the measured neodymium concentrations in the fuel.

EPMA was accomplished using the shielded electron microprobe, Model 450, manufactured some twenty years ago by Materials Analysis Corporation. The examination involves exposing a mounted fuel sample to an electron beam after the sample has been specially ground and carbon coated. The electron beam operates at 25 keV and 100 to 500 nA. Electrons striking the fuel sample cause characteristic x-rays to be emitted from the sample at a 45° emergence angle. X-rays emitted from the fuel sample are passed through three crystals located on a single plane. The crystals can be independently rotated to diffract the incoming x-ray beam for analysis of a desired element by wavelength dispersive spectrometry.

The concentrations of three elements were simultaneously determined during a radial scan that examined fuel material from the outer edge of the fuel to the fuel center. The first five data points are separated by about 75 μm; the remaining approximately 25 data points are separated by about 180 μm. Counting time was 100 seconds for each step.

Each element analyzed was compared with a standard emplaced in a special examination ring positioned around the mounted sample. Standards used were elemental metals or oxides as supplied by the microprobe manufacturer, except for UO_2 and PuO_2 which were added locally. A list of the standards and crystals used to detect each element is provided in Table F.1. No certification

TABLE F.1. Standards and Crystals Used in Performing EPMA for Sample 104-MKP109-H.

Element	Absorption Line Used	Standard	Detectability Limits, wt%	Crystal Used
Pu	Mβ	PuO2	0.04	PET
Am	Mα	Pu	0.04	LiF
U	Mβ	UO_2	0.18	PET
Cs	Lα	(a)	0.01	PET
Xe	Lα	(a)	0.01	PET
Tc	Lα	(b)	0.02	LiF
Nd	Lα	Sb	0.02	PET
Ru	Lα	(b)	0.02	LiF
I	Lα	(a)	0.04	LiF

(a) Based on extrapolation of Sn, Sb and Te standards.
(b) Based on interpolation of Mo and Pd standards.
PET = Pentaerythritol. LiF = Lithium Fluoride

of purity or composition is available. However, the location of the desired analytical line at the expected wavelength effectively identifies the element.

Elements for which no standard was available were compared against standards for elements with the closest atomic number possible. These data were plotted versus atomic number and the necessary standards data were obtained by extrapolation or interpolation to find an appropriate value for the element of interest. Iodine, xenon, cesium, and neodymium standards were not available. For these elements, measurements were made on tin, antimony, and tellurium and the data extrapolated for the missing standards. The extrapolations for iodine, xenon and cesium are short to moderate, being one, two, and three atomic numbers away, respectively. However, the extrapolation for Nd is eight atomic numbers away from the nearest standard. Therefore, the standard used to approximate neodymium was antimony. Ruthenium and technetium are another pair for which standards are not available in the microprobe. These standards were obtained by interpolation of molybdenum and palladium data. Americium is also not available as a standard; therefore, plutonium was used to approximate it.

The x-ray intensities for the sample and an appropriate standard are measured by EPMA. The sample beam intensity divided by the standard's beam intensity provides the K ratio for the material of interest in the specimen. MAGIC IV is a computer code used make a ZAF adjustment to the K ratios for atomic number (Z), absorption (A), and florescence (F) to output element wt% (Colby 1971). All negative K ratios (such as for americium) were set to a slightly positive value (0.00001) because the MAGIC IV code does not accept negative or zero values for input. Iodine was not included in the input because it was not detected above background levels.

The measured elemental concentrations for neodymium, cesium, xenon, plutonium, uranium, americium, technetium, and ruthenium are provided in Table F.2. While a standard is used to obtain absolute values for the elemental concentrations, there can be significant uncertainties for some of the elements, such as explained above for extrapolating values for the standards. Thus, measured values for neodymium, cesium, xenon, plutonium, and uranium were corrected such that the volume integrated concentrations of the element from EPMA yielded a concentration equal to that obtained from the known bulk average burnup of 44.3 MWd/kgM in Sample 104-MKP109-H (see Equation [1] in Section 7.1.1 and Appendices B and C). The elemental concentrations for the known burnup of 44.3 MWd/kgM were obtained from the ORIGEN2 output in Appendix D. As noted in Table F.2, the corrections were less than 5% for neodymium, xenon, plutonium, and uranium; the cesium EPMA data was decreased 16% to bring the EPMA bulk-average concentration to the expected level. Corrected profiles for americium, technetium, and ruthenium have not been determined; the ruthenium values appear to be three times too high based on the bulk average burnup for this sample.

Plots of the radial profiles of the corrected concentrations for neodymium, cesium, xenon, plutonium, and uranium are given in Figures F.1 through F.5, respectively. Figure F.3 also includes a curve for the xenon concentration expected based on the neodymium concentrations at each radial location; the decrease in xenon near the fuel edge has been observed by other experimenters and is discussed in Section 7.3.2 (Pati, Garde, and Clink 1988). Plots of EPMA data for americium, technetium, and ruthenium are presented in Figures F.6 through F.8 without any correction for the expected bulk-average concentrations.

TABLE F.2. Measured and Corrected Results for EPMA of Sample 104-MKP109-H

Step	Radial Position	Burnup MWd/kgM	Neodymium Exp.	Neodymium Corr(a)	Cesium Exp.	Cesium Corr(a)	Xenon Exp.	Xenon Corr(a)	Plutonium Exp.	Plutonium Corr(a)	Uranium Exp.	Uranium Corr(a)	Am Exp.	Tc Exp.	Ru Exp.
			Measured and Corrected Elemental Concentrations, wt% of fuel												
0	0	42.17	0.45	0.444	0.34	0.284	0.49	0.545	0.77	0.778	88.96	85.292	0.00	0.42	0.92
1	83	42.17	0.44	0.444	0.33	0.284	0.57	0.586	0.74	0.768	39.26	85.580	0.02	0.38	0.88
2	263	42.167	0.44	0.444	0.30	0.258	0.50	0.514	0.76	0.788	88.58	84.928	0.04	0.38	0.90
3	443	39.141	0.41	0.414	0.25	0.215	0.53	0.545	0.72	0.747	86.63	83.058	0.00	0.36	0.86
4	630	42.167	0.44	0.444	0.33	0.284	0.51	0.525	0.67	0.695	88.38	84.736	0.00	0.37	0.81
5	807	42.167	0.44	0.444	0.30	0.258	0.50	0.514	0.76	0.788	87.36	83.758	0.00	0.39	0.91
6	987	38.132	0.40	0.404	0.30	0.258	0.53	0.545	0.74	0.768	87.24	83.643	0.00	0.36	0.88
7	1169	39.141	0.41	0.414	0.31	0.267	0.50	0.514	0.72	0.747	86.09	82.541	0.00	0.29	0.86
8	1349	40.150	0.42	0.424	0.34	0.292	0.51	0.525	0.76	0.788	88.45	84.803	0.01	0.40	0.90
9	1525	39.141	0.41	0.414	0.27	0.232	0.54	0.556	0.76	0.788	87.94	84.314	0.02	0.37	0.90
10	1705	41.158	0.43	0.434	0.34	0.292	0.57	0.586	0.76	0.788	88.56	84.909	0.01	0.38	0.91
11	1885	41.158	0.43	0.434	0.35	0.301	0.58	0.597	0.76	0.788	88.54	84.890	0.02	0.41	0.91
12	2064	45.194	0.47	0.474	0.31	0.267	0.56	0.576	0.81	0.840	88.98	85.312	0.01	0.42	0.97
13	2245	40.150	0.42	0.424	0.28	0.241	0.55	0.566	0.77	0.799	87.95	84.324	0.02	0.37	0.92
14	2425	43.176	0.45	0.454	0.31	0.267	0.57	0.586	0.80	0.830	87.77	84.151	0.03	0.38	0.95
15	2606	41.158	0.43	0.434	0.32	0.275	0.56	0.576	0.79	0.820	87.72	84.104	0.02	0.40	0.95
16	2789	40.150	0.42	0.424	0.32	0.275	0.57	0.586	0.76	0.788	88.00	84.372	0.03	0.38	0.91
17	2965	44.185	0.46	0.464	0.34	0.292	0.59	0.607	0.79	0.820	87.72	84.104	0.00	0.40	0.94
18	3148	42.167	0.44	0.444	0.29	0.249	0.60	0.617	0.79	0.820	87.89	84.267	0.04	0.38	0.95
19	3327	46.203	0.48	0.484	0.35	0.301	0.62	0.638	0.80	0.830	88.33	84.688	0.03	0.40	0.95
20	3507	42.167	0.44	0.444	0.33	0.284	0.61	0.628	0.76	0.788	87.06	83.471	0.01	0.37	0.91
21	3687	42.167	0.44	0.444	0.29	0.249	0.58	0.597	0.79	0.820	86.25	82.694	0.01	0.34	0.95
22	3945	44.185	0.46	0.464	0.35	0.301	0.61	0.628	0.82	0.851	87.45	83.845	0.04	0.35	0.98
23	4122	48.220	0.50	0.505	0.35	0.301	0.66	0.679	0.87	0.902	86.84	83.260	0.00	0.33	1.04
24	4300	43.176	0.45	0.454	0.31	0.267	0.66	0.679	0.85	0.882	84.32	80.844	0.00	0.32	1.02
25	4482	46.203	0.48	0.484	0.35	0.301	0.66	0.679	0.99	1.027	83.62	80.173	0.05	0.32	1.17
26	4556	51.247	0.53	0.535	0.38	0.327	0.68	0.700	1.08	1.120	84.10	80.633	0.03	0.29	1.28
27	4632	51.247	0.53	0.535	0.44	0.378	0.67	0.689	1.27	1.317	82.73	79.319	0.08	0.26	1.51
28	4707	62.344	0.64	0.646	0.48	0.413	0.60	0.617	1.58	1.639	81.89	78.514	0.08	0.32	1.87
29	4782	70.415	0.72	0.727	0.51	0.439	0.45	0.463	2.16	2.241	79.79	76.500	0.12	0.29	2.54

(a) Experimental values were corrected for apparent differences between bulk averages from EPMA and those based on bulk average using the known burnup of 44.3 MWd/kgM and data in Appendix D. Corrections are 0.991 for Nd, 1.163 for Cs, 0.972 for Xe, 0.964 for Pu, and 1.043 for U. EPMA values for UO_2 were converted to U concentrations using 0.8814 gU/gUO_2. PuO_2 was converted to Pu concentrations using 0.8828 $gPu/gPuO_2$.

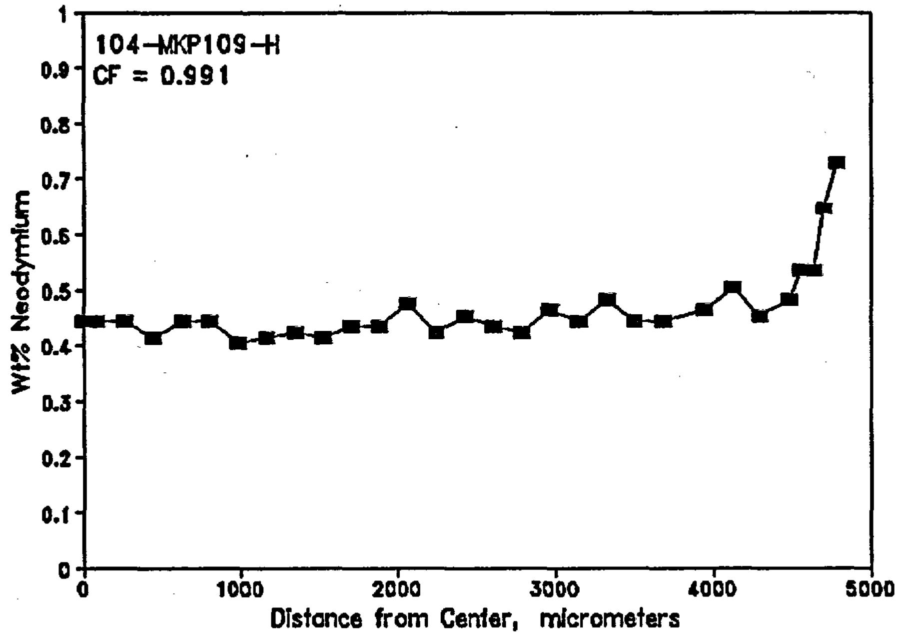


FIGURE F.1. Radial Profile of Neodymium in Sample 104-MKP109-H

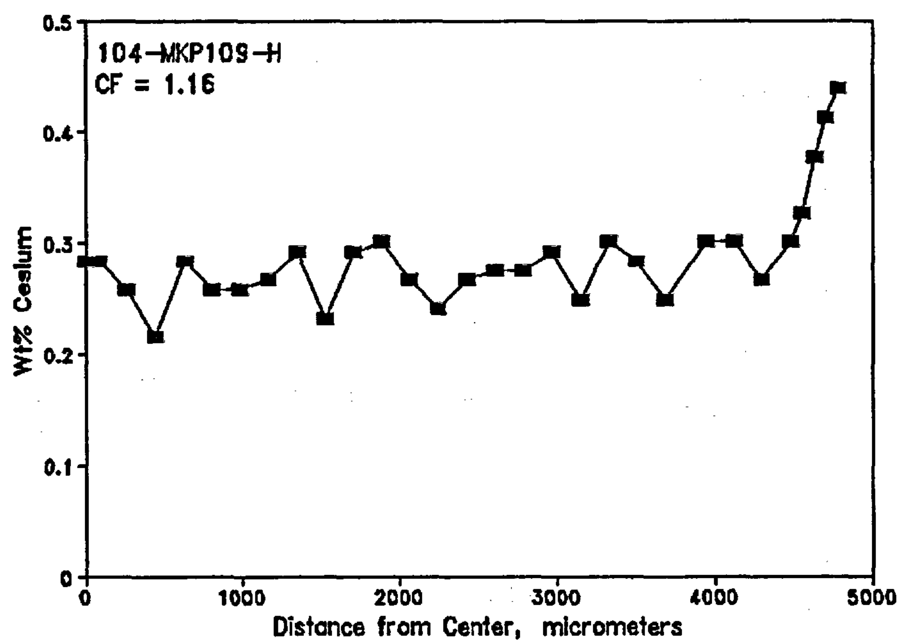


FIGURE F.2. Radial Profile of Cesium in Sample 104-MKP109-H

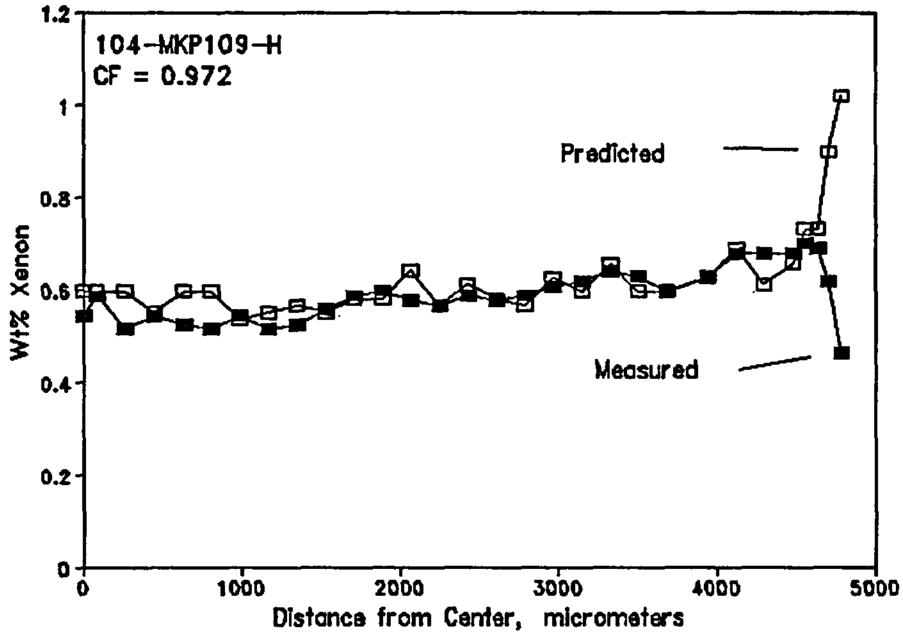


FIGURE F.3. Radial Profile of Xenon in Sample 104-MKP109-H

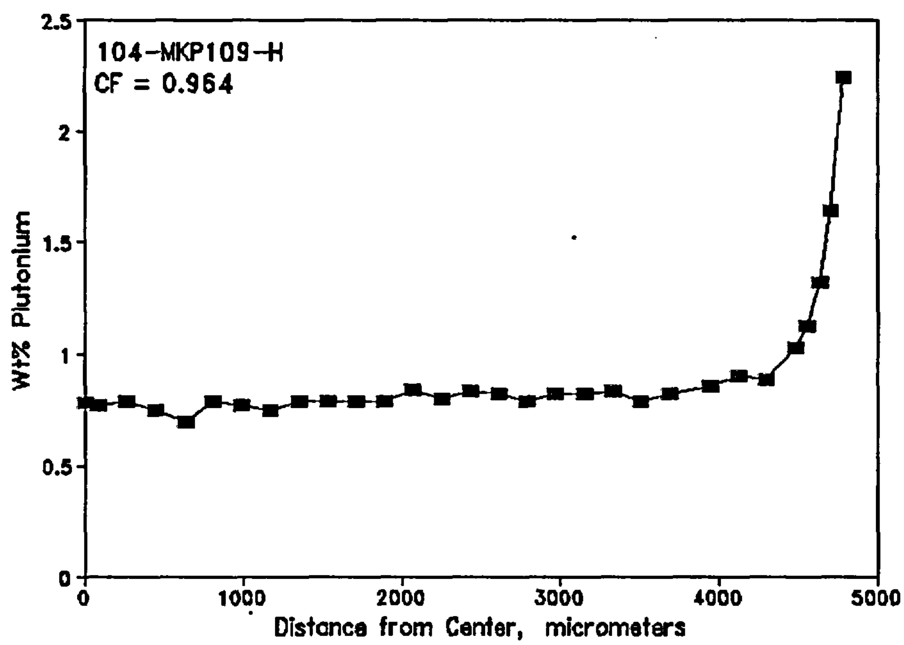


FIGURE F.4. Radial Profile of Plutonium in Sample 104-MKP109-H

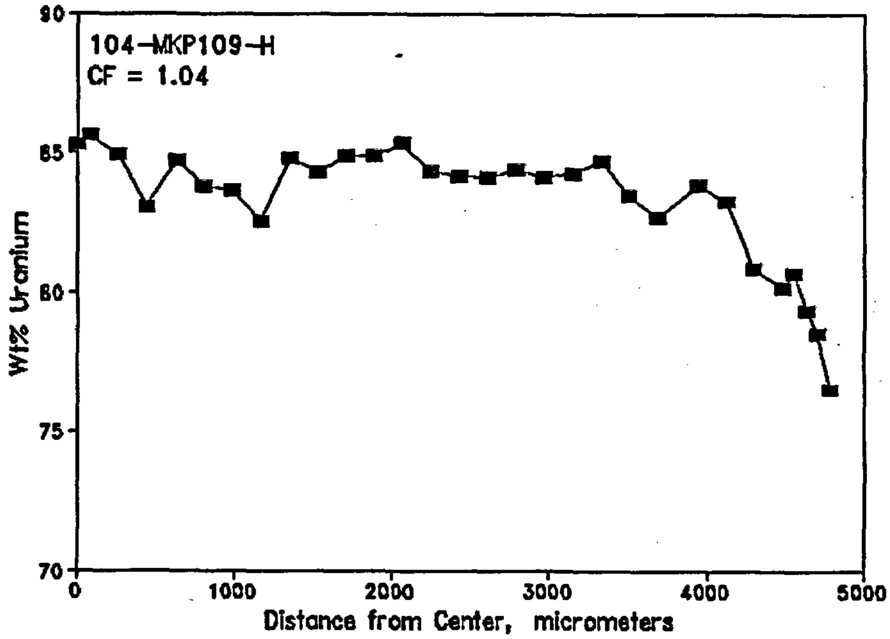


FIGURE F.5. Radial Profile of Uranium in Sample 104-MKP109-H

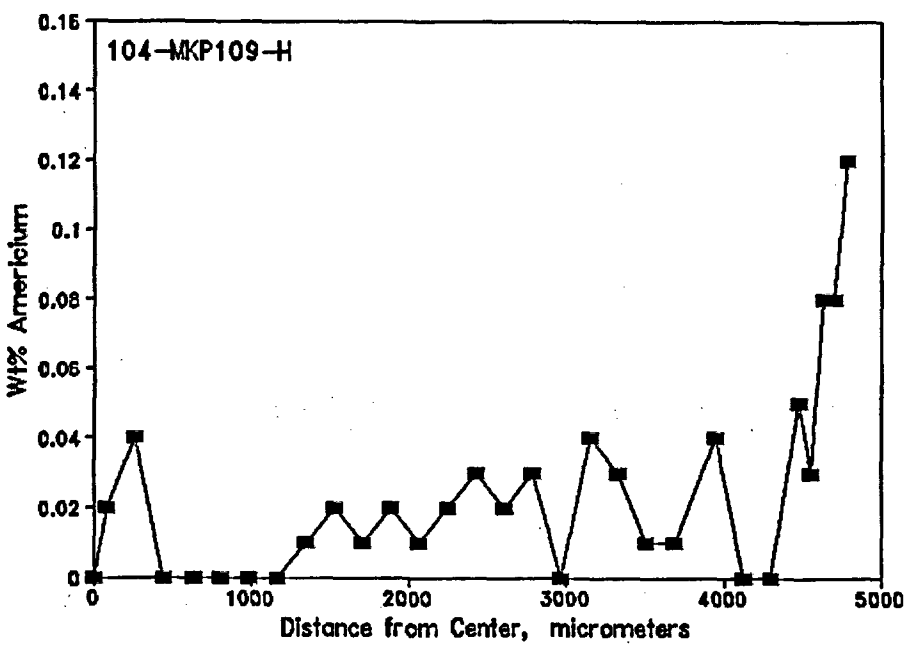


FIGURE F.6. Radial Profile of Americium in Sample 104-MKP109-H

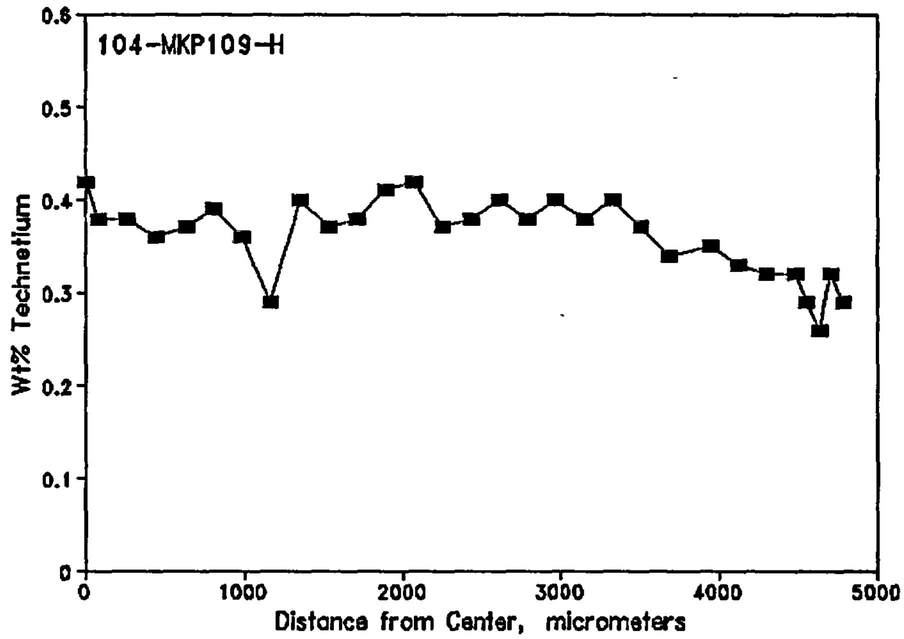


FIGURE F.7. Radial Profile of Technetium in Sample 104-MKP109-H

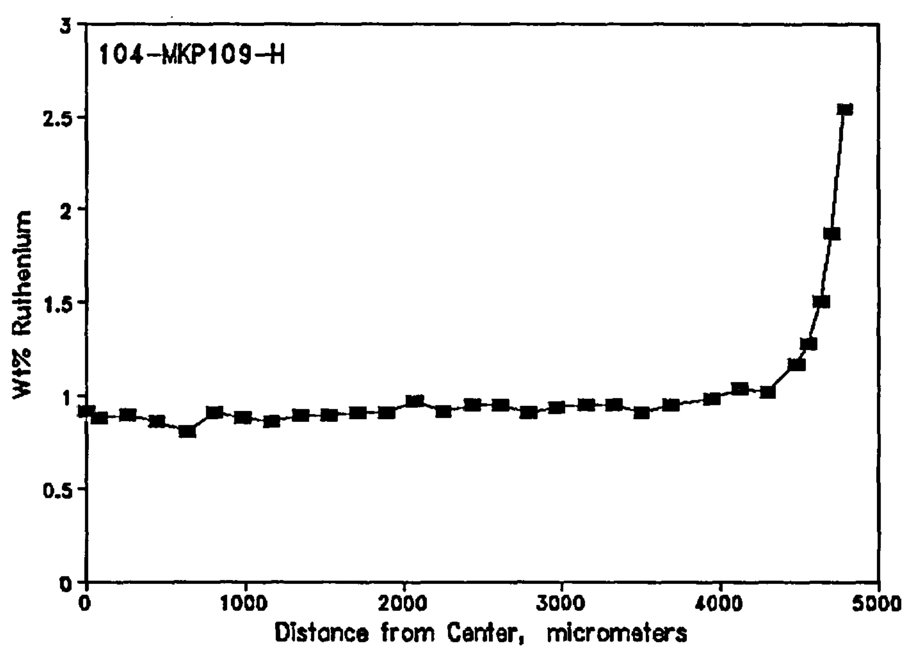


FIGURE F.8. Radial Profile of Ruthenium in Sample 104-MKP109-H

Because the concentration of neodymium is indicative of the fuel burnup, the neodymium profile can be converted to a radial burnup profile as shown in Figure F.9. The radial burnup profile was obtained by using the corrected EPMA data given in Table F.1 and the burnups associated with the neodymium values predicted by ORIGEN2 in Appendix D.

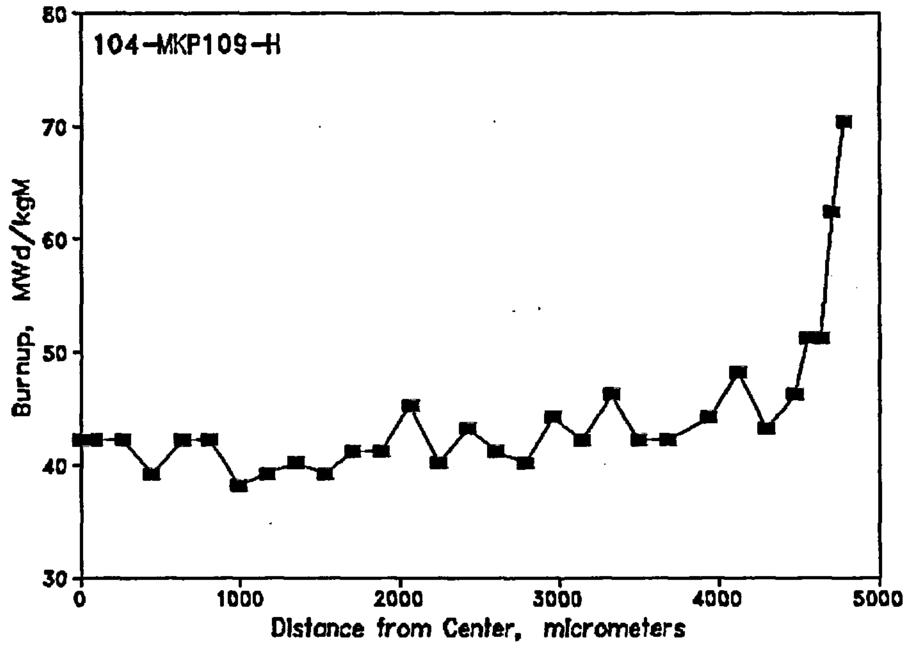


FIGURE F.9. Radial Burnup Profile in Sample 104-MKP109-H with a Pellet-Average Burnup of 44.3 MWd/kgM

APPENDIX G

FISSION GAS SAMPLING

APPENDIX G

FISSION GAS SAMPLING

OPERATING PROCEDURE

There are three objectives for fission gas sampling operations. The first objective is to collect the fission gas from the fuel rods for analysis without contaminating the sample. The other two objectives are to determine the volume of fission gas present in the fuel rod and to determine the fuel rod void volume. To accomplish these objectives a system of leak-tight piping, valves, and calibrated flasks connected to vacuum pumps was fabricated. This system (referred to as the fission gas sample cart) is located in the operating gallery or the "cold" side of the hot cell facility. Piping runs from this cart to a wall plug that extends through the wall of the hot cell. All operations of the system are carried out with a partial vacuum using the current procedure. The top of the fuel rod is inserted into the machined "head" with a flange which, when clamped to the other end of the wall plug, makes a leak-tight connection between the fuel rod and the fission gas sample cart (Figure G.1).

The entire system is evacuated by vacuum pumps to the lowest pressure obtainable, as indicated by a Baratron® gauge. This pressure is usually less than 10^{-1} mm Hg. The system is purged with argon and re-evacuated to remove residual air or other contaminants. The valve to the vacuum pumps is closed, and the readout on the pressure gauge is observed for at least 1 min to determine whether there are any leaks in the system. If no leaks are indicated, the valves to all of the calibrated flasks are closed and fission gas sampling can be conducted. A laser is used to make a small hole in the fuel rod by focusing the laser to a pinhole-sized beam to breach the cladding. The fission gas flows into the evacuated sample cart system. Valves to the calibrated flasks are opened until the Baratron gauge is on scale. This pressure, referred to as the system pressure P_s, is recorded. Valves are

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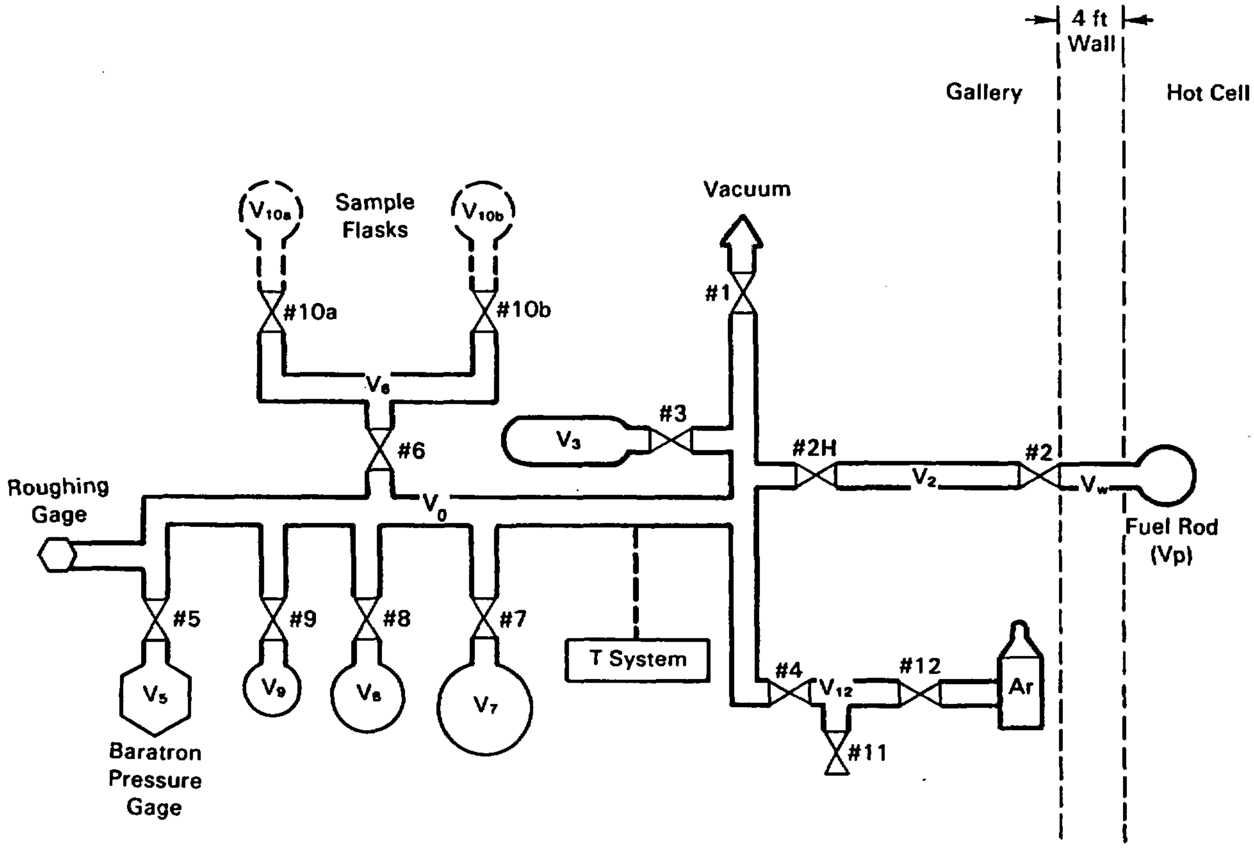

FIGURE G.1. Schematic of Fission Gas Sampling System

then opened to the evacuated analytical sample flasks (to obtain the samples for analysis). Two samples are taken in case the fission gas analysis needs to be repeated. The valves to these flasks are closed and the entire system is again evacuated to remove residual fission gas in the rod. The sample flasks are removed from the cart and transferred to the analytical lab.

FUEL ROD VOID VOLUME

After the fuel rod gas is collected, the fuel rod void volume is determined. The entire piping system is evacuated. Then the valves to the evacuated calibrated flasks are closed, and the fission gas system piping and the fuel rod are pressurized with argon. The argon is permitted to flow into the fuel rod until equilibrium is reached (as indicated by no change in pressure on the Baratron gauge). This pressure is recorded, and the valve to one of the calibrated flasks is opened. When a second equilibrium is reached, the void volume calculation can be completed. The fuel rod void volume is calculated from Boyle's law:

$$Vp = \frac{(P_2)\ (V_s) + P_2\ (V_x) - P_1\ (V_s)}{P_1 - P_2}$$

where: P_1 = first pressure reading, mm Hg
P_2 = second pressure reading, mm Hg
V_s = volume of fission gas system piping ($V_o + V_2 + V_w$), cm^3
V_x = volume of selected calibrated flask, cm^3
v_p = fuel rod void volume, cm^3.

QUANTITY OF GAS COLLECTED

Once V_p has been determined, the number of moles of gas collected from the fuel rod can be determined according to the ideal gas law.

$$n = \frac{(P_s)\ (\Sigma V\ )_i}{(62360)\ \ (273 + T)}$$

where: P_s = system pressure recorded after fuel rod puncture, mm Hg
T = system temperature, °C
ΣV_i = volume of system piping (V_s plus V_p plus volume of all calibrated flasks opened to obtain P_s)
n = moles of gas
62360 = gas low constant in appropriate units.

Because V_p is a very small value compared with the other volumes used to determine ΣV_i, normal errors in V_p have only a minor effect on the values reported for n.

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