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NUCLEAR WASTE PROJECTIONS AND
SOURCE-TERM DATA FOR FY 1977

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April 26, 1978

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OFFICE OF WASTE ISOLATION
OAK RIDGE, TENNESSEE

*prepared for the U.S. DEPARTMENT OF ENERGY under
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FOREWORD

This report was prepared by staff members of the Office of Waste Isolation with assistance from the UCC-ND Operations Analysis and Planning Division and is part of the National Waste Terminal Storage (NWTs) Program. The principal objective of the NWTs Program is to establish facilities, or repositories, in various deep geologic formations at several locations in the United States which will safely dispose of commercial radioactive waste.

Projections of the commercial radioactive waste from nuclear power generation are vital in planning and designing waste repositories and in assessing the potential environmental effects of the stored waste. In satisfying the need for a coherent waste projection data base, this waste projection study provides OWI with precise fuel cycle data in support of all projects associated with program planning, system studies, and repository design. This report documents the waste projection and source-term data distributed to OWI project managers and contractors during fiscal year 1977.

ABSTRACT

A description of the light-water reactor (LWR) fuel cycle and the nature of the radioactive wastes is basic to the design and evaluation of terminal waste repositories. For these projections, the fuel cycle is represented as a typical system of operations related to the back end of the LWR fuel cycle. Wastes, as prepared for disposal, are described in terms of form, volume, radioactivity, heat generation, and weight. To obtain these waste projections, three fuel management computer codes were used: ORIGEN, KWIKPLAN, and WASPR. A brief description of these codes and their usage is included. Also included are descriptions of the containers assumed to be used for the handling and geologic disposal of the various waste types. The principal purpose of the report is to document the data generated for the Office of Waste Isolation (OWI) and its subcontractors.

Projections of LWR fuel cycle wastes are based on OWI modification of the ERDA "mid-case" forecast of 1976 for nuclear power growth in the United States.¹ In this case, the installed nuclear electric capacity rises from a nominal 50 GW(e) in year 1977 to a nominal 480 GW(e) in the year 2000. The power reactor grid is assumed to consist entirely of LWRs.

The four basic fuel cycle scenarios considered follow the same growth curve. These fuel cycles range from spent unprocessed fuel (SURF) through full recycle of both uranium and plutonium. The overall objective is to compare the impacts of the alternative fuel cycles rather than to describe the impacts of reactor growth scenarios or the use of raw materials for power generation.

1. INTRODUCTION

Projections of the quantity, radioactivity, and heat generation of radioactive waste from commercial nuclear electric power generation are required for the design and sizing of waste disposal facilities and equipment and for evaluating the environmental impact of waste management activities. Several waste projections have been published previously.²⁻⁴ However, because of changes in fuel cycle strategies, the need for more comprehensive data than were previously available, and the need for consistent data (based on a common set of assumptions), a new set of waste projections has been developed. These projections, generated for use by the Office of Waste Isolation (OWI) and its sub-contractors, are presented in this report. These waste projections were coordinated with, and based on, work done by J. O. Blomeke of Oak Ridge National Laboratory (ORNL).

The waste projection data available from this report are of two types: source term [based on 1 metric ton of heavy metal (MTHM) charged to the reactor] and fuel cycle waste generation. Typical source-term data are decay heat generation rates, radioactivity, mass, and photon spectra. These data are given as a function of decay time for different waste types. The waste generation data are volume, mass, heat, and radioactivity for each waste type produced per year in the United States as a function of the nuclear electric generation forecast.

The forecast used for the OWI projections produces a nominal 480 GW(e) of commercial nuclear power in the year 2000. This amount was derived from the "mid-case" forecast of nuclear power growth in the United States developed in 1976 by the ERDA Office of the Assistant Administrator for Planning and Analysis¹ by dropping all fast breeder reactor contributions and converting all high temperature gas-cooled reactors (HTGRs) to light-water reactors (LWRs). The resulting forecast projected 478.1 GW(e) at year 2000 assuming approximate nuclear kilowatt-hour growth rates of 5.8% per year through 1985 and of 4.5% per year through 2000 (see Table 1.1 and Fig. 1.1). This projection uses essentially all the presently estimated uranium resources* at reasonable

*Current estimates of U.S. uranium resources range between 1.8 and 3.7 million tons (U_3O_8).⁵

Table 1.1 Projected Nuclear Generating Capacity, GW(e)

(Valid for all fuel cycles considered)

Year	PWR ^a	BWR ^b	Total	Year	PWR ^a	BWR ^b	Total
1963	0.0	0.0	0.0	2003	318.5	159.6	478.1
1964	0.0	0.0	0.0	2004	318.5	159.6	478.1
1965	0.4	0.3	0.7	2005	318.1	159.3	477.4
1966	0.6	0.4	1.0	2006	317.9	159.2	477.1
1967	0.9	0.5	1.4	2007	317.6	159.1	476.7
1968	1.2	0.8	2.0	2008	317.3	158.8	476.1
1969	1.8	1.2	3.0	2009	316.7	158.4	475.1
1970	2.5	2.5	5.0	2010	316.0	157.1	473.1
1971	4.0	4.0	8.0	2011	314.5	155.6	470.1
1972	4.5	5.5	10.0	2012	314.0	154.1	468.1
1973	7.0	8.0	15.0	2013	311.5	151.6	463.1
1974	10.0	13.0	23.0	2014	308.5	146.6	455.1
1975	16.6	15.5	32.1	2015	301.9	144.1	446.0
1976	27.4	16.6	44.0	2016	291.1	143.0	434.1
1977	32.0	17.5	49.5	2017	286.5	142.1	428.6
1978	38.2	17.5	55.7	2018	280.3	142.1	422.4
1979	41.8	18.3	60.1	2019	276.7	141.3	418.0
1980	46.0	22.1	68.1	2020	272.5	137.5	410.0
1981	52.0	26.7	78.7	2021	266.5	132.9	399.4
1982	61.7	28.8	90.5	2022	256.8	130.8	387.6
1983	73.0	32.9	105.9	2023	245.5	126.7	372.2
1984	87.0	39.7	126.7	2024	231.5	119.9	351.4
1985	97.5	48.9	146.4	2025	221.0	110.7	331.7
1986	110.8	55.6	166.4	2026	207.7	104.0	311.7
1987	124.1	62.3	186.4	2027	194.4	97.3	291.7
1988	138.1	69.3	207.4	2028	180.4	90.3	270.7
1989	152.8	76.6	229.4	2029	165.7	83.0	248.7
1990	166.9	83.6	250.5	2030	151.6	76.0	227.6
1991	182.2	91.3	273.5	2031	136.3	68.3	204.6
1992	197.5	99.0	296.5	2032	121.0	60.6	181.6
1993	213.5	107.0	320.5	2033	105.0	52.6	157.6
1994	229.5	115.0	344.5	2034	89.0	44.6	133.6
1995	245.5	123.0	368.5	2035	73.0	36.6	109.6
1996	260.9	130.6	391.5	2036	57.6	29.0	86.6
1997	275.5	138.0	413.5	2037	43.0	21.6	64.6
1998	290.1	145.4	435.5	2038	28.4	14.2	42.6
1999	304.8	152.7	457.5	2039	13.7	6.9	20.6
2000	318.5	159.6	478.1	2040	0.0	0.0	0.0
2001	318.5	159.6	478.1	2041	0.0	0.0	0.0
2002	318.5	159.6	478.1				

^aPWR = pressurized-water reactor.^bBWR = boiling-water reactor.

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Figure 1.1 Projected nuclear operating capacity through year 2000. Decommissioning of reactors built through year 2000 is represented by the dashed curve.

production cost and enrichment capabilities. Each reactor scheduled in this projection was assumed to have a 40-year life following initial start-up. Because of the arbitrary uranium resource limitation, no reactors were assumed to be started after year 2000; the remaining reactors were allowed to finish their 40-year life before being decommissioned. (This latter assumption accounts for the generating capacity and waste production beyond year 2000.) However, notice should be taken that any reactors started after year 2000 could be readily superimposed on this forecast. To facilitate comparisons, the OWI forecast has been applied to all the fuel cycle alternatives covered in this report.

2. FUEL CYCLES

The fuel cycle for commercial nuclear power reactors can be operated to include recovery of uranium and plutonium from spent fuel so that these energy resources can be used in new fuel elements and recycled to the power reactors. The fuel cycle can also be operated so that neither of these materials is recovered and recycled or so that either of them is recycled. Therefore, numerous alternatives are available for the back end of the nuclear fuel cycle. The technologies used and the recycle scheme selected will affect the quantities and types of wastes generated. Holdup times (e.g., storage time for spent fuel prior to reprocessing) will also affect waste quantities to be managed at any time and logistical factors such as capacity of waste storage facilities. Consequently, waste management requirements are highly dependent on how the back end of the fuel cycle is operated. The basic fuel cycle/operating modes considered are represented in the following sections:

- 2.1 Spent Unreprocessed Fuel
- 2.2 Total Recycle (Plutonium and Uranium)
- 2.3 Partial Recycle (Uranium Only)
- 2.4 Fresh Uranium (Reprocessing with No Current Recycle)

The HTGR, liquid-metal fast-breeder reactor (LMFBR), and thorium dilution fuel cycles are not treated in any of these fuel cycle scenarios.

2.1 Spent Unreprocessed Fuel

The spent unreprocessed fuel (SURF) cycle is also referred to as the once-through fuel cycle or the throwaway fuel cycle. ERDA is currently emphasizing long-term storage and possible disposal of spent fuel.⁶ Spent nuclear fuel is discharged from a reactor and is stored in a water basin at the discharging reactor for an interim period of time. The spent fuel is then transported from the reactor either to a federal repository for storage or disposal or to an interim storage facility. The assumption is made that if additional interim storage of spent fuel is selected, the spent fuel may be encapsulated at the storage facility

and, after this interim storage period, may be transferred to a federal repository for terminal storage. In any event, the spent fuel assemblies are assumed to be received at the repository ten years after being discharged from the reactor.

The wastes generated by this fuel cycle which requires terminal storage at a federal repository are essentially limited to encapsulated spent fuel along with an amount of low-level waste generated by spent fuel handling and transportation operations and by decommissioning of facilities. The spent fuel cycle is shown diagrammatically in Fig. 2.1, and descriptions of the wastes generated are given in Sect. 4.1 and 4.7.

2.2 Total Recycle (Plutonium and Uranium)

Since the inception of the commercial nuclear power generation industry, the recycle of both uranium and plutonium has been the reference LWR fuel cycle. This fuel cycle consists of chemically reprocessing spent nuclear fuels to recover uranium and plutonium. The recovered uranium is then reenriched in ^{235}U , fabricated into fresh nuclear fuel, and returned to reactors for the production of more electrical power. The recovered plutonium is converted to plutonium dioxide, mixed with uranium dioxide, fabricated into fresh fuel, and also returned to reactors for the production of more electrical power. This fuel is often referred to as mixed oxide (MOX) fuel.

The radioactive transuranic-contaminated wastes generated by complete recycle are diverse in nature and are the results of (1) the operation of nuclear fuel processing and reprocessing plants, (2) reactor operations, (3) the operation of plutonium nitrate-to-plutonium oxide conversion facilities, (4) the operation of plutonium fuels fabrication facilities, and (5) support activities such as transportation, storage, and decommissioning of major facilities. The flowsheet for total recycle is shown in Fig. 2.2, and descriptions of the wastes generated [high-level waste (HLW), cladding waste (CW), intermediate-level transuranic waste (IL-TRU), and low-level transuranic waste (LL-TRU)] are given in Sect. 4.2, 4.5, 4.6, and 4.7.

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Figure 2.1 Spent unprocessed fuel cycle (SURF) flow diagram.

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Figure 2.2 Full recycle (uranium and plutonium) fuel cycle flow diagram.

2.3 Partial Recycle (Uranium Only)

Partial recycle consists of chemically reprocessing spent nuclear fuel for the recovery of uranium. The recovered uranium is reenriched in ^{235}U , fabricated into fresh nuclear fuel, and returned to a reactor as fuel for the generation of additional power. The plutonium content of the spent nuclear fuel is allowed to leave the reprocessing facility as either a component of the HLW or a product for separate storage.

The nuclear wastes generated by this fuel cycle which require terminal storage at a federal repository consist primarily of those wastes generated by the operations of the fuel processing and reprocessing facilities, but they also include those wastes generated by support activities such as transportation and facility decommissioning. The flowsheet for uranium recycle with the plutonium included as a component of the HLW as shown in Fig. 2.3. The flowsheet for uranium recycle with the plutonium held in separate storage (e.g., at the surface) is shown in Fig. 2.4. The descriptions of wastes generated from these cycles are given in Sect. 4.2 through 4.7.

2.4 Fresh Uranium (Reprocessing with No Current Recycle)

During the period from initiation of reprocessing until the first spent fuel from either recycled uranium or plutonium is reprocessed, a subfuel cycle occurs which can be characterized as the fresh uranium fuel cycle. This subcycle has been included in both the total and partial recycle options discussed above. Its inclusion at this point is to indicate the impact of the generation and extended storage of the separated plutonium and uranium, prior to recycle, on HLW and ILW. Numerous scenarios can be envisioned for this extended storage, or subcycle, ranging from the separation of volatile fission products from spent fuel (through reprocessing) prior to disposal of the remaining fission products to long-term storage of separated uranium and plutonium while awaiting the development of an advanced technology for nuclear energy conversion. The flowsheet for the subfuel cycle is shown in Fig. 2.5, and the wastes generated are described in Sects. 4.2 and 4.4 to 4.7.

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Figure 2.3 Partial recycle (uranium only) fuel cycle with plutonium isolated in the high-level waste.

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Figure 2.4 Partial recycle (uranium only) fuel cycle with plutonium stored separately.

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Figure 2.5 Fresh uranium fuel cycle (reprocessing with no current recycle) with plutonium stored separately.

3. WASTE PROJECTION CODES AND CHARACTERISTICS

This section describes the basic computer codes and assumptions used in generating the OWI waste projections.

3.1 Reactor Characteristics

The physical and operational characteristics of the reference LWR were taken from PWR and BWR standard safety analysis reports.^{7,8} Table 3.1 displays the fuel-cycle-related fundamental characteristics for middle-of-reactor-life mass flows. Where applicable, the isotopic buildup and depletion of LWRs is based on charge and discharge data⁹ given for the following isotopes:

<u>Uranium</u>	<u>Neptunium</u>	<u>Plutonium</u>	<u>Americium</u>	<u>Curium</u>
²³⁴ U	²³⁷ Np	²³⁸ Pu	²⁴¹ Am	²⁴² Cm
²³⁵ U	²³⁹ Np	²³⁹ Pu	²⁴² Am	²⁴³ Cm
²³⁶ U		²⁴⁰ Pu	²⁴³ Am	²⁴⁴ Cm
²³⁸ U		²⁴¹ Pu		
		²⁴² Pu		

The lifetime of an individual reactor is assumed to be 40 years with on-line capacity factors as follows:²

<u>Year of Operation</u>	<u>Capacity Factor (%)</u>
1	40
2-3	65
4-15	70
16-40	Declines 2% per year to 40%

Refueling is assumed to take place annually with approximately one-third and one-fourth of the core completely replaced for PWRs and BWRs, respectively. Each fuel assembly is assumed to contain 461.4 kg of heavy metal for the PWR and 183.3 kg of heavy metal for the BWR.^{7,8} For LWRs using MOX fuels, the percentage of fuel assemblies that are plutonium enriched is 35.1% and 37.9% for PWRs and BWRs, respectively.

Table 3.1. Assumed Characteristics of Light-Water Reactors^a

	PWR-U	PWR-Pu			BWR-U	BWR-Pu		
		U fraction	Pu fraction	Total		U fraction	Pu fraction	Total
Electric power, MW(e)	1250	811	439	1250	1250	776	474	1250
Thermal power, MW(t)	3800	2465	1335	3800	3800	2359	1441	3800
Avg. specific power, ^b MW(t)/ton heavy metal	37.5	37.5	37.5	37.5	25.9	25.9	25.9	25.9
Avg. fuel burnup, MWd/ton heavy metal	33,000	33,000	33,000	33,000	27,500	27,500	27,500	27,500
Irradiation duration, full-power days	880	880	880	880	1062	1062	1062	1062
Steady-state charge, kg								
²³⁵ U	1081	701	81	782	943	585	95	680
Total U	33,778	21,915	11,323	33,238	36,680	22,771	13,364	36,135
Fissile Pu ^c	0	0	345	345	0	0	338	338
Total Pu ^d	0	0	539	539	0	0	546	546
Total heavy metal	33,778	21,915	11,862	33,777	36,680	22,771	13,910	36,681
Steady-state discharge, kg								
²³⁵ U	272	176	37	213	244	151	46	197
Total U	32,261	20,931	11,031	31,962	35,278	21,901	13,077	34,978
Fissile Pu ^c	222	144	201	345	220	137	201	338
Total Pu ^d	316	205	378	583	315	196	389	585
Total (U + Pu)	32,577	21,136	11,409	32,545	35,593	22,097	13,466	35,563

^aSource (except for enrichment data): Kee, C. W.; Croff, A. G.; and Blomeke, J.O.; Updated Projections of Radioactive Wastes to Be Generated by the U. S. Nuclear Power Industry, Oak Ridge National Laboratory, ORNL/TM-5427, Table 2.1, p. 7 (December 1976). Data in this table are based upon middle-of-life mass flows only.

^bBased upon full power and fuel charged.

^c²³⁹Pu + ²⁴¹Pu.

^d²³⁸Pu + ²³⁹Pu + ²⁴⁰Pu + ²⁴¹Pu + ²⁴²Pu.

Fuel assembly structural materials for LWRs are comprised of Zircaloy, stainless steel, Inconel, and other miscellaneous materials that constitute the structural components of a fuel assembly and the fuel pin cladding. For reprocessing cycles, these materials remain in the fuel dissolver after the fuel itself has been completely dissolved. Although their radioactivity arises mainly from neutron-induced isotopes, the structural materials are similar in some respects to HLW in that they are assumed to (1) contain up to 0.05% of the actinides and fission products originally in the spent fuel, (2) need biological shielding equivalent to several inches of lead, and (3) have heat generation rates of 1 to 50 W/ft³.

The mass, composition, and assumed exposure of the residual structural materials from 1 metric ton of PWR and BWR fuel are summarized in Table 3.2. The percentage exposure reflects the fact that the structural material, which is not in close proximity to the fuel itself (e.g., the stainless steel end fittings), is exposed to a reduced flux level as compared to the cladding. This distance results in less activation of these components.

3.2 Fuel Management Computer Codes

To obtain the waste projections and source terms, three fuel management computer codes were used: ORIGEN,¹⁰ KWIKPLAN,¹¹ and WASPR. These codes are currently maintained by J. O. Blomeke's staff at ORNL. The individual code interactions and input/output requirements pertinent to this analysis are illustrated in Fig. 3.1. Through the use of the computer code network, the tables representing an accumulated total of waste data at a federal waste repository were obtained (see Appendix). The tables that characterize each specific fuel cycle are based on separate ORIGEN runs.

3.2.1 ORIGEN

The ORIGEN program is a versatile point depletion code that solves the equations of radioactive growth and decay for large numbers of isotopes through arbitrary coupling. In modeling this radioactive

Table 3.2 Mass, Composition, and Exposure
of Fuel Assembly Structural Materials ^a

Structural material	Pressurized-water reactor		Boiling-water reactor	
	Mass ^b (kg/MTHM) ^c	Percentage exposure ^d	Mass ^e (kg/MTHM)	Percentage exposure ^d
Zircaloy	235.0	100	316.0	100
302 SS	4.2	60	0	
304 SS	37.1	40	50.0	50
316 SS	0		0	
Inconel	12.8	100	3.4	100
Microbrazed 50	2.6	100	0	
Total	291.7		369.4	

^aSource: Kee, C. W.; Croff, A. G.; and Blomeke, J. O.; Updated Projections of Radioactive Wastes to Be Generated by the U.S. Nuclear Power Industry, Oak Ridge National Laboratory, ORNL/TM-5427, Table 4.20, p. 42 (December 1976).

^bKilp, G. R., Westinghouse Electric Corporation, Nuclear Fuel Division, Pittsburgh, Pennsylvania, personal communication to J. O. Blomeke, ORNL, December 19, 1975.

^cMTHM = metric ton of heavy metal.

^dU.S. Energy Research and Development Administration, Alternatives for Managing Wastes from Reactors and Post-Fission Operations in the LWR Fuel Cycle, ERDA-76-43, Vol. 2, Chap. 7.0 (May 1976).

^eM. O. Marlowe, General Electric Company, San Jose, California, personal communication to J. O. Blomeke, ORNL, February 18, 1976.

Figure 3.1 Waste projection code input/output diagram.

growth and decay, ORIGEN uses the matrix exponential method to solve the coupled, linear, first-order ordinary differential equations with constant coefficients. To run the ORIGEN code, an extensive library of nuclear data is required, including half-lives and decay schemes, neutron adsorption cross sections, fission yields, and disintegration energies. The latest nuclear data libraries are used. With respect to the present analysis, the ORIGEN code was used to model an equilibrium fuel cycle for each specific reactor type, from the time the fuel is charged through its discharge and subsequent decay. All the information obtained from these runs was based on a metric ton of heavy metal initially charged to a reactor.

A more detailed explanation of the ORIGEN code is given in the report, *ORIGEN - The ORNL Isotope Generation and Depletion Code*.¹⁰

3.2.2 KWIKPLAN

The KWIKPLAN code is used to model the annual fuel cycle throughputs associated with a given projection of nuclear power generation. The user provides various input requirements such as the types of reactors to be used, the construction and operating schedule of each type, and the mass-balance history for each of these reactors over its operating lifetime. To convert the input mass balances, which are initially based on an 80% capacity factor, to actual charges and discharges at some other desired capacity factor, the refueling is assumed to continue to take place on an annual schedule, and the amounts of material charged and discharged are assumed to be proportional to the capacity factor. In this way, the capacity factor influences the quantity rather than the frequency of charges and discharges, thereby providing a method of accounting for the initial charges as well as for the decommissioning discharges. Once these input requirements have been properly coded, the program calculates the annual requirements for fuel fabrication, fuel reprocessing, uranium mining, and plutonium use and production. The mass balances are used to calculate the reprocessing load, fabrication load, fissile plutonium usage and production, and the enriched uranium usage. Through the use of an internal conversion scheme, the code also calculates the natural uranium mining requirements. In modeling a

nuclear power scenario in which plutonium recycle to LWRs is considered a viable alternative, the amount of plutonium recycled from a stockpile is defined by initially specifying the number of tons of plutonium to be recycled each year. In determining these figures, an important factor to note is that the plutonium discharged from the plutonium recycle cores is added to the stockpile at the time of reprocessing, which occurs 16 quarters later regardless of the reactor type (i.e., PWR, BWR).

In the foregoing analysis, reprocessing is limited by either the available reprocessing capacity (input requirement) or by the cumulative available reprocessing loads. Since MOX LWR fuels contain greater amounts of fissile plutonium, they were reprocessed preferentially to UO_2 fuels. The UO_2 fuels were reprocessed from backlog on a first-in, first-out basis since this procedure would allow reprocessing plants to work with older feedstocks during the earlier years of operation. However, in this particular case, the code considers all fuel to be delayed only one year following discharge regardless of its actual pre-reprocessing age. Manipulation of the reprocessing capacity limitations, however, made it possible to model the schedule for working off the backlog as previously indicated.

A detailed description of the KWIKPLAN code is provided in the report, *KWIKPLAN - A Computer Program for Projecting the Annual Requirements of Nuclear Fuel Cycle Operations*.¹¹

3.2.3 WASPR

The ORNL computer code WASPR is designed to calculate the volume, radioactivity, thermal power, isotopic composition, and toxicity of the various waste streams that result from a projected nuclear power economy. The waste streams that are of particular importance for this analysis are (1) spent fuel, (2) solidified HLW, (3) CW, (4) IL-TRU waste, and (5) LL-TRU waste. As input requirements, WASPR uses the following mass-flow data for each year of study: (1) annual mining requirements, (2) annual production and consumption rates of plutonium, (3) annual amounts of fuel fabricated for each reactor type, (4) annual amount of fuel reprocessed for each reactor type, (5) annual amount of fuel reprocessed at rated exposure, (6) the operating capacity, and (7) the

discharge composition of reactor fuel. These input requirements are generated by the ORIGEN and KWIKPLAN codes, as illustrated in Fig. 3.1. WASPR also requires input information that describes the specific waste characteristics (e.g., compaction factors, volume conversion factors, etc.) and establishes the process delay times (e.g., time from discharge to accumulation at the repository) associated with each scenario examined. The program uses these input requirements to produce tabular output in a form described by the user. ORIGEN subroutines are used to model the effects of radioactive decay during and after the waste stream accumulation.

4. WASTE CHARACTERISTICS, PROJECTIONS, AND CONTAINERS

Many important factors that concern waste management are in the evolutionary stages of development. Although extensive research and development work has been accomplished, little commercial plant operating experience exists from which reliable estimates of characteristics (such as waste volumes, specific waste material form, generation rates, and shipment schedules corresponding to spent fuel recycle flowsheets) can be derived. The principal characteristics of radioactive wastes from the nuclear fuel cycle, the factors that influence their generation, and the bases for projecting their future quantities were adopted from the previous work cited.^{2,3}

The radioactive waste resulting from nuclear reactor operation and from the reprocessing of irradiated reactor fuels may be enclosed in the appropriate container for the given waste type prior to geologic waste disposal. For this report, wastes were assumed to be packaged in either canisters or drums, depending on the waste form. A summary of the assumed waste characteristics and packages appears in Table 4.1. The calculated "equivalent fuel density [metric ton of uranium (MTU) container]" column refers to the mass of spent reactor fuel that will give rise to one full container of the respective waste.

4.1 Spent Unreprocessed Fuel

The annual refueling of a nuclear power plant involves the replacement of spent fuel assemblies with fresh fuel assemblies within the reactor core. Generally, one-third and one-fourth of the core is replaced annually for PWRs and BWRs, respectively, with each PWR fuel assembly containing 461.4 kg of heavy metal and each BWR fuel assembly containing 183.3 kg of heavy metal (plutonium and/or uranium charged to the reactor).^{7,8} In addition to the fission products, a large quantity of fertile and fissile actinides (principally uranium and plutonium) remains within these spent fuel assemblies. Consequently, significant amounts of decay heat and radioactivity are generated which are the source of safety concerns during transportation, handling, and disposal of spent fuel assemblies.

Table 4.1. Waste Characteristics and Reference Containers

Waste Type	Diameter (in.)	Length (ft)	Active Length (ft)	Volume (active)	Waste Generation Assumptions (ft ³ /MTHM)	Equiv. fuel density (MTU/container)	Plutonium (Kg)	Backfill	Container description
High-level solidified waste (glass)	12	10	8	6.28 ft ³ 0.178 m ³	3	2.09		5 psig helium	Stainless 304L
High-level solidified waste (calcine)	8	10	8	2.79 ft ³ 0.079 m ³	1.5	1.86		5 psig helium	Stainless 304L
High-level solidified waste with PuO ₂ (glass)	12	10	8	6.28 ft ³ 0.178 m ³	3	2.09	19.6 ^a	5 psig helium	Stainless 304L
High-level solidified waste with PuO ₂ (calcine)	8	10	8	2.79 ft ³ 0.079 m ³	1.5	1.86	17.5 ^a	5 psig helium	Stainless 304L
Cladding hulls	12	10	8	6.28 ft ³ 0.178 m ³	2.3 (PWR) 2.9 (BWR)	2.45		5 psig helium	Stainless 304L
Intermediate-level solid TRU	12	10	8	6.28 ft ³ 0.178 m ³	10,000 ^b	0.550		5 psig helium	
Low-level TRU	22.5	2.92		7.35 ft ³ 0.208 m ³	34,000 ^c maximum	0.220		None	55-gallon 17C or 17H drum
Spent fuel (PWR)	12.75 (ID)	16		2.8 ft ³ 0.08 m ³		0.461	4.22 3.06 (fiss)	5 psig helium	No metal matrix. Schedule 40, 14-in. pipe
Spent fuel (BWR)	8.5 (ID)	16		1.1 ft ³ 0.03 m ³		0.183	1.43 0.98 (fiss)	5 psig helium	No metal matrix. Schedule 40, 10-in. pipe
PuO ₂	22.5	2.92		0.16 ft ³ 0.0045 m ³			9.03 ^d	None	PuO ₂ contained in #8 Can

^a6.56 kg Pu fissile/MTU; 9.4 kg total Pu/MTU.^bft³/MTPu (reprocessing).^c10,000 ft³/MTPu (preparation); 20,000 ft³/MTPu (fabrication); 4,000 ft³/MTPu (reprocessing).^d0.24 kg PuO₂.

This projection assumes that by 1985 spent fuel assemblies that have been cooled for ten years either at the reactor site or at an interim storage facility may be encapsulated in a specially designed canister and shipped to a repository for either retrievable or non-retrievable storage. At present, spent fuel assemblies are stored primarily in fuel storage pools located at their respective reactor sites. Because of the assumed ten-year cooling period, assemblies accumulated prior to 1975 constitute the backlog in the last quarter of 1985 when the first repository begins receiving waste. The backlog, 920 PWR and 2910 BWR assemblies (as indicated in ERDA-77-25),¹² is assumed to be worked off linearly between 1991 and 1995. A five-year delay following the start-up of a repository is assumed before backlog assemblies are shipped in order to keep the receiving rate low during the initial operating phase of repository systems.

A reference canister size of 12.75 in. minimum ID (Schedule 40, 14-in. pipe) by 16 ft long was assumed for an active PWR fuel assembly volume of 2.8 ft³ (0.08 m³), containing 0.461 MTU, and backfilled to 5-psig overpressure with helium* for improved heat transfer and leak detection. Each canister was assumed to contain about 4.22 kg (assuming full burnup) of total plutonium (~3.06 kg fissile plutonium) at discharge; this amount is equivalent to one PWR assembly per canister.

A reference canister size of 8.5 in. minimum ID (Schedule 40, 10-in. pipe) by 16 ft long was assumed for an active BWR fuel assembly volume of 1.1 ft³ (0.03 m³), containing 0.183 MTU, and backfilled with 5 psig of helium as mentioned above. Each canister was assumed to contain about 1.43 kg of total plutonium (~0.98 kg fissile plutonium) at discharge; this amount is equivalent to one BWR assembly per canister.

Data on the number of spent fuel assemblies received and accumulated annually after reactor exposure and ten years of subsequent cooling are listed in the appendix; Table A.1[†] gives the preliminary data and

*Conceptual repository design studies are currently considering a fill of dry sand and no overpressure of helium.

[†]Table A.1 represents preliminary data released prior to actual computer tabulation. These data are based on the spent fuel discharge rates given in Table 3.6 of ORNL/TM-5427.² Variations in receiving rates between Tables A.1 and A.2 average less than 7% and are attributed to propagated roundoff errors and minor variations in computational constants in the input data files used in the computer codes, KWIKPLAN and WASPR (see Sects. 3.2.2 and 3.2.3).

Table A.2 gives the final computer-calculated data (see Table 3.1 for burnup and other assumptions). The calculated (ORIGEN code) decay heat and radioactivity for spent fuel on a metric ton basis are listed in the appendix, Tables A.3 and A.4. Also listed in the appendix, Table A.5, is the annual accumulation of spent fuel assemblies with an assumed five-year cooling period.

4.2 High-Level Waste

High-level wastes are defined in federal regulations¹³ as "those aqueous wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, in a facility for reprocessing irradiated reactor fuels". These wastes contain virtually all the non-volatile fission products and are assumed to contain 0.5% of the uranium and plutonium originally in the spent fuel. The HLW also contains all the other actinides formed by the transmutation of uranium and plutonium in the reactor cores. The makeup of HLW is primarily fission products. The volatiles and actinides are assumed to be removed as follows:

1. tritium and noble gases (He, Kr, and Xe) - 100% removed;
2. iodine and bromine - 99.9% removed; and
3. uranium and plutonium - 99.5% removed.

These wastes can generally be characterized by their intense, penetrating radiation; high decay heat generation rates; and relatively long decay periods. Federal regulations require that liquid HLW be solidified within five years after generation and also that the resultant stable solids be shipped to a federal repository within ten years after generation.¹³

For the purposes of this study, the spent fuel assemblies (having undergone full burnup) are assumed to be shipped to a reprocessing facility and reprocessed at the end of the first year; thereafter, the solid HLW is delayed nine years before shipment to a repository. Therefore, all HLW arriving at the repository is assumed to have decayed for ten years following reactor discharge.

The reference canister size for HLW in borosilicate glass was assumed to be 1 ft in diameter (Schedule 40, 12-in. pipe) by 10 ft long with an active length of 8 ft (nominal 80% fill capacity). An internal volume of 6.28 ft³ (0.177 m³) was assumed.

For studies involving calcined HLW, a canister size of 8 in. in diameter (Schedule 40, 8-in. pipe) by 10 ft long, with an active length of 8 ft (80% nominal fill capacity) and an internal volume of 2.79 ft³ (0.079 m³), was assumed.

The average equivalent fuel density was assumed to be 3 ft³/MTU for glass and 1.5 ft³/MTU for calcine, or 2.09 and 1.85 MTU equivalent per canister, respectively. Before the canisters were sealed, they were assumed to have been backfilled with 5-psig overpressure of helium for improved heat transfer and leak detection.

The HLW accumulation rates, the calculated (ORIGEN code) decay heat generation rates of the actinides and fission products, and the calculated radioactivity of the actinides and fission products for the fresh uranium (reprocessing with no current recycle), partial recycle (uranium only), and total recycle (uranium and plutonium) fuel cycles are listed in the appendix, Tables A.6 to A.20.

4.3 High-Level Waste with Plutonium Dioxide

This waste type was assumed to be generated by reprocessing cycles in which plutonium has neither been stored nor recycled but rather has been treated as a waste material. No recovery of plutonium would be considered once the mixture is vitrified. The total volume of HLW + PuO₂ is assumed to be equal to that of the HLW taken separately.

The same HLW canisters described in Sect. 4.2 were assumed to be used for the encapsulation of HLW + PuO₂. The average fuel equivalent was assumed to be 6.56 kg Pu (fissile)/MTU (about 9.4 kg total Pu/MTU). Therefore, a canister was assumed to contain 19.7 kg total Pu in glass or 17.4 kg total Pu in calcine and was also assumed to be backfilled with 5 psig of helium.

The HLW + PuO₂ accumulation rates for the partial (uranium only) fuel cycle are listed in the appendix, Table A.21. The decay heat

generation rates of the actinides and the fission products and the radioactivity of the actinides and the fission products for this waste type are listed in the appendix, Tables A.22 to A.25.

4.4 Plutonium

Plutonium is formed in the reactor core by the transmutation of ^{238}U and occurs in all LWR fuel cycles. The plutonium may be either recycled, permanently isolated, or temporarily stored depending on the fuel cycle chosen. Prior to the operation of a reprocessing facility, no backlog of plutonium is assumed to exist except that which is already contained within the spent fuel assemblies. The isotopic composition of the plutonium is taken as 1% ^{238}Pu , 50% ^{239}Pu , 24% ^{240}Pu , 12% ^{241}Pu , and 4% ^{242}Pu .^{2,3} This composition applies to once-through fuel only; with the recycling of plutonium, the composition will favor the heavier isotopes.

A 55-gal drum (22.5-in. diam $\times$ 35-in. length) outer package with a 0.16 ft³ or 0.0045 m³ usable volume was assumed to be used as a shipping and storage container for PuO_2 when separate storage is applicable. The PuO_2 was assumed to be packed in number 8 cans that are placed inside the outer package. Two cans are packaged per drum for a total of 10.24 kg PuO_2 (9.03 kg total Pu) net weight per shipping container.

The shipping and storage container for plutonium dioxide was assumed to use the design quoted from ERDA-40, *The Environmental Impact of Transportation of Nuclear Materials in the LMFBR Program*.¹⁴

4.5.2.1.3 Plutonium Dioxide

Packages currently approved for the shipment of PuO_2 have been tested extensively under both hypothetical accident conditions¹⁵ and extremely severe accident conditions.¹⁶ Future PuO_2 packages may have the same external appearance but probably will have different interior construction. A hydrogenous, nonflammable insulating material such as concrete, would be used to provide shielding, spacing (for criticality control), and fire protection. The inner cans would meet special form requirements in accordance with currently proposed regulations,¹⁷ and two containment barriers probably would be provided.

Package specifications for plutonium dioxide have been condensed from the ERDA document as follows:

Type, 55-gal drum	Inner container height, 18 in.
Height, 35 in.	Usable volume, 0.16 ft ³
Diameter, 22.5 in.	Tare weight of package, 90.9 kg
Inner container diameter, 4.81 in.	Net weight PuO ₂ , 10.24 kg

The annual accumulation of PuO₂ for the fresh uranium and partial recycle fuel cycles appears in the appendix, Tables A.26 and A.27. The decay heat generation rates and radioactivity for PuO₂ on a metric ton basis appear in the appendix, Tables A.28 and A.29.

4.5 Cladding Waste

Cladding waste originates in the head-end of the reprocessing cycle as a result of the chopping of fuel elements and the dissolving of the fuel from within the chopped fuel-rod pieces. Unlike other waste types, the quantity of CW generated is more closely governed by the overall electric capacity and fuel burnup than by the type of fuel cycle chosen; further, the isotopic constituents of the CW remain nearly constant from one fuel cycle to another. Therefore, a single set of CW projections can be applied to all the fuel cycles treated in this report without a significant sacrifice of accuracy.

The fuel assembly structural materials are assumed to be compacted to 70% of their theoretical density, resulting in final structural material volumes of 2.29 ft³/MTU for PWRs and 2.92 ft³/MTU for BWRs. After a storage period of four years at the reprocessing plants (for a total of five years after reactor discharge), the canistered CW is assumed to be shipped in shielded shipping casks by rail to a repository.

The same canister assumed to be used for storing HLW in borosilicate glass was assumed to be used for storing CW (see Sect. 4.2). The equivalent fuel density was assumed to be 2.45 MTU/canister. As with the HLW, these canisters were assumed to be backfilled with 5-psig overpressure of helium.

The CW accumulation rates and the decay heat generation rates and radioactivity for actinides, fission products, and light elements appear in the appendix, Tables A.30 to A.36.

4.6 Intermediate-Level Transuranic Waste

Intermediate-level wastes are defined as those solid materials, other than HLW and CW, which have beta and/or gamma radiation levels sufficient to require biological shielding and remote handling techniques (typical surface dose rates lie between 10 and 1000 millirems/hr).² These wastes arise at fuel reprocessing plants and consist of an assortment of materials. They contain an average of 0.025 g of plutonium or uranium per cubic foot,¹⁸ plus an assumed 0.025% of the fission products in the spent fuel.

About 10,000 ft³ of ILW are generated per ton of plutonium processed.² The wastes are assumed to be compacted or otherwise reduced in volume by factors of 3 to 10 according to the following schedule:

<u>Calendar year</u>	<u>Compaction factor</u>
1976 - 1981	3
1982 - 1983	4
1984 - 1985	5
1986 - 1987	7.5
1988 - 2000	10

The same canister assumed to be used for storing HLW in borosilicate glass was also assumed to be used for the ILW (see Sect. 4.2). The equivalent fuel density was assumed to be 0.55 MTU/canister. As with the HLW, these canisters were assumed to be backfilled with 5-psig of helium.

Also, these wastes are assumed to be shipped and accumulated at a repository five years following discharge after generation (i.e., five-year decay after initial activation). The ILW accumulation rates for the fuel cycle alternatives appear in the appendix, Tables A.37 to A.39.

4.7 Low-Level Waste

For this report, LL-TRU wastes are defined as those solid materials that contain plutonium or other long-lived alpha emitters in concentrations greater than 10 nCi/g and yet have sufficiently low external radiation levels that they can be handled directly without supplementary shielding (surface dose rates less than 10 millirems/hr.).¹⁹ The criterion of 10 nCi/g was adopted as a lower activity density for LL-TRU wastes because this rate corresponds to the upper range of alpha-emitting isotopes in naturally occurring mineral deposits.¹⁹ Wastes containing less alpha activity than 10 nCi/g can reasonably be regarded as disposable in near-surface burial grounds; however, TRU wastes should be stored in special repositories that offer maximum assurance of long-term containment.

Low-level TRU wastes arise principally at fuel preparation and fabrication plants and, to a lesser extent, at fuel reprocessing plants.^{18,20} Some low-level wastes are generated at the reactor site, but generally, transuranic content is far less than that generated by the other sources. These wastes consist of a wide assortment of solid materials, including immobilized salts and sludges that arise in the treatment of liquid waste streams and filters from the cleanup of off-gas, as well as contaminated items made of paper, cloth, wood, plastic, rubber, glass, ceramics, and metal. The transuranium-element content of these wastes ranges from trace amounts to several grams per cubic foot and averages about 0.25 g/ft³. About one-half to two-thirds of these wastes (by volume) are combustible, and via incineration their volume and weight can be reduced by factors of about 50 and 20, respectively.² About one-half to three-fourths of the wastes (by volume) can be reduced by factors of 2 to 10 through compaction. (See the compaction schedule in Sect. 4.6 for details.)

A survey of operations at ERDA laboratories and production facilities (1970) indicated that future large plants will generate about 10,000, 20,000, and 4,000 ft³ of uncompacted LL-TRU waste per ton of plutonium processed in fuel preparation, fabrication, and reprocessing, respectively.¹⁸ Thus an average plutonium concentration in the waste of 0.25 g/ft³ represents unrecovered fuel losses of 0.25% in fuel preparation, 0.5% in fabrication, and 0.1% in reprocessing.

Wastes arising from the reprocessing cycles were assumed to be packaged in 55-gal drums (Department of Transportation type 17C or 17H) 22.5 in. in diameter $\times$ 35 in. high with an internal volume of 7.35 ft³ or 0.208 m³. The average equivalent fuel density is about 0.22 MTU/drum. Currently these drums are not backfilled with helium.

The same drums as were used for the reprocessing cycles were to be used for the spent fuel cycle. However, the average equivalent fuel density was assumed to be 0.46 MTU/drum. The low-level waste from the spent fuel cycle was assumed to contain up to about 8 mCi/1000 m³ of radioactivity and to have a thermal power of up to 1 kW/1000 m³.^{21,22}

Low-level TRU wastes arising from the reprocessing fuel cycles were assumed to be shipped and accumulated at a repository five years following their discharge; however, low-level wastes originating from the spent fuel cycle were assumed to be shipped and accumulated at a repository one year following discharge. The low-level waste accumulation rates for the fuel cycle alternatives appear in the appendix, Tables A.40 to A.42. Low-level wastes from the partial (uranium only) recycle and fresh uranium cycles are assumed to be identical in quantity.

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Table A.1 Accumulation of Ten-Year-Old
Discharged Spent Fuel at a Repository (Preliminary Data)

Year	Pressurized-water reactor		Boiling-water reactor	
	Assemblies Received	Assemblies Accumulated	Assemblies Received	Assemblies Accumulated
1985	139	139	454	454
1986	555	694	1,814	2,268
1987	979	1,673	2,124	4,392
1988	1,390	3,063	2,435	6,827
1989	1,657	4,720	2,524	9,351
1990	1,906	6,626	2,596	11,947
1991	2,336	8,962	3,723	15,670
1992	2,582	11,545	4,338	20,008
1993	2,953	14,498	4,814	24,822
1994	3,446	17,945	5,235	30,057
1995	4,045	21,990	6,021	36,078
1996	4,388	26,378	6,391	42,469
1997	4,976	31,354	7,520	49,989
1998	5,616	36,970	8,453	58,442
1999	6,270	43,240	9,422	67,864
2000	6,955	50,195	10,445	78,309
2001	7,637	57,832	11,436	89,745
2002	8,323	66,155	12,441	102,186
2003	9,026	75,181	13,498	115,684
2004	9,739	84,920	14,575	130,259
2005	10,506	95,426	15,734	145,993
2006	11,240	106,666	16,838	162,831
2007	11,953	118,619	17,903	180,734
2008	12,642	131,261	18,938	199,672
2009	13,301	144,562	19,910	219,582
2010	13,915	158,477	20,882	240,464
2011	13,939	172,416	20,980	261,444
2012	13,932	186,348	20,849	282,293
2013	13,932	200,280	20,917	303,210
2014	13,932	214,212	20,826	324,036
2015	13,932	228,144	20,826	344,862
2016	14,043	242,187	20,826	365,688
2017	13,877	256,064	20,826	386,514

Table A.1 (continued)

Year	Pressurized-water reactor		Boiling-water reactor	
	Assemblies Received	Assemblies Accumulated	Assemblies Received	Assemblies Accumulated
2018	14,008	270,072	20,826	407,340
2019	13,812	283,884	21,476	428,816
2020	13,938	297,822	20,609	449,425
2021	13,951	311,773	21,594	471,019
2022	13,961	325,734	21,269	492,288
2023	14,261	339,995	21,738	514,026
2024	13,728	353,723	21,667	535,693
2025	13,428	367,151	21,027	556,720
2026	12,873	380,024	18,892	575,612
2027	12,925	392,949	18,192	593,804
2028	12,476	405,425	18,613	612,417
2029	12,404	417,829	18,050	630,467
2030	11,643	429,472	18,855	649,322
2031	11,974	441,446	19,893	669,215
2032	11,773	453,219	19,287	688,502
2033	11,460	464,679	17,864	706,366
2034	11,635	476,314	17,356	723,722
2035	10,393	486,707	18,616	742,338
2036	9,515	496,222	16,537	758,875
2037	8,794	505,016	15,523	774,398
2038	8,247	513,263	14,835	789,233
2039	7,779	521,042	14,295	803,528
2040	7,324	528,366	13,804	817,332
2041	6,752	535,118	13,133	830,465
2042	6,141	541,259	12,413	842,878
2043	5,413	546,672	11,496	854,374
2044	4,939	551,611	10,923	865,297
2045	4,126	555,737	10,040	875,337
2046	3,180	558,917	8,830	884,167
2047	2,249	561,166	7,640	891,807
2048	1,319	562,485	6,452	898,259
2049	261	562,746	5,306	903,565
2050	0	562,746	3,893	907,458

Table A.2 Accumulation of ten-year-old discharged spent fuel at a repository (Final Data)

Year	Annual Addition						Accumulation Through End of Year					
	Number of Assemblies Discharged		Volume (Thousands of m ³)	Actinide Mass (MT)	Radio-Activity (MCi)	Thermal Power (MW)	Number of Assemblies Discharged		Volume (Thousands of m ³)	Actinide Mass (MT)	Radio-Activity (MCi)	Thermal Power (MW)
	BWR	PWR					BWR	PWR				
1985	492.	223.	0.033	186.7	50.85	0.2	492.	223.	0.033	186.7	51.	0.2
1986	2389.	720.	0.131	745.2	192.31	0.6	2881.	942.	0.164	931.9	241.	0.8
1987	3247.	931.	0.175	992.1	256.37	0.9	6128.	1873.	0.339	1924.0	489.	1.6
1988	2940.	1344.	0.198	1121.0	313.59	1.0	9068.	3217.	0.538	3044.9	785.	2.6
1989	2894.	1691.	0.224	1267.5	400.66	1.3	11962.	4908.	0.762	4312.5	1157.	3.9
1990	2793.	1957.	0.242	1367.7	465.99	1.5	14755.	6865.	1.004	5680.1	1583.	5.3
1991	3645.	2687.	0.327	1844.1	647.33	2.2	18401.	9552.	1.331	7524.2	2177.	7.3
1992	4395.	2941.	0.370	2090.8	709.54	2.4	22796.	12493.	1.701	9615.1	2812.	9.5
1993	4852.	3327.	0.415	2344.0	782.17	2.6	27648.	15821.	2.116	11959.1	3500.	11.8
1994	5315.	3896.	0.475	2679.2	892.53	3.0	32963.	19716.	2.591	14638.2	4277.	14.4
1995	6297.	4571.	0.559	3154.3	1035.91	3.4	39260.	24287.	3.149	17792.6	5172.	17.5
1996	7043.	4667.	0.590	3329.9	1094.50	3.6	46303.	28955.	3.739	21122.5	6098.	20.7
1997	7997.	5314.	0.671	3787.7	1260.79	4.2	54300.	34269.	4.409	24910.2	7162.	24.3
1998	8909.	5950.	0.749	4232.5	1430.01	4.8	63210.	40219.	5.159	29142.7	8362.	28.4
1999	9935.	6620.	0.835	4713.5	1609.16	5.3	73145.	46839.	5.993	33856.2	9704.	33.1
2000	10954.	7320.	0.922	5206.1	1788.26	5.9	84099.	54159.	6.915	39062.3	11183.	38.2
2001	11917.	7984.	1.004	5673.0	1966.01	6.5	96016.	62143.	7.919	44735.3	12795.	43.8
2002	12966.	8692.	1.093	6174.5	2147.28	7.1	108982.	70834.	9.013	50909.8	14538.	49.8
2003	14030.	9390.	1.182	6674.7	2331.55	7.7	123012.	80225.	10.194	57584.5	16413.	56.4
2004	15119.	10116.	1.273	7191.3	2520.12	8.4	138130.	90341.	11.468	64775.8	18419.	63.4
2005	16217.	10837.	1.365	7707.5	2712.12	9.0	154347.	101177.	12.832	72483.3	20557.	70.9
2006	17296.	11554.	1.455	8218.6	2904.23	9.7	171643.	112731.	14.287	80701.9	22822.	78.8
2007	18304.	12236.	1.541	8701.7	3091.47	10.3	189947.	124968.	15.828	89403.5	25207.	87.2
2008	19272.	12869.	1.621	9155.4	3269.85	10.9	209220.	137837.	17.449	98558.9	27700.	96.1
2009	20230.	13485.	1.700	9599.9	3440.15	11.4	229449.	151322.	19.189	108158.8	30289.	105.3
2010	21144.	14084.	1.776	10029.2	3602.68	12.0	250594.	165406.	20.924	118187.9	32964.	114.8
2011	21966.	14623.	1.844	10415.3	3755.27	12.5	272560.	180030.	22.768	128603.2	35714.	124.7
2012	21807.	14518.	1.831	10339.9	3831.99	12.7	294367.	194547.	24.599	138943.1	38461.	134.6
2013	21548.	14399.	1.813	10241.2	3846.82	12.8	315914.	208947.	26.412	149184.3	41144.	144.4
2014	21394.	14222.	1.794	10135.1	3820.77	12.7	337308.	223169.	28.207	159319.3	43726.	153.9
2015	21314.	14080.	1.781	10057.5	3787.59	12.6	358623.	237249.	29.987	169376.8	46203.	163.1
2016	20885.	13831.	1.747	9870.1	3719.62	12.4	379507.	251079.	31.735	179246.9	48545.	171.9
2017	20563.	13623.	1.721	9720.5	3622.72	12.2	400070.	264702.	33.456	188967.7	50768.	180.4
2018	20332.	13384.	1.695	9572.9	3504.93	12.0	420402.	278086.	35.150	198540.3	52874.	188.5
2019	19991.	13174.	1.668	9418.7	3344.63	11.8	440392.	291260.	36.818	207958.9	54866.	196.4
2020	20088.	12909.	1.650	9318.4	3497.48	11.6	460481.	304169.	38.467	217277.3	56760.	203.9
2021	19675.	12725.	1.622	9163.0	3434.02	11.4	480156.	316894.	40.090	226440.3	58543.	211.1
2022	19114.	12249.	1.567	8851.4	3321.28	11.0	499270.	329143.	41.656	235291.6	60169.	217.9
2023	19126.	12222.	1.565	8841.3	3299.66	11.0	518396.	341365.	43.221	244132.9	61734.	224.4
2024	19936.	11920.	1.566	8851.3	3277.01	10.9	538332.	353285.	44.788	252984.1	63239.	230.8
2025	17551.	12045.	1.502	8482.4	3149.96	10.5	555883.	365330.	46.290	261466.5	64580.	236.7
2026	16041.	12151.	1.463	8260.8	3061.86	10.2	571924.	377481.	47.753	269727.3	65802.	242.2
2027	15393.	10676.	1.326	7889.5	2797.03	9.3	587317.	388157.	49.079	277216.8	66731.	246.8
2028	14373.	10505.	1.281	7231.4	2700.99	9.0	601690.	398661.	50.360	284448.2	67548.	251.0
2029	14471.	9710.	1.221	6895.3	2575.37	8.6	616161.	408371.	51.581	291343.4	68224.	254.7
2030	15846.	9463.	1.244	7030.3	2592.81	8.6	632007.	417834.	52.825	298373.7	68906.	258.5
2031	15685.	9391.	1.233	6969.4	2555.17	8.5	647692.	427225.	54.059	305343.1	69539.	262.1
2032	13521.	9560.	1.179	6659.7	2448.63	8.1	661213.	436785.	55.238	312002.7	70054.	265.4
2033	14288.	9348.	1.186	6701.1	2435.48	8.1	675497.	446133.	56.424	318703.8	70548.	268.5
2034	15330.	9271.	1.213	6852.9	2452.85	8.2	690827.	455404.	57.637	325556.6	71052.	271.7
2035	16004.	8257.	1.153	6521.9	2318.82	7.7	706831.	463662.	58.791	332078.5	71413.	274.4
2036	13587.	8261.	1.078	6093.6	2172.95	7.2	720418.	471923.	59.869	338172.0	71624.	276.6
2037	12903.	7810.	1.021	5770.9	2051.31	6.8	733321.	479733.	60.890	343942.9	71714.	278.4
2038	12429.	7478.	0.980	5539.0	1957.87	6.5	745751.	487211.	61.871	349481.9	71715.	279.9
2039	11961.	7147.	0.939	5308.6	1864.91	6.2	757712.	494358.	62.810	354790.4	71630.	281.1
2040	11141.	6633.	0.873	4933.6	1729.08	5.8	768853.	500991.	63.683	359724.0	71418.	281.9
2041	10971.	6410.	0.850	4804.3	1668.05	5.5	779824.	507401.	64.533	364528.3	71158.	282.4
2042	10325.	5983.	0.796	4499.3	1553.11	5.2	790149.	513383.	65.329	369027.5	70796.	282.7
2043	9858.	5656.	0.756	4270.6	1460.80	4.9	800007.	519039.	66.085	373298.1	70359.	282.6
2044	9187.	5209.	0.699	3952.4	1340.83	4.5	809194.	524248.	66.784	377250.4	69821.	282.2
2045	8515.	4762.	0.643	3634.3	1220.83	4.1	817709.	529010.	67.427	380884.7	69183.	281.4
2046	7606.	4230.	0.572	3235.6	1077.12	3.6	825315.	533241.	68.000	384120.3	68427.	280.2
2047	6849.	3687.	0.506	2859.0	940.54	3.1	832164.	536927.	68.505	386979.3	67561.	278.6
2048	6227.	3279.	0.454	2567.1	830.55	2.8	838391.	540206.	68.959	389546.4	66616.	276.7
2049	5547.	2886.	0.402	2271.1	719.52	2.4	843938.	543092.	69.361	391817.4	65592.	274.5
2050	4696.	2333.	0.331	1873.7	577.96	1.9	848634.	545425.	69.692	393691.1	64462.	272.0

TIME AFTER SHUTDOWN, YEARS

100	848634.	545425.	69.692	393691.1	7452.9	91.1
300	848634.	545425.	69.692	393691.1	1514.7	46.6
1000	848634.	545425.	69.692	393691.1	628.6	19.8
3000	848634.	545425.	69.692	393691.1	288.9	8.6
10000	848634.	545425.	69.692	393691.1	181.4	5.3
30000	848634.	545425.	69.692	393691.1	78.9	2.2
100000	848634.	545425.	69.692	393691.1	24.2	0.5
300000	848634.	545425.	69.692	393691.1	16.2	0.3
1000000	848634.	545425.	69.692	393691.1	9.2	0.2

TABLE A.3

Spent Fuel

Watts vs Time

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (WATTS/MTHM)</u>	<u>BWR (WATTS/MTHM)</u>
0	0.1742E 07	0.1204E 07
1	0.1043E 05	0.7787E 04
2	0.5640E 04	0.4307E 04
3	0.3598E 04	0.2807E 04
4	0.2568E 04	0.2045E 04
5	0.2011E 04	0.1629E 04
6	0.1688E 04	0.1384E 04
7	0.1487E 04	0.1230E 04
8	0.1353E 04	0.1127E 04
9	0.1259E 04	0.1052E 04
10	0.1189E 04	0.9963E 03
20	0.8904E 03	0.7464E 03
30	0.7394E 03	0.6199E 03
40	0.6246E 03	0.5253E 03
50	0.5340E 03	0.4509E 03
100	0.2886E 03	0.2490E 03
200	0.1627E 03	0.1437E 03
400	0.1099E 03	0.9799E 02
600	0.8455E 02	0.7576E 02
1000	0.5547E 02	0.5018E 02
10000	0.1380E 02	0.1286E 02
30000	0.5507E 01	0.5061E 01
100000	0.1069E 01	0.9469E 00
1000000	0.3919E 00	0.3463E 00

TABLE A.4

Spent fuel

Curies vs Time

YEARS
AFTER
DISCHARGE

PWR
(CURIES/MTHM)

BWR
(CURIES/MTHM)

0	0.1821E 09	0.1267E 09
1	0.2348E 07	0.1774E 07
2	0.1341E 07	0.1043E 07
3	0.9173E 06	0.7300E 06
4	0.7058E 06	0.5719E 06
5	0.5918E 06	0.4852E 06
6	0.5245E 06	0.4331E 06
7	0.4808E 06	0.3987E 06
8	0.4497E 06	0.3737E 06
9	0.4258E 06	0.3543E 06
10	0.4063E 06	0.3382E 06
20	0.2912E 06	0.2420E 06
30	0.2209E 06	0.1833E 06
40	0.1699E 06	0.1409E 06
50	0.1321E 06	0.1094E 06
100	0.4205E 05	0.3496E 05
200	0.8324E 04	0.7135E 04
400	0.3501E 04	0.3112E 04
600	0.2649E 04	0.2371E 04
1000	0.1756E 04	0.1587E 04
10000	0.4761E 03	0.4401E 03
30000	0.2042E 03	0.1849E 03
100000	0.5801E 02	0.5003E 02
1000000	0.2092E 02	0.1846E 02

Table A.5 Accumulation of five-year-old discharged spent fuel at a repository

Year	Annual Addition					Accumulation Through End of Year				
	Number of Assemblies Discharged	Volume (Thousands of m ³)	Actinide Mass (MT)	Radio-Activity (NCI)	Thermal Power (MW)	Number of Assemblies Discharged	Volume (Thousands of m ³)	Actinide Mass (MT)	Radio-Activity (NCI)	Thermal Power (MW)
1985	1115.	430.	0.069	389.9	134.29	0.5	1115.	430.	0.069	389.9
1986	5094.	1472.	0.275	1561.2	540.14	1.9	6209.	1902.	0.344	1951.1
1987	4503.	2259.	0.319	1806.5	701.11	2.5	10712.	4161.	0.664	3757.5
1988	4313.	2903.	0.365	2058.9	924.60	3.3	15024.	7064.	1.028	5816.4
1989	4791.	3465.	0.424	2394.1	1114.13	3.9	19815.	10529.	1.452	8210.5
1990	6056.	4030.	0.508	2870.9	1282.86	4.5	25871.	14559.	1.961	11081.4
1991	9313.	6776.	0.828	4672.2	2069.34	7.3	35185.	21335.	2.788	15753.6
1992	10610.	7283.	0.908	5128.8	2244.76	7.9	45795.	28618.	3.696	20882.4
1993	11763.	7827.	0.987	5575.6	2482.36	8.8	57558.	36445.	4.683	26458.0
1994	12755.	8507.	1.072	6055.0	2742.15	9.7	70314.	44952.	5.755	32513.0
1995	13785.	9206.	1.160	6549.0	2993.96	10.6	84099.	54158.	6.915	39062.0
1996	11918.	7985.	1.005	5673.5	2620.09	9.3	96016.	62143.	7.919	44735.4
1997	12966.	8692.	1.093	6174.5	2861.44	10.1	108982.	70834.	9.013	50909.9
1998	14030.	9390.	1.182	6674.7	3107.03	11.0	123012.	80225.	10.194	57584.6
1999	15119.	10116.	1.273	7191.3	3358.30	11.9	138131.	90341.	11.468	64775.9
2000	16217.	10837.	1.365	7707.5	3614.13	12.8	154348.	101177.	12.832	72483.3
2001	17296.	11554.	1.455	8218.6	3870.11	13.7	171644.	112731.	14.287	80701.9
2002	18304.	12236.	1.541	8701.7	4119.61	14.6	189948.	124968.	15.828	89403.6
2003	19272.	12869.	1.621	9155.4	4357.27	15.4	209220.	137837.	17.449	98558.9
2004	20230.	13485.	1.700	9599.9	4584.17	16.2	229450.	151322.	19.149	108158.8
2005	21144.	14084.	1.776	10029.2	4800.72	17.0	250594.	165406.	20.924	118188.0
2006	21966.	14623.	1.844	10415.3	5004.03	17.7	272560.	180030.	22.768	128603.3
2007	21807.	14518.	1.831	10339.9	5106.19	18.0	294367.	194547.	24.599	138943.1
2008	21548.	14399.	1.813	10241.2	5125.89	18.1	315915.	208947.	26.412	149184.3
2009	21394.	14222.	1.794	10135.1	5091.04	18.0	337309.	223169.	28.207	159319.4
2010	21314.	14080.	1.781	10057.5	5046.77	17.8	358623.	237249.	29.987	169376.9
2011	20885.	13831.	1.747	9870.1	4956.22	17.5	379508.	251079.	31.735	179246.9
2012	20563.	13623.	1.721	9720.5	4880.41	17.3	400071.	264702.	33.456	188967.4
2013	20332.	13384.	1.695	9572.9	4803.36	17.0	420402.	278086.	35.150	198540.3
2014	19991.	13174.	1.668	9418.7	4723.02	16.7	440393.	291260.	36.818	207959.0
2015	20088.	12909.	1.650	9318.4	4660.00	16.5	460481.	304169.	38.467	217277.4
2016	19675.	12725.	1.622	9163.0	4575.50	16.2	480157.	316894.	40.090	226440.3
2017	19114.	12249.	1.567	8851.4	4425.23	15.6	499270.	329143.	41.656	235291.6
2018	19126.	12222.	1.565	8841.3	4396.39	15.5	518397.	341365.	43.222	244132.9
2019	19936.	11920.	1.566	8851.3	4365.74	15.4	538333.	353285.	44.788	252984.2
2020	17551.	12045.	1.502	8482.4	4197.44	14.8	555883.	365330.	46.290	261466.6
2021	16041.	12151.	1.463	8260.8	4080.66	14.4	571925.	377481.	47.753	269727.4
2022	15393.	10676.	1.326	7489.5	3727.19	13.2	587318.	388157.	49.079	277216.8
2023	14373.	10505.	1.281	7231.4	3599.50	12.7	601690.	398661.	50.360	284448.3
2024	14471.	9710.	1.221	6895.3	3431.62	12.1	616162.	408371.	51.581	291343.5
2025	15846.	9463.	1.244	7030.3	3454.17	12.2	632007.	417834.	52.825	298373.8
2026	15685.	9391.	1.233	6969.4	3404.03	12.0	647692.	427255.	54.059	305343.1
2027	13521.	9560.	1.179	6659.7	3262.99	11.5	661214.	436785.	55.238	312002.8
2028	14284.	9388.	1.186	6701.1	3245.02	11.5	675497.	446133.	56.424	318703.8
2029	15330.	9271.	1.213	6852.9	3267.70	11.6	690827.	455404.	57.637	325556.7
2030	16004.	8257.	1.153	6521.9	3088.28	10.9	706832.	463662.	58.791	332078.6
2031	13587.	8261.	1.078	6093.6	2894.85	10.2	720419.	471923.	59.869	338172.1
2032	12903.	7810.	1.021	5770.9	2732.76	9.7	733322.	479733.	60.890	343942.9
2033	12429.	7478.	0.980	5539.0	2608.24	9.2	745751.	487211.	61.871	349481.9
2034	11961.	7147.	0.939	5308.6	2484.36	8.8	757712.	494358.	62.810	354790.5
2035	11141.	6633.	0.873	4933.6	2303.39	8.1	768853.	500991.	63.683	359724.1
2036	10971.	6410.	0.850	4804.3	2222.00	7.9	779825.	507401.	64.533	364528.3
2037	10325.	5983.	0.796	4499.3	2068.85	7.3	790150.	513383.	65.329	369027.6
2038	9858.	5656.	0.756	4270.6	1945.83	6.9	800008.	519639.	66.085	373298.1
2039	9187.	5209.	0.699	3952.4	1785.98	6.3	809195.	524248.	66.784	377250.5
2040	8515.	4762.	0.643	3634.3	1626.08	5.7	817710.	529010.	67.427	380884.8
2041	7606.	4230.	0.572	3235.6	1434.64	5.1	825316.	533241.	68.000	384120.4
2042	6849.	3687.	0.506	2859.0	1252.63	4.4	832164.	536927.	68.505	386979.3
2043	6227.	3279.	0.454	2567.1	1106.08	3.9	838392.	540206.	68.959	389546.4
2044	5547.	2886.	0.402	2271.1	958.17	3.4	843938.	543092.	69.361	391817.5
2045	4696.	2333.	0.331	1873.7	769.56	2.7	848634.	545425.	69.692	393691.2
TIME AFTER SHUTDOWN, YEARS										
100						848634.	545425.	69.692	393691.2	8138.8
300						848634.	545425.	69.692	393691.2	1535.5
1000						848634.	545425.	69.692	393691.2	631.3
3000						848634.	545425.	69.692	393691.2	289.1
10000						848634.	545425.	69.692	393691.2	181.5
30000						848634.	545425.	69.692	393691.2	78.9
100000						848634.	545425.	69.692	393691.2	24.2
300000						848634.	545425.	69.692	393691.2	16.2
1000000						848634.	545425.	69.692	393691.2	9.2

Table A.6 Accumulation of solidified HLW at a repository:
Fresh Uranium Cycle (reprocessing with no recycle)

Year	Volume (m ³)	Actinide Mass (MT)	Radio- activity (MCi)	Thermal Power (MW)	Annual Number of Canisters	Volume (m ³)	Actinide Mass (MT)	Radio- activity (MCi)	Thermal Power (MW)
1985	16.4	1.1	40.1	0.1	92	16.4	1.1	40	0.1
1986	65.4	4.3	151.7	0.5	368	81.8	5.4	190	0.7
1987	87.1	5.7	202.1	0.7	490	168.9	11.1	385	1.3
1988	98.5	6.5	247.5	0.9	554	267.3	17.6	619	2.1
1989	111.4	7.4	316.5	1.1	626	378.7	25.1	914	3.1
1990	120.2	8.0	368.4	1.3	676	498.9	33.1	1251	4.3
1991	162.1	10.9	512.0	1.8	911	661.0	44.0	1722	5.9
1992	183.7	12.3	561.2	1.9	1033	844.8	56.2	2227	7.6
1993	206.0	13.8	618.7	2.1	1158	1050.8	70.0	2774	9.5
1994	235.5	15.8	706.0	2.5	1324	1286.2	85.8	3392	11.5
1995	277.2	18.6	819.5	2.8	1559	1563.5	104.4	4106	14.0
1996	292.6	19.6	865.8	3.0	1646	1856.1	123.9	4845	16.5
1997	332.9	22.2	997.2	3.5	1872	2189.0	146.2	5694	19.3
1998	372.0	24.9	1131.0	3.9	2092	2561.0	171.0	6652	22.6
1999	414.2	27.7	1272.6	4.4	2329	2975.2	198.7	7725	26.2
2000	457.5	30.6	1414.2	4.9	2573	3432.7	229.3	8908	30.2
2001	498.6	33.3	1554.8	5.4	2804	3931.3	262.6	10197	34.5
2002	542.6	36.3	1698.1	5.9	3051	4473.9	298.9	11594	39.2
2003	586.6	39.2	1843.8	6.4	3299	5060.5	338.1	13096	44.3
2004	632.0	42.2	1992.9	6.9	3554	5692.5	380.4	14706	49.7
2005	677.4	45.3	2144.7	7.4	3809	6369.9	425.6	16422	55.5
2006	722.3	48.3	2296.6	8.0	4062	7092.1	473.9	18242	61.6
2007	764.7	51.1	2444.6	8.5	4300	7856.9	525.0	20161	68.1
2008	804.6	53.8	2585.7	9.0	4525	8661.5	578.8	22168	74.8
2009	843.7	56.4	2720.3	9.4	4744	9505.1	635.2	24255	81.8
2010	881.4	58.9	2848.8	9.9	4956	10386.5	694.1	26414	89.0
2011	915.3	61.2	2969.4	10.3	5147	11301.8	755.3	28636	96.5
2012	908.7	60.7	3030.0	10.5	5110	12210.5	816.0	30859	103.9
2013	900.0	60.2	3041.6	10.6	5061	13110.6	876.2	33037	111.2
2014	890.7	59.5	3020.9	10.5	5009	14001.3	935.7	35137	118.2
2015	883.9	59.1	2994.5	10.4	4970	14885.1	994.8	37160	124.9
2016	867.4	58.0	2940.8	10.2	4878	15752.5	1052.8	39079	131.3
2017	854.3	57.1	2895.8	10.1	4804	16606.8	1109.9	40907	137.3
2018	841.3	56.2	2850.1	9.9	4731	17448.1	1166.1	42647	143.1
2019	827.7	55.3	2802.4	9.7	4655	18275.8	1221.4	44299	148.6
2020	818.9	54.7	2764.9	9.6	4605	19094.7	1276.1	45875	153.8
2021	805.2	53.8	2714.8	9.4	4528	19899.9	1329.9	47366	158.7
2022	777.8	52.0	2625.6	9.1	4374	20677.7	1381.8	48734	163.2
2023	777.0	51.9	2608.5	9.1	4369	21454.7	1433.7	50055	167.5
2024	777.7	51.9	2589.9	9.0	4374	22232.4	1485.6	51328	171.7
2025	745.5	49.9	2490.8	8.6	4192	22977.9	1535.4	52474	175.5
2026	726.1	48.6	2421.9	8.4	4083	23704.0	1584.1	53527	178.9
2027	658.2	44.0	2211.7	7.7	3701	24362.2	1628.1	54348	181.6
2028	635.6	42.6	2136.2	7.4	3574	24997.8	1670.7	55079	183.9
2029	606.0	40.5	2036.2	7.1	3408	25603.8	1711.2	55697	185.9
2030	617.7	41.2	2049.1	7.1	3474	26221.5	1752.4	56318	187.9
2031	612.4	40.8	2019.3	7.0	3444	26833.9	1793.2	56899	189.8
2032	585.3	39.2	1936.3	6.7	3291	27419.2	1832.4	57385	191.4
2033	588.9	39.3	1925.3	6.7	3312	28008.1	1871.8	57852	192.9
2034	602.1	40.2	1938.4	6.7	3386	28610.3	1911.9	58324	194.4
2035	572.9	38.1	1831.4	6.4	3222	29183.2	1950.0	58860	195.5
2036	535.4	35.7	1717.2	6.0	3011	29718.6	1985.8	58915	196.2
2037	507.1	33.8	1621.1	5.6	2851	30225.7	2019.6	59053	196.6
2038	486.7	32.5	1547.2	5.4	2737	30712.4	2052.1	59118	196.8
2039	466.4	31.1	1473.7	5.1	2623	31178.8	2083.2	59112	196.7
2040	433.5	28.9	1366.3	4.7	2438	31612.3	2112.1	59002	196.3
2041	422.1	28.1	1318.0	4.6	2374	32034.4	2140.2	58851	195.7
2042	395.3	26.4	1227.1	4.3	2223	32429.8	2166.6	58617	194.9
2043	375.2	25.0	1154.1	4.0	2110	32805.0	2191.6	58319	193.9
2044	347.3	23.1	1059.3	3.7	1953	33152.2	2214.7	57938	192.5
2045	319.3	21.3	964.4	3.3	1796	33471.5	2236.0	57475	190.9
2046	284.3	18.9	850.8	3.0	1599	33755.8	2254.9	56913	189.0
2047	251.2	16.7	742.8	2.6	1412	34007.0	2271.6	56262	186.8
2048	225.5	15.0	655.8	2.3	1268	34232.5	2286.6	55545	184.4
2049	199.5	13.3	568.1	2.0	1122	34432.0	2299.9	54761	181.7
2050	164.6	10.9	456.2	1.6	926	34596.6	2310.9	53889	178.8
TIME AFTER SHUTDOWN, YEARS									
100						34596.6	2310.9	5214.6	19.9
300						34596.6	2310.9	184.4	3.4
1000						34596.6	2310.9	50.3	1.3
3000						34596.6	2310.9	21.6	0.3
10000						34596.6	2310.9	15.2	0.2
30000						34596.6	2310.9	9.5	0.1
100000						34596.6	2310.9	6.5	0.0
300000						34596.6	2310.9	4.6	0.0
1000000						34596.6	2310.9	2.4	0.0

TABLE A.7

HLW for No-Recycle

Watts vs Time

Actinides and Their Daughter Products

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (WATTS/MTHM)</u>	<u>BWR (WATTS/MTHM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.2889E 03	0.2212E 03	0.2664E 03
2	0.1222E 03	0.9667E 02	0.1137E 03
3	0.8504E 02	0.6887E 02	0.7965E 02
4	0.7538E 02	0.6159E 02	0.7078E 02
5	0.7160E 02	0.5870E 02	0.6730E 02
6	0.6913E 02	0.5678E 02	0.6501E 02
7	0.6700E 02	0.5513E 02	0.6304E 02
8	0.6499E 02	0.5357E 02	0.6119E 02
9	0.6308E 02	0.5208E 02	0.5941E 02
10	0.6123E 02	0.5064E 02	0.5770E 02
20	0.4616E 02	0.3890E 02	0.4374E 02
30	0.3578E 02	0.3081E 02	0.3412E 02
40	0.2862E 02	0.2521E 02	0.2748E 02
50	0.2366E 02	0.2131E 02	0.2287E 02
100	0.1385E 02	0.1349E 02	0.1373E 02
200	0.1043E 02	0.1043E 02	0.1043E 02
400	0.7608E 01	0.7591E 01	0.7602E 01
600	0.5707E 01	0.5657E 01	0.5690E 01
1000	0.3393E 01	0.3311E 01	0.3365E 01
10000	0.4873E 00	0.4246E 00	0.4664E 00
30000	0.1860E 00	0.1571E 00	0.1764E 00
100000	0.6181E-01	0.5158E-01	0.5840E-01
1000000	0.8112E-01	0.6786E-01	0.7670E-01

TABLE A.8

HLW for No-Recycle

Watts vs Time

Fission Products

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (WATTS/MTHM)</u>	<u>BWR (WATTS/MTHM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.9985E 04	0.7350E 04	0.9107E 04
2	0.5378E 04	0.4020E 04	0.4925E 04
3	0.3372E 04	0.2556E 04	0.3100E 04
4	0.2351E 04	0.1807E 04	0.2169E 04
5	0.1795E 04	0.1398E 04	0.1663E 04
6	0.1471E 04	0.1159E 04	0.1367E 04
7	0.1270E 04	0.1009E 04	0.1183E 04
8	0.1136E 04	0.9092E 03	0.1060E 04
9	0.1041E 04	0.8380E 03	0.9733E 03
10	0.9704E 03	0.7845E 03	0.9085E 03
20	0.6668E 03	0.5460E 03	0.6265E 03
30	0.5149E 03	0.4223E 03	0.4840E 03
40	0.4022E 03	0.3301E 03	0.3782E 03
50	0.3155E 03	0.2589E 03	0.2966E 03
100	0.9546E 02	0.7841E 02	0.8978E 02
200	0.8920E 01	0.7335E 01	0.8392E 01
400	0.1047E 00	0.8695E-01	0.9881E-01
600	0.2191E-01	0.1853E-01	0.2078E-01
1000	0.1972E-01	0.1666E-01	0.1870E-01
10000	0.1881E-01	0.1589E-01	0.1783E-01
30000	0.1710E-01	0.1445E-01	0.1622E-01
100000	0.1243E-01	0.1050E-01	0.1179E-01
1000000	0.9012E-03	0.7714E-03	0.8580E-03

TABLE A.9

HLW for No-Recycle

Curies vs Time

Actinides and Their Daughter Products

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (CURIES/MTHM)</u>	<u>BWR (CURIES/MTHM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.8608E 04	0.6673E 04	0.7963E 04
2	0.4053E 04	0.3268E 04	0.3791E 04
3	0.3015E 04	0.2488E 04	0.2839E 04
4	0.2724E 04	0.2266E 04	0.2571E 04
5	0.2594E 04	0.2164E 04	0.2450E 04
6	0.2500E 04	0.2089E 04	0.2363E 04
7	0.2417E 04	0.2023E 04	0.2286E 04
8	0.2339E 04	0.1960E 04	0.2213E 04
9	0.2264E 04	0.1900E 04	0.2143E 04
10	0.2192E 04	0.1842E 04	0.2076E 04
20	0.1612E 04	0.1377E 04	0.1534E 04
30	0.1222E 04	0.1064E 04	0.1169E 04
40	0.9590E 03	0.8534E 03	0.9238E 03
50	0.7804E 03	0.7100E 03	0.7570E 03
100	0.4429E 03	0.4350E 03	0.4403E 03
200	0.3338E 03	0.3351E 03	0.3343E 03
400	0.2456E 03	0.2443E 03	0.2452E 03
600	0.1870E 03	0.1840E 03	0.1860E 03
1000	0.1164E 03	0.1120E 03	0.1150E 03
10000	0.2154E 02	0.1870E 02	0.2059E 02
30000	0.7348E 01	0.6228E 01	0.6974E 01
100000	0.2625E 01	0.2194E 01	0.2481E 01
1000000	0.3417E 01	0.2859E 01	0.3231E 01

TABLE A.10

HLW for No-Recycle

Curies vs Time

Fission Products

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (CURIES/MTHM)</u>	<u>BWR (CURIES/MTHM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.2195E 07	0.1637E 07	0.2009E 07
2	0.1204E 07	0.9201E 06	0.1110E 07
3	0.7886E 06	0.6149E 06	0.7307E 06
4	0.5838E 06	0.4631E 06	0.5436E 06
5	0.4758E 06	0.3821E 06	0.4445E 06
6	0.4141E 06	0.3353E 06	0.3878E 06
7	0.3756E 06	0.3057E 06	0.3523E 06
8	0.3494E 06	0.2852E 06	0.3280E 06
9	0.3300E 06	0.2700E 06	0.3100E 06
10	0.3149E 06	0.2579E 06	0.2959E 06
20	0.2323E 06	0.1909E 06	0.2185E 06
30	0.1818E 06	0.1494E 06	0.1710E 06
40	0.1431E 06	0.1177E 06	0.1346E 06
50	0.1129E 06	0.9284E 05	0.1062E 06
100	0.3481E 05	0.2866E 05	0.3276E 05
200	0.3501E 04	0.2894E 04	0.3299E 04
400	0.1082E 03	0.9203E 02	0.1028E 03
600	0.3523E 02	0.2994E 02	0.3347E 02
1000	0.2278E 02	0.1915E 02	0.2157E 02
10000	0.2157E 02	0.1811E 02	0.2041E 02
30000	0.2038E 02	0.1711E 02	0.1929E 02
100000	0.1688E 02	0.1418E 02	0.1598E 02
1000000	0.3662E 01	0.3092E 01	0.3472E 01

Table A.11 Accumulation of solidified HLW at a repository:
Uranium Only Recycle

Year	Volume (m ³)	Annual Addition Actinide Mass (MT)	Radio- activity (MCi)	Thermal Power (MW)	Annual Number of Canisters	Volume (m ³)	Actinide Mass (MT)	Radio- activity (MCi)	Thermal Power (MW)
1985	16.4	1.1	40.2	0.1	92	16.4	1.1	40.	0.1
1986	65.4	4.3	152.0	0.5	368	81.8	5.4	191.	0.7
1987	87.1	5.7	202.5	0.7	490	168.9	11.1	386.	1.3
1988	98.5	6.5	248.0	0.9	554	267.3	17.6	620.	2.1
1989	111.4	7.4	317.1	1.1	626	378.7	25.1	916.	3.1
1990	120.2	8.0	369.1	1.3	676	498.9	33.1	1254.	4.3
1991	162.1	10.9	512.9	1.8	911	661.0	44.0	1726.	5.9
1992	183.7	12.3	562.3	1.9	1033	844.8	56.2	2232.	7.6
1993	206.0	13.8	619.8	2.1	1158	1050.8	70.0	2780.	9.4
1994	235.5	15.8	707.3	2.4	1324	1286.2	85.8	3400.	11.5
1995	277.2	18.6	821.0	2.8	1559	1563.5	104.4	4115.	13.9
1996	292.6	19.6	867.4	3.0	1646	1856.1	123.9	4855.	16.4
1997	332.9	22.2	999.1	3.4	1872	2189.0	146.2	5707.	19.2
1998	372.0	24.9	1133.1	3.9	2092	2561.0	171.0	6667.	22.5
1999	414.2	27.7	1275.0	4.4	2329	2975.2	198.7	7742.	26.1
2000	457.5	30.6	1416.9	4.9	2573	3432.7	229.3	8928.	30.0
2001	498.6	33.3	1557.7	5.4	2804	3931.3	262.6	10220.	34.4
2002	542.6	36.3	1701.3	5.9	3051	4473.9	298.9	11620.	39.1
2003	586.6	39.2	1847.3	6.4	3299	5060.5	338.1	13126.	44.1
2004	632.0	42.2	1996.7	6.9	3554	5692.5	380.4	14739.	49.5
2005	677.4	45.3	2148.8	7.4	3809	6369.9	425.6	16459.	55.2
2006	722.3	48.3	2300.9	7.9	4062	7092.1	473.9	18284.	61.3
2007	764.7	51.1	2449.3	8.4	4300	7856.9	525.0	20207.	67.8
2008	804.6	53.8	2590.6	8.9	4525	8661.5	578.8	22219.	74.5
2009	843.7	56.4	2725.4	9.4	4744	9505.1	635.2	24311.	81.5
2010	881.4	58.9	2854.2	9.8	4956	10386.5	694.1	26475.	88.7
2011	915.3	61.2	2975.0	10.2	5147	11301.8	755.3	28702.	96.1
2012	908.7	60.7	3035.7	10.5	5110	12210.5	816.0	30931.	103.5
2013	900.0	60.2	3047.4	10.5	5061	13110.6	876.2	33114.	110.8
2014	890.7	59.5	3026.6	10.4	5009	14001.3	935.7	35220.	117.7
2015	883.9	59.1	3000.3	10.3	4970	14885.1	994.8	37247.	124.4
2016	867.4	58.0	2946.4	10.1	4878	15752.5	1052.8	39771.	130.8
2017	854.3	57.1	2901.3	10.0	4804	16606.8	1109.9	41005.	136.8
2018	841.3	56.2	2855.5	9.8	4731	17448.1	1166.1	42749.	142.6
2019	827.7	55.3	2807.8	9.7	4655	18275.8	1221.4	44405.	148.0
2020	818.9	54.7	2770.2	9.5	4605	19094.7	1276.1	45986.	153.2
2021	805.2	53.8	2720.0	9.4	4528	19899.9	1329.9	47481.	158.1
2022	777.8	52.0	2630.6	9.1	4374	20677.7	1381.8	48852.	162.6
2023	777.0	51.9	2613.5	9.0	4369	21454.7	1433.7	50177.	167.0
2024	777.7	51.9	2595.0	8.9	4374	22232.4	1485.6	51454.	171.2
2025	745.5	49.9	2495.5	8.6	4192	22977.9	1535.4	52603.	174.9
2026	726.1	48.6	2426.4	8.4	4083	23704.0	1584.1	53659.	178.4
2027	658.2	44.0	2215.9	7.6	3701	24362.2	1628.1	54482.	181.0
2028	635.6	42.6	2140.2	7.4	3574	24997.8	1670.7	55215.	183.4
2029	606.0	40.5	2040.1	7.0	3408	25603.8	1711.2	55835.	185.4
2030	617.7	41.2	2053.1	7.1	3474	26221.5	1752.4	56459.	187.4
2031	612.4	40.8	2023.3	7.0	3444	26833.9	1793.2	57041.	189.2
2032	585.3	39.2	1939.9	6.7	3291	27419.2	1832.4	57529.	190.8
2033	588.9	39.3	1929.0	6.6	3312	28008.1	1871.8	57997.	192.3
2034	602.1	40.2	1942.2	6.7	3386	28610.3	1911.9	58471.	193.9
2035	572.9	38.1	1835.1	6.3	3222	29183.2	1950.0	58828.	195.0
2036	535.4	35.7	1720.6	5.9	3011	29718.6	1985.8	59065.	195.7
2037	507.1	33.8	1624.3	5.6	2851	30225.7	2019.6	59203.	196.1
2038	486.7	32.5	1550.2	5.3	2737	30742.4	2052.1	59269.	196.3
2039	466.4	31.1	1476.6	5.1	2623	31178.8	2083.2	59263.	196.2
2040	433.5	28.9	1369.0	4.7	2438	31612.3	2112.1	59153.	195.8
2041	422.1	28.1	1320.6	4.5	2374	32038.4	2140.2	59002.	195.3
2042	395.3	26.4	1229.5	4.2	2223	32429.8	2166.6	58768.	194.4
2043	375.2	25.0	1156.4	4.0	2110	32805.0	2191.6	58470.	193.4
2044	347.3	23.1	1061.4	3.7	1953	33152.2	2214.7	58088.	192.1
2045	319.3	21.3	966.3	3.3	1796	33471.5	2236.0	57624.	190.5
2046	284.3	18.9	852.5	2.9	1599	33755.8	2254.9	57062.	188.6
2047	251.2	16.7	744.3	2.6	1412	34007.0	2271.6	56409.	186.4
2048	225.5	15.0	657.2	2.3	1268	34232.5	2286.6	55690.	184.0
2049	199.5	13.3	569.3	2.0	1122	34432.0	2299.9	54905.	181.4
2050	164.6	10.9	457.2	1.6	926	34596.6	2310.9	54031.	178.4

TIME AFTER SHUTDOWN, YEARS	Volume (m ³)	Actinide Mass (MT)	Radio- activity (MCi)	Thermal Power (MW)
100	34596.6	2310.9	5225.8	19.9
300	34596.6	2310.9	181.2	3.3
1000	34596.6	2310.9	48.3	1.2
3000	34596.6	2310.9	20.5	0.3
10000	34596.6	2310.9	14.7	0.2
30000	34596.6	2310.9	9.7	0.1
100000	34596.6	2310.9	7.2	0.0
300000	34596.6	2310.9	5.7	0.1
1000000	34596.6	2310.9	3.6	0.1

TABLE A.12
HLW for U Recycle

Watts vs Time

Actinides and Their Daughter Products

<u>YEARS</u> <u>AFTER</u> <u>DISCHARGE</u>	<u>PWR</u> <u>(WATTS/MTHM)</u>	<u>BWR</u> <u>(WATTS/MTHM)</u>	<u>PWR AND BWR</u> <u>IN A</u> <u>2 TO 1 RATIO</u>
1	0.2635E 03	0.2003E 03	0.2424E 03
2	0.1093E 03	0.8648E 02	0.1017E 03
3	0.7505E 02	0.6116E 02	0.7042E 02
4	0.6628E 02	0.5460E 02	0.6238E 02
5	0.6294E 02	0.5206E 02	0.5932E 02
6	0.6082E 02	0.5042E 02	0.5735E 02
7	0.5900E 02	0.4900E 02	0.5566E 02
8	0.5729E 02	0.4767E 02	0.5408E 02
9	0.5566E 02	0.4639E 02	0.5257E 02
10	0.5409E 02	0.4517E 02	0.5112E 02
20	0.4125E 02	0.3512E 02	0.3920E 02
30	0.3239E 02	0.2818E 02	0.3099E 02
40	0.2626E 02	0.2336E 02	0.2529E 02
50	0.2200E 02	0.1999E 02	0.2133E 02
100	0.1344E 02	0.1310E 02	0.1333E 02
200	0.1020E 02	0.1015E 02	0.1018E 02
400	0.7380E 01	0.7327E 01	0.7362E 01
600	0.5513E 01	0.5438E 01	0.5488E 01
1000	0.3255E 01	0.3162E 01	0.3224E 01
10000	0.4540E 00	0.3943E 00	0.4341E 00
30000	0.1891E 00	0.1622E 00	0.1802E 00
100000	0.9690E-01	0.8777E-01	0.9386E-01
1000000	0.1513E 00	0.1396E 00	0.1474E 00

TABLE A.13

HLW for U Recycle

Watts vs Time

Fission Products

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (WATTS/MTHM)</u>	<u>BWR (WATTS/MTHM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.9860E 04	0.7255E 04	0.8992E 04
2	0.5301E 04	0.3962E 04	0.4855E 04
3	0.3325E 04	0.2520E 04	0.3057E 04
4	0.2320E 04	0.1785E 04	0.2142E 04
5	0.1775E 04	0.1385E 04	0.1645E 04
6	0.1459E 04	0.1151E 04	0.1356E 04
7	0.1262E 04	0.1005E 04	0.1176E 04
8	0.1131E 04	0.9070E 03	0.1056E 04
9	0.1038E 04	0.8372E 03	0.9710E 03
10	0.9688E 03	0.7849E 03	0.9075E 03
20	0.6584E 03	0.5487E 03	0.6285E 03
30	0.5166E 03	0.4246E 03	0.4859E 03
40	0.4036E 03	0.3320E 03	0.3797E 03
50	0.3166E 03	0.2605E 03	0.2979E 03
100	0.9580E 02	0.7888E 02	0.9016E 02
200	0.8946E 01	0.7373E 01	0.8422E 01
400	0.1047E 00	0.8708E-01	0.9885E-01
600	0.2174E-01	0.1838E-01	0.2062E-01
1000	0.1955E-01	0.1650E-01	0.1853E-01
10000	0.1865E-01	0.1574E-01	0.1768E-01
30000	0.1696E-01	0.1432E-01	0.1608E-01
100000	0.1235E-01	0.1042E-01	0.1171E-01
1000000	0.9051E-03	0.7765E-03	0.8622E-03

TABLE A.14

HLW for U Recycle

Curies vs Time

Actinides and Their Daughter Products

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (CURIES/MTHM)</u>	<u>BWR (CURIES/MTHM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.7886E 04	0.6079E 04	0.7284E 04
2	0.3672E 04	0.2965E 04	0.3437E 04
3	0.2715E 04	0.2254E 04	0.2561E 04
4	0.2450E 04	0.2052E 04	0.2317E 04
5	0.2333E 04	0.1960E 04	0.2209E 04
6	0.2250E 04	0.1894E 04	0.2131E 04
7	0.2176E 04	0.1835E 04	0.2062E 04
8	0.2107E 04	0.1779E 04	0.1998E 04
9	0.2041E 04	0.1726E 04	0.1936E 04
10	0.1977E 04	0.1674E 04	0.1876E 04
20	0.1464E 04	0.1261E 04	0.1396E 04
30	0.1120E 04	0.9835E 03	0.1074E 04
40	0.8875E 03	0.7961E 03	0.8571E 03
50	0.7299E 03	0.6686E 03	0.7094E 03
100	0.4293E 03	0.4215E 03	0.4267E 03
200	0.3253E 03	0.3251E 03	0.3252E 03
400	0.2374E 03	0.2351E 03	0.2366E 03
600	0.1800E 03	0.1762E 03	0.1787E 03
1000	0.1112E 03	0.1065E 03	0.1096E 03
10000	0.2024E 02	0.1754E 02	0.1934E 02
30000	0.7754E 01	0.6709E 01	0.7406E 01
100000	0.4282E 01	0.3899E 01	0.4154E 01
1000000	0.6369E 01	0.5877E 01	0.6205E 01

TABLE A.15

HLW for U Recycle

Curies vs Time

Fission Products

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (CURIES/MTHM)</u>	<u>BWR (CURIES/MTHM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.2179E 07	0.1626E 07	0.1995E 07
2	0.1196E 07	0.9140E 06	0.1102E 07
3	0.7838E 06	0.6118E 06	0.7265E 06
4	0.5813E 06	0.4618E 06	0.5415E 06
5	0.4746E 06	0.3818E 06	0.4437E 06
6	0.4136E 06	0.3355E 06	0.3876E 06
7	0.3756E 06	0.3063E 06	0.3525E 06
8	0.3496E 06	0.2860E 06	0.3284E 06
9	0.3304E 06	0.2709E 06	0.3106E 06
10	0.3153E 06	0.2588E 06	0.2965E 06
20	0.2328E 06	0.1918E 06	0.2191E 06
30	0.1823E 06	0.1502E 06	0.1716E 06
40	0.1435E 06	0.1183E 06	0.1351E 06
50	0.1132E 06	0.9328E 05	0.1065E 06
100	0.3489E 05	0.2879E 05	0.3286E 05
200	0.3508E 04	0.2906E 04	0.3307E 04
400	0.1085E 03	0.9251E 02	0.1032E 03
600	0.3529E 02	0.3005E 02	0.3354E 02
1000	0.2279E 02	0.1917E 02	0.2158E 02
10000	0.2157E 02	0.1813E 02	0.2043E 02
30000	0.2039E 02	0.1714E 02	0.1931E 02
100000	0.1690E 02	0.1421E 02	0.1600E 02
1000000	0.3678E 01	0.3113E 01	0.3490E 01

Table A.16 Accumulation of solidified HLW at a repository:
Uranium, Plutonium Recycle

Year	* * * * Volume (m ³)	Annual Addition Actinide Mass (MT)	* * * * Radio- activity (MCi)	* * * * Thermal Power (MW)	Annual Number of Canisters	* Accumulation Through Volume (m ³)	Actinide Mass (MT)	End of Radio- activity (MCi)	Year * Thermal Power (MW)
1985	16.4	1.1	40.2	0.1	92	16.4	1.1	40.	0.1
1986	65.4	4.3	152.0	0.5	368	81.8	5.4	191.	0.7
1987	87.1	5.7	202.5	0.7	490	168.9	11.1	386.	1.3
1988	98.5	6.5	248.0	0.9	554	267.3	17.6	620.	2.1
1989	111.4	7.4	317.1	1.1	626	378.7	25.1	916.	3.1
1990	120.2	8.0	369.1	1.3	676	498.9	33.1	1254.	4.3
1991	162.1	10.9	512.9	1.8	911	661.0	44.0	1726.	5.9
1992	183.7	12.3	562.3	1.9	1033	844.8	56.2	2232.	7.6
1993	206.0	13.8	619.8	2.1	1158	1050.8	70.0	2780.	9.4
1994	235.5	15.8	707.3	2.4	1324	1286.2	85.8	3400.	11.5
1995	277.2	18.6	821.0	2.8	1559	1563.5	104.4	4115.	13.9
1996	292.6	19.6	867.4	3.0	1646	1856.1	123.9	4855.	16.4
1997	332.9	22.4	999.0	3.5	1872	2189.0	146.3	5707.	19.3
1998	372.0	25.3	1132.5	4.1	2092	2561.0	171.6	6667.	22.7
1999	414.2	28.1	1274.3	4.6	2329	2975.2	199.7	7741.	26.6
2000	457.5	31.1	1416.2	5.2	2573	3432.7	230.8	8925.	30.8
2001	498.6	34.3	1556.4	5.9	2804	3931.3	265.0	10216.	35.6
2002	542.6	37.7	1699.2	6.7	3051	4473.9	302.8	11613.	41.1
2003	586.6	40.7	1845.3	7.2	3299	5060.5	343.5	13117.	46.8
2004	632.0	43.9	1994.3	7.8	3554	5692.5	387.4	14726.	53.0
2005	677.3	47.5	2145.6	8.6	3809	6369.9	434.9	16442.	59.9
2006	722.3	50.9	2297.2	9.4	4062	7092.2	485.9	18262.	67.3
2007	764.7	54.2	2444.9	10.1	4300	7856.9	540.1	20179.	75.2
2008	804.6	57.2	2585.7	10.8	4525	8661.5	597.3	22183.	83.5
2009	843.7	60.5	2719.7	11.6	4744	9505.1	657.8	24267.	92.3
2010	881.4	63.4	2847.9	12.3	4956	10386.5	721.2	26422.	101.6
2011	915.3	66.3	2967.9	13.0	5147	11301.9	787.5	28638.	111.3
2012	908.7	66.2	3028.1	13.4	5110	12210.6	853.7	30855.	121.2
2013	900.0	66.5	3038.5	13.9	5061	13110.6	920.2	33023.	131.2
2014	890.7	66.5	3016.9	14.2	5009	14001.3	986.7	35114.	141.2
2015	883.9	66.7	2989.6	14.5	4970	14885.1	1053.4	37124.	151.3
2016	867.4	66.2	2934.9	14.6	4878	15752.5	1119.6	39029.	161.1
2017	854.3	66.1	2888.7	14.9	4804	16606.8	1185.7	40842.	171.0
2018	841.3	66.0	2841.8	15.1	4731	17448.1	1251.7	42564.	180.8
2019	827.7	65.4	2793.7	15.1	4655	18275.8	1317.1	44196.	190.4
2020	818.9	64.9	2755.9	15.1	4605	19094.7	1382.0	45752.	199.6
2021	805.2	61.6	2709.1	13.6	4528	19899.9	1443.6	47224.	207.1
2022	777.8	60.0	2619.4	13.4	4374	20677.7	1503.5	48573.	214.3
2023	776.9	59.9	2602.3	13.4	4369	21454.7	1563.5	49874.	221.1
2024	777.7	59.9	2583.8	13.3	4373	22232.4	1623.4	51128.	227.8
2025	745.5	57.0	2485.6	12.4	4192	22977.9	1680.3	52255.	233.4
2026	726.1	55.7	2416.6	12.2	4083	23704.0	1736.0	53289.	238.6
2027	658.2	51.0	2206.2	11.4	3701	24362.2	1787.0	54091.	243.0
2028	635.6	49.0	2131.2	10.9	3574	24997.8	1836.0	54804.	246.7
2029	606.0	47.0	2031.1	10.5	3408	25603.8	1883.0	55404.	250.0
2030	617.7	47.5	2044.3	10.5	3474	26221.5	1930.5	56008.	253.2
2031	612.4	46.9	2014.9	10.2	3444	26833.9	1977.4	56571.	256.1
2032	585.3	45.0	1931.7	9.9	3291	27419.2	2022.4	57041.	258.5
2033	588.9	44.9	1921.3	9.6	3312	28008.1	2067.3	57493.	260.7
2034	602.1	45.7	1934.5	9.7	3386	28610.2	2113.0	57949.	262.9
2035	572.9	43.4	1827.6	9.2	3222	29183.2	2156.4	58290.	264.6
2036	535.4	40.9	1713.4	8.7	3011	29718.6	2197.3	58512.	265.7
2037	507.1	38.9	1617.2	8.3	2851	30225.7	2236.1	58636.	266.5
2038	486.7	37.5	1543.2	8.1	2737	30712.4	2273.6	58688.	267.0
2039	466.4	35.9	1469.9	7.7	2623	31178.8	2309.5	58669.	267.1
2040	433.5	33.4	1362.6	7.2	2438	31612.3	2343.0	58548.	266.8
2041	422.1	32.5	1314.5	6.9	2374	32034.4	2375.5	58385.	266.2
2042	395.3	30.6	1223.6	6.5	2223	32429.8	2406.0	58140.	265.3
2043	375.2	29.0	1150.8	6.2	2110	32805.0	2435.0	57833.	264.1
2044	347.3	26.9	1056.1	5.7	1953	33152.2	2461.9	57442.	262.4
2045	319.3	24.9	961.3	5.3	1796	33471.5	2486.8	56971.	260.5
2046	284.3	22.3	847.8	4.8	1599	33755.8	2509.1	56402.	258.1
2047	251.2	19.9	739.7	4.3	1412	34006.9	2529.1	55743.	255.4
2048	225.5	18.0	653.0	3.9	1268	34232.5	2547.1	55019.	252.3
2049	199.5	16.0	565.4	3.5	1122	34432.0	2563.1	54230.	248.9
2050	164.6	13.5	453.6	2.9	926	34596.5	2576.6	53353.	245.2

TIME AFTER SHUTDOWN, YEARS

100	34596.5	2576.6	5441.1	32.2
300	34596.5	2576.6	486.5	11.9
1000	34596.5	2576.6	188.9	4.9
3000	34596.5	2576.6	91.4	1.9
10000	34596.5	2576.6	54.5	1.1
30000	34596.5	2576.6	20.6	0.4
100000	34596.5	2576.6	8.3	0.1
300000	34596.5	2576.6	5.9	0.1
1000000	34596.5	2576.6	3.6	0.1

TABLE A.17

HLW For U and Pu Recycle

Watts vs Time

ACTINIDES AND THEIR DAUGHTER PRODUCTS

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (WATTS/MTHM)</u>	<u>BWR (WATTS/MTHM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.4578E 04	0.3236E 04	0.4131E 04
2	0.2463E 04	0.1787E 04	0.2238E 04
3	0.1963E 04	0.1443E 04	0.1790E 04
4	0.1807E 04	0.1334E 04	0.1649E 04
5	0.1725E 04	0.1275E 04	0.1575E 04
6	0.1661E 04	0.1229E 04	0.1517E 04
7	0.1603E 04	0.1187E 04	0.1464E 04
8	0.1547E 04	0.1146E 04	0.1413E 04
9	0.1493E 04	0.1108E 04	0.1365E 04
10	0.1442E 04	0.1071E 04	0.1318E 04
20	0.1022E 04	0.7666E 03	0.9367E 03
30	0.7347E 03	0.5587E 03	0.6760E 03
40	0.5382E 03	0.4163E 03	0.4976E 03
50	0.4036E 03	0.3186E 03	0.3752E 03
100	0.1512E 03	0.1342E 03	0.1456E 03
200	0.9303E 02	0.8861E 02	0.9155E 02
400	0.6736E 02	0.6468E 02	0.6647E 02
600	0.5134E 02	0.4917E 02	0.5061E 02
1000	0.3315E 02	0.3096E 02	0.3242E 02
10000	0.7822E 01	0.6305E 01	0.7316E 01
30000	0.2492E 01	0.2010E 01	0.2331E 01
100000	0.3567E 00	0.2972E 00	0.3369E 00
1000000	0.1522E 00	0.1544E 00	0.1529E 00

TABLE A.18

HLW for U and Pu Recycle

Watts vs Time

Fission Products

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (WATTS/MTHM)</u>	<u>BWR (WATTS/MTHM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.1079E 05	0.7850E 04	0.9807E 04
2	0.5747E 04	0.4244E 04	0.5246E 04
3	0.3483E 04	0.2615E 04	0.3194E 04
4	0.2327E 04	0.1778E 04	0.2144E 04
5	0.1704E 04	0.1325E 04	0.1577E 04
6	0.1348E 04	0.1065E 04	0.1254E 04
7	0.1133E 04	0.9053E 03	0.1057E 04
8	0.9937E 03	0.8014E 03	0.9296E 03
9	0.8983E 03	0.7295E 03	0.8420E 03
10	0.8292E 03	0.6768E 03	0.7784E 03
20	0.5513E 03	0.4569E 03	0.5199E 03
30	0.4220E 03	0.3505E 03	0.3982E 03
40	0.3284E 03	0.2731E 03	0.3100E 03
50	0.2573E 03	0.2141E 03	0.2429E 03
100	0.7843E 02	0.6526E 02	0.7404E 02
200	0.7505E 01	0.6240E 01	0.7083E 01
400	0.1018E 00	0.8461E-01	0.9609E-01
600	0.2738E-01	0.2270E-01	0.2582E-01
1000	0.2484E-01	0.2057E-01	0.2342E-01
10000	0.2360E-01	0.1954E-01	0.2225E-01
30000	0.2128E-01	0.1762E-01	0.2006E-01
100000	0.1501E-01	0.1246E-01	0.1416E-01
1000000	0.9208E-03	0.7946E-03	0.8787E-03

TABLE A.19

HLW for U and Pu Recycle

CURIES VS TIME

ACTINIDES AND THEIR DAUGHTER PRODUCTS

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (CURIES/MTM)</u>	<u>BWR (CURIES/MTM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.1311E 06	0.9310E 05	0.1184E 06
2	0.7346E 05	0.5363E 05	0.6685E 05
3	0.5967E 05	0.4411E 05	0.5449E 05
4	0.5522E 05	0.4097E 05	0.5047E 05
5	0.5279E 05	0.3923E 05	0.4827E 05
6	0.5086E 05	0.3782E 05	0.4651E 05
7	0.4907E 05	0.3652E 05	0.4489E 05
8	0.4738E 05	0.3528E 05	0.4335E 05
9	0.4575E 05	0.3410E 05	0.4186E 05
10	0.4418E 05	0.3295E 05	0.4044E 05
20	0.3144E 05	0.2366E 05	0.2884E 05
30	0.2276E 05	0.1733E 05	0.2095E 05
40	0.1684E 05	0.1301E 05	0.1556E 05
50	0.1279E 05	0.1006E 05	0.1188E 05
100	0.5200E 04	0.4490E 04	0.4963E 04
200	0.3324E 04	0.3041E 04	0.3229E 04
400	0.2385E 04	0.2216E 04	0.2329E 04
600	0.1833E 04	0.1706E 04	0.1791E 04
1000	0.1242E 04	0.1130E 04	0.1205E 04
10000	0.3447E 03	0.2793E 03	0.3229E 03
30000	0.9642E 02	0.7821E 02	0.9035E 02
100000	0.1309E 02	0.1105E 02	0.1241E 02
1000000	0.6414E 01	0.6504E 01	0.6444E 01

TABLE A.20

HLW for U and Pu Recycle

CURIES VS TIME

Fission Products

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (CURIES/MTHM)</u>	<u>BWR (CURIES/MTHM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.2337E 07	0.1719E 07	0.2131E 07
2	0.1267E 07	0.9522E 06	0.1162E 07
3	0.8002E 06	0.6151E 06	0.7385E 06
4	0.5676E 06	0.4460E 06	0.5271E 06
5	0.4451E 06	0.3560E 06	0.4154E 06
6	0.3761E 06	0.3046E 06	0.3523E 06
7	0.3343E 06	0.2730E 06	0.3138E 06
8	0.3067E 06	0.2519E 06	0.2884E 06
9	0.2871E 06	0.2366E 06	0.2703E 06
10	0.2722E 06	0.2248E 06	0.2564E 06
20	0.1975E 06	0.1640E 06	0.1863E 06
30	0.1543E 06	0.1282E 06	0.1456E 06
40	0.1216E 06	0.1010E 06	0.1147E 06
50	0.9601E 05	0.7980E 05	0.9061E 05
100	0.3000E 05	0.2493E 05	0.2831E 05
200	0.3160E 04	0.2628E 04	0.2983E 04
400	0.1214E 03	0.1021E 03	0.1150E 03
600	0.3884E 02	0.3267E 02	0.3678E 02
1000	0.2299E 02	0.1928E 02	0.2175E 02
10000	0.2156E 02	0.1807E 02	0.2039E 02
30000	0.2029E 02	0.1702E 02	0.1920E 02
100000	0.1660E 02	0.1394E 02	0.1571E 02
1000000	0.3396E 01	0.2905E 01	0.3232E 01

Table A.21 Accumulation of solidified HLW with plutonium included at a repository:
Uranium Only Recycle

Year	* * * * Volume (M3)	Annual Addition Actinide Mass (MT)	* * * * Radio- Activity (MCI)	* * * * Thermal Power (MW)	Annual Number of Canisters	* Accumulation Volume (M3)	Through End of Year Actinide Mass (MT)	* Radio- Activity (MCI)	* Thermal Power (MW)
1985	16.4	2.5	51.1	0.2	92	16.4	2.5	51.	0.2
1986	65.4	10.0	193.3	0.6	368	81.8	12.5	242.	0.8
1987	87.1	13.3	257.6	0.9	490	168.9	25.8	491.	1.6
1988	98.5	15.5	315.2	1.1	554	267.3	41.3	788.	2.6
1989	111.4	18.2	402.8	1.3	626	378.7	59.6	1162.	3.9
1990	120.2	20.2	468.5	1.6	676	498.9	79.8	1590.	5.3
1991	162.1	27.6	650.9	2.2	911	661.0	107.3	2186.	7.3
1992	183.7	30.9	713.5	2.4	1033	844.8	138.2	2824.	9.5
1993	206.0	34.5	786.5	2.6	1158	1050.8	172.7	3515.	11.8
1994	235.5	39.4	897.5	3.0	1324	1286.2	212.0	4295.	14.5
1995	277.2	46.1	1041.7	3.5	1559	1563.5	258.1	5194.	17.6
1996	292.6	48.6	1100.6	3.7	1646	1856.1	306.7	6124.	20.7
1997	332.9	55.5	1267.8	4.2	1872	2189.0	362.2	7192.	24.4
1998	372.0	62.3	1438.0	4.8	2092	2561.0	424.5	8397.	28.6
1999	414.2	69.6	1618.1	5.4	2329	2975.2	494.2	9745.	33.2
2000	457.5	77.1	1798.2	6.0	2573	3432.7	571.3	11230.	38.3
2001	498.6	84.3	1976.9	6.6	2804	3931.3	655.5	12849.	44.0
2002	542.6	91.8	2159.1	7.2	3051	4473.9	747.4	14600.	50.0
2003	586.6	99.5	2344.5	7.8	3299	5060.5	846.9	16482.	56.6
2004	632.0	107.3	2534.1	8.4	3554	5692.5	954.1	18497.	63.6
2005	677.4	115.1	2727.1	9.1	3809	6369.9	1069.3	20645.	71.2
2006	722.3	123.0	2920.3	9.7	4062	7092.1	1192.2	22920.	79.2
2007	764.7	130.4	3108.6	10.4	4300	7856.9	1322.6	25316.	87.6
2008	804.6	137.5	3287.9	11.0	4525	8661.5	1460.1	27820.	96.5
2009	843.7	144.3	3459.2	11.5	4744	9505.1	1604.4	30421.	105.7
2010	881.4	150.9	3622.6	12.1	4956	10386.5	1755.4	33108.	115.3
2011	915.3	156.9	3776.0	12.6	5147	11301.8	1912.3	35871.	125.2
2012	908.7	157.2	3853.1	12.8	5110	12210.5	2069.5	38631.	135.2
2013	900.0	156.5	3868.0	12.9	5061	13140.6	2226.0	41327.	145.0
2014	890.7	155.1	3841.8	12.8	5009	14001.3	2381.1	43921.	154.5
2015	883.9	154.0	3808.4	12.7	4970	14885.1	2535.1	46410.	163.8
2016	867.4	151.2	3740.1	12.5	4878	15752.5	2686.3	48765.	172.6
2017	854.3	148.9	3682.8	12.3	4804	16606.8	2835.1	50999.	181.1
2018	841.3	146.5	3624.7	12.1	4731	17448.1	2981.6	53118.	189.3
2019	827.7	144.1	3564.1	11.9	4655	18275.8	3125.7	55122.	197.2
2020	818.9	142.3	3516.6	11.7	4605	19094.7	3268.0	57028.	204.8
2021	805.2	139.7	3452.8	11.5	4528	19899.9	3407.7	58822.	212.0
2022	777.8	135.1	3339.4	11.1	4374	20677.7	3542.8	60459.	218.8
2023	777.0	134.4	3317.7	11.1	4369	21454.7	3677.2	62036.	225.4
2024	777.7	133.7	3294.7	11.0	4374	22232.4	3810.9	63551.	231.9
2025	745.5	128.4	3167.3	10.5	4192	22977.9	3939.3	64903.	237.8
2026	726.1	124.9	3079.0	10.3	4083	23704.0	4064.2	66135.	243.3
2027	658.2	113.9	2812.5	9.4	3701	24362.2	4178.1	67074.	247.9
2028	635.6	110.0	2716.0	9.0	3574	24997.8	4288.1	67899.	252.2
2029	606.0	104.9	2589.5	8.6	3408	25603.8	4393.0	68583.	256.0
2030	617.7	105.9	2606.8	8.7	3474	26221.5	4498.9	69274.	259.8
2031	612.4	104.5	2569.0	8.6	3444	26833.9	4603.5	69915.	263.4
2032	585.3	100.1	2462.1	8.2	3291	27419.2	4703.6	70438.	266.7
2033	588.9	99.9	2448.8	8.2	3312	28008.1	4803.4	70939.	269.9
2034	602.1	101.0	2466.1	8.2	3386	28610.3	4904.4	71450.	273.1
2035	572.9	95.6	2331.0	7.8	3222	29183.2	5000.0	71817.	275.8
2036	535.4	89.5	2184.6	7.3	3011	29718.6	5089.5	72033.	278.1
2037	507.1	84.6	2062.3	6.9	2851	30225.7	5174.0	72129.	279.9
2038	486.7	80.8	1968.4	6.6	2737	30712.4	5254.8	72134.	281.4
2039	466.4	77.1	1874.9	6.2	2623	31178.8	5331.9	72053.	282.6
2040	433.5	71.5	1738.3	5.8	2438	31612.3	5403.4	71845.	283.4
2041	422.1	69.2	1677.0	5.6	2374	32034.4	5472.6	71588.	284.0
2042	395.3	64.5	1561.4	5.2	2223	32429.8	5537.1	71228.	284.2
2043	375.2	60.8	1468.6	4.9	2110	32805.0	5597.9	70793.	284.2
2044	347.3	55.9	1348.0	4.5	1953	33152.2	5653.8	70255.	283.8
2045	319.3	51.0	1227.3	4.1	1796	33471.5	5704.8	69619.	283.0
2046	284.3	45.1	1082.8	3.6	1599	33755.8	5750.0	68862.	281.8
2047	251.2	39.5	945.4	3.2	1412	34007.0	5789.5	67995.	280.2
2048	225.5	35.1	834.8	2.8	1268	34232.5	5824.6	67049.	278.3
2049	199.5	30.6	723.3	2.4	1122	34432.0	5855.1	66023.	276.1
2050	164.6	24.7	580.9	1.9	926	34596.6	5879.8	64890.	273.6
TIME AFTER SHUTDOWN, YEARS									
100						34596.6	5879.8	7463.0	91.4
300						34596.6	5879.8	1501.6	46.7
1000						34596.6	5879.8	626.6	19.8
3000						34596.6	5879.8	286.6	8.6
10000						34596.6	5879.8	179.0	5.3
30000						34596.6	5879.8	76.0	2.1
100000						34596.6	5879.8	20.6	0.4
300000						34596.6	5879.8	12.5	0.2
1000000						34596.6	5879.8	6.9	0.1

TABLE A.22

HLW for U Recycle
(with 100% Pu)

Watts vs Time

ACTINIDES AND THEIR DAUGHTER PRODUCTS

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (WATTS/MTHM)</u>	<u>BWR (WATTS/MTHM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.4577E 03	0.3952E 03	0.4368E 03
2	0.3081E 03	0.2852E 03	0.3004E 03
3	0.2782E 03	0.2634E 03	0.2733E 03
4	0.2735E 03	0.2602E 03	0.2691E 03
5	0.2740E 03	0.2608E 03	0.2696E 03
6	0.2755E 03	0.2621E 03	0.2710E 03
7	0.2771E 03	0.2634E 03	0.2725E 03
8	0.2785E 03	0.2646E 03	0.2739E 03
9	0.2799E 03	0.2657E 03	0.2751E 03
10	0.2811E 03	0.2667E 03	0.2763E 03
20	0.2871E 03	0.2712E 03	0.2818E 03
30	0.2858E 03	0.2692E 03	0.2803E 03
40	0.2804E 03	0.2634E 03	0.2747E 03
50	0.2728E 03	0.2558E 03	0.2672E 03
100	0.2301E 03	0.2139E 03	0.2247E 03
200	0.1697E 03	0.1552E 03	0.1649E 03
400	0.1119E 03	0.1006E 03	0.1081E 03
600	0.8410E 02	0.7546E 02	0.8122E 02
1000	0.5490E 02	0.4963E 02	0.5314E 02
10000	0.1392E 02	0.1299E 02	0.1361E 02
30000	0.5575E 01	0.5156E 01	0.5436E 01
100000	0.1068E 01	0.9968E 00	0.1045E 01
1000000	0.3635E 00	0.3289E 00	0.3520E 00

TABLE A.23

HLW for U Recycle
(with 100% Pu)

Watts vs Time

Fission Products

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (WATTS/MTHM)</u>	<u>BWR (WATTS/MTHM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.9860E 04	0.7255E 04	0.8992E 04
2	0.5301E 04	0.3962E 04	0.4855E 04
3	0.3325E 04	0.2520E 04	0.3057E 04
4	0.2320E 04	0.1785E 04	0.2142E 04
5	0.1775E 04	0.1385E 04	0.1645E 04
6	0.1459E 04	0.1151E 04	0.1356E 04
7	0.1262E 04	0.1005E 04	0.1176E 04
8	0.1131E 04	0.9070E 03	0.1056E 04
9	0.1038E 04	0.8372E 03	0.9710E 03
10	0.9688E 03	0.7849E 03	0.9075E 03
20	0.6684E 03	0.5487E 03	0.6285E 03
30	0.5166E 03	0.4246E 03	0.4859E 03
40	0.4036E 03	0.3320E 03	0.3797E 03
50	0.3166E 03	0.2605E 03	0.2979E 03
100	0.9580E 02	0.7888E 02	0.9016E 02
200	0.8946E 01	0.7373E 01	0.8422E 01
400	0.1047E 00	0.8708E-01	0.9885E-01
600	0.2174E-01	0.1838E-01	0.2062E-01
1000	0.1955E-01	0.1650E-01	0.1853E-01
10000	0.1865E-01	0.1574E-01	0.1768E-01
30000	0.1696E-01	0.1432E-01	0.1608E-01
100000	0.1235E-01	0.1042E-01	0.1171E-01
1000000	0.9051E-03	0.7765E-03	0.8622E-03

TABLE A.24

HLW for U Recycle
(with 100% Pu)

Curies vs Time

Actinides and Their Daughter Products

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (CURIES/MTHM)</u>	<u>BWR (CURIES/MTHM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.1311E 06	0.1133E 06	0.1252E 06
2	0.1216E 06	0.1056E 06	0.1162E 06
3	0.1155E 06	0.1005E 06	0.1105E 06
4	0.1105E 06	0.9616E 05	0.1057E 06
5	0.1057E 06	0.9209E 05	0.1012E 06
6	0.1013E 06	0.8823E 05	0.9692E 05
7	0.9701E 05	0.8455E 05	0.9285E 05
8	0.9294E 05	0.8103E 05	0.8897E 05
9	0.8906E 05	0.7768E 05	0.8527E 05
10	0.8536E 05	0.7448E 05	0.8174E 05
20	0.5650E 05	0.4952E 05	0.5418E 05
30	0.3839E 05	0.3385E 05	0.3688E 05
40	0.2699E 05	0.2397E 05	0.2599E 05
50	0.1978E 05	0.1771E 05	0.1909E 05
100	0.8061E 04	0.7429E 04	0.7850E 04
200	0.5177E 04	0.4740E 04	0.5031E 04
400	0.3425E 04	0.3084E 04	0.3311E 04
600	0.2589E 04	0.2326E 04	0.2501E 04
1000	0.1712E 04	0.1549E 04	0.1657E 04
10000	0.4545E 03	0.4237E 03	0.4442E 03
30000	0.1832E 03	0.1694E 03	0.1786E 03
100000	0.3944E 02	0.3692E 02	0.3860E 02
1000000	0.1531E 02	0.1387E 02	0.1483E 02

TABLE A.25

HLW for U Recycle
(with 100% Pu)

Curies vs Time

Fission Products

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (CURIES/MTHM)</u>	<u>BWR (CURIES/MTHM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.2179E 07	0.1626E 07	0.1995E 07
2	0.1196E 07	0.9140E 06	0.1102E 07
3	0.7838E 06	0.6118E 06	0.7265E 06
4	0.5813E 06	0.4618E 06	0.5415E 06
5	0.4746E 06	0.3818E 06	0.4437E 06
6	0.4136E 06	0.3355E 06	0.3876E 06
7	0.3756E 06	0.3063E 06	0.3525E 06
8	0.3496E 06	0.2860E 06	0.3284E 06
9	0.3304E 06	0.2709E 06	0.3106E 06
10	0.3153E 06	0.2588E 06	0.2965E 06
20	0.2328E 06	0.1918E 06	0.2191E 06
30	0.1823E 06	0.1502E 06	0.1716E 06
40	0.1435E 06	0.1183E 06	0.1351E 06
50	0.1132E 06	0.9328E 05	0.1065E 06
100	0.3489E 05	0.2879E 05	0.3286E 05
200	0.3508E 04	0.2906E 04	0.3307E 04
400	0.1085E 03	0.9251E 02	0.1032E 03
600	0.3529E 02	0.3005E 02	0.3354E 02
1000	0.2279E 02	0.1917E 02	0.2158E 02
10000	0.2157E 02	0.1813E 02	0.2043E 02
30000	0.2039E 02	0.1714E 02	0.1931E 02
100000	0.1690E 02	0.1421E 02	0.1600E 02
1000000	0.3678E 01	0.3113E 01	0.3490E 01

Table A.26 Accumulation of plutonium dioxide at a repository:
Fresh Uranium Cycle (reprocessing with no recycle)

Year	* * * * Annual Addition * * * *				Annual Number of Canisters	* Accumulation Through End of Year *			
	Volume (M3)	Actinide Mass (MT)	Radio- Activity (MCI)	Thermal Power (KW)		Volume (M3)	Actinide Mass (MT)	Radio- Activity (MCI)	Thermal Power (KW)
1985	0.8	1.38	13.4	16.1	153	1.	1.38	13.4	16.1
1986	3.2	5.69	55.5	66.4	631	4.	7.07	68.3	83.1
1987	4.3	7.60	74.0	88.7	842	8.	14.67	139.4	174.7
1988	5.1	9.01	87.8	105.1	998	13.	23.68	221.1	285.8
1989	6.1	10.80	105.2	126.0	1196	19.	34.49	316.8	421.4
1990	6.9	12.16	118.5	141.8	1347	26.	46.65	421.6	576.8
1991	9.4	16.72	162.9	195.0	1852	36.	63.37	566.2	789.9
1992	10.5	18.59	181.1	216.8	2059	46.	81.96	722.9	1031.0
1993	11.7	20.69	201.5	241.2	2291	58.	102.65	893.3	1303.0
1994	13.3	23.58	229.7	275.0	2612	71.	126.23	1084.5	1616.0
1995	15.6	27.53	268.2	321.1	3049	87.	153.76	1306.1	1983.1
1996	16.4	29.06	283.1	338.9	3218	103.	182.83	1533.0	2377.2
1997	18.8	33.25	323.9	387.8	3682	122.	216.08	1791.1	2829.6
1998	21.2	37.44	364.7	436.6	4186	143.	253.52	2079.0	3341.5
1999	23.7	41.92	408.3	488.8	4642	167.	295.44	2398.3	3917.5
2000	26.3	46.53	453.2	542.6	5153	193.	341.97	2748.8	4560.4
2001	28.8	50.96	496.3	594.3	5643	222.	392.93	3127.6	5269.3
2002	31.4	55.58	541.3	648.1	6154	253.	448.50	3535.2	6047.5
2003	34.0	60.24	586.8	702.5	6671	287.	508.74	3971.0	6896.7
2004	36.7	65.03	633.4	758.4	7202	324.	573.77	4434.9	7819.4
2005	39.5	69.86	680.4	814.7	7736	364.	643.63	4926.2	8817.1
2006	42.2	74.67	727.3	870.8	8270	406.	718.31	5443.7	9890.7
2007	44.8	79.30	772.4	924.8	8782	451.	797.61	5984.4	11039.0
2008	47.3	83.69	815.1	975.9	9268	498.	881.30	6545.0	12259.9
2009	49.7	87.93	856.5	1025.4	9738	548.	969.23	7123.3	13552.5
2010	52.0	92.01	896.2	1073.0	10190	600.	1061.24	7717.0	14915.5
2011	54.1	95.76	932.7	1116.7	10605	654.	1157.00	8322.4	16345.3
2012	54.5	96.50	939.9	1125.4	10687	708.	1253.50	8909.6	17807.3
2013	54.4	96.30	937.9	1123.0	10664	763.	1349.80	9470.3	19289.4
2014	54.0	95.62	931.3	1115.0	10589	817.	1445.41	10001.1	20784.7
2015	53.6	94.88	924.2	1106.5	10507	870.	1540.30	10502.9	22291.0
2016	52.7	93.19	907.7	1086.8	10320	923.	1633.49	10967.6	23795.8
2017	51.8	91.76	893.8	1070.1	10162	975.	1725.25	11399.5	25300.3
2018	51.0	90.31	879.7	1053.2	10001	1026.	1815.57	11799.7	26802.6
2019	50.2	88.79	864.8	1035.4	9832	1076.	1904.35	12169.1	28300.4
2020	49.5	87.57	853.0	1021.2	9698	1125.	1991.92	12511.9	29795.8
2021	48.6	85.94	837.1	1002.2	9517	1174.	2077.86	12825.4	31282.7
2022	47.0	83.15	809.8	969.6	9208	1221.	2161.01	13099.5	32746.2
2023	46.6	82.49	803.5	962.0	9135	1268.	2243.50	13356.8	34209.3
2024	46.2	81.82	796.9	954.1	9061	1314.	2325.32	13597.9	35671.1
2025	44.4	78.56	765.2	916.1	8700	1358.	2403.88	13798.2	37100.6
2026	43.1	76.25	742.7	889.2	8444	1401.	2480.13	13968.9	38507.1
2027	39.5	69.87	680.6	814.8	7738	1441.	255.0	14071.7	39841.7
2028	38.1	67.45	656.9	786.5	7469	1479.	2617.44	14147.9	41147.7
2029	36.4	64.39	627.2	750.9	7131	1515.	2681.83	14192.6	42416.3
2030	36.6	64.72	630.4	754.7	7167	1552.	2746.55	14240.1	43685.9
2031	36.0	63.68	620.2	742.6	7052	1588.	2810.23	14276.9	44940.4
2032	34.4	60.94	593.6	710.7	6749	1622.	2871.17	14287.1	46159.8
2033	34.2	60.51	589.4	705.7	6701	1656.	2931.68	14294.2	47369.8
2034	34.3	60.78	592.0	708.8	6731	1691.	2992.46	14305.2	48578.4
2035	32.5	57.47	559.8	670.2	6365	1723.	3049.94	14285.0	49744.1
2036	30.4	53.77	523.7	627.0	5954	1754.	3103.71	14231.1	50860.9
2037	28.7	50.72	494.0	591.5	5617	1782.	3154.43	14151.4	51935.1
2038	27.3	48.34	470.9	563.8	5354	1810.	3202.77	14053.5	52973.4
2039	26.0	45.98	447.9	536.2	5092	1836.	3248.75	13938.3	53975.3
2040	24.1	42.61	415.0	496.9	4719	1860.	3291.36	13796.7	54928.3
2041	23.2	41.02	399.5	478.3	4542	1883.	3332.38	13647.2	55852.2
2042	21.5	38.13	371.4	444.7	4223	1904.	3370.51	13477.5	56731.5
2043	20.2	35.79	348.6	417.3	3963	1925.	3406.30	13293.8	57571.8
2044	18.5	32.78	319.3	382.3	3630	1943.	3439.08	1309.0	58364.9
2045	16.8	29.78	290.0	347.2	3297	1960.	3468.86	12867.2	59109.9
2046	14.8	26.21	255.3	305.6	2902	1975.	3495.07	12620.6	59799.7
2047	12.9	22.82	222.3	266.1	2527	1988.	3517.89	12353.0	60435.4
2048	11.3	20.06	195.4	234.0	2222	1999.	3537.95	12071.3	61023.5
2049	9.8	17.28	168.3	201.5	1914	2009.	3555.23	11776.0	61563.3
2050	7.8	13.78	134.3	160.7	1526	2016.	3569.02	11460.5	62046.0
TIME AFTER SHUTDOWN, YEARS									
100						2016.	3569.02	1826.2	57407.4
300						2016.	3569.02	1241.9	40729.1
1000						2016.	3569.02	585.7	18870.4
3000						2016.	3569.02	270.0	8416.0
10000						2016.	3569.02	166.2	5156.7
30000						2016.	3569.02	65.8	2028.7
100000						2016.	3569.02	10.8	309.2
300000						2016.	3569.02	4.1	96.2
1000000						2016.	3569.02	2.9	68.9

Table A.27 Accumulation of plutonium dioxide at a repository:
Uranium Only Recycle

Year	Volume (M3)	Annual Addition Actinide Mass (MT)	Radio- Activity (NCI)	Thermal Power (KW)	Annual Number of Canisters	Volume (M3)	Actinide (MT)	Radio- activity (NCI)	Thermal Power (KW)
1985	0.8	1.38	13.4	16.1	153	1.	1.38	13.4	16.1
1986	3.2	5.69	55.5	66.4	631	4.	7.07	68.3	83.1
1987	4.3	7.60	74.0	88.7	842	8.	14.67	139.4	174.7
1988	5.1	9.01	87.8	105.1	998	13.	23.68	221.1	285.8
1989	6.1	10.80	105.2	126.0	1196	19.	34.49	316.8	421.4
1990	6.9	12.16	118.5	141.8	1347	26.	46.65	421.6	576.8
1991	9.4	16.72	162.9	195.0	1852	36.	63.37	566.2	789.9
1992	10.5	18.59	181.1	216.8	2059	46.	81.96	722.9	1031.0
1993	11.7	20.69	201.5	241.2	2291	58.	102.65	893.3	1303.0
1994	13.3	23.58	229.7	275.0	2612	71.	126.23	1084.5	1616.0
1995	15.6	27.53	268.2	321.1	3049	87.	153.76	1306.1	1983.1
1996	16.4	29.06	283.1	338.9	3218	103.	182.83	1533.0	2377.2
1997	18.8	33.25	323.9	387.8	3682	122.	216.08	1791.1	2829.6
1998	21.2	37.44	364.7	436.6	4186	143.	253.52	2079.0	3341.5
1999	23.7	41.92	408.3	488.8	4642	167.	295.44	2398.3	3917.5
2000	26.3	46.53	453.2	542.6	5153	193.	341.97	2748.8	4560.4
2001	28.8	50.96	496.3	594.3	5643	222.	392.93	3127.6	5269.3
2002	31.4	55.58	541.3	648.1	6154	253.	448.50	3535.2	6047.5
2003	34.0	60.24	586.8	702.5	6671	287.	508.74	3971.0	6896.7
2004	36.7	65.03	633.4	758.4	7202	324.	573.77	4434.9	7819.4
2005	39.5	69.86	680.4	814.7	7736	364.	643.63	4926.2	8817.1
2006	42.2	74.67	727.3	870.8	8270	406.	718.31	5403.7	9890.7
2007	44.8	79.30	772.4	924.8	8782	451.	797.61	5984.4	11039.0
2008	47.3	83.69	815.1	975.9	9268	498.	881.30	6545.0	12259.9
2009	49.7	87.93	856.5	1025.4	9738	548.	969.23	7123.3	13552.5
2010	52.0	92.01	896.2	1073.0	10190	600.	1061.24	7717.0	14915.5
2011	54.1	95.76	932.7	1116.7	10605	654.	1157.00	8322.4	16345.3
2012	54.5	96.50	939.9	1125.4	10687	708.	1253.50	8909.6	17807.3
2013	54.4	96.30	937.9	1123.0	10664	763.	1349.80	9470.3	19289.4
2014	54.0	95.62	931.3	1115.0	10589	817.	1445.41	10001.1	20784.7
2015	53.6	94.88	924.2	1106.5	10507	870.	1540.30	10502.9	22291.0
2016	52.7	93.19	907.7	1086.8	10320	923.	1633.49	10967.6	23795.8
2017	51.8	91.76	893.8	1070.1	10162	975.	1725.25	11399.5	25300.3
2018	51.0	90.31	879.7	1053.2	10001	1026.	1815.57	11799.7	26802.6
2019	50.2	88.79	864.8	1035.4	9832	1076.	1904.35	12169.1	28300.4
2020	49.5	87.57	853.0	1021.2	9698	1125.	1991.92	12511.9	29795.8
2021	48.6	85.94	837.1	1002.2	9517	1174.	2077.86	12825.4	31282.7
2022	47.0	83.15	809.8	969.6	9208	1221.	2161.01	13099.5	32746.2
2023	46.6	82.49	803.5	962.0	9135	1268.	2243.50	13356.8	34209.3
2024	46.2	81.82	796.9	954.1	9061	1314.	2325.32	13597.9	35671.1
2025	44.4	78.56	765.2	916.1	8700	1358.	2403.88	13798.2	37100.6
2026	43.1	76.25	742.7	889.2	8444	1401.	2480.13	13968.9	38507.1
2027	39.5	69.87	680.6	814.8	7738	1441.	2550.00	14071.7	39841.7
2028	38.1	67.45	656.9	786.5	7469	1479.	2617.44	14147.9	41147.7
2029	36.4	64.39	627.2	750.9	7131	1515.	2681.83	14192.6	42416.3
2030	36.6	64.72	630.4	754.7	7167	1552.	2746.55	14240.1	43685.9
2031	36.0	63.68	620.2	742.6	7052	1588.	2810.23	14276.9	44940.4
2032	34.4	60.94	593.6	710.7	6749	1622.	2871.17	14287.1	46159.8
2033	34.2	60.51	589.4	705.7	6701	1656.	2931.68	14294.2	47369.8
2034	34.3	60.78	592.0	708.8	6731	1691.	2992.46	14305.2	48578.4
2035	32.5	57.47	559.8	670.2	6365	1723.	3049.94	14285.0	49744.1
2036	30.4	53.77	523.7	627.0	5954	1754.	3103.71	14231.1	50860.9
2037	28.7	50.72	494.0	591.5	5617	1782.	3154.43	14151.4	51935.1
2038	27.3	48.34	470.9	563.8	5354	1810.	3202.77	14053.5	52973.4
2039	26.0	45.98	447.9	536.2	5092	1836.	3248.75	13938.3	53975.3
2040	24.1	42.61	415.0	496.9	4719	1860.	3291.36	13796.7	54928.3
2041	23.2	41.02	399.5	478.3	4542	1883.	3332.38	13647.2	55852.2
2042	21.5	38.13	371.4	444.7	4223	1904.	3370.51	13477.5	56731.5
2043	20.2	35.79	348.6	417.3	3963	1925.	3406.30	13293.8	57571.8
2044	18.5	32.78	319.3	382.3	3630	1943.	3439.08	13090.0	58364.9
2045	16.8	29.78	290.0	347.2	3297	1960.	3468.86	12867.2	59109.9
2046	14.8	26.21	255.3	305.6	2902	1975.	3495.07	12620.6	59799.7
2047	12.9	22.82	222.3	266.1	2527	1988.	3517.89	12353.0	60435.4
2048	11.3	20.06	195.4	234.0	2222	1999.	3537.95	12071.3	61023.5
2049	9.8	17.28	168.3	201.5	1914	2009.	3555.23	11776.0	61563.3
2050	7.8	13.78	134.3	160.7	1526	2016.	3569.02	11460.5	62046.0
TIME AFTER SHUTDOWN, YEARS									
100						2016.	3569.02	1826.2	57407.4
300						2016.	3569.02	1241.9	40729.1
1000						2016.	3569.02	505.7	18070.4
3000						2016.	3569.02	270.0	8416.0
10000						2016.	3569.02	166.2	5156.7
30000						2016.	3569.02	65.8	2028.7
100000						2016.	3569.02	10.8	309.2
300000						2016.	3569.02	4.1	96.2
1000000						2016.	3569.02	2.9	68.9

TABLE A.28

Pu Oxide From U Recycle

Watts vs Time

Actinides and Their Daughter Products

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (WATTS/MTHM)</u>	<u>BWR (WATTS/MTHM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.1952E 03	0.1959E 03	0.1954E 03
2	0.1998E 03	0.1997E 03	0.1998E 03
3	0.2042E 03	0.2033E 03	0.2039E 03
4	0.2083E 03	0.2066E 03	0.2077E 03
5	0.2121E 03	0.2098E 03	0.2114E 03
6	0.2158E 03	0.2127E 03	0.2147E 03
7	0.2192E 03	0.2155E 03	0.2179E 03
8	0.2224E 03	0.2180E 03	0.2209E 03
9	0.2253E 03	0.2204E 03	0.2237E 03
10	0.2281E 03	0.2226E 03	0.2263E 03
20	0.2471E 03	0.2373E 03	0.2439E 03
30	0.2547E 03	0.2422E 03	0.2505E 03
40	0.2554E 03	0.2413E 03	0.2507E 03
50	0.2521E 03	0.2370E 03	0.2471E 03
100	0.2178E 03	0.2018E 03	0.2124E 03
200	0.1603E 03	0.1458E 03	0.1555E 03
400	0.1050E 03	0.9379E 02	0.1013E 03
600	0.7898E 02	0.7038E 02	0.7611E 02
1000	0.5191E 02	0.4670E 02	0.5017E 02
10000	0.1353E 02	0.1266E 02	0.1324E 02
30000	0.5413E 01	0.5019E 01	0.5282E 01
100000	0.9764E 00	0.9136E 00	0.9555E 00
1000000	0.2133E 00	0.1903E 00	0.2056E 00

TABLE A.29

Pu Oxide From U Recycle

Curies vs Time

Actinides and Their Daughter Products

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (CURIES/MTM)</u>	<u>PWR (CURIES/MTM)</u>	<u>PWR AND BWR IN A 2 TO 1 RATIO</u>
1	0.1238E 06	0.1078E 06	0.1185E 06
2	0.1185E 06	0.1032E 06	0.1134E 06
3	0.1134E 06	0.9878E 05	0.1085E 06
4	0.1086E 06	0.9459E 05	0.1039E 06
5	0.1039E 06	0.9058E 05	0.9948E 05
6	0.9952E 05	0.8677E 05	0.9527E 05
7	0.9531E 05	0.8313E 05	0.9125E 05
8	0.9129E 05	0.7965E 05	0.8741E 05
9	0.8746E 05	0.7634E 05	0.8375E 05
10	0.8381E 05	0.7317E 05	0.8026E 05
20	0.5531E 05	0.4851E 05	0.5304E 05
30	0.3746E 05	0.3304E 05	0.3599E 05
40	0.2624E 05	0.2329E 05	0.2526E 05
50	0.1914E 05	0.1712E 05	0.1847E 05
100	0.7670E 04	0.7043E 04	0.7461E 04
200	0.4876E 04	0.4437E 04	0.4730E 04
400	0.3203E 04	0.2864E 04	0.3090E 04
600	0.2421E 04	0.2160E 04	0.2334E 04
1000	0.1608E 04	0.1449E 04	0.1555E 04
10000	0.4364E 03	0.4082E 03	0.4270E 03
30000	0.1763E 03	0.1635E 03	0.1720E 03
100000	0.3534E 02	0.3319E 02	0.3462E 02
1000000	0.8982E 01	0.8028E 01	0.8664E 01

Table A.30 Accumulation of cladding waste at a repository:
All Cycles

Year	* * * * Annual Addition * * * * *				* * * * Accumulation Through End of Year * * * *			
	Volume (Hundreds of m ³)	Actinide Mass (MT)	Radio- activity (MCi)	Thermal Power (MW)	Volume (Thousands of m ³)	Actinide Mass (MT)	Radio- activity (MCi)	Thermal Power (MW)
1985	0.30	0.19	1.1	0.007	0.03	0.19	1.	0.01
1986	1.21	0.78	4.7	0.033	0.15	0.97	6.	0.04
1987	1.36	0.90	5.7	0.037	0.29	1.88	10.	0.07
1988	1.52	1.03	7.2	0.044	0.44	2.90	16.	0.11
1989	1.76	1.20	8.4	0.049	0.62	4.10	22.	0.14
1990	2.12	1.43	9.7	0.056	0.83	5.54	28.	0.18
1991	3.44	2.33	15.5	0.089	1.17	7.87	39.	0.24
1992	3.79	2.56	16.8	0.096	1.55	10.43	50.	0.31
1993	4.13	2.79	18.7	0.108	1.96	13.22	61.	0.37
1994	4.48	3.03	20.7	0.121	2.41	16.24	73.	0.45
1995	4.84	3.27	22.7	0.133	2.90	19.52	85.	0.52
1996	4.20	2.83	19.8	0.116	3.31	22.35	93.	0.57
1997	4.57	3.09	21.7	0.127	3.77	25.44	102.	0.62
1998	4.94	3.34	23.6	0.138	4.27	28.77	111.	0.68
1999	5.32	3.59	25.5	0.150	4.80	32.37	122.	0.74
2000	5.70	3.85	27.4	0.161	5.37	36.22	133.	0.81
2001	6.08	4.11	29.4	0.173	5.98	40.32	145.	0.88
2002	6.44	4.35	31.3	0.184	6.62	44.67	157.	0.95
2003	6.77	4.57	33.1	0.195	7.30	49.25	170.	1.02
2004	7.10	4.80	34.9	0.206	8.01	54.04	183.	1.10
2005	7.42	5.01	36.6	0.216	8.75	59.05	196.	1.17
2006	7.71	5.20	38.1	0.225	9.52	64.26	209.	1.25
2007	7.65	5.17	39.0	0.231	10.28	69.42	222.	1.32
2008	7.58	5.12	39.2	0.233	11.04	74.54	234.	1.39
2009	7.50	5.06	39.0	0.232	11.79	79.61	244.	1.44
2010	7.44	5.03	38.7	0.231	12.54	84.63	254.	1.49
2011	7.30	4.93	38.0	0.227	13.27	89.56	261.	1.53
2012	7.19	4.86	37.4	0.223	13.99	94.42	268.	1.56
2013	7.09	4.78	36.9	0.220	14.69	99.20	274.	1.59
2014	6.97	4.71	36.2	0.216	15.39	103.91	279.	1.61
2015	6.91	4.66	35.9	0.216	16.08	108.57	284.	1.62
2016	6.79	4.58	35.2	0.211	16.76	113.14	288.	1.63
2017	6.56	4.42	34.1	0.205	17.42	117.57	291.	1.64
2018	6.56	4.42	33.9	0.204	18.07	121.98	294.	1.64
2019	6.59	4.42	34.0	0.208	18.73	126.41	298.	1.65
2020	6.26	4.24	32.0	0.189	19.36	130.64	299.	1.63
2021	6.07	4.13	30.6	0.177	19.96	134.77	300.	1.61
2022	5.53	3.74	28.4	0.167	20.52	138.51	298.	1.58
2023	5.32	3.61	27.2	0.159	21.05	142.13	297.	1.55
2024	5.10	3.45	26.3	0.156	21.56	145.57	295.	1.52
2025	5.23	3.51	27.0	0.165	22.08	149.09	295.	1.50
2026	5.19	3.48	26.6	0.163	22.60	152.57	295.	1.49
2027	4.91	3.33	24.8	0.146	23.09	155.90	293.	1.46
2028	4.96	3.35	25.0	0.150	23.59	159.24	292.	1.43
2029	5.10	3.42	25.5	0.156	24.10	162.67	293.	1.42
2030	4.90	3.26	24.8	0.157	24.59	165.93	293.	1.41
2031	4.53	3.04	22.6	0.138	25.04	168.97	291.	1.38
2032	4.29	2.88	21.3	0.131	25.47	171.85	289.	1.35
2033	4.12	2.77	20.4	0.125	25.88	174.62	286.	1.32
2034	3.95	2.65	19.5	0.120	26.28	177.27	283.	1.29
2035	3.67	2.46	18.1	0.111	26.65	179.74	279.	1.25
2036	3.58	2.40	17.5	0.108	27.00	182.14	276.	1.21
2037	3.36	2.25	16.3	0.101	27.34	184.38	272.	1.18
2038	3.19	2.13	15.4	0.096	27.66	186.52	268.	1.14
2039	2.95	1.97	14.2	0.089	27.95	188.49	264.	1.10
2040	2.72	1.82	12.9	0.081	28.22	190.31	259.	1.06
2041	2.42	1.62	11.4	0.072	28.47	191.92	254.	1.01
2042	2.14	1.43	10.1	0.064	28.68	193.35	248.	0.96
2043	1.93	1.28	8.9	0.057	28.87	194.63	242.	0.92
2044	1.70	1.13	7.8	0.050	29.04	195.77	236.	0.87
2045	1.41	0.94	6.3	0.041	29.18	196.70	229.	0.82
TIME AFTER SHUTDOWN, YEARS								
100					29.2	196.70	67.	0.057
300					29.2	196.70	16.	0.026
1000					29.2	196.70	2.	0.010
3000					29.2	196.70	1.	0.004
10000					29.2	196.70	1.	0.003
30000					29.2	196.70	1.	0.001
100000					29.2	196.70	1.	0.000
300000					29.2	196.70	0.	0.000
1000000					29.2	196.70	0.	0.000

TABLE A.31

Cladding

Watts vs Time

Actinides and Their Daughter Products

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (WATTS/MTHM)</u>	<u>BWR (WATTS/MTHM)</u>
1	0.1982E 00	0.1581E 00
2	0.1175E 00	0.9814E-01
3	0.1015E 00	0.8647E-01
4	0.9916E-01	0.8494E-01
5	0.9958E-01	0.8550E-01
6	0.1005E 00	0.8644E-01
7	0.1015E 00	0.8740E-01
8	0.1025E 00	0.8832E-01
9	0.1034E 00	0.8918E-01
10	0.1042E 00	0.8998E-01
20	0.1095E 00	0.9524E-01
30	0.1111E 00	0.9707E-01
40	0.1106E 00	0.9693E-01
50	0.1090E 00	0.9570E-01
100	0.9654E-01	0.8527E-01
200	0.7687E-01	0.6820E-01
400	0.5488E-01	0.4895E-01
600	0.4227E-01	0.3787E-01
1000	0.2772E-01	0.2508E-01
10000	0.6891E-02	0.6424E-02
30000	0.2745E-02	0.2523E-02
100000	0.5284E-03	0.4682E-03
1000000	0.1955E-03	0.1727E-03

TABLE A.32

Cladding

Watts vs Time

Fission Products

YEARS
AFTER
DISCHARGE

PWR
(WATTS/MTHM)

BWR
(WATTS/MTHM)

1	0.4999E 01	0.3680E 01
2	0.2695E 01	0.2015E 01
3	0.1692E 01	0.1283E 01
4	0.1181E 01	0.9079E 00
5	0.9025E 00	0.7031E 00
6	0.7405E 00	0.5834E 00
7	0.6394E 00	0.5083E 00
8	0.5721E 00	0.4580E 00
9	0.5244E 00	0.4222E 00
10	0.4889E 00	0.3952E 00
20	0.3353E 00	0.2746E 00
30	0.2585E 00	0.2120E 00
40	0.2016E 00	0.1655E 00
50	0.1580E 00	0.1297E 00
100	0.4774E-01	0.3922E-01
200	0.4460E-02	0.3667E-02
400	0.5238E-04	0.4348E-04
600	0.1096E-04	0.9273E-05
1000	0.9871E-05	0.8339E-05
10000	0.9414E-05	0.7953E-05
30000	0.8562E-05	0.7232E-05
100000	0.6227E-05	0.5257E-05
1000000	0.4604E-06	0.3940E-06

TABLE A.33

Cladding

Watts vs Time

Light Elements

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (WATTS/MTM)</u>	<u>BWR (WATTS/MTM)</u>
1	0.3099E 02	0.1042E 03
2	0.1437E 02	0.8020E 02
3	0.1100E 02	0.6874E 02
4	0.8827E 01	0.5941E 02
5	0.7213E 01	0.5153E 02
6	0.5966E 01	0.4480E 02
7	0.4976E 01	0.3900E 02
8	0.4178E 01	0.3399E 02
9	0.3527E 01	0.2964E 02
10	0.2992E 01	0.2587E 02
20	0.7069E 00	0.6800E 01
30	0.2291E 00	0.1837E 01
40	0.1072E 00	0.5164E 00
50	0.7181E-01	0.1617E 00
100	0.4169E-01	0.2286E-01
200	0.1969E-01	0.1069E-01
400	0.4482E-02	0.2410E-02
600	0.1114E-02	0.5787E-03
1000	0.1997E-03	0.8379E-04
10000	0.1025E-03	0.5804E-04
30000	0.7211E-04	0.5751E-04
100000	0.6195E-04	0.5567E-04
1000000	0.3403E-04	0.3673E-04

TABLE A.34

Cladding

Curies vs Time

Actinides and Their Daughter Products

<u>YEARS AFTER DISCHARGE</u>	<u>PWR (CURIES/MTHM)</u>	<u>BWR (CURIES/MTHM)</u>
1	0.6603E 02	0.5681E 02
2	0.6105E 02	0.5277E 02
3	0.5795E 02	0.5014E 02
4	0.5535E 02	0.4790E 02
5	0.5294E 02	0.4582E 02
6	0.5065E 02	0.4384E 02
7	0.4847E 02	0.4196E 02
8	0.4640E 02	0.4017E 02
9	0.4442E 02	0.3845E 02
10	0.4253E 02	0.3682E 02
20	0.2781E 02	0.2410E 02
30	0.1860E 02	0.1614E 02
40	0.1283E 02	0.1115E 02
50	0.9201E 01	0.8013E 01
100	0.3485E 01	0.3073E 01
200	0.2348E 01	0.2087E 01
400	0.1681E 01	0.1501E 01
600	0.1302E 01	0.1168E 01
1000	0.8647E 00	0.7829E 00
10000	0.2255E 00	0.2100E 00
30000	0.9045E-01	0.8303E-01
100000	0.1971E-01	0.1739E-01
1000000	0.8545E-02	0.7594E-02

TABLE A.35

Cladding

Curies vs Time

Fission Products

<u>YEARS</u> <u>AFTER</u> <u>DISCHARGE</u>	<u>PWR</u> <u>(CURIES/MTHM)</u>	<u>BWR</u> <u>(CURIES/MTHM)</u>
1	0.1102E 04	0.8223E 03
2	0.6066E 03	0.4636E 03
3	0.3984E 03	0.3107E 03
4	0.2957E 03	0.2346E 03
5	0.2415E 03	0.1940E 03
6	0.2104E 03	0.1704E 03
7	0.1909E 03	0.1554E 03
8	0.1776E 03	0.1450E 03
9	0.1678E 03	0.1372E 03
10	0.1600E 03	0.1311E 03
20	0.1175E 03	0.9655E 02
30	0.9161E 02	0.7531E 02
40	0.7194E 02	0.5915E 02
50	0.5663E 02	0.4658E 02
100	0.1741E 02	0.1433E 02
200	0.1751E 01	0.1447E 01
400	0.5413E-01	0.4603E-01
600	0.1763E-01	0.1498E-01
1000	0.1141E-01	0.9587E-02
10000	0.1080E-01	0.9068E-02
30000	0.1021E-01	0.8571E-02
100000	0.8459E-02	0.7104E-02
1000000	0.1847E-02	0.1560E-02

TABLE A.36

Cladding

Curies vs Time

Light Elements

YEARS
AFTER
DISCHARGE

PWR
(CURIES/MTHM)

BWR
(CURIES/MTHM)

1	0.9690E 04	0.1434E 05
2	0.5935E 04	0.1010E 05
3	0.4617E 04	0.8222E 04
4	0.3670E 04	0.6783E 04
5	0.2955E 04	0.5641E 04
6	0.2408E 04	0.4724E 04
7	0.1988E 04	0.3982E 04
8	0.1664E 04	0.3377E 04
9	0.1412E 04	0.2881E 04
10	0.1216E 04	0.2472E 04
20	0.5527E 03	0.7286E 03
30	0.4548E 03	0.3576E 03
40	0.4132E 03	0.2536E 03
50	0.3816E 03	0.2149E 03
100	0.2625E 03	0.1425E 03
200	0.1256E 03	0.6819E 02
400	0.3087E 02	0.1677E 02
600	0.9866E 01	0.5381E 01
1000	0.4164E 01	0.2293E 01
10000	0.3491E 01	0.1992E 01
30000	0.2919E 01	0.1712E 01
100000	0.1676E 01	0.1037E 01
1000000	0.1304E 00	0.1572E 00

Table A. 37 Accumulation of IL-TRU waste at a repository:
Fresh Uranium Cycle (reprocessing with no recycle)

Year	Annual Addition				Accumulation Through End of Year			
	Volume (Hundreds of m ³)	Actinide Mass (kg)	Radio- activity (MCi)	Thermal Power (kW)	Volume (Thousands of m ³)	Actinide Mass (kg)	Radio- activity (MCi)	Thermal Power (kW)
1985	2.7	0.7	0.0	0.1	0.3	1.	0.04	0.1
1986	8.5	3.0	0.2	0.6	1.1	4.	0.19	0.7
1987	10.5	3.7	0.2	0.7	2.2	7.	0.37	1.3
1988	10.3	4.5	0.3	0.9	3.2	12.	0.60	2.1
1989	12.3	5.4	0.3	1.1	4.4	17.	0.86	3.0
1990	9.6	6.3	0.4	1.3	5.4	24.	1.15	4.0
1991	15.5	10.3	0.6	2.1	6.9	34.	1.65	5.7
1992	12.7	11.2	0.6	2.3	8.2	45.	2.15	7.5
1993	13.9	12.3	0.7	2.5	9.6	57.	2.70	9.3
1994	15.2	13.4	0.8	2.8	11.1	71.	3.29	11.3
1995	16.6	14.6	0.8	3.0	12.8	85.	3.92	13.5
1996	14.4	12.7	0.7	2.7	14.2	98.	4.41	15.1
1997	15.7	13.9	0.8	2.9	15.8	112.	4.95	16.9
1998	17.1	15.1	0.9	3.1	17.5	127.	5.55	18.9
1999	18.4	16.3	0.9	3.4	19.3	143.	6.18	21.1
2000	19.8	17.5	1.0	3.7	21.3	161.	6.87	23.5
2001	21.1	18.7	1.1	3.9	23.4	180.	7.59	26.0
2002	22.5	19.8	1.1	4.2	25.7	199.	8.35	28.6
2003	23.7	20.9	1.2	4.4	28.0	220.	9.14	31.3
2004	24.9	22.0	1.3	4.6	30.5	242.	9.97	34.2
2005	26.1	23.0	1.3	4.9	33.1	265.	10.81	37.1
2006	27.1	23.9	1.4	5.1	35.8	289.	11.69	40.2
2007	27.3	24.1	1.4	5.2	38.6	313.	12.55	43.2
2008	27.3	24.1	1.4	5.2	41.3	337.	13.39	46.1
2009	27.1	23.9	1.4	5.2	44.0	361.	14.19	48.9
2010	26.9	23.7	1.4	5.1	46.7	385.	14.95	51.6
2011	26.4	23.3	1.4	5.0	49.3	408.	15.67	54.1
2012	26.0	22.9	1.4	5.0	51.9	431.	16.35	56.6
2013	25.6	22.6	1.3	4.9	54.5	454.	16.98	58.9
2014	25.1	22.2	1.3	4.8	57.0	476.	17.58	61.1
2015	24.8	21.9	1.3	4.7	59.5	498.	18.16	63.2
2016	24.3	21.5	1.3	4.7	61.9	519.	18.69	65.3
2017	23.5	20.8	1.2	4.5	64.3	540.	19.18	67.1
2018	23.4	20.6	1.2	4.5	66.6	561.	19.64	68.9
2019	23.2	20.5	1.2	4.5	68.9	581.	20.10	70.7
2020	22.2	19.6	1.2	4.3	71.2	601.	20.49	72.3
2021	21.6	19.1	1.1	4.1	73.3	620.	20.84	73.8
2022	19.8	17.5	1.0	3.8	75.3	637.	21.10	75.0
2023	19.1	16.9	1.0	3.6	77.2	654.	21.32	76.0
2024	18.2	16.1	1.0	3.5	79.0	670.	21.50	76.9
2025	18.3	16.2	1.0	3.5	80.9	687.	21.69	77.9
2026	18.0	15.9	1.0	3.5	82.7	703.	21.87	78.9
2027	17.3	15.2	0.9	3.3	84.4	718.	22.01	79.7
2028	17.1	15.1	0.9	3.3	86.1	733.	22.15	80.5
2029	17.2	15.2	0.9	3.3	87.8	748.	22.29	81.4
2030	16.3	14.4	0.9	3.2	89.4	762.	22.40	82.1
2031	15.2	13.4	0.8	3.0	91.0	776.	22.44	82.6
2032	14.4	12.7	0.8	2.8	92.4	789.	22.45	83.0
2033	13.7	12.1	0.7	2.7	93.8	801.	22.43	83.3
2034	13.0	11.5	0.7	2.5	95.1	812.	22.38	83.5
2035	12.1	10.7	0.6	2.4	96.3	823.	22.29	83.6
2036	11.6	10.3	0.6	2.3	97.4	833.	22.19	83.6
2037	10.8	9.5	0.6	2.1	98.5	843.	22.06	83.6
2038	10.1	8.9	0.5	2.0	99.5	852.	21.90	83.4
2039	9.3	8.2	0.5	1.8	100.5	860.	21.72	83.1
2040	8.4	7.4	0.5	1.7	101.3	867.	21.50	82.8
2041	7.4	6.6	0.4	1.5	102.1	874.	21.24	82.3
2042	6.5	5.7	0.4	1.3	102.7	879.	20.95	81.6
2043	5.7	5.0	0.3	1.1	103.3	884.	20.63	80.9
2044	4.9	4.3	0.3	1.0	103.8	889.	20.29	80.1
2045	3.9	3.4	0.2	0.8	104.1	892.	19.92	79.2
TIME AFTER SHUTDOWN, YEARS								
100					104.1	892.	2.16	24.5
300					104.1	892.	0.40	12.2
1000					104.1	892.	0.16	5.2
3000					104.1	892.	0.07	2.2
10000					104.1	892.	0.05	1.4
30000					104.1	892.	0.02	0.6
100000					104.1	892.	0.01	0.1
300000					104.1	892.	0.00	0.1
1000000					104.1	892.	0.00	0.0

Table A.38 Accumulation of IL-TBU waste at a repository:
Uranium only recycle

Year	Volume (Hundreds of m ³)	Actinide Mass (kg)	Radio- activity (HCi)	Thermal Power (kW)	Volume (Thousands of m ³)	Actinide Mass (kg)	Radio- activity (HCi)	Thermal Power (kW)
1985	2.7	0.7	0.0	0.1	0.3	1.	0.04	0.1
1986	8.5	3.0	0.2	0.6	1.1	4.	0.19	0.7
1987	10.5	3.7	0.2	0.7	2.2	7.	0.37	1.3
1988	10.3	4.5	0.3	0.9	3.2	12.	0.60	2.1
1989	12.3	5.4	0.3	1.1	4.4	17.	0.86	3.0
1990	9.6	6.3	0.4	1.3	5.4	24.	1.15	4.0
1991	15.5	10.3	0.6	2.1	6.9	34.	1.65	5.7
1992	12.7	11.2	0.6	2.3	8.2	45.	2.15	7.5
1993	13.9	12.3	0.7	2.5	9.6	57.	2.70	9.3
1994	15.2	13.4	0.8	2.8	11.1	71.	3.29	11.3
1995	16.6	14.6	0.8	3.0	12.8	85.	3.92	13.5
1996	14.4	12.7	0.7	2.7	14.2	98.	4.41	15.1
1997	15.7	13.9	0.8	2.9	15.8	112.	4.95	16.9
1998	17.1	15.1	0.9	3.1	17.5	127.	5.55	18.9
1999	18.4	16.3	0.9	3.4	19.3	143.	6.18	21.1
2000	19.8	17.5	1.0	3.7	21.3	161.	6.87	23.5
2001	21.1	18.7	1.1	3.9	23.4	180.	7.59	26.0
2002	22.5	19.8	1.1	4.2	25.7	199.	8.35	28.6
2003	23.7	20.9	1.2	4.4	28.0	220.	9.14	31.3
2004	24.9	22.0	1.3	4.6	30.5	242.	9.97	34.2
2005	26.1	23.0	1.3	4.9	33.1	265.	10.81	37.1
2006	27.1	23.9	1.4	5.1	35.8	289.	11.69	40.2
2007	27.3	24.1	1.4	5.2	38.6	313.	12.55	43.2
2008	27.3	24.1	1.4	5.2	41.3	337.	13.39	46.1
2009	27.1	23.9	1.4	5.2	44.0	361.	14.19	48.9
2010	26.9	23.7	1.4	5.1	46.7	385.	14.95	51.6
2011	26.4	23.3	1.4	5.0	49.3	408.	15.67	54.1
2012	26.0	22.9	1.4	5.0	51.9	431.	16.35	56.6
2013	25.6	22.6	1.3	4.9	54.5	454.	16.98	58.9
2014	25.1	22.2	1.3	4.8	57.0	476.	17.58	61.1
2015	24.8	21.9	1.3	4.7	59.5	498.	18.16	63.2
2016	24.3	21.5	1.3	4.7	61.9	519.	18.69	65.3
2017	23.5	20.8	1.2	4.5	64.3	540.	19.18	67.1
2018	23.4	20.6	1.2	4.5	66.6	561.	19.64	68.9
2019	23.2	20.5	1.2	4.5	68.9	581.	20.10	70.7
2020	22.2	19.6	1.2	4.3	71.2	601.	20.49	72.3
2021	21.6	19.1	1.1	4.1	73.3	620.	20.84	73.8
2022	19.8	17.5	1.0	3.8	75.3	637.	21.10	75.0
2023	19.1	16.9	1.0	3.6	77.2	654.	21.32	76.0
2024	18.2	16.1	1.0	3.5	79.0	670.	21.50	76.9
2025	18.3	16.2	1.0	3.5	80.9	687.	21.69	77.9
2026	18.0	15.9	1.0	3.5	82.7	703.	21.87	78.9
2027	17.3	15.2	0.9	3.3	84.4	718.	22.01	79.7
2028	17.1	15.1	0.9	3.3	86.1	733.	22.15	80.5
2029	17.2	15.2	0.9	3.3	87.8	748.	22.29	81.4
2030	16.3	14.4	0.9	3.2	89.4	762.	22.40	82.1
2031	15.2	13.4	0.8	3.0	91.0	776.	22.44	82.6
2032	14.4	12.7	0.8	2.8	92.4	789.	22.45	83.0
2033	13.7	12.1	0.7	2.7	93.8	801.	22.43	83.3
2034	13.0	11.5	0.7	2.5	95.1	812.	22.38	83.5
2035	12.1	10.7	0.6	2.4	96.3	823.	22.29	83.6
2036	11.6	10.3	0.6	2.3	97.4	833.	22.19	83.6
2037	10.8	9.5	0.6	2.1	98.5	843.	22.06	83.6
2038	10.1	8.9	0.5	2.0	99.5	852.	21.90	83.4
2039	9.3	8.2	0.5	1.8	100.5	860.	21.72	83.1
2040	8.4	7.4	0.5	1.7	101.3	867.	21.50	82.8
2041	7.4	6.6	0.4	1.5	102.1	874.	21.24	82.3
2042	6.5	5.7	0.4	1.3	102.7	879.	20.95	81.6
2043	5.7	5.0	0.3	1.1	103.3	884.	20.63	80.9
2044	4.9	4.3	0.3	1.0	103.8	889.	20.29	80.1
2045	3.9	3.4	0.2	0.8	104.1	892.	19.92	79.2

TIME AFTER SHUTDOWN, YEARS	Volume (Thousands of m ³)	Actinide Mass (kg)	Radio- activity (HCi)	Thermal Power (kW)
100	104.1	892.	2.16	24.5
300	104.1	892.	0.40	12.2
1000	104.1	892.	0.16	5.2
3000	104.1	892.	0.07	2.2
10000	104.1	892.	0.05	1.4
30000	104.1	892.	0.02	0.6
100000	104.1	892.	0.01	0.1
300000	104.1	892.	0.00	0.1
1000000	104.1	892.	0.00	0.0

Table A.39 Accumulation of II-TRU waste at a repository:
Uranium, Plutonium Recycle

Year	* * * * Annual Addition * * * * *				* * * * Accumulation Through End of Year * * * *			
	Volume (Hundreds of m ³)	Actinide Mass (kg)	Radio- activity (MCi)	Thermal Power (kW)	Volume (Thousands of m ³)	Actinide Mass (kg)	Radio- activity (MCi)	Thermal Power (kW)
1985	2.7	0.7	0.0	0.1	0.3	1.	0.04	0.1
1986	8.5	3.0	0.2	0.6	1.1	4.	0.19	0.7
1987	10.5	3.7	0.2	0.7	2.2	7.	0.37	1.3
1988	10.3	4.5	0.3	0.9	3.2	12.	0.60	2.1
1989	12.3	5.4	0.3	1.1	4.4	17.	0.86	3.0
1990	9.6	6.3	0.4	1.3	5.4	24.	1.15	4.0
1991	15.5	10.3	0.6	2.1	6.9	34.	1.65	5.7
1992	12.9	11.4	0.6	2.3	8.2	45.	2.16	7.5
1993	14.7	13.0	0.7	2.5	9.7	58.	2.70	9.3
1994	16.1	14.2	0.8	2.8	11.3	73.	3.29	11.3
1995	17.5	15.5	0.8	3.0	13.1	88.	3.92	13.5
1996	16.3	14.4	0.7	2.7	14.7	102.	4.41	15.1
1997	18.6	16.4	0.8	2.9	16.6	119.	4.95	16.9
1998	19.9	17.6	0.9	3.1	18.5	136.	5.55	18.9
1999	21.7	19.2	0.9	3.4	20.7	156.	6.18	21.1
2000	24.2	21.4	1.0	3.7	23.1	177.	6.87	23.5
2001	26.4	23.3	1.1	3.9	25.8	200.	7.59	26.0
2002	28.6	25.3	1.1	4.2	28.6	226.	8.35	28.6
2003	30.5	26.9	1.2	4.4	31.7	253.	9.14	31.3
2004	33.0	29.1	1.3	4.6	35.0	282.	9.97	34.2
2005	34.9	30.8	1.3	4.9	38.5	312.	10.81	37.1
2006	37.2	32.9	1.4	5.1	42.2	345.	11.69	40.2
2007	38.1	33.7	1.4	5.2	46.0	379.	12.55	43.2
2008	39.8	35.1	1.4	5.2	50.0	414.	13.39	46.1
2009	40.8	36.0	1.4	5.2	54.1	450.	14.19	48.9
2010	41.9	37.0	1.4	5.1	58.3	487.	14.95	51.6
2011	42.6	37.6	1.4	5.0	62.5	525.	15.67	54.1
2012	43.8	38.7	1.4	5.0	66.9	563.	16.34	56.6
2013	44.9	39.6	1.3	4.9	71.4	603.	16.98	58.9
2014	45.0	39.8	1.3	4.8	75.9	643.	17.58	61.1
2015	44.9	39.6	1.3	4.7	80.4	682.	18.16	63.2
2016	39.8	35.1	1.3	4.7	84.4	718.	18.69	65.3
2017	39.4	34.8	1.2	4.5	88.3	752.	19.18	67.1
2018	39.2	34.6	1.2	4.5	92.2	787.	19.64	68.9
2019	39.0	34.4	1.2	4.5	96.1	821.	20.10	70.7
2020	36.3	32.0	1.2	4.3	99.7	853.	20.49	72.3
2021	35.5	31.3	1.1	4.1	103.3	885.	20.84	73.8
2022	33.6	29.7	1.0	3.8	106.6	914.	21.10	75.0
2023	31.9	28.1	1.0	3.6	109.8	942.	21.32	76.0
2024	31.0	27.4	1.0	3.5	112.9	970.	21.50	76.9
2025	30.8	27.2	1.0	3.5	116.0	997.	21.69	77.9
2026	29.9	26.4	1.0	3.5	119.0	1023.	21.87	78.9
2027	28.8	25.4	0.9	3.3	121.9	1049.	22.01	79.7
2028	28.1	24.8	0.9	3.3	124.7	1074.	22.15	80.5
2029	28.1	24.8	0.9	3.3	127.5	1098.	22.29	81.4
2030	26.8	23.7	0.9	3.2	130.2	1122.	22.40	82.1
2031	25.4	22.4	0.8	3.0	132.7	1144.	22.44	82.6
2032	24.3	21.4	0.8	2.8	135.1	1166.	22.45	83.0
2033	23.6	20.8	0.7	2.7	137.5	1187.	22.43	83.3
2034	22.5	19.8	0.7	2.5	139.7	1207.	22.38	83.5
2035	21.0	18.5	0.6	2.4	141.9	1225.	22.29	83.6
2036	20.2	17.8	0.6	2.3	143.9	1243.	22.19	83.6
2037	19.1	16.9	0.6	2.1	145.8	1260.	22.06	83.6
2038	18.1	15.9	0.5	2.0	147.6	1276.	21.90	83.4
2039	16.7	14.7	0.5	1.8	149.3	1290.	21.72	83.1
2040	15.5	13.7	0.5	1.7	150.8	1304.	21.50	82.8
2041	14.2	12.5	0.4	1.5	152.2	1317.	21.24	82.3
2042	12.8	11.3	0.4	1.3	153.5	1328.	20.95	81.6
2043	11.6	10.2	0.3	1.1	154.7	1338.	20.63	80.9
2044	10.4	9.1	0.3	1.0	155.7	1347.	20.29	80.1
2045	8.9	7.8	0.2	0.8	156.6	1355.	19.92	79.2
TIME AFTER SHUTDOWN, YEARS								
100					156.6	1355.	2.16	24.5
300					156.6	1355.	0.40	12.2
1000					156.6	1355.	0.16	5.2
3000					156.6	1355.	0.07	2.2
10000					156.6	1355.	0.05	1.4
30000					156.6	1355.	0.02	0.6
100000					156.6	1355.	0.01	0.1
300000					156.6	1355.	0.00	0.1
1000000					156.6	1355.	0.00	0.0

Table A.40 Accumulation of Low-Level Waste at a Repository:
Spent Unreprocessed Fuel Cycle (SURF)

Year	Number of LLW Drums		Year	Number of LLW Drums	
	Annual	Accumulated		Annual	Accumulated
1985	208	208	2013	3,081	74,435
1986	962	1,170	2014	3,048	77,483
1987	1,093	2,263	2015	2,995	80,478
1988	1,225	3,488	2016	2,935	83,413
1989	1,363	4,851	2017	2,057	85,470
1990	1,508	6,359	2018	2,823	88,293
1991	2,438	8,797	2019	2,782	91,075
1992	2,589	11,386	2020	2,753	93,828
1993	2,741	14,127	2021	2,698	96,526
1994	2,899	17,026	2022	2,628	99,154
1995	3,056	20,082	2023	2,550	101,704
1996	2,423	22,505	2024	2,449	104,153
1997	2,575	25,080	2025	2,312	106,465
1998	2,719	27,799	2026	2,182	108,647
1999	2,866	30,665	2027	2,051	110,698
2000	3,011	33,676	2028	1,919	112,618
2001	3,147	36,823	2029	1,781	114,399
2002	3,147	39,970	2030	1,636	116,035
2003	3,147	43,117	2031	1,498	117,533
2004	3,147	46,264	2032	1,346	118,879
2005	3,147	49,411	2033	1,195	120,074
2006	3,147	52,558	2034	1,037	121,111
2007	3,147	55,705	2035	879	121,990
2008	3,147	58,852	2036	721	122,711
2009	3,147	61,999	2037	570	123,281
2010	3,147	65,146	2038	425	123,706
2011	3,114	68,260	2039	280	123,986
2012	3,094	71,354	2040	136	124,122

Table A.41 Accumulation of LL-TRU waste at a repository:
Uranium only recycle

Year	* * * * Annual Addition * * * * *				* * * * Accumulation Through End of Year * * * *			
	Volume (Thousands of m ³)	Actinide Mass (MT)	Radio- activity (MCi)	Thermal Power (kW)	Volume (Thousands of m ³)	Actinide Mass (MT)	Radio- activity (MCi)	Thermal Power (kW)
1985	0.1	0.003	0.0	0.0	0.1	0.00	0.0	0.0
1986	0.3	0.012	0.1	0.1	0.4	0.01	0.1	0.2
1987	0.4	0.015	0.1	0.2	0.9	0.03	0.3	0.4
1988	0.4	0.018	0.2	0.2	1.3	0.05	0.4	0.6
1989	0.5	0.022	0.2	0.3	1.8	0.07	0.6	0.8
1990	0.4	0.025	0.2	0.3	2.2	0.09	0.9	1.2
1991	0.6	0.041	0.4	0.5	2.8	0.14	1.2	1.7
1992	0.5	0.045	0.4	0.5	3.3	0.18	1.6	2.3
1993	0.6	0.049	0.5	0.6	3.8	0.23	2.0	2.9
1994	0.6	0.054	0.5	0.6	4.4	0.28	2.4	3.6
1995	0.7	0.058	0.6	0.7	5.1	0.34	2.9	4.4
1996	0.6	0.051	0.5	0.6	5.7	0.39	3.3	5.1
1997	0.6	0.056	0.5	0.6	6.3	0.45	3.7	5.9
1998	0.7	0.060	0.6	0.7	7.0	0.51	4.1	6.8
1999	0.7	0.065	0.6	0.8	7.7	0.57	4.6	7.7
2000	0.8	0.070	0.7	0.8	8.5	0.64	5.1	8.7
2001	0.8	0.075	0.7	0.9	9.4	0.72	5.6	9.8
2002	0.9	0.079	0.8	0.9	10.3	0.80	6.1	10.9
2003	0.9	0.084	0.8	1.0	11.2	0.88	6.7	12.2
2004	1.0	0.088	0.9	1.0	12.2	0.97	7.2	13.5
2005	1.0	0.092	0.9	1.1	13.3	1.06	7.8	14.8
2006	1.1	0.096	0.9	1.1	14.3	1.16	8.4	16.3
2007	1.1	0.097	0.9	1.1	15.4	1.25	9.0	17.7
2008	1.1	0.096	0.9	1.1	16.5	1.35	9.6	19.2
2009	1.1	0.096	0.9	1.1	17.6	1.45	10.1	20.7
2010	1.1	0.095	0.9	1.1	18.7	1.54	10.6	22.2
2011	1.1	0.093	0.9	1.1	19.7	1.63	11.0	23.7
2012	1.0	0.092	0.9	1.1	20.8	1.73	11.5	25.2
2013	1.0	0.090	0.9	1.1	21.8	1.82	11.9	26.8
2014	1.0	0.089	0.9	1.0	22.8	1.90	12.2	28.3
2015	1.0	0.088	0.9	1.0	23.8	1.99	12.6	29.8
2016	1.0	0.086	0.8	1.0	24.8	2.08	12.9	31.2
2017	0.9	0.083	0.8	1.0	25.7	2.16	13.2	32.7
2018	0.9	0.082	0.8	1.0	26.6	2.24	13.4	34.2
2019	0.9	0.082	0.8	1.0	27.6	2.33	13.7	35.6
2020	0.9	0.079	0.8	0.9	28.5	2.40	13.8	37.1
2021	0.9	0.076	0.7	0.9	29.3	2.48	14.0	38.5
2022	0.8	0.070	0.7	0.8	30.1	2.55	14.1	39.8
2023	0.8	0.067	0.7	0.8	30.9	2.62	14.2	41.1
2024	0.7	0.064	0.6	0.8	31.6	2.68	14.2	42.4
2025	0.7	0.065	0.6	0.8	32.3	2.75	14.3	43.7
2026	0.7	0.064	0.6	0.7	33.1	2.81	14.3	44.9
2027	0.7	0.064	0.6	0.7	33.8	2.87	14.3	46.1
2028	0.7	0.061	0.6	0.7	34.4	2.93	14.3	47.4
2029	0.7	0.061	0.6	0.7	35.1	2.99	14.3	48.6
2030	0.7	0.057	0.6	0.7	35.8	3.05	14.3	49.7
2031	0.6	0.054	0.5	0.6	36.4	3.10	14.3	50.9
2032	0.6	0.051	0.5	0.6	37.0	3.15	14.2	51.9
2033	0.5	0.048	0.5	0.6	37.5	3.20	14.1	53.0
2034	0.5	0.046	0.4	0.5	38.0	3.25	14.0	54.0
2035	0.5	0.043	0.4	0.5	38.5	3.29	13.8	54.9
2036	0.5	0.041	0.4	0.5	39.0	3.33	13.7	55.9
2037	0.4	0.038	0.4	0.4	39.4	3.37	13.5	56.7
2038	0.4	0.036	0.3	0.4	39.8	3.41	13.3	57.6
2039	0.4	0.033	0.3	0.4	40.2	3.44	13.1	58.4
2040	0.3	0.030	0.3	0.3	40.5	3.47	12.9	59.1
2041	0.3	0.026	0.3	0.3	40.8	3.50	12.6	59.8
2042	0.3	0.023	0.2	0.3	41.1	3.52	12.4	60.4
2043	0.2	0.020	0.2	0.2	41.3	3.54	12.1	61.0
2044	0.2	0.017	0.2	0.2	41.5	3.56	11.8	61.6
2045	0.2	0.014	0.1	0.2	41.7	3.57	11.5	62.1
TIME AFTER SHUTDOWN, YEARS								
100					41.662	3.57	1.0	57.4
300					41.662	3.57	1.2	40.7
1000					41.662	3.57	0.6	18.9
3000					41.662	3.57	0.3	8.4
10000					41.662	3.57	0.2	5.2
30000					41.662	3.57	0.1	2.0
100000					41.662	3.57	0.0	0.3
300000					41.662	3.57	0.0	0.1
1000000					41.662	3.57	0.0	0.1

Table A.42 Accumulation of LL-TRU waste at a repository:
Uranium, Plutonium Recycle

Year	* * * * Annual Addition * * * * *				* * * * Accumulation Through End of Year * * * *			
	Volume (Thousands of m ³)	Actinide Mass (MT)	Radio- activity (MCi)	Thermal Power (kW)	Volume (Thousands of m ³)	Actinide Mass (MT)	Radio- activity (MCi)	Thermal Power (kW)
1985	0.1	0.003	0.0	0.0	0.1	0.00	0.0	0.0
1986	0.3	0.012	0.1	0.1	0.4	0.01	0.1	0.2
1987	0.4	0.015	0.1	0.2	0.9	0.03	0.3	0.4
1988	0.8	0.035	0.3	0.4	1.7	0.06	0.6	0.8
1989	1.9	0.085	0.8	1.0	3.6	0.15	1.4	1.8
1990	1.4	0.092	0.9	1.1	5.0	0.24	2.2	2.9
1991	1.7	0.115	1.1	1.3	6.7	0.36	3.3	4.4
1992	2.1	0.182	1.8	2.1	8.8	0.54	4.9	6.6
1993	3.0	0.268	2.6	3.1	11.8	0.81	7.3	10.0
1994	3.1	0.272	2.7	3.2	14.9	1.08	9.6	13.5
1995	3.5	0.310	3.0	3.6	18.4	1.39	12.2	17.5
1996	4.4	0.390	3.8	4.5	22.8	1.78	15.5	22.6
1997	5.2	0.459	4.5	5.4	28.0	2.24	19.3	28.6
1998	6.0	0.531	5.2	6.2	34.0	2.77	23.7	35.6
1999	6.6	0.584	5.7	6.8	40.7	3.35	28.3	43.4
2000	7.8	0.690	6.7	8.0	48.5	4.04	33.8	52.6
2001	8.5	0.753	7.3	8.8	57.0	4.80	39.7	62.9
2002	9.7	0.858	8.4	10.0	66.7	5.66	46.4	74.5
2003	10.4	0.915	8.9	10.7	77.1	6.57	53.3	87.1
2004	11.9	1.052	10.2	12.3	89.0	7.62	61.3	101.6
2005	13.0	1.148	11.2	13.4	102.0	8.77	69.8	117.6
2006	14.3	1.259	12.3	14.7	116.3	10.03	79.1	135.2
2007	15.3	1.348	13.1	15.7	131.5	11.38	88.9	154.2
2008	16.7	1.472	14.3	17.2	148.2	12.85	99.4	175.0
2009	18.0	1.590	15.5	18.5	166.2	14.44	110.7	197.7
2010	18.5	1.637	15.9	19.1	184.8	16.08	121.9	221.3
2011	18.7	1.652	16.1	19.3	203.5	17.73	132.8	245.6
2012	14.8	1.309	12.7	15.3	218.3	19.04	139.9	266.3
2013	15.2	1.342	13.1	15.7	233.5	20.38	147.0	287.6
2014	15.2	1.346	13.1	15.7	248.8	21.73	153.9	309.3
2015	15.2	1.341	13.1	15.6	263.9	23.07	160.4	331.1
2016	13.5	1.189	11.6	13.9	277.4	24.26	165.3	351.4
2017	13.3	1.177	11.5	13.7	290.7	25.43	169.7	371.7
2018	13.3	1.173	11.4	13.7	304.0	26.61	174.0	392.1
2019	12.4	1.094	10.7	12.8	316.4	27.70	177.4	411.7
2020	12.3	1.084	10.6	12.6	328.7	28.78	180.5	431.2
2021	12.0	1.060	10.3	12.4	340.7	29.84	183.3	450.6
2022	11.4	1.005	9.8	11.7	352.1	30.85	185.4	469.3
2023	11.1	0.978	9.5	11.4	363.2	31.83	187.2	487.8
2024	10.5	0.927	9.0	10.8	373.7	32.75	188.4	505.7
2025	10.4	0.922	9.0	10.7	384.1	33.67	189.6	523.5
2026	10.1	0.893	8.7	10.4	394.2	34.57	190.5	541.0
2027	9.8	0.862	8.4	10.0	404.0	35.43	191.0	558.0
2028	9.5	0.839	8.2	9.8	413.5	36.27	191.3	574.8
2029	9.5	0.839	8.2	9.8	423.0	37.11	191.6	591.5
2030	9.1	0.802	7.8	9.3	432.1	37.91	191.6	607.7
2031	8.6	0.759	7.4	8.9	440.7	38.67	191.2	623.4
2032	8.2	0.725	7.1	8.5	448.9	39.39	190.4	638.6
2033	8.0	0.705	6.9	8.2	456.9	40.10	189.6	653.4
2034	7.6	0.672	6.5	7.8	464.5	40.77	188.4	667.8
2035	7.1	0.628	6.1	7.3	471.6	41.40	187.0	681.5
2036	6.8	0.602	5.9	7.0	478.4	42.00	185.3	694.8
2037	6.5	0.571	5.6	6.7	484.9	42.57	183.4	707.6
2038	6.1	0.539	5.3	6.3	491.0	43.11	181.4	719.9
2039	5.6	0.499	4.9	5.8	496.6	43.61	179.0	731.6
2040	5.3	0.464	4.5	5.4	501.9	44.07	176.4	742.7
2041	4.8	0.423	4.1	4.9	506.7	44.50	173.6	753.2
2042	4.3	0.383	3.7	4.5	511.0	44.88	170.5	763.0
2043	0.5	0.041	0.4	0.5	511.5	44.92	164.2	768.7
2044	0.4	0.037	0.4	0.4	511.9	44.96	158.2	773.9
2045	0.4	0.031	0.3	0.4	512.2	44.99	152.4	778.8

TIME AFTER SHUTDOWN, YEARS				
100	512.236	44.99	23.2	727.1
300	512.236	44.99	15.7	515.2
1000	512.236	44.99	7.4	238.4
3000	512.236	44.99	3.4	106.1
10000	512.236	44.99	2.1	65.0
30000	512.236	44.99	0.8	25.6
100000	512.236	44.99	0.1	3.9
300000	512.236	44.99	0.1	1.2
1000000	512.236	44.99	0.0	0.9

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