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Volume 1

HIGH-LEVEL RADIOACTIVE WASTE MANAGEMENT ALTERNATIVES

SECTION 1: SUMMARY
SECTION 2: BACKGROUND AND DATA BASE
SECTION 3: EVALUATION METHODOLOGY

May 1974

Battelle
Pacific Northwest Laboratories
Richland, Washington 99352

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FOREWORD

This report is a comprehensive overview study of potential alternative methods for long-term management of high-level radioactive waste. The study includes a compilation of information relevant to technical feasibility, safety, cost, environmental considerations, policy conflicts, public response and research and development needs for:

1. Disposal in terrestrial locations
   a. In geologic settings on land
   b. In the seabed
   c. In ice sheets
2. Disposal into space
3. Elimination by transmutation (nuclear transformation of certain waste constituents into nuclides having less long-term toxicity).

The study is limited to the management of high-level radioactive waste from nuclear power by variations of these alternatives. Consideration of alternative types of electrical power generation are not within the scope of the study. In addition, evaluation of interim storage of radioactive waste in retrievable surface storage facilities is not part of this study. Disposal of waste in bedded salt deposits was studied extensively in other AEC programs, and the concept is included here as part of the overall matrix of geologic disposal techniques.

To complement these studies, investigations were also conducted on waste partitioning (separation of radionuclides in radioactive waste into different elements or groups of elements according to their long-term toxicity or suitability for different disposal methods), and systems methodology was developed to assess the effects of radionuclides from waste introduced into man's ecological cycle, assuming some failure of the primary waste containment.

Information pertinent to evaluating the various potential waste disposal techniques was developed without promoting any single disposal concept. The study is concerned with management of the waste and does not consider the potential for recovery of resources within the waste, including the heat. Concepts are developed only to the detail necessary to describe them for the overall investigation and in general are studied on a systematic, generic basis. This information can be used in comparing and assessing the various disposal concepts as a basis for decisions regarding their further study.

The evaluations of feasibility are not restricted to currently available technology. Rather, the study attempts to take into account technology which can be developed or is expected to be available at least within the next four decades. Indeed, most of the concepts studied are estimated to require 15 to 30 years for full implementation.

The study includes most currently known waste management alternatives, but is not considered to be all-inclusive. As new data become available, and as new or varied concepts become evident (e.g., disposal in rocks in permafrost areas, isotopic dilution of selected materials, etc.,) comparable follow-on studies will be carried out.

This investigation has been performed largely by a multiple-discipline technical staff at the Pacific Northwest Laboratory of Battelle Memorial Institute with significant input from a large number of consultants and outside contributors. This wide involvement of persons was an attempt to assure up-to-date and accurate coverage of the broad scope of subject matter, including areas where there are diversities of opinions.

This report is issued as nine major sections in four volumes:

Volume 1	Section 1	Summary[a]
	Section 2	Background and Data Base
	Section 3	Evaluation Methodology
Volume 2	Section 4	Geologic Disposal
Volume 3	Section 5	Ice Sheet Disposal
	Section 6	Seabed Disposal
Volume 4	Section 7	Waste Partitioning
	Section 8	Extraterrestrial Disposal
	Section 9	Transmutation Processing

Appendix material is included with its own respective volume.

In general, metric system units are used in this report. Conversion factors to English units are given in Appendix 1.A.

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a. This section is almost identical to WASH 1297, High-Level Radioactive Waste Management Alternatives, US AEC Division of Waste Management and Transportation, May 1974.

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Abbreviated contents of the total 4-volume report are listed here. Detailed contents of each of the nine sections are listed at the front of each section.

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1.0 SUMMARY

1.1 INTRODUCTION

This section is a summary of a comprehensive overview study of potential alternatives for long-term management of high-level radioactive waste sponsored by the United States Atomic Energy Commission Division of Waste Management and Transportation.[a] The report describes the various waste management alternatives that have been studied by the Pacific Northwest Laboratory and outlines the methods being used for evaluation. The following items in Table 1.1 were subjects of the study.

TABLE 1.1 Concepts Under Study for High-Level Radioactive Waste Management

A. PROCESSING

Partitioning*

B. DISPOSAL ON THE EARTH

Geologic	Seabed	Ice Sheet
Mined Cavity	Stable Deep Sea Floor	Ice Burial - Free Flow
Nuclear Cavity	Subduction Zones and Deep Trenches	Ice Burial - Anchored
Deep Hole	Rapid Sedimentation Areas	Ice Surface Facility
Drilled Hole Matrix		
Manmade Structures in Geologic Formations		
Hydraulic Fracturing		

C. DISPOSAL OFF THE EARTH

Extraterrestrial

- Solar Impact
- Earth and Solar Orbit
- Solar Escape to Deep Space

D. ELIMINATION

Transmutation

- Accelerator
- Fission Reactor
- Nuclear Explosive
- Controlled Thermonuclear Reactor (Fusion Reactor)

* Partitioning is a chemical separation of waste constituents into two fractions: one which contains the long-lived actinide elements and one which contains the fission products. Variations from this basic definition are also included in the study.

a. See Section 1.3 of this report for a description of high-level radioactive waste.

For each waste management alternative under investigation the information in Table 1.2 is presented:

TABLE 1.2. Investigation Objectives for Each Waste Management Alternative

Compile and Investigate:

- Technical Feasibility Information
- Safety Information and Methodology for Analysis
- Policy, Environmental, and Public Response Considerations
- Advantages and Disadvantages
- Needed Research and Development

Estimate:

- Research and Development Costs
- Schedules and Capital and Operating Costs for Implementation

In this general order the report describes:

- High-level nuclear waste management
- High-level nuclear waste--its origin, characteristics and conditioning processes
- Study methodology
- Safety considerations
- Disposal concepts--descriptions and system requirements
- Technical feasibility, advantages and disadvantages of concepts
- Research and development needs and commercialization schedules
- Capital and operating costs
- Special nonradiological environmental considerations
- Policy considerations
- Public response considerations

Following the description of waste management considerations and methodology for this investigation, all the elements listed from "Technical Feasibility" (Section 1.7) through "Public Response Considerations" (Section 1.12) are discussed for each disposal concept. The disposal concepts were studied on a systematic, generic basis and developed only to the extent necessary to perform the overall evaluations. Continued studies will develop a plan for development of advanced concepts which might be selected.

1.2 HIGH-LEVEL RADIOACTIVE WASTE MANAGEMENT

Radioisotopes of concern in high-level waste originate in a nuclear reactor. The fission products (other chemical elements formed by nuclear fragmentation of actinide elements such as uranium or plutonium, etc.) accumulate in the nuclear fuel, along with plutonium and other transuranic[a] nuclides.

Fuel discharged from the nuclear reactor is reprocessed to recover uranium and plutonium by chemical dissolution and treatment. During this step currently favored treatment processes form high-level waste as an acidic aqueous stream. Other processes are being considered which would produce high-level waste in different forms. This high-level waste contains most of the reactor-produced fission products and actinides, with slight residues of the uranium and plutonium. These waste products generate sufficient heat to require substantial cooling and emit large amounts of potentially hazardous ionizing radiation. Because the reprocessing step normally does not dissolve much of the nuclear fuel cladding, high-level waste normally contains only a small amount of the radionuclides formed as activation products within the cladding. This cladding hull waste is currently managed as a separate solid waste stream and has not been considered in this study.

The first high-level waste was produced in the mid-1940's as a result of Manhattan Project activities. Since then such waste, arising from defense production and nuclear power development, has been stored as either aqueous solutions or solids at AEC installations, and as aqueous solutions at the one only operational commercial fuel reprocessing plant (Nuclear Fuel Services at West Valley, New York).

The exponential growth of nuclear power in the United States will result in increased quantities of high-level waste. Installed U.S. nuclear electrical generating capacity is projected to increase from about 25,000 megawatts in 1974 to about 1,200,000 megawatts by the year 2000. The anticipated volume of solidified high-level waste accumulated from now until the year 2000 is about 13,000 cubic meters. If this amount of solid waste were stacked as a solid cube, the cube would be about 25 meters on a side. Approximately 150,000 megacuries of radioactivity and 700 megawatts of heat will be associated with this projected waste inventory in the year 2000. This heat content is equivalent to about one-third of the waste heat rejected from one Light Water Reactor (LWR) which generates 1000 megawatts of electricity. This study uses the LWR as the reference type of nuclear

a. Transuranic elements are those higher than uranium on the periodic table of chemical elements. Transuranic elements are also actinide elements.

reactor and generally considers the projected amount of waste accumulated in the U.S. through the year 2000.

Major options for waste management are shown in Figure 1.1. This logic diagram indicates most of the potential routings of nuclear waste, starting with its presence in the discharged reactor fuel and continuing to its final disposal or elimination step. Partitioning (removal of actinides), fractionation (removal of certain fission products), fixation or conversion to encapsulated solids, and retrievable storage are identified as processing steps of the waste management scheme used.

Constituents in high-level nuclear waste may be broadly categorized as a mixture of long-lived and short-lived radioisotopes from the standpoint of waste management. The short-lived

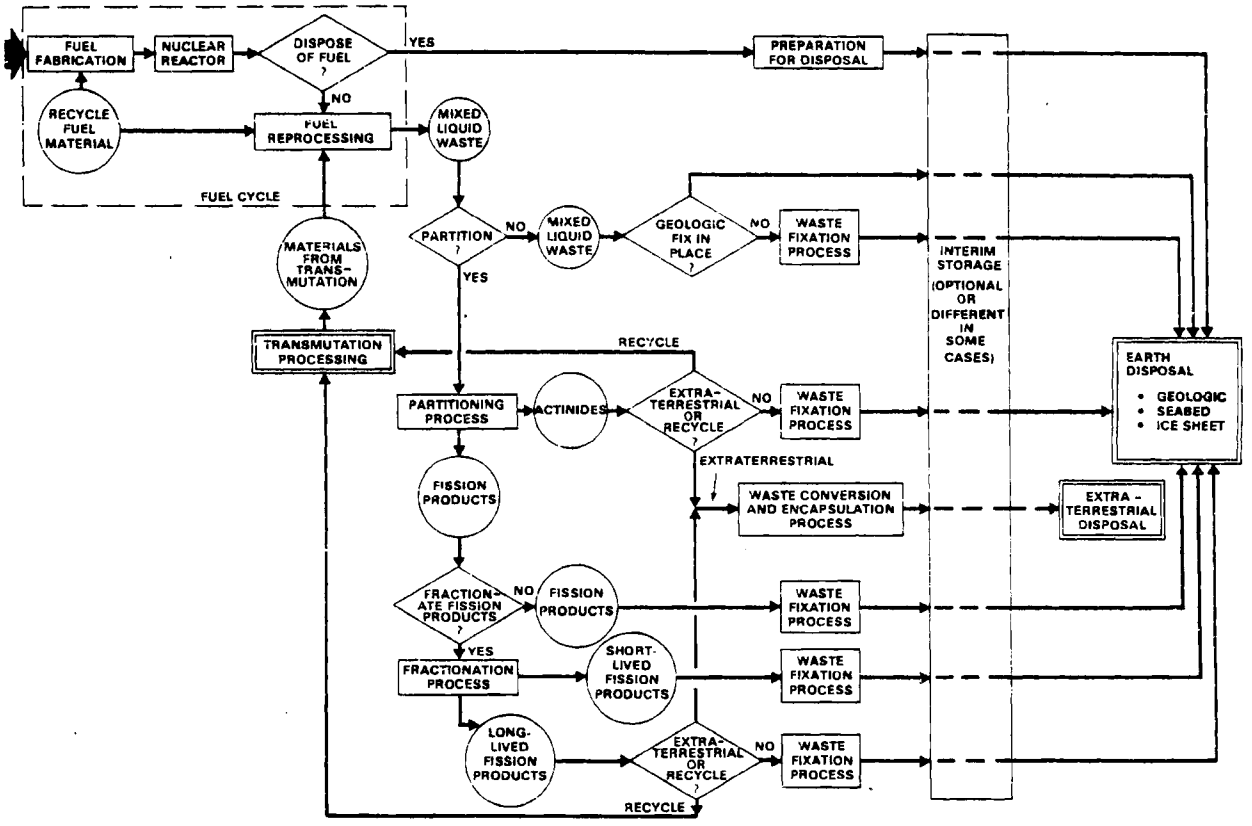

FIGURE 1.1. High-Level Radioactive Waste Management Options

waste materials are defined as those with radioactive decay half-lives of no more than tens of years, whereas the long-lived are those with half-lives of hundreds or more years.

Partitioning treatment of the waste is a key element in certain of the waste management systems. Dividing the high-level waste into long- and short-lived fractions allows the two waste fractions to be managed separately. The short-lived fraction will diminish to very low levels in about a thousand years, and the long-lived fraction, much smaller in quantity and heat generation rate, can be handled by other waste management options. In the broadest sense only three management options exist for the longer-lived and highly toxic actinide fraction of the waste: 1) elimination of the waste constituents by beneficial transmutation (nuclear conversion to other less undesirable isotopes), or 2) safe extraterrestrial transport off the earth, or 3) isolation from man's environment somewhere on earth for long time periods to allow natural radioactive decay.

In this report "disposal" refers to a plan to permanently place the waste in isolation, sometimes supplemented by manmade barriers to provide adequate protection for the time required to decay to unimportant radioactivity levels. The short-lived waste fractions will decay to become nonradioactive in relatively short times--times short enough to perhaps consider long-term storage such as in manmade structures. Manmade artifacts have existed for periods of time well in excess of 1000 years. Art objects from Chinese and Egyptian cultures are in good condition after time periods more than 6000 years. Modern man should be able to equal or better this performance and beneficially use containment to supplement isolation for the short-lived fraction of waste.

To produce a short-lived waste fraction which would decay to unimportant radioactivity in about 1000 years would require separation of the actinide elements and perhaps samarium, technetium, tin, iodine, and nickel (radioactive nickel is present due to irradiation and dissolution of some fuel cladding). Very large decontamination factors (ratio of initial concentration in waste to final concentration in waste) in the 10^6 to 10^8 range would be required for some of the elements, particularly the actinides, to render the remainder of the waste materials nonradioactive after ~1000 years' decay time. Realistically, it is reasonable to take into account the actual circumstances of a waste release, including dilution of waste within a geologic formation, the low leach rate of many solidified waste forms and the sorption of radionuclides in the soil. With these natural attenuation factors, the long-lived radionuclides may not need to be removed so completely from the mixed wastes. Preliminary use of failure mode and radiological pathway analyses on sample cases indicates that perhaps only the actinide elements need be removed and these only by decontamination factors of 100 to 1000 (10^2 to 10^3).

1.3 HIGH-LEVEL RADIOACTIVE WASTE

Typical constituents of the liquid high-level waste expected from the solvent extraction reprocessing of irradiated fuels from Light Water Reactors (LWR), Liquid Metal Fast Breeder Reactors (LMFBR), and High Temperature Gas-Cooled Reactors (HTGR) are shown in Table 1.3. The waste is a nitric acid solution of chemical salts which typically contains a few volume percent of solids. The waste constituents include nonradioactive chemicals added during reprocessing, almost all the fission products (radioactive and nonradioactive), the transuranium actinides formed in the reactor, and about 0.5 percent of the fuel materials (uranium, plutonium, thorium) which are not recovered during reprocessing. Most of the chemical materials are those added during fuel reprocessing.

Present Atomic Energy Commission (AEC) regulations require that the liquid high-level waste from fuel reprocessing 1) be converted to a solid material within 5 years after separation in the fuel reprocessing step, and 2) be encapsulated and shipped to a federal repository within 10 years of its production for long-term management by the AEC. For this study the solidified high-level waste is assumed to be encased in steel canisters averaging 30 centimeters (12 inches) in diameter and 300 centimeters (10 feet) long. Thus solidification and encapsulation must occur prior to initiation of most disposal schemes.

Four solidification processes have been developed in the United States to the point of radioactive demonstration on an engineering scale: fluidized bed calcination, spray solidification, pot calcination, and phosphate glass solidification. In all four processes, heat is applied to drive off volatile constiuents, primarily water and nitrates, resulting in either a calcined solid or a melt that will cool to a monolithic solid. The latter generally requires dilution of the waste with nonradioactive materials (20 to 40 percent of the total solid) to incorporate the waste into materials (glass or ceramics) that have low solubility in water and are fusible at reasonably low temperatures (less than about 1200°C).

Characteristics of typical final solid waste forms from the four processes are shown in Table 1.4. The processes are described briefly below.

Fluidized Bed Calcination. Liquid waste is atomized into a heated fluidized bed where it is deposited and calcined on granular bed particles. The resulting granular "spheres" of waste calcine may be the final waste form or they may be incorporated into crystalline or glassy solids in a melting stage.

Spray Solidification. Atomized droplets of waste fall through a heated chamber where flash evaporation results in solid oxide particles. Glassmaking solid frit or phosphoric acid can then be added to provide for

TABLE 1.3. Typical Materials in High-Level Liquid Waste

	Material[b]	Grams/MT from Reactor Type[a] LWR[c]	HTGR[d]	LMFBR[e]
Reprocessing Chemicals	Hydrogen	400	3,800	1,300
	Iron	1,100	1,500	26,200
	Nickel	100	400	3,300
	Chromium	200	300	6,900
	Silicon	--	200	--
	Lithium	--	200	--
	Boron	--	1,000	--
	Molybdenum	--	40	--
	Aluminum	--	6,400	--
	Copper	--	40	--
	Borate	--	--	98,000
	Nitrate	65,800	435,000	244,000
	Phosphate	900	--	--
	Sulfate	--	1,100	--
	Fluoride	--	1,900	--
	Sub-total	68,500	452,000	380,000
Fuel Product Losses[f,g]	Uranium	4,800	250	4,300
	Thorium	--	4,200	--
	Plutonium	40	1,000	500
	Sub-total	4,840	5,450	4,800
Transuranic Elements[g]	Neptunium	480	1,400	260
	Americium	140	30	1,250
	Curium	40	10	50
	Sub-total	660	1,440	1,560
Other Actinides[g]		<0.001	20	<0.001
Total Fission Products[h]		28,800	79,400	33,000
	TOTAL	103,000	538,000	419,000

a. Water content is not shown; all quantities are rounded.
b. Most constituents are present in soluble, ionic form.
c. U-235 enriched PWR, using 378 liters of aqueous waste per metric ton, 33000 MWd/MT exposure. (Integrated reactor power is expressed in megawatt-days [Mwd] per unit of fuel in metric tons [MT].)
d. Combined waste from separate reprocessing of "fresh" fuel and fertile particles, using 3,785 liters of aqueous waste per metric ton, 94,200 MWd/MT exposure.
e. Mixed core and blanket, with boron as soluble poison, 10% of cladding dissolved, 1,249 liters per metric ton, 37,100 MWd/MT average exposure.
f. 0.5% product loss to waste.
g. At time of reprocessing.
h. Volatile fission products (tritium, noble gases, iodine and bromine) excluded.

TABLE 1.4. Characteristics of Solidified High-Level Waste

	Pot Calcine	Spray Phosphate Ceramic	Phosphate Glass	Borosilicate Glass[a]	Fluidized Bed Calcine
Form	Scale	Monolithic	Monolithic	Monolithic	Granular
Description	Calcine Cake, Friable	Ceramic Hard, Tough	Glass Hard, Brittle	Glass Hard, Brittle	Calcine, Mean Particle Diam. 100 to 500 μ
Bulk Density g/cm^3	1.2 to 1.4	2.7 to 3.3	2.7 to 3.0	3.0 to 3.5	1.0 to 1.7
Wt% Fission Product Oxides (Max.)	90	30	25	50	50
Thermal Conductivity, W/(m2) (°C/m)	0.3 to 0.4	1.0 to 1.4	0.8 to 1.2	1.0 to 1.4	0.2 to 0.4
Leachability in Cold Water, g/cm^2-day	1.0 to 10^{-1}	10^{-3} to 10^{-5}	10^{-4} to 10^{-6}[b]	10^{-5} to 10^{-7}	1.0 to 10^{-1}

a. Produced by either spray or fluidized bed calcining followed by melting, or by in-canister vitrification processing.
b. Devitrified phosphate glass exhibits increased leachability (leach rates = 10^{-2} to 10^{-3} g/cm2-day).

melting and glass formation in a continuous melter or directly in the vessel that will serve as the waste canister. The molten glass or ceramic is cooled and solidified.

Pot Calcination. Liquid is continuously added to and boiled away in a processing vessel which also serves as the storage canister. When the canister is full of solids, the addition of aqueous waste is stopped and the solid then heated and held at about 900°C to complete denitration and dehydration. Feed additives can be used to result in a glass rather than a calcine cake.

Phosphate Glass Solidification. Liquid waste and phosphoric acid are mixed and concentrated to a thick sludge in an evaporator. The sludge goes to a melter where dehydration and denitration are completed and the material is melted. The molten phosphate glass then drops into a storage canister where it cools and solidifies.

The AEC has in progress at the Pacific Northwest Laboratory a Waste Fixation Program (WFP). Its chief goal is to provide technology and assistance for reprocessors by developing appropriate calcining and melting technology for high-level waste. Developed systems will be taken all the way through a radioactive pilot plant demonstration. Solid waste forms produced from these demonstrations will be studied to determine the suitability of the waste forms and their resistance to adverse effects of time and environment.

The major emphasis of the WFP is to provide early solidification technolcgy by working with silicate glass or ceramic systems. Because these

solids have had prior extensive development effort on a worldwide basis, development of acceptable systems to produce the solids should be near-term. The silicate solids will offer a significant improvement in waste management safety over liquids or calcined solids because of their resistance to leaching and physical transport in the environment.

In an effort parallel to the silicate solid development, studies are aimed at determining and developing a final waste form capable of longer term containment. An example of this would be a multiple-barrier material. This could involve coating small pieces of chemically stable solid waste with a protective inert material. The coated solids could then be dispersed and further encased in a protective matrix to consolidate the particles in a massive solid. Additional protection could be provided by outer wrappers.

1.4 STUDY METHODOLOGY

The overall method of analysis by which each disposal concept and its waste management system elements were studied is presented briefly in this section. The relationships among the major study elements are shown in Figure 1.2.

The waste management concepts were first developed to the detail needed to describe them for overall investigations and in general were studied on a systematic, generic basis. Concepts were generally developed on the reference basis of having the capability to handle the waste from a plant which reprocesses 5 metric tons/day (1825 MT/yr) of spent nuclear fuel.[a] This reference capacity was then scaled up as a function of time to accommodate the total need for the U.S. nuclear economy through the year 2000.

After the various disposal concepts were defined, the technical feasibility of each potential concept was determined in this study by answering the questions:

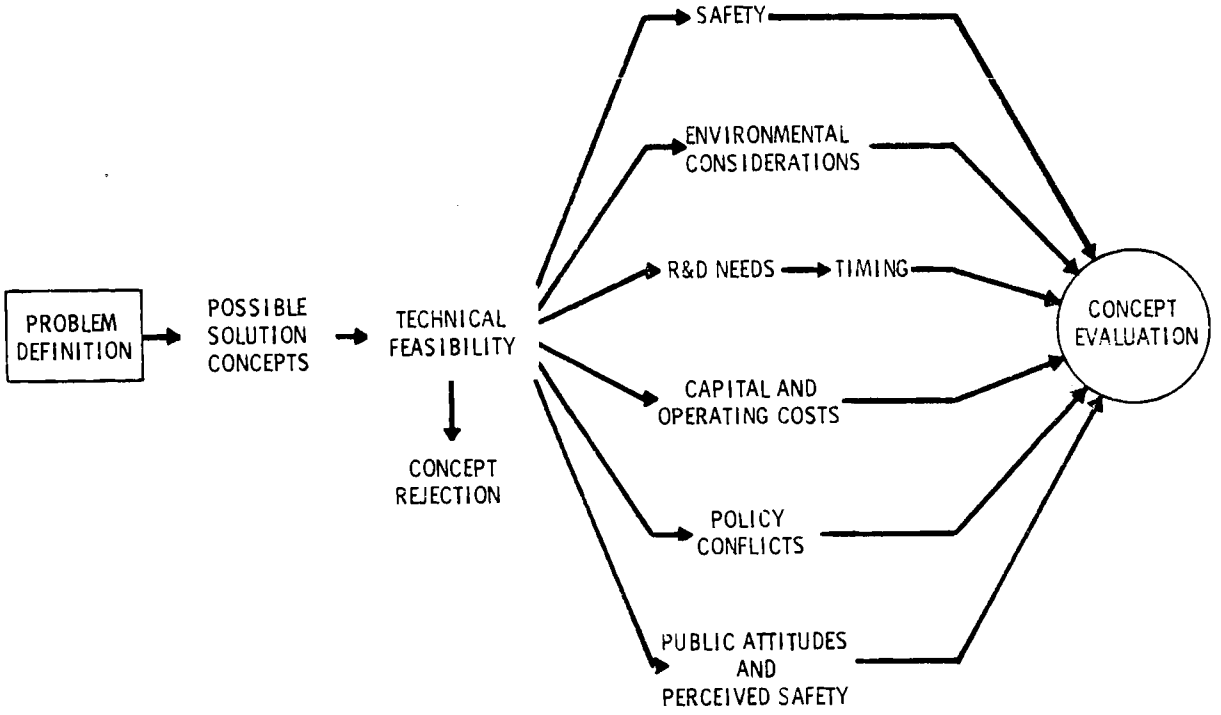

FIGURE 1.2. Relationships Among Evaluation Factors

a. High-level waste produced is about 1900 liters/day as aqueous waste. This quantity amounts to 45,625 metric tons of fuel reprocessed during the assumed 25-year life of the plant. Total accumulated solid waste is in 14,700 "typical" canisters 30 centimeters in diameter and 3 meters long.

1) Can the disposal concept be implemented using today's technology?

2) Or can the disposal concept be implemented with future technology based upon current theory?

3) Can the disposal concept provide the potential for confining or eliminating the waste over the required time period?

4) Does the concept have a favorable energy balance?

Those few concepts that did not pass this technical feasibility test (i.e., some transmutation and space disposal variations) were rejected from further studies.

Once the technical feasibility of a concept was established, the other elements were studied in parallel. The potential for system safety was scanned for each concept. A sample safety analysis was performed for one generic type of geologic disposal concept to develop and test the safety analysis methodology. The safety analysis (discussed later) estimated the radiation dose[a] from a hypothetical release of waste from a disposal area.

Environmental considerations, aside from the potential release of radioactive materials, were reviewed such as overall effects on land, air, sea or water use.

The technology needs were assessed, and Research and Development needs (scope, time, and dollars) were estimated. From the Research and Development time needs, the total time for implementation of each concept was estimated.

Capital and operating costs were estimated, using the basic assumption that the necessary Research and Development had been successfully completed. Costs were estimated and summed for total waste management system activities such as partitioning, interim liquid and solid storage, shipping and disposal.

Major policy conflicts that a concept would have with international and national policies were reviewed such as agreements that prohibit the use of the oceans or the Antarctic continent for waste disposal. The problems involved with changes can then be weighed against the safety and economic potentials of a particular waste management concept.

The potential public response to a chosen waste management scheme was examined in a preliminary pilot test. Obviously this is a complex subject and very difficult to evaluate. An initial study of methodology was designed to identify those aspects of the waste management systems that might be deemed most important by the general public. With future analysis in depth, information on public attitudes could be factored into concept design. The public's acceptance of a technically sound waste management system is a most important goal.

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a. Radiation dose is an expression for the energy absorbed by matter as a result of exposure to radiation and has the unit "rad." For these safety studies we have actually used the radiation dose-equivalent, expressed in "rem," which is a measure of the physiological effects of radiation on people.

The final product of the study is a compilation of information regarding the evaluation factors for the various disposal concepts. The outcome of each of these elements is described in different units. Therefore, the concepts cannot be evaluated by simply adding up the performance level by elements. Instead, the technique being developed for future studies is one of determining if a disposal concept passes a performance test for each evaluation factor listed. For instance, a passing of the technical feasibility hurdle or test would be required before detailed analysis of other requirements be undertaken. The order in which the pass-reject tests are applied and the criteria for the various performance hurdles (or concept evaluation factor tests) have not been developed in this study.

1.5 SAFETY CONSIDERATIONS

Safety is a major consideration in decisions on the use of any potential disposal scheme. An acceptable option must provide adequate protection during operational phases and provide the necessary isolation during the long time periods of the disposal phase.

Long-term immobilization or isolation and containment of disposed waste are the two major protective devices requisite to the implementation of a nuclear waste management system. Substantial interaction can and does exist between these two factors. In this context, isolation is used to mean the factors which influence the time required for migration of waste to man's environment; containment is used to mean immobilization and confinement of the waste constituents within known barriers. Typical isolation factors could include distance, the ion-exchange capacity of interposed earth materials, the lack of a transfer medium such as water, etc. If waste is adequately isolated so that the migration times are greater than the time for radioactive decay, isolation alone can provide adequate protection. Conversely, if adequate containment is provided by manmade barriers which immobilize the waste--again for the length of time for decay--the waste could be placed in many selected locations even within man's environment. Here the word "barrier" is used to include the matrix for the waste, e.g., silicate glasses, wrappings such as metallic sheets, and facilities such as a concrete building, which serve to provide effective barriers to the escape of radioactive materials.

The disposal options explored in this report seek to utilize the maximum benefits from both isolation and containment although principal emphasis is on isolation.

For this study "safety" was equated directly to the potential risk to man (in terms of radiation dose) that could result if a disposal option were implemented. The key elements in a method of assessing potential risk are illustrated in Figure 1.3.

Assessment of the risk of a proposed concept starts with the general description of the disposal concept. This implies a generic site description (e.g., ice sheet disposal defines a general location, surrounding geology, and population density), and it implies the characteristics of the waste (e.g., the waste form, containerization, radionuclide content, and age). The most likely sequences of failure events leading to possible release of radioactive materials to man's environment are then defined and the probability of these sequences taking place is determined. The next step follows the most likely sequences through the physical and chemical mechanisms required to release the waste constituents into man's immediate environment. The generic site defines the media (granite, salt, shale, air, water, etc.) through which radionuclides must move

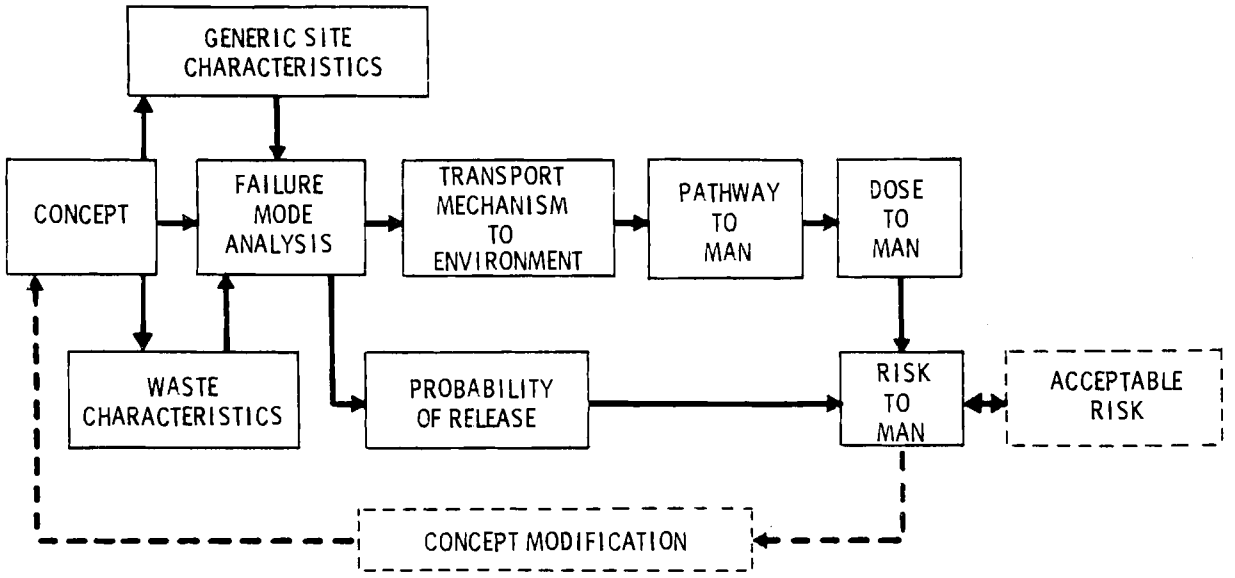

FIGURE 1.3. Interrelationships Among Pathway, Probability and Risk

into man's environment. Next, based on the population estimated to come in contact with the waste materials, the potential exposure pathways, and the calculated waste release rate, the radiation dose to the population can be estimated.

Finally, the probabilistic risk (dose) to man can be determined by multiplying the probability of the event taking place times the dose if it takes place. By comparing the total integrated risks of proposed concepts with appropriate criteria, it can be determined whether or not the risk to man exceeds acceptable criteria. If the risk level is unacceptably high, the concept could be rejected or changes could be made in the concept to reduce the risk. If the risk for a concept meets all criteria, the concept would be considered to have met the safety requirements, although further improvements may still be made in the concept. Of course, concepts in which the risk is substantially lower than the measurement criteria would be rated as most favorable.

Development of suitable safety criteria is most important in a final evaluation of waste management practices. Development of such criteria was beyond the scope of this study, but the following are proposed as representative of major safety criteria:

1) On a probabilistic basis, the risk to the world population from waste management should represent only a minor increase in the total risk presently assumed by the operation of nuclear power plants. The risk contribution from probabilistic releases from the waste production of a power plant should be no more than a fraction of the risk from chronic effluent releases from the plant.

2) Because the risk to man from waste may exist substantially longer

than the use of fission reactors as a power source, its risk to future man should compare favorably with other involuntary risks that give little or no benefit. Being struck by lightning, being killed in an earthquake or flood and being hit by a fallen aircraft are examples of involuntary risks with little benefit to those exposed to the risk. Such risks result in about one death per million population per year.[a] Comparison of the risk from waste management practices would require conversion of radiation dose to deaths to establish a criterion. Several such conversions have been postulated but remain controversial.

3) The dose to the population in the immediate disposal area should not be great enough to put the population at serious immediate risk. This may require that some protective reaction from a release of waste materials be available; for example, the population in the affected area may be evacuated or restricted or the water supplies may be relocated. It is assumed that evacuation may be required if the estimated exposure to a population group were to exceed some maximum standard which could not be decreased through curtailed operation.

The basic problem with this analytical technique is that the values used to describe probabilities of system failures, the actual rates of movement through environmental media to man, and even the population distribution around the release from a plant 1,000 years or more in the future are obviously in question. In addition, information on the interrelationships between dose to man, risk to man in units of potential deaths or dollar costs and acceptable risk were found to be controversial. Information on these subjects must be developed in future studies.

1.5.1 Failure Mode Analysis and Release Probabilities

Evaluation of the safety of any disposal concept requires identification of mechanisms and probabilities of possible releases of radioactive waste constituents to man's environment. The fault tree analysis technique was determined to be the preferred method to provide for achieving these requirements. The method provides for calculating the risk to man (in terms of radiation exposure in this study) on a probabilistic basis.

As an illustration of the method, a generic fault tree was developed for geologic disposal in a mined cavity. In all, 77 basic failure events were identified as possible contributors to a waste release from a geologic disposal site.

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a. There is a great deal of concern about natural disasters but essentially no concern about accidents caused by lightning. In natural disasters, the concern is high because many people could be exposed to a single event. These simple comparisons show that perception of risk is very complex and that numerous factors must be considered.

For the fault tree to be fully utilized each failure event must be amenable to analysis. Each must have a predictable failure threshold, and it must be possible either to obtain a reasonable data base for predicting the frequency of the event or else to show that the failure event is not an important safety consideration.

Of the 77 failure events in the example studied, over 60 are believed to have predictable failure thresholds; thus it should be possible to develop data base for predicting probabilities. They are fully amenable to analysis.

Of the remaining 17 failure events, the majority were associated with man's future activities. Although man's future activities can never be exactly quantified, the importance of man's presence can be bracketed by first assuming the site is not actively administered and alternatively by assuming that man is actively controlling activities in the area. Thus the degree of reliance placed on man's presence in the region can be roughly quantified. It is believed that disposal concepts which place minimum reliance on man's presence can be found. Thus, for those concepts the final criterion is met; i.e., the failure events associated with man's activity are not an important safety consideration.

The remaining failure events were associated with future tectonic activity. Areas of high tectonic activity may not be readily amenable to analysis because the forces involved are potentially large, they may not be well known, and they are particularly difficult to quantify. However, areas of high tectonic stability are available, and disposal in these locations should be amenable to fault tree analysis.

Section 3 of this report shows an approach to evaluating each of the 77 basic failure elements identified by the generic fault tree for this example.

1.5.1.1 Sample Waste Release Probability Estimate

The next step of analysis is to follow each release sequence through its pathway to man's environment and ultimately to man. One release sequence, obtained from the geologic fault tree developed in the above-referenced study, is followed here. The numbers presented in this analysis are based on very limited data. Thus they serve primarily to demonstrate the safety evaluation method.

The example waste release sequence considers the release of waste to man's environment by water. This is considered to be one of the more likely release sequences.

The release sequence starts with the premise of "An Aquifer in the Waste Disposal Region" and requires the following three conditions: "Water Finds Path into Disposal Site," "Water Is Flowing" and "Water Flow Cannot be Controlled by Man." All three conditions must occur together before a release of waste constituents can take place. Based on present tunneling experience, the probability that an undetected flaw in a barrier exists which will allow water

entry in a region where there is no detectable aquifer is estimated to occur at a rate of once in 100,000 kilometers of tunnel length. Thus the failure element "Water Finds Path into Disposal Site" is estimated to occur at a rate of 10^{-5}/km of tunnel constructed for geologic disposal. This and the following numbers are order of magnitude estimates. Based on the description for the mined cavity concept, 90 kilometers of tunnels will be in existence in the year 2000; thus the probability of a defect allowing water entry is expected to be once in every one thousand mines (or 10^{-3}) with 90 kilometers of tunnel.

Conditions which could cause an aquifer in the region in the next year were estimated to be once in one billion (10^{-9}). After one million years, the probability of an active aquifer in the region is taken to be much greater, 10^{-1}. At the 1000-year period, an intermediate number was used. It was assumed that man would not be able to control the aquifer and the aquifer would be flowing; thus the failure elements "Water Is Flowing" and "Water Flow Cannot be Controlled by Man" have probabilities of one.

Table 1.5 summarizes the sample failure event probabilities and the resultant cumulative probabilities obtained by multiplying the individual probabilities in each vertical column. The ranges of probabilities given reflect uncertainty in the above data.

The table summarizes a release probability estimate from one sample failure sequence. To estimate the overall safety, all significant paths must be analyzed and the probabilities times the respective consequences must be summed.

TABLE 1.5. Sample Components of Release Sequence Probabilities for Geologic Disposal

Failure Event	Probability of Waste Release During Operational Period	During 1000 Years	During 1,000,000 Years
Aquifer Develops in the Region Where One Did Not Exist Previously	10^{-10} to 10^{-8}	10^{-6} to 10^{-4}	10^{-2} to 10^{-1}
Water Finds Path into Disposal Site	10^{-4} to 10^{-2}	10^{-4} to 10^{-2}	10^{-4} to 10^{-2}
Water Flow Cannot Be Controlled by Man	1	1	1
Water Is Flowing	1	1	1
Cumulative Release Probability in the Time Given	10^{-14} to 10^{-10}	10^{-10} to 10^{-6}	10^{-6} to 10^{-3}

1.5.1.2 Application of Fault Trees to Other Disposal Concepts

Preliminary failure modes were identified for seabed, ice sheet and extraterrestrial disposal concepts in the first reference. Fault tree analysis can be applied to these disposal concepts in the same manner as to the geologic concepts.

The preliminary analysis pointed out how relatively little data are available to assess the seabed and ice sheet environments. For example, in the seabed environment, very little information is known about the long-term behavior of ocean sediments. In like manner, there is little experience with drilling, placement and sealing of waste canisters in the seabed. Thus its apparent safety is uncertain, chiefly because of lack of detailed knowledge about it. The same is true of the ice sheet environment except that more known mechanisms for release of waste can be identified.

For the extraterrestrial disposal concepts, NASA has accumulated experience with manned space flights as a basis for estimating the safety which can be achieved. Failures on the launch pad, by burnup in the atmosphere, or meltdown after loss on the earth's surface are the failure elements of greatest concern and can be estimated with improved confidence as the number of launches accumulates.

1.5.2 Transport Mechanisms

All disposal concepts under study provide substantial containment or isolation barriers to initially separate the constituents of nuclear waste from man's environment. A failure or degeneration of these barriers is required before transport to man's environment can be initiated. However, a barrier failure does not necessarily result in release of waste materials into man's immediate environment where exposure takes place; transport mechanisms are required.

The primary transport mechanisms are naturally occurring water and air. In most cases, transport by water will be through soils and/or rock with extensive chemical interaction (ion exchange) taking place. The quantities, rate, and timing of radioisotopes entering man's environment will depend on a host of parameters such as the rate of release of radioisotopes at the source (i.e., solubility of waste in groundwater), the flow rate of the water, the distance travelled to reach man's environment, the efficiency of ion exchange, chemical species, etc.

Transport by air could be achieved as a result of either a single or a two-step process. In the first, an accident could both directly expose the waste to air and fracture it to such an extent that air currents would resuspend and transport material. In the two-stage process, it is postulated that naturally occurring water would transport the radioisotopes to a water (or earth)-air

interface. Resuspension and transport could then occur from the residues of evaporation.

Quantification of the decontamination factors (i.e., radioisotope adsorption and holdup time) in the transport process requires an accurate model of the geologic system.

Sample transport decontamination factors were calculated for an aquifer 16 kilometers in length flowing at 30 cm/day in typical western soil. This calculation assumed that an aquifer penetrated a failed barrier in a geologic disposal site. Dose reduction factors were in the range of 10^5 to 10^6; that is, the calculated doses to man with soil retention were 5 to 6 orders of magnitude lower than those without soil retention. The significance of this calculation is that for properly sited disposal concepts, the earth itself can provide major safety factors.

1.5.3 Dose to Man

A comprehensive dose computational model, developed and used for other Atomic Energy Commission Studies, was adapted to permit ready calculation of radiation doses to individuals and population groups for alternative waste disposal concepts. Typical inputs include source terms (radionuclide release rates to man's immediate environment), population densities, dilution quantities, and consumption rates of food and water. Outputs include individual pathway doses, total doses to individuals and to specified population groups, and fractional dose contributions of specific nuclides.

To demonstrate the capability, calculated doses are shown in Table 1.6. for a hypothetical release of radioactive waste from geologic disposal (assuming sorption and retention on soil). Also shown in the table is the limiting individual dose from non-occupational and non-medical radiation exposure according to the latest recommendations of the National Council on Radiation Protection and Measurements. For comparison, the average annual radiation dose in the United States from natural sources is on the order of 120 to 140 mrem. The dose indicated in the table for the Maximum Individual is less than that received during a cross-country jet airplane flight.

The potential doses (following releases from a geologic disposal site) are highly dependent on the sorption capacity of the soil or other receiving media, the characteristics (especially the leach rate) of the waste, and the measures taken to prevent release.

Calculations can be based on postulated release of the waste materials to man's immediate environment at any period after disposal, but calculated doses at periods of 1,000 years or more would be much less due to decay of shorter-lived nuclides. The most significant nuclides in terms of dose would generally be strontium-90 and cesium-137 at 100 years, various radionuclides of americium and plutonium at 1,000 to 10,000 years, and uranium daughter nuclides at longer periods.

Doses calculated with the model for various generic cases are primarily valuable for comparative purposes,

TABLE 1.6. Calculated Whole Body Radiation Doses from Hypothetic Release of Waste Inventory of Year 2000 in Geologic Disposal

	Maximum Annual Dose (mrem)	NCRP Non-Occupational Guide
Maximum Individual	0.4	500
	Annual Dose to Population (man-rem)	
Population	30	(a)

Assumptions

- Total waste inventory exposed in the assumed releases is all of the waste resulting from the projected cumulative 167,000 equivalent metric tons of fuel processed in the U.S. through year 2000. (The latest projection is 185,000 equivalent metric tons.)
- Initial release to soil occurs 100 years after disposal.
- Geologic disposal is in arid western region, with release to aquifer.
- Source release rate (or the rate of dissolution of the waste material) is 0.3% per year of total inventory.
- Aquifer is 16 kilometers long; average groundwater velocity is 30 cm/day.
- Soil is typical western desert soil, with its normally good ion-exchange capacity.
- Population is 180,000 people within an 80-km radius of the point of release to man's immediate environment.
- Aquifer flows into a river which flows through the center of the region and which provides both drinking water and irrigation.
- Average river flow rate is 280 m^3/sec.

a. Guides are not available, but dividing the indicated dose of 30 man-rem by the assumed population size of 180,000 gives an average annual dose of 0.16 mrem for comparison with the dose to the hypothetical Maximum Individual.

and such doses would be, at worst, the result of a series of unpredictable or low-probability events leading to the release of radioactivity to man's immediate environment. Detailed analyses will be required to assess the risks to man from specific concepts, sites, and operations.

1.5.4 Risk to Man

The sample calculations of probability given in Table 5 can be multiplied by doses such as those shown in Table 6 to obtain a hypothetical risk of radiation dose to man from the disposal concept. The maximum measure of risk to an individual from the given failure mechanisms and pathways would then be in the range of 10^{-14} to 10^{-10} mrem/year to the whole body during the operational period, 10^{-10} to 10^{-6} mrem/year at 1,000 years after disposal, and 10^{-6} to 10^{-3} mrem/year at 1,000,000 years after disposal. Similarly, the risk to the affected large population

group would be less than 10^{-8}, 10^{-4}, and 10^{-1} man-rem/year for the same respective three time intervals.

These previous sections demonstrate the methodology for calculating the probabilistic risk to man from radioactive waste disposal. For actual application of risk calculations, analyses will be required for specific concepts, sites, and operations. In addition, the risks from all major mechanisms and pathways must be summed to obtain the total calculated risk.

An alternative measure of risk would be derived from estimation of harmful effects (deaths or illness) on people from the calculated radiation dose increments associated with each disposal concept. Recent studies sponsored by the United Nations Scientific Committee on the Effects of Atomic Radiation and by the U.S. Environmental Protection Agency address what is known and what is assumed for low-level radiation concerning the radiation dose/radiation effects problem. Considering the large uncertainties in the derived conversions and the problem of making equivalent conversions for radiation doses to different organs of the body, we have chosen not to attempt estimates of harmful effects for these concept comparison studies.

Attempts have been made by others to place a dollar value on estimates of increased harmful effects on people to provide a more direct method of comparisons than the above. Such a procedure involves not only still larger uncertainties, but the basic philosophical question of equating dollars to human lives, and is not being considered for these studies.

1.6 DISPOSAL CONCEPTS - DESCRIPTION AND SYSTEMS

Listed in Table 1.7 are the various waste management concepts. The table highlights key differences of the various alternative system characteristics compared to a reference disposal concept. The reference concept was arbitrarily selected to be a concept comparable to salt mine disposal: total waste encapsulated as a solid and emplaced in a mined cavity with no auxiliary fluid cooling. The simplified table does not show all the variations studied for each of the generic concepts listed. Brief concept and systems descriptions are presented in the following sections.

1.6.1 Geologic Disposal Concepts

The basic requirement for any geologic environment to be suitable for disposal of radioactive waste is the capability to safely contain and isolate the emplaced radioactive material until decay has reduced the radioactivity to nonhazardous levels. Geologic environments exist which have been physically and chemically stable for millions of years, would provide isolation from man's environment, and have acted as effective barriers for isolation of naturally occurring radioactive uranium and thorium deposits from man's environment.

Relative to other terrestrial locations, a large amount of information is available on the geology of the conterminous United States, the primary area of interest for this waste disposal study.

A geologic formation can be penetrated and altered in several ways to provide a repository for waste emplacement. This study considers the use of drilling, mining (mechanical and dissolution), exploded cavity formation and hydraulic fracturing. Many combinations of potential geologic environments and methods of their penetration, along with methods for placement of waste within these systems, were studied in an attempt to cover the broad range of potential possibilities.

Ten methods for disposing of waste in geologic formations were considered in this study. Two primary disposal geometries, i.e., cavities and a drilled hole, several means for forming cavities, and several operational modes were examined, as shown in Table 1.8.

In all concepts the final waste form is a solid. In some concepts, waste is emplaced in the geologic formation as a liquid and converted in-place to a solid form for long-term disposal. For concepts 5, 6, and 9, the self-generated heat within the liquid waste is used to dry and melt the waste and some of the surrounding rock which, when cooled, forms a solid waste-rock matrix. In concept 10, the liquid waste is incorporated within a self-curing cement.

Because of the potential hazards of shipping aqueous high-level waste, the liquid emplacement concepts require locating the fuel reprocessing

TABLE 1.7. Summary of System Characteristics for Alternative Waste Management Systems

Concept	Requirements for the System: Interim Liquid Waste Storage at Reprocessing Plant?	Partitioning of Waste into Two or More Fractions?	Solidification into Canned Silicate Glass or Special Forms?	Interim Solid Waste Storage?	Overland Transportation to Disposal or Recycle Facility?	Involves Final Disposal of Waste Constituents?	Disposal of Total High-Level Waste Constituents?	Other
"Reference" Concept (solid waste emplaced in mined cavity, no fluid cooling or melting).	Not needed	No	Glass	Optional	Yes	Yes	Yes	None
Differences from Above Requirements are Listed Below								
Geologic Concepts								
1. Solid waste emplaced in mined cavity; no fluid cooling or melting	--	--	--	--	--	--	--	--
2. Solid waste emplaced in mined cavity; initial water cooling; melting	--	--	Also in-place melt-conversion to rock-waste matrix.	--	--	--	--	--
3. Solid waste emplaced in manmade structure in mined cavity; initial air cooling; no melting	--	--	--	--	--	--	--	--
4. Solid waste emplaced in manmade structure in mined cavity; initial water cooling; no melting	--	--	--	--	--	--	--	--
5. Liquid waste emplaced in mined cavity; initial reflux cooling; melting	--	--	Liquid; in-place melt-conversion to rock-waste matrix.	No	No	--	--	Disposal/processing operations are combined; extra transport of fuel to reprocessing plant.
6. Liquid waste emplaced in exploded cavity; initial reflux cooling; melting	--	--	Liquid; in-place melt-conversion to rock-waste matrix.	No	No	--	--	Disposal/processing operations are combined; extra transport of fuel to reprocessing plant.
7. Solid waste emplaced in matrix of drill holes; no fluid cooling or melting	--	--	--	--	--	--	--	--
8. Solid waste emplaced in deep holes; no fluid cooling; melting or nonmelting [a]	--	--	--	--	--	--	--	(a)
9. Liquid waste emplaced in deep holes; initial reflux cooling; melting	--	--	Liquid; in-place melt-conversion to rock-waste matrix.	No	No	--	--	Disposal/processing operations are combined; extra transport of fuel to reprocessing plant.
10. Liquid waste emplaced by hydrofracture; in-place curing	Yes	--	In-place curing to waste-cement matrix	No	No	--	--	Disposal/processing operations are combined; extra transport of fuel to reprocessing plant.
Ice Sheet Concepts								
1. Self melt through ice 2. Anchored storage/disposal 3. Ice surface storage/disposal	--	--	--	--	Also over-sea, over-ice transport	--	--	--
Seabed Concepts								
1. Subduction zones and other deep-sea trenches 2. Stable deep-sea floors 3. Rapid sedimentation	--	--	--	--	Also over-sea transport	--	--	--
Extraterrestrial Concepts								
1. Solar and Earth Orbits 2. Solar impact 3. Solar escape	Desired	Yes	Special capsule forms	No	--	--	No, transuranics only	--
Transmutation Concepts								
1. Fission reactors 2. Fusion reactors 3. Accelerators 4. Nuclear explosives	Desired	Yes	Special capsule forms	No	--	Recycle/ elimination	No, actinides only and selected fission products	--

a. For deep drill hole, both prior solidification and in-place solidification were studied.

TABLE 1.8. Characteristics of Geologic Disposal Concepts

Concept	Type of Cavity	Waste Form at Time of Emplacement	Fluid Cooling	Waste-Rock Reactions
1	Mined	Solid	No	No
2	Mined	Solid	Water	Melt
3	Mined[a]	Solid	Air[c]	No
4	Mined[a]	Solid	Water[c]	No
5	Mined	Liquid[b]	No	Melt
6	Exploded	Liquid[b]	No	Melt
7	Matrix of Drilled Holes	Solid	No	No
8	Deep Hole	Solid	No	No/Melt[d]
9	Deep Hole	Liquid[b]	No	Melt
10	Hydrofracture	Liquid[b]	No	No

a. Includes underground manmade structures.
b. All liquid emplacement concepts involve in-place conversion to a solid form.
c. Cooling is provided for an interim period of tens of years until the heat generation rate has decreased to a point that melting will not occur.
d. This deep hole concept is studied for both melting and nonmelting cases.

plant at the disposal site.[a] The solid emplacement concepts involve transportation of the waste, already converted to a solid at the fuel reprocessing plant, cross-country to a central Federal disposal site, assumed to be separate from the reprocessing plant.[b] These basic systems requirements for high-level waste management in terrestrial locations (geologic formations, ice sheet, and seabed) are shown in Figure 1.4.

It was assumed in this study that geologic disposal options are aimed at managing the total high-level waste, including the long-lived radionuclides, without preconditioning or partitioning of the aqueous waste.

The ten geologic disposal concepts are shown schematically in Figures 1.5 through 1.14 and discussed below.

1.6.1.1 Solid Waste Emplaced in Mined Cavity - No Fluid Cooling or Melting

The concept depicted in Figure 1.5 shows previously solidified waste buried in the floor of rooms or tunnels that have been excavated in the

a. It may be possible to ship calcined waste to the repository and dispose of it as an aqueous slurry by any of the liquid waste disposal concepts. This concept may be looked at as a variation of the liquid waste disposal concept.

b. A Federal repository, the Retrievable Surface Storage Facility, is planned for interim retrievable storage of solidified waste until a disposal concept is ready for use.

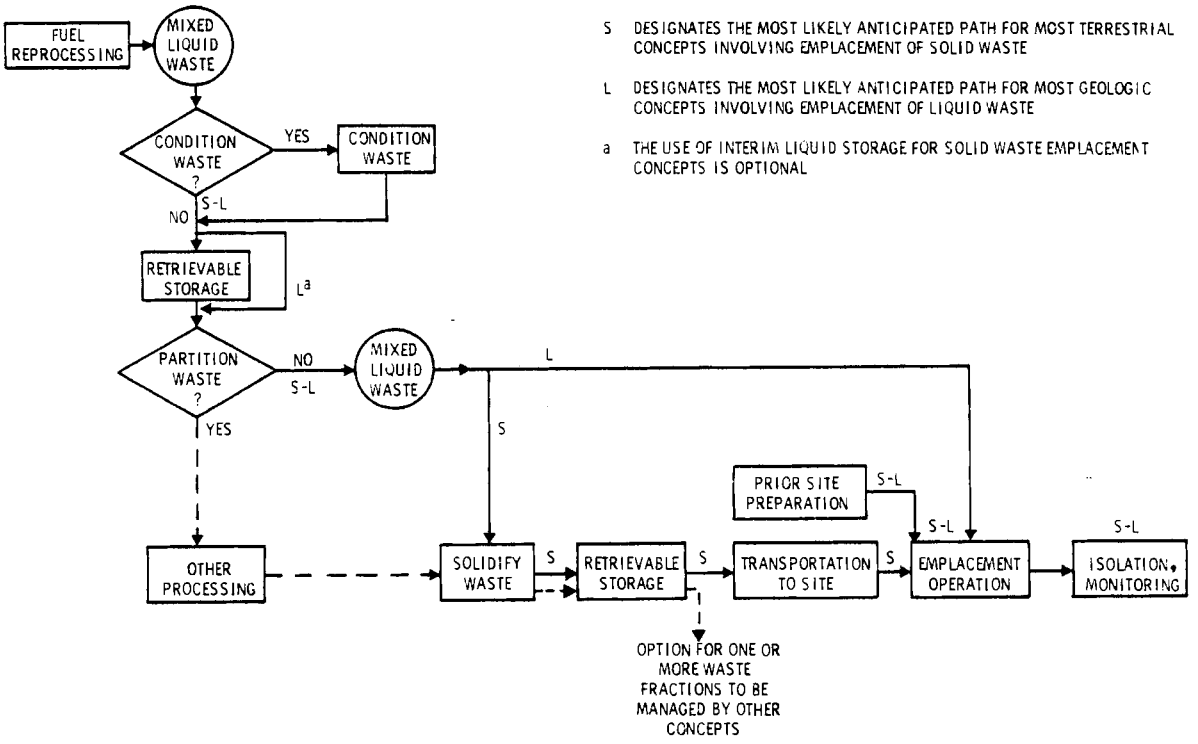

FIGURE 1.4. System Requirements for High-Level Radioactive Waste Management in Terrestrial Locations

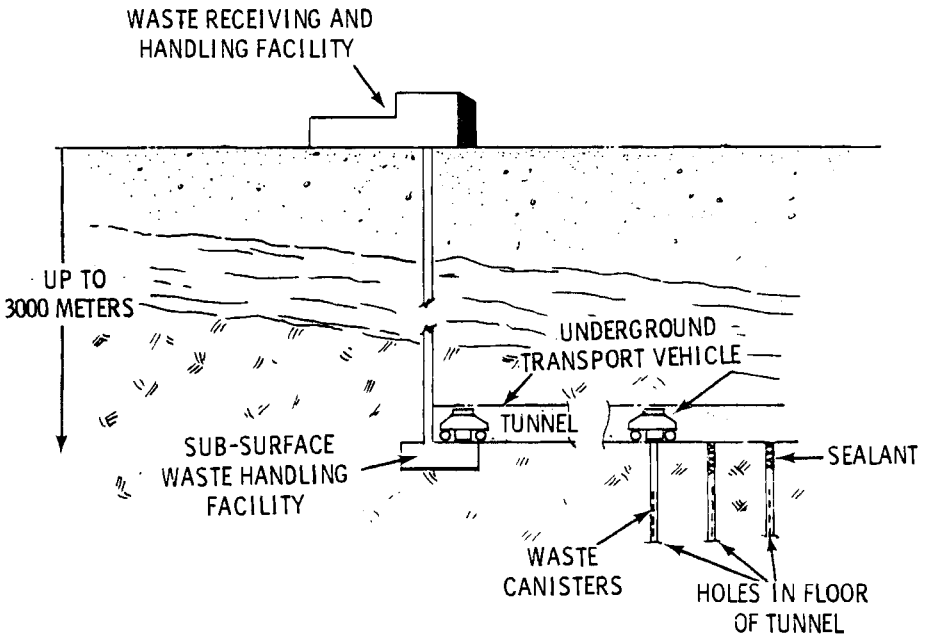

FIGURE 1.5. Solid Waste Emplacement in a Mined Cavity - No Fluid Cooling or Melting

geologic formation. This generic concept includes the bedded salt disposal concept that has received emphasis in major Research and Development studies sponsored by the Atomic Energy Commission over the past 15 years. Studies on the bedded salt concept were initiated based on recommendations of the National Academy of Sciences - National Research Council.

Upon arrival at the repository, the shipping cask and transport vehicle are moved into a cask unloading area which is inside a building. The cask is removed from its carrier and lowered into a shielded handling cell. Individual canisters are removed from the cask and transported to a shaft where they are lowered by cable into the subsurface complex. The lower end of the shaft terminates in a transfer vault or shielded handling cell located in the geologic formation at the mine level.

At the mine level, individual waste canisters are moved from the sub-surface shielded cell into a shielded transfer vehicle. After receiving the canister, the subsurface transfer vehicle transports the waste package to a previously mined and prepared burial tunnel or room with predrilled holes in the floor. The transfer vehicle is located over a hole, and the waste package is lowered into the hole. The hole may be backfilled with material to provide some shielding to the tunnel area and to act as a partial barrier against escape of radionuclides into the tunnel area in the event a can fails. After the last can is lowered into a hole, the top 1.8 to 2.4 meters (6 to 8 feet) of the hole are filled with a sealant to provide isolation and shielding. The system is designed so that the heat from the waste will be conducted through the geologic formations without causing melting or deterioration of the geologic media.

After all the holes have been filled and sealed, individual burial tunnels or rooms are sealed from the rest of the repository by a bulkhead. The tunnel or room will eventually be backfilled.

It is estimated that about 90 kilometers of burial tunnel, 4.6 meters on a side, would be required to dispose of the 14,700 canisters of high-level waste produced by the reference reprocessing plant. In addition, nearly 11 kilometers of access tunnel will be required.

1.6.1.2 Solid Waste Emplaced in Mined Cavities - Interim Liquid Cooling and Conversion to Rock-Waste Matrix

A pictorial description of this concept is shown in Figure 1.6. Waste canisters are removed from shipping casks in a waste receiving facility, lowered through a drill hole into a lined cavity, and deposited on the cavity floor in a random array. Waste within the cavity is immersed in a boiling water bath. Steam generated is condensed in a surface facility and returned to the hole for cooling the waste. Operation of the surface cooling system will be continued until the cavity contents are permitted to melt by allowing the cooling water to boil away.

The reference case for this concept assumes eventual waste-rock melting after shutdown of the water

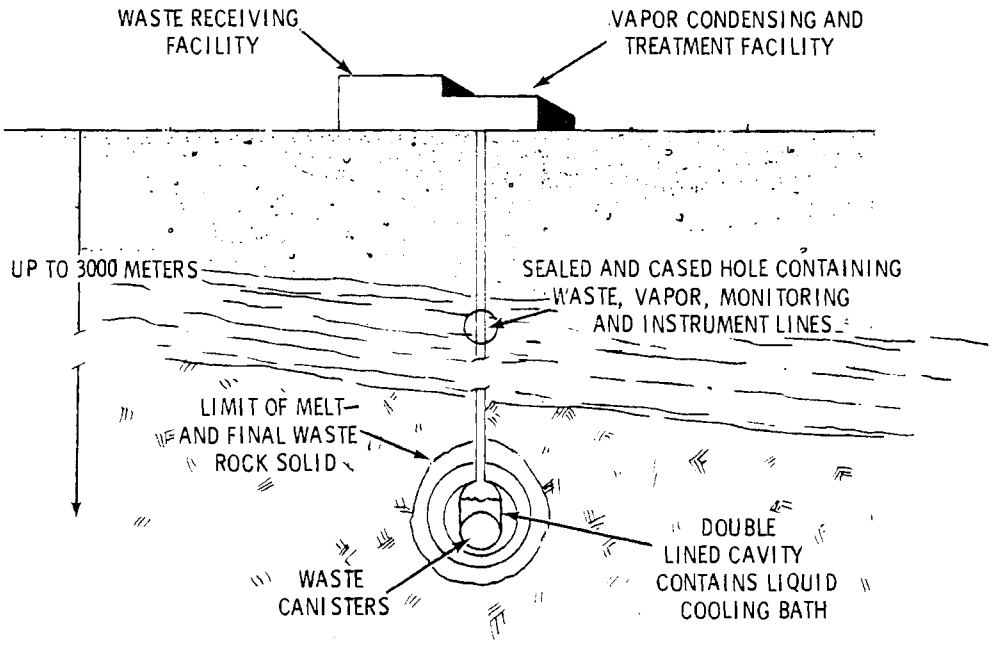

FIGURE 1.6. Solid Waste Emplacement in a Mined Cavity - Interim Liquid Cooling and Waste-Rock Melting

cooling phase of cavity operation. Cavity shutdown is started by stopping return of the condensed steam. The cavity begins to dry and the temperature of the contained materials starts to rise. The cased hole is sealed by plugging at an appropriate time, and the waste is allowed to melt. The waste will melt from its own heat within a few days because it is concentrated in a small volume with little cooling by the surrounding rock. Over a few tens to one hundred years the heat from the waste will melt some of the surrounding rock and form a larger molten mass which dilutes the waste concentration. After a few hundred years, the molten rock-waste mixture will cool and solidify into a rock-waste matrix as the heat provided by radioactivity diminishes.

A cavity volume of about 13,000 cubic meters would be required to receive and serve as a repository for the high-level waste generated by the reference reprocessing plant.

1.6.1.3 Solid Waste Emplaced in Man-made Structures in Geologic Formations - Interim Air Cooling

Figure 1.7 is a graphic description of a concept using natural convection air cooling of waste canisters inside individual pods designed to conduct the heat to the air coolant. A canister of waste is sealed inside the bottom of a thick-walled metal pod buried in the floor of the tunnel to shield operating personnel from radiation. Radioactive decay heat is conducted through the metal pod wall and is dissipated from the

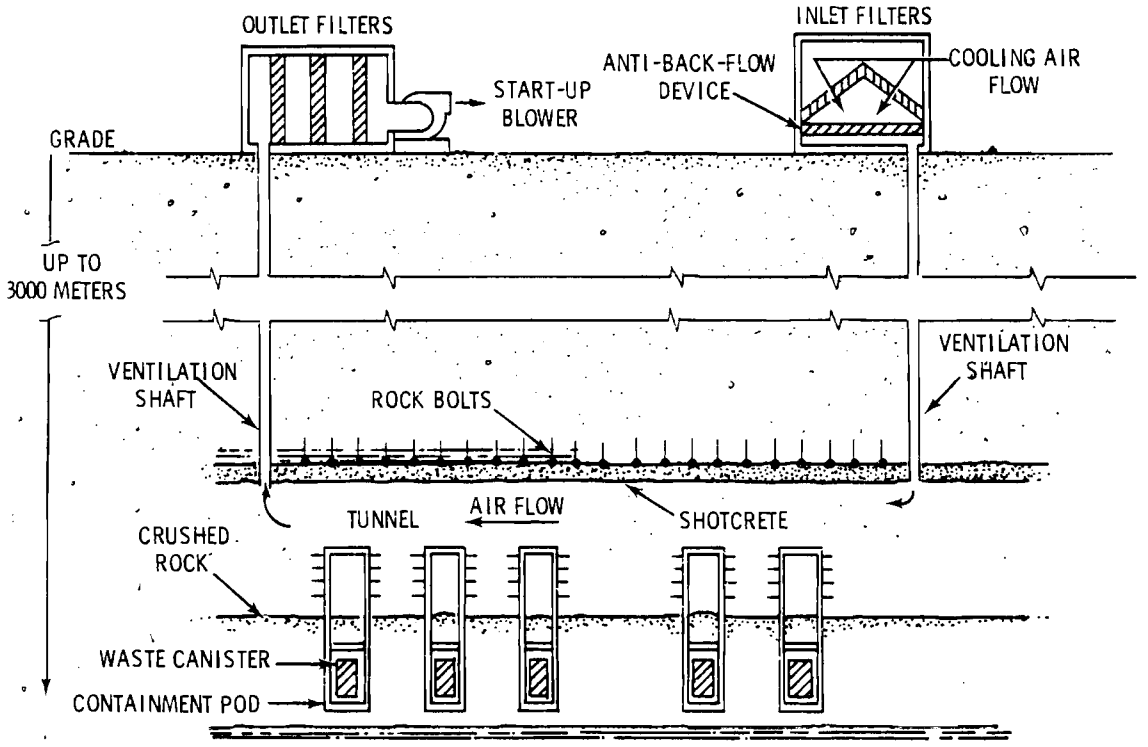

FIGURE 1.7. Solid Waste Emplacement in a Mined Tunnel - Interim Natural Convection Air Cooling, No Melting

finned surface to the flowing cooling air. The single pass cooling air flows by natural convection once the draft has been initiated. After a predetermined time, the access areas are sealed and the waste heat is transferred to the surrounding rock as in concept 1.

Upon arrival at the repository, a waste canister is unloaded inside a building and transferred to the below-ground facilities much as in concept 1 (see Figure 1.5). At the mine level, the waste canister is placed in the containment pod. The pod is placed in a hole or trench within a tunnel, the hole is backfilled with crushed rock, and the top of the pod is sealed. Other emplacement operations are similar to those for concept 1.

About 5.5 kilometers of burial tunnel, 9 meters in diameter, would be required to dispose of the high-level waste produced by the reference reprocessing plant.

1.6.1.4 Solid Waste Emplaced in Manmade Structures in Geologic Formations - Interim Water Cooling

A schematic diagram of a water-cooled system is shown in Figure 1.8. This is a typical cross-sectional view of a tunnel containing the underground facility, a manmade structure designed to withstand earthquakes and shifting of the rock formation. Upon arrival at the repository, the waste

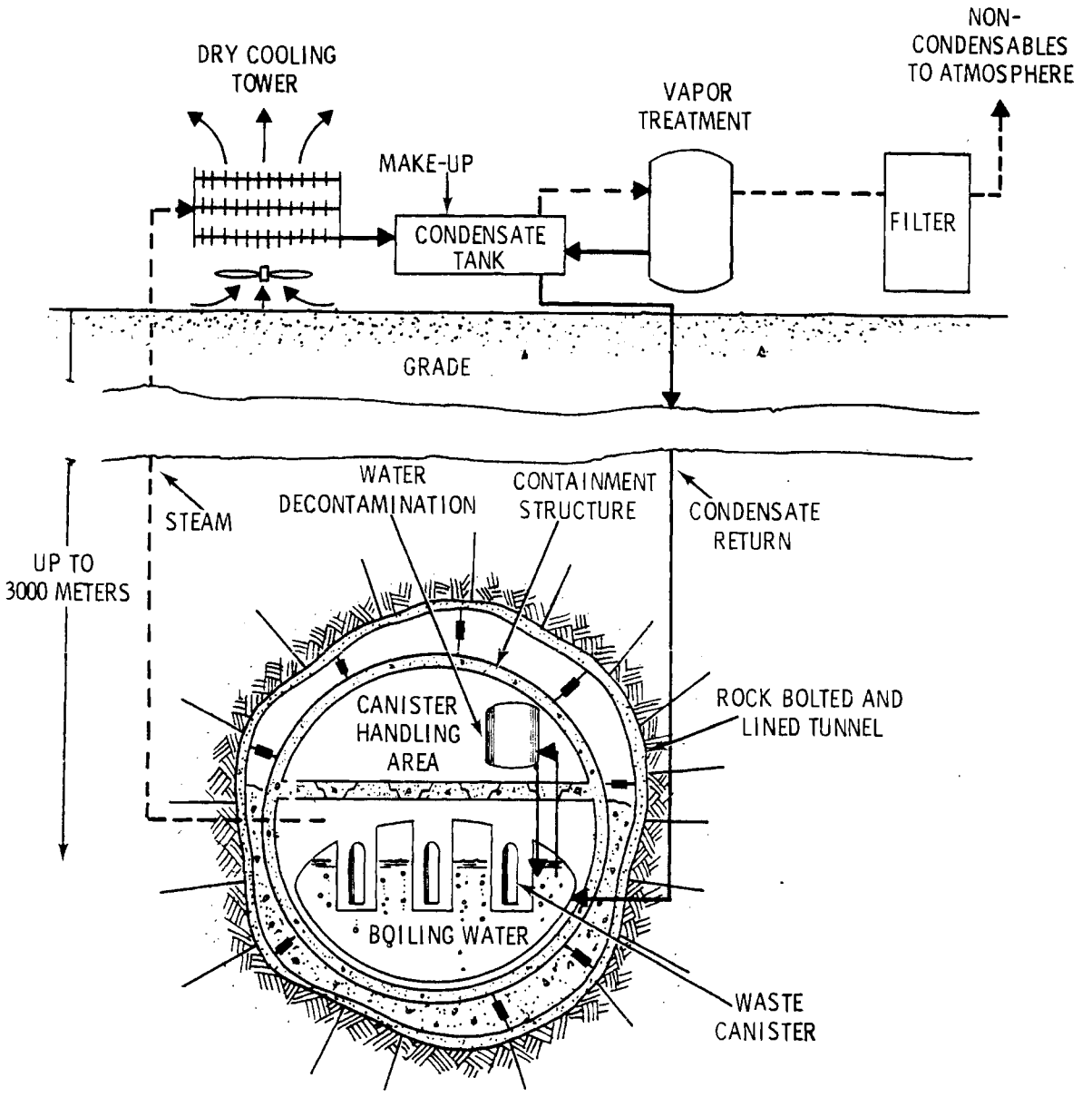

FIGURE 1.8. Solid Waste Emplacement in Manmade Structure with Interim Boiling Water Cooling, No Melting

canister is unloaded inside a building, transferred to the below-ground facilities, transported to the disposal location through the waste canister handling area of the tunnel and lowered into the hole, similarly to other concepts. The waste is placed in the shielded lower part of a cylindrically-shaped water-filled storage vessel in the mined cavity. Typically the concrete shell would be 30 feet in diameter and the tunnel would be 50 feet in diameter. Steam generated by the waste is piped to a heat-exchange system at the earth's surface where it is condensed and returned to the waste storage area. A side stream of the coolant is

treated to remove radioactivity which may be present from leaking or externally contaminated canisters. After a predetermined time the cooling water is removed from the system. The access areas are sealed, and the waste heat is transferred to the surrounding rock without melting as in concept 1. Tunnel requirements would be about the same as in the previous concept. Auxiliary facilities such as personnel access shafts, air locks and waste transfer shafts are not shown in Figure 1.8 but would be similar to those in concept 1.

1.6.1.5 Liquid Waste Emplaced in a Mined Cavity - In-Place Drying and Conversion to Rock-Waste Matrix

Figure 1.9 shows this concept. Liquid waste is stored in a mined cavity below the fuel reprocessing plant. The cavity contains a high-integrity liner or tank connected through high-integrity piping to a specially designed condensing and treatment facility for the radioactivity-containing vapor, located adjacent to the fuel reprocessing plant at the surface. Liquid waste is continuously added to the cavity and cooled by recycling condensed vapors from the surface facility. When the reprocessing plant is to be shut down or the cavity is to be converted to its permanent disposal mode, recycle of the condensed coolant is stopped and the cavity contents are allowed to boil to dryness and to melt. When it is certain that no excessive pressure will build up in the cavity, the access shafts and piping are sealed. During a few tens to one hundred

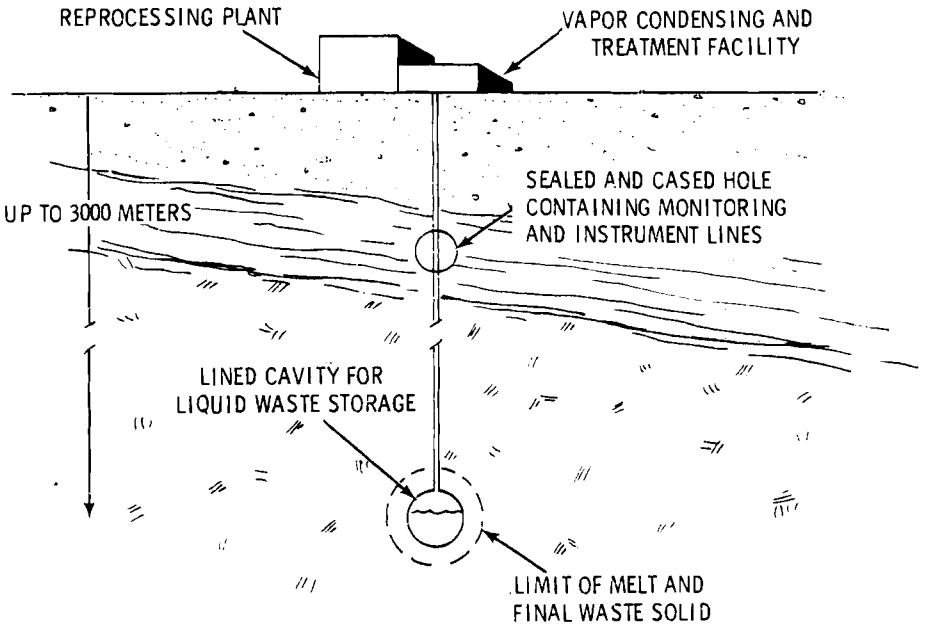

FIGURE 1.9. Liquid Waste Emplacement in a Mined Cavity - In-Place Drying and Conversion to Rock-Waste Matrix

years the waste will melt the liner and some of the surrounding rock. After a few hundred years the molten rock-waste mixture will cool and progressively solidify into a rock-waste matrix.

About 4,000 cubic meters are required for the cavity volume to dispose of the high-level liquid waste generated by the reference reprocessing plant.

This concept has some similarities to that studied at AEC's Savannah River site for storage of aqueous alkaline waste in bedrock without in-place solidification. The National Academy of Sciences concluded that such long-term storage disposal of aqueous waste in bedrock would require substantial research and development before it could be implemented.

1.6.1.6 Liquid Waste Emplaced in Exploded Cavities - In-Place Drying and Conversion to Rock-Waste Matrix

This concept, shown in Figure 1.10, is similar to concept 5 (see Figure 1.9) except that an unlined, rubble-filled cavity is formed by nuclear explosion (or possibly by conventional explosive). The rock rubble filling the cavity provides the material for initial formation of the rock-waste matrix. The rubble-filled hole must provide about 4,000 cubic meters of free volume to contain the high-level liquid waste discharged by the reference reprocessing plant.

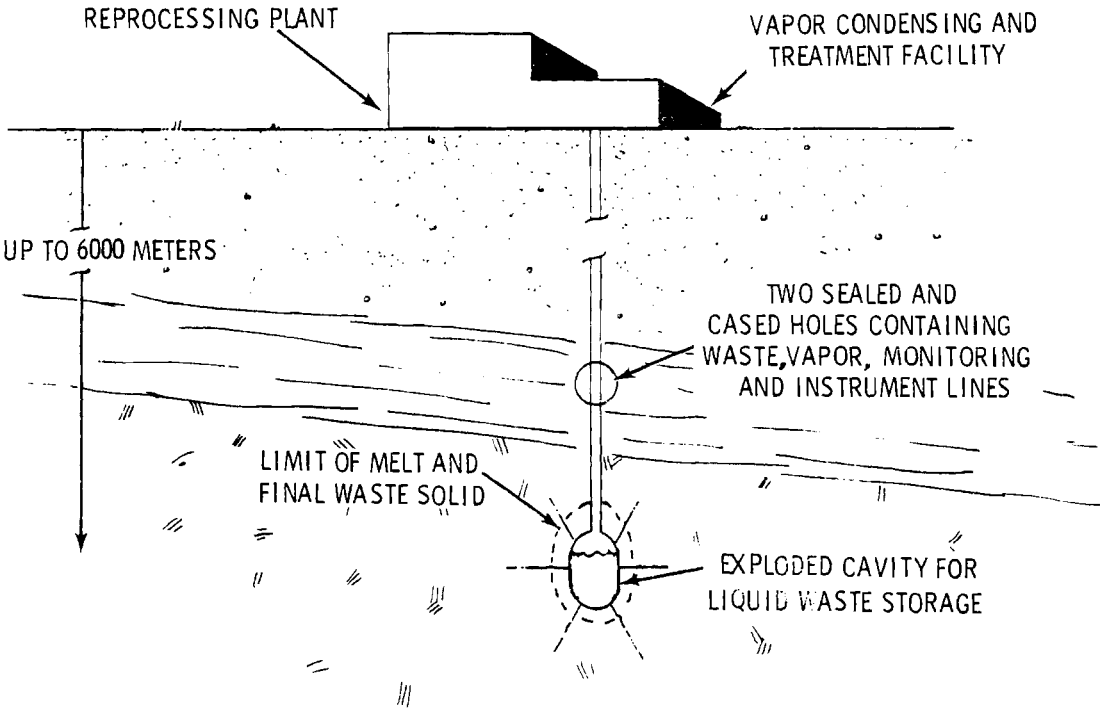

FIGURE 1.10. Liquid Waste Emplacement in an Exploded Cavity - In-Place Drying and Conversion to Rock-Waste Matrix

1.6.1.7 Solid Waste Emplaced in a Matrix of Drilled Holes - No Melting

In this concept all operations are performed from the earth's surface, as shown in Figure 1.11. Canisters full of solidified high-level waste are brought to the handling facility where they are transferred to a specially designed transfer and emplacement (charging) vehicle. The vehicle moves to a previously drilled hole where each waste canister is carefully lowered into the hole and placed on the preceding canister. When the hole is filled with waste canisters to a predetermined level, it is sealed, and waste is emplaced in the next hole of the array. For the reference case in this study, 300 canisters were assumed to be contained in the lower portion of each 4500-meter-deep hole.

1.6.1.8 Solid Waste Emplaced in a Deep Hole - In-Place Conversion to a Rock-Waste Matrix

This concept, shown in Figure 1.12, is similar to the previous drilled matrix hole concept except that each drill hole penetrates to an extreme depth, nominally 16 kilometers (10 miles) deep. The concept can be designed for a nonmelting or a melting case (the latter is shown in Figure 1.12). For the melting case, the capability for handling vapors from volatilization of small amounts of water in geologic formations may be necessary within the surface facility. The waste in the lower portion of the hole will be molten while waste is added from above. After each hole is filled to the predetermined level with waste canisters, the hole is sealed. A few hundred years after emplacement of the waste,

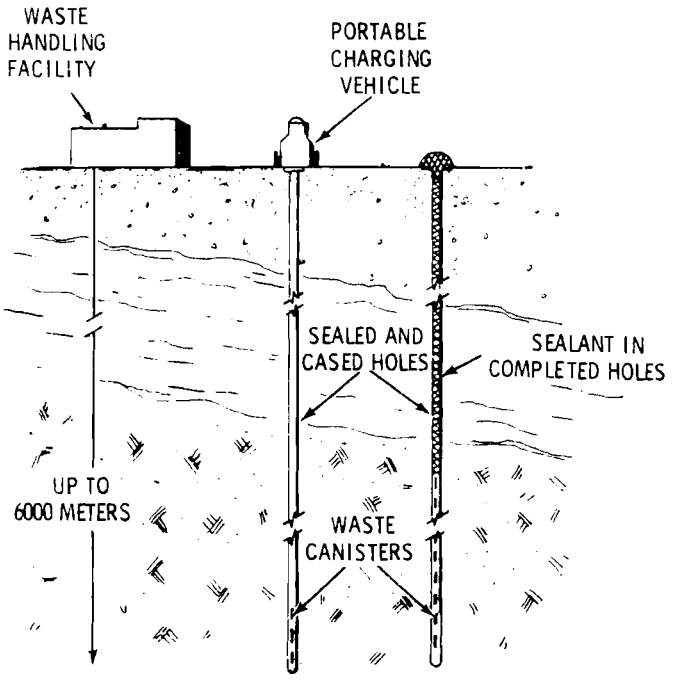

FIGURE 1.11. Solid Waste Emplacement in a Matrix of Drilled Holes - No Melting

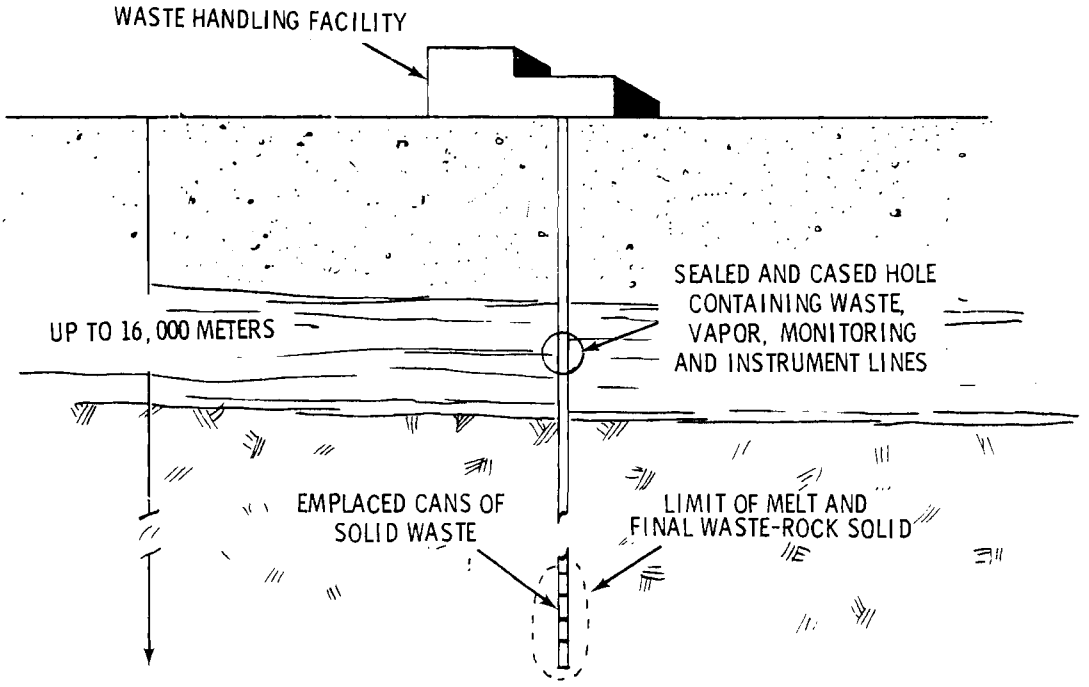

FIGURE 1.12. Solid Waste Emplacement in a Deep Hole with In-Place Conversion to a Rock-Waste Matrix

the molten waste-rock mixture will cool and solidify into a tall column of rock-waste matrix. For the reference case in this study, 2,500 canisters were assumed to be in the lower 7,500-meter portion of each hole.

1.6.1.9 Liquid Waste Emplaced in a Deep Hole - In-Place Drying and Conversion to a Rock-Waste Matrix

This concept, shown in Figure 1.13, is somewhat similar to concept 5, but uses very deep (16-kilometer) holes. The deep hole is drilled at the reprocessing plant site. Liquid waste is continually added to the hole, and the vapor from the hot waste is removed in a vapor condensing facility at the surface. Below the small pool of boiling aqueous waste is a layer of dried and calcined waste. Below this layer is one of molten waste and melting rock. When the hole is filled to the predetermined level (assumed in this study to be the lower 7,500-meter portion of the hole), a second hole is then used, the waste in the first hole is allowed to dry and the hole is sealed. After a few hundred years the molten waste-rock mixture will cool and form a waste-rock matrix.

It is estimated that three deep holes with high-level waste filling the bottom 7,500 meters would be required to contain the waste produced by the reference reprocessing plant.

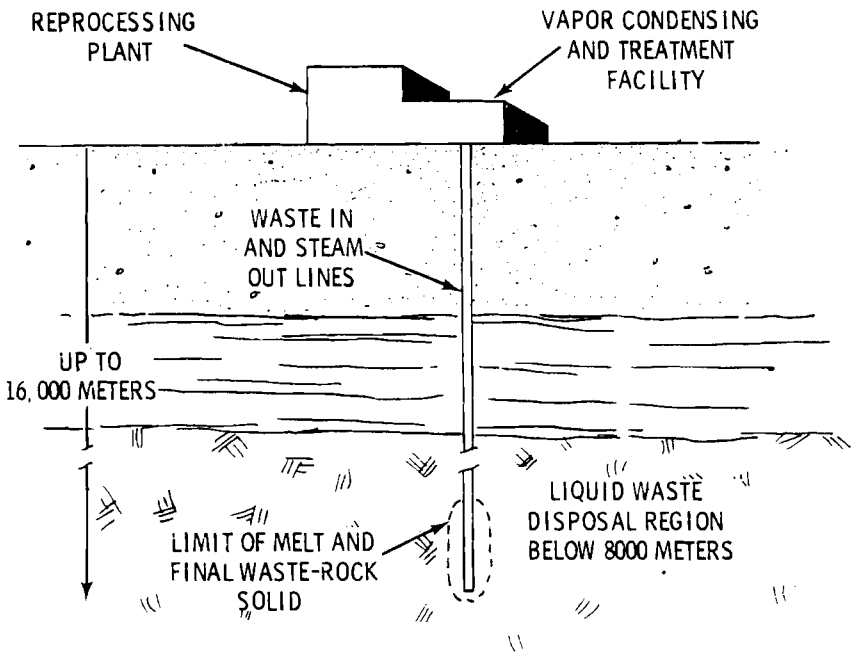

FIGURE 1.13. Liquid Waste Emplacement in a Deep Hole - In-Place Drying and Conversion to Rock-Waste Matrix

1.6.1.10 Liquid Waste Emplaced by Hydraulic Fracturing - In-Place Conversion to a Solid

In this concept, shown in Figure 1.14, liquid waste is mixed with cement grout to form a slurry which is pumped under pressure into a well. The pressurized slurry spreads out to form and fill thin horizontal fractures in the geologic formation which were initiated previously by forcing water at high pressure to fracture the rocks along the bedding planes. The slurry cures in-place within a few days to form a sheet of solid waste-cement mixture typically 3 millimeters in thickness and 350 meters in diameter around the well. Several layers of the sheets of waste-cement can be emplaced one above the other, before sealing the access hole and moving to another well location. Operations are all conducted at the surface from a shielded cell facility. The dilution and heat transfer conditions are designed to keep the waste and rock at low temperatures (100°C or less).

About thirty disposal wells would be required to accept the waste discharged by the reference reprocessing plant.

1.6.2 Ice Sheet Disposal Concepts

Ice sheets are large permanent masses of ice overlying continental land masses. They have several potential advantages as a disposal medium. The Antarctic ice sheet, which is international territory, has

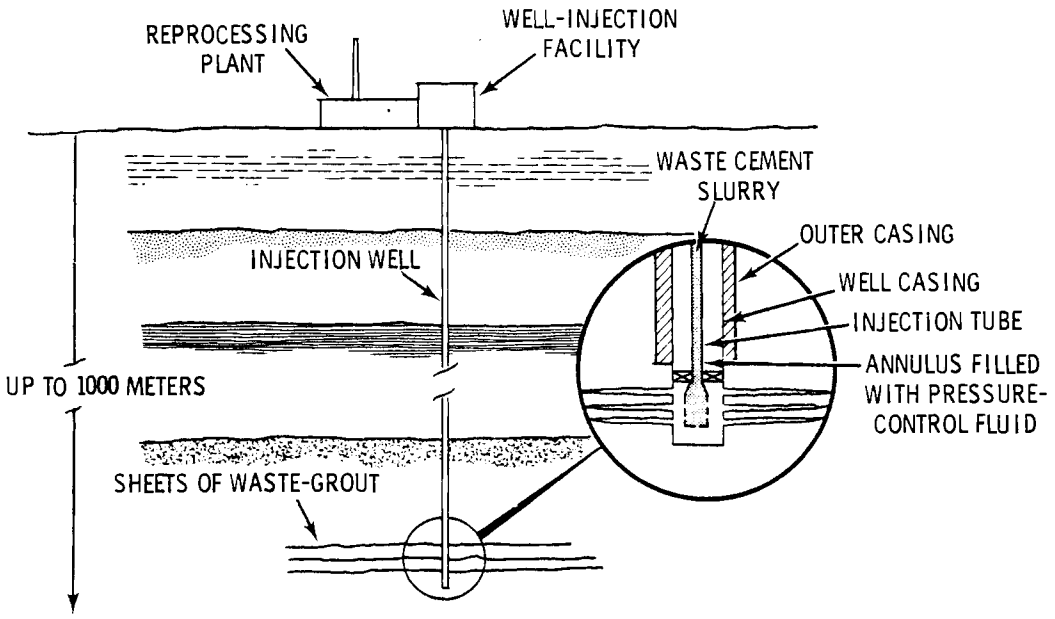

FIGURE 1.14. Liquid Waste Emplacement by Hydraulic Fracturing - In-Place Conversion to a Solid

the potential to provide an international repository. Large quantities of ice with great thickness are available at locations remote from man's activities and with low likelihood for future developments. Ice, if its average temperature remains well below the freezing point, self-heals fractures. It has low permeability to water and has a thermal conductivity comparable to common rock types. Biological activity is low. The natural capability of the ice sheets to dissipate heat from radioactive waste canisters at low temperatures is conducive to maintaining integrity of the waste materials.

Three potential disposal concepts were developed for the ice sheet areas such as Antarctica or Greenland. These concepts, aimed at managing the solidified high-level waste without partitioning, are:

1) Meltdown or free flow--the waste canister is placed in an individual shallow drilled hole in the ice and allowed to melt down through the ice sheet to bedrock.

2) Anchored emplacement--the waste canister is placed in an individual shallow drilled hole in the ice but connected to surface anchors by cables or chains, which stop its descent and maintain its position for some extended period, perhaps on the order of 100 years.

3) Surface storage/disposal--the waste canisters are placed in a shielded cell storage facility with jack-up piers on the ice sheet surface to provide heat removal to the ambient air and to prevent covering over by further ice accumulation. After about 50 years, the facility is allowed to become covered by accumulating snow and is eventually

buried in the ice sheet for final disposal.

The waste management system for all ice sheet concepts (shown diagrammatically in Figure 1.4 and pictorially in Figure 1.15) consists of transporting previously solidified and canned bulk waste in protective casks from the reprocessing plant to special embarkation ports; transporting the waste in protective casks by ships (equipped to monitor and examine the waste canisters) to harbor facilities adjacent to the ice sheet; offloading the waste canisters and casks at a debarkation facility on land in an ice-free area or near the edge of the ice; over-ice transporting by surface vehicles (envisioned as tractor-sled trains or surface-effect vehicles); and emplacing at the disposal site. The area around the disposal site would be monitored for a yet undetermined time.

The embarkation port would contain a receiving facility for inspecting the canisters and placing them individually in special casks for loading onto the transport ship.

Sea transport would be by specially designed ship(s) with facilities for cooling, inspecting, and handling the waste canisters. The hull would be designed for protection against damage due to pack ice. Ice-breaker escorts would be used for routine operation. The transport ship would operate outside normal sea lanes to

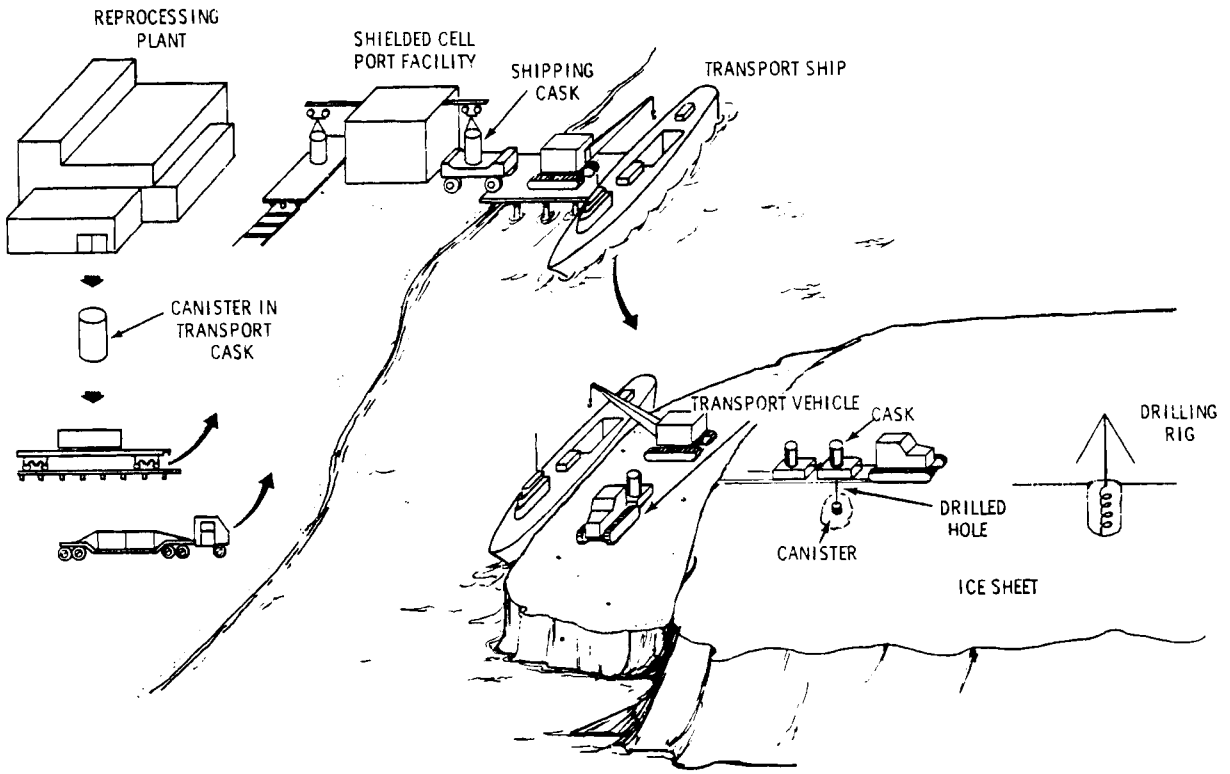

FIGURE 1.15. Operations in Ice Sheet Disposal

reduce the risk of collision at sea and would dock and unload the casks onto the over-ice transport vehicles.

Crawler-type tractors pulling sleds are at present probably the most dependable means of over-ice transport under the severe operating conditions of the ice sheet areas. However, other types of transportation may be used such as aircraft or surface effect vehicles (hovercraft), with fuel supplied by aircraft fuel drops. Hovercraft would require further development and testing to prove their capability for routine operation.

For the meltdown and anchored emplacement concepts, shown in Figure 1.16, the canister is placed in a drilled hole 50 to 100 meters deep and released to begin its descent by self-melting. Cables or chains, 200 to 500 meters long and attached to surface anchors, are fastened to the canister for the anchored emplacement concept. The canisters are emplaced one per hole on 1-kilometer centers. This spacing should maintain separation between canisters during descent. Disposal would be accomplished by self-melting and refreezing of the ice above the canisters as they descend. The waste canister must be encapsulated to accommodate high pressures and contain the waste.

In the surface storage facility disposal concept, storage would be accomplished by placing the canisters in a surface facility on the ice sheet. Disposal would occur when the facility is eventually covered by accumulating snow and ice.

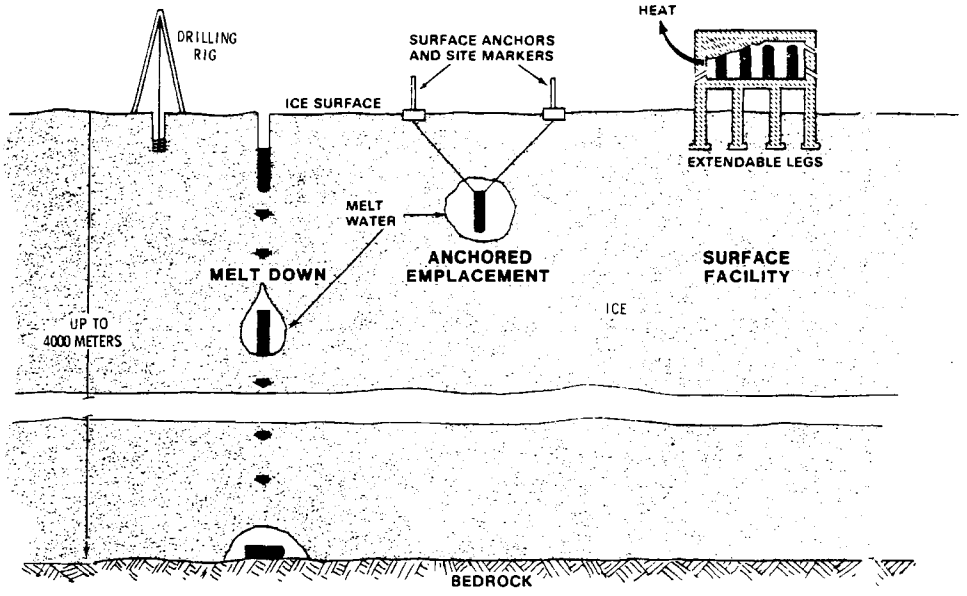

FIGURE 1.16. Ice Sheet Disposal Concepts

1.6.3 Seabed Disposal Concepts

Disposal of high-level waste within the floor of the world's oceans has a number of potentially attractive features. Since disposal of nuclear waste is a multinational problem, consideration of a "common territory" as an international solution appears to have merit. The oceans comprise a large fraction of the earth's surface. There are areas of extreme remoteness that have not been identified with resources of significant use to man, that are biologically nonproliferating, and that are geologically stable. Large areas are available at depths that would provide isolation and safety from natural disasters such as storms, as well as from sabotage or accidental disturbance. The high ion-exchange capacity of sea floor sediments could provide additional isolation barriers. Large volumes of seawater may help cool the waste and would provide very high dilution of any material which accidentally escapes.

Geologic settings and certain areas of the sea floor were studied, i.e.:

1) Stable Deep Sea Floor--areas such as deep ocean basins and abyssal plains, which are considered geologically stable. The waste would be placed in the bedrock below the unconsolidated sedimentary cover.

2) Subduction Zones/Deep Sea Trenches--areas where, according to crustal plate tectonics theory, one edge of certain crustal plates is moving under the other crustal plates and down into the earth's mantle. The waste would be placed in these trench areas to be carried down, or subducted, into the earth's mantle with the crustal plate.(a)

3) High Sedimentation Rate Areas--areas where major rivers are building deltas into the ocean. The waste would be placed in the bedrock below the accumulating deltaic sediments.

It is assumed that the seabed disposal concepts are aimed at disposal of all solidified high-level waste without partitioning. The waste must be encapsulated to accommodate the high pressures and potential corrosion during emplacement.

Waste management systems for all seabed disposal concepts, identical except for the site, are shown diagrammatically in Figure 1.4 and are presented pictorially in Figure 1.17. The concepts would consist of transporting the previously solidified and canned bulk waste from the reprocessing plant in protective casks to special ports of embarkation for short-term storage of the waste and for integrity of the waste canister to be checked; transport in protective casks by ship (equipped to monitor and examine the waste canisters) to the disposal site; disposal of a number of waste canisters into each predrilled hole in the basement rock from a special drilling platform; and filling the upper part of each hole

a. It should be noted that the detailed mechanism for this geologic activity is not well known. The descriptions in this report are based upon inferred and generally acceptable hypotheses, but the actual circumstances of geologic activity of this type have not been confirmed in any area.

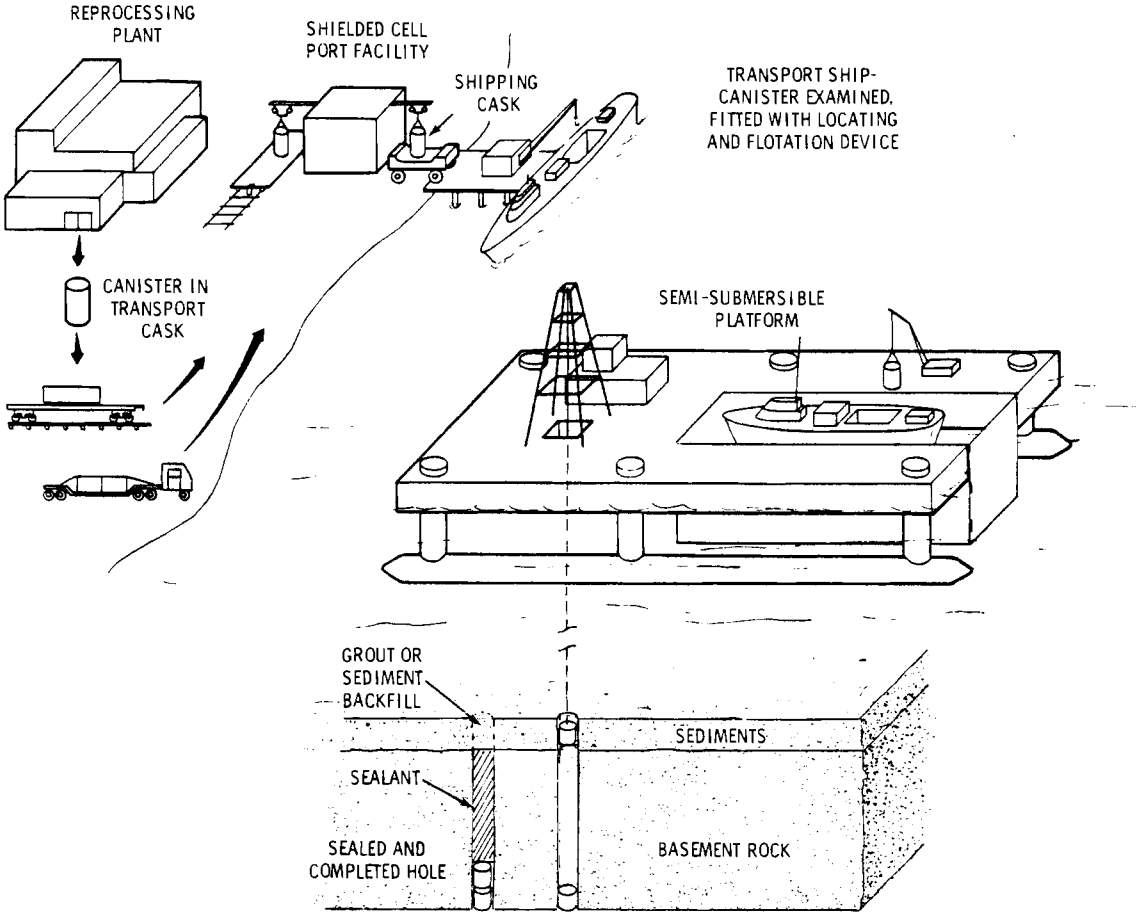

FIGURE 1.17. Operations in Seabed Disposal

with a sealant. The area around the waste disposal holes would be monitored for a yet undetermined time.

Emplacement in all cases is considered to be in the dense basement rock of the seabed, underlying the unconsolidated softer sediments of the sea floor, as shown in Figure 1.18. The waste is thus removed from direct contact with the seawater, is less likely to be exposed by submarine geologic processes and may be further isolated from seawater by the high ion-exchange capacity of the sediments.

The embarkation port would consist of a receiving facility for handling and final inspecting of the waste canisters before they are placed individually in special casks and loaded aboard a transport ship.

Sea transport would be by conventional surface ships equipped to provide cooling of the waste and facilities for monitoring and inspection during transport. The transport ship would be docked within a chamber of the emplacement platform, where the waste canisters would be unloaded, removed from the cask and emplaced

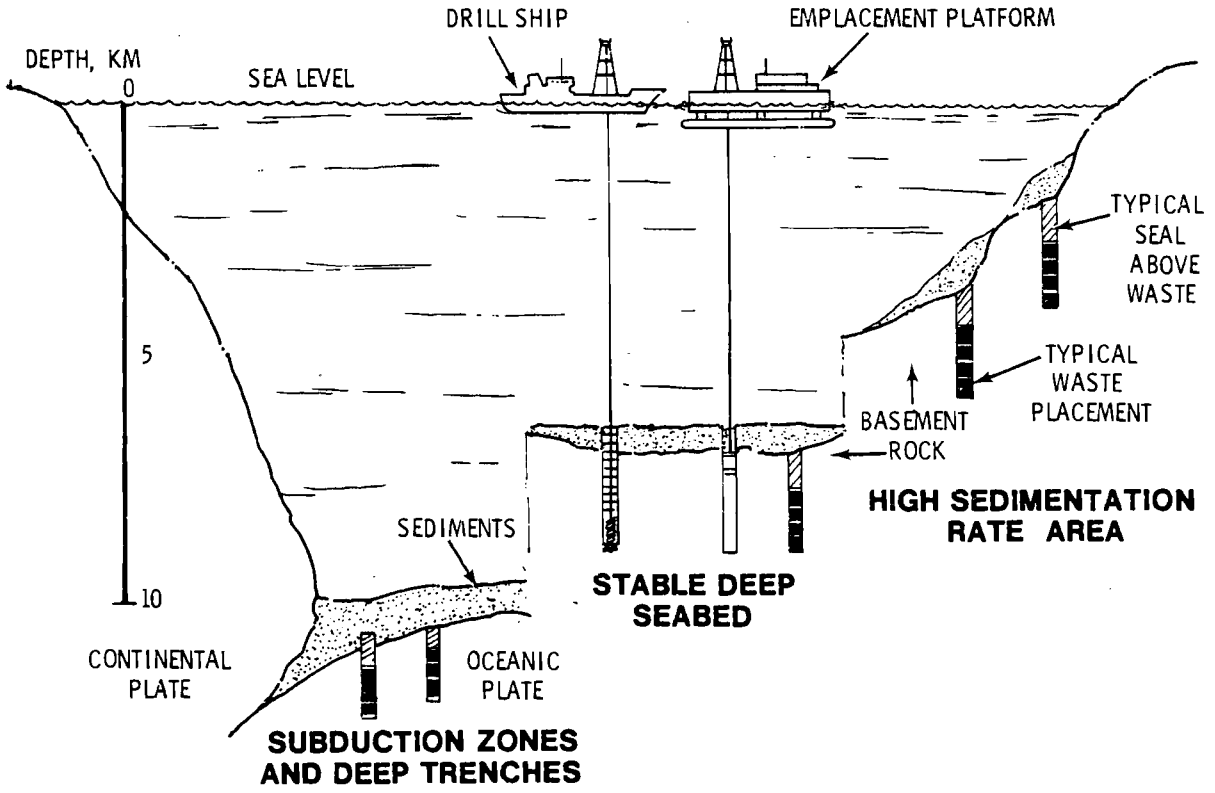

FIGURE 1.18. Seabed Disposal Concepts

from a semi-submersible drilling-emplacement platform. The waste canisters are assumed to be emplaced 100 per drilled hole. The holes would be about 800 meters in depth and drilled on about 1.6-kilometer centers to compensate for limitations on hole locating accuracy and for heat dissipation. Disposal is completed by filling and sealing the top 200 meters of the holes with cement or grout and by replacement of the sediment.

1.6.4 Extraterrestrial Disposal Concepts

If a stable non-earth intercept trajectory or orbit can be assured, extraterrestrial disposal offers the complete removal of long-lived nuclear waste constituents from the earth and the potential for an international solution to waste management. The primary unfavorable features are that the concept deals with only part of the waste, there are possible launch safety problems, retrievability and monitoring, if necessary, are difficult and the concept will require international agreements.

Extraterrestrial disposal of the total waste constituents and of only the transuranic elements were both considered. However, space disposal of the transuranics only is believed to be the most practical scheme, primarily because of the very high space transport cost per unit of weight (at

least $2000/kg of waste material). Because of the high shielding weight and cooling systems required for space disposal of the total high-level waste, disposal of transuranic element waste separated from the other waste constituents received primary emphasis and is used as the base case in this study. The remaining waste must be disposed of by some other means.

The overall waste management system, shown in Figure 1.19, consists of likely interim aqueous waste storage to allow for decay and simplification of partitioning; partitioning of the aqueous waste into a transuranic element fraction contaminated by no more than 1% of the fission products and the remaining waste which must be disposed of by an alternative method; converting the actinide waste at the reprocessing plant to a refractory oxide and encapsulating this into high-integrity, multiple-barrier capsules; transporting the capsules overland to a space launch site; launching the waste into space to an initial low-earth orbit with a reusable space shuttle, followed by space tug transport to the final destination; and monitoring for control to destinations and for off-standard events and radioactivity in the upper atmosphere.

The launch deployment sequence using a shuttle and a tug is shown in

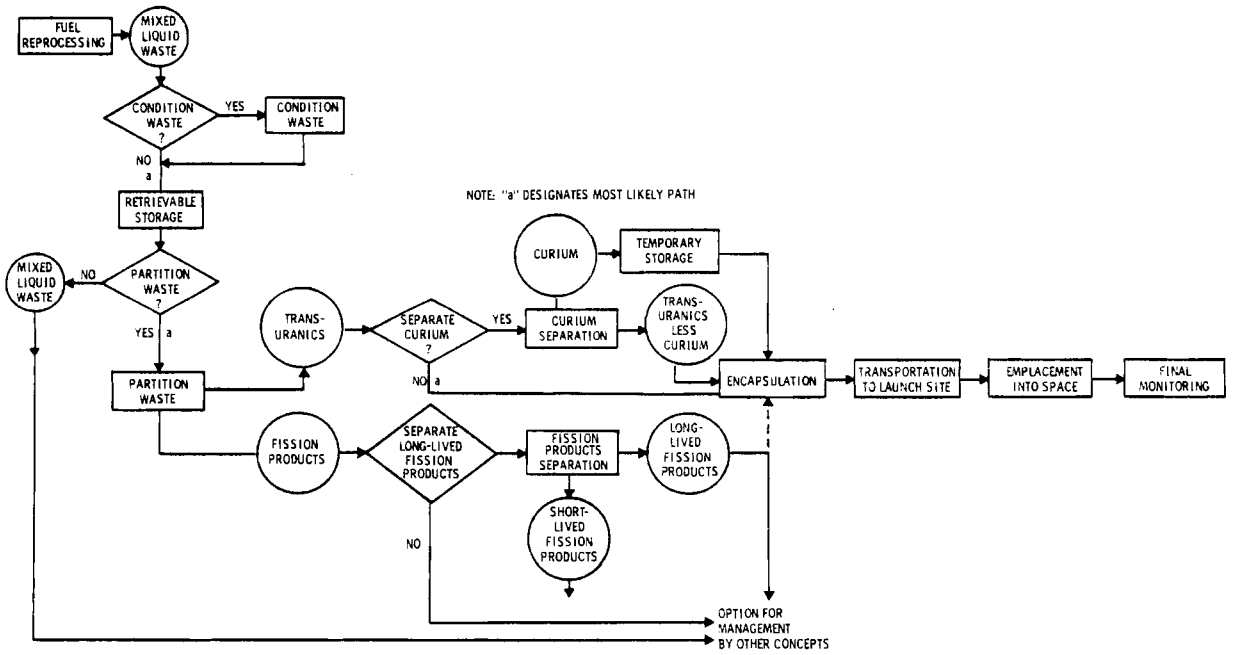

FIGURE 1.19. System Requirements for Managing High-Level Radioactive Waste by Extraterrestrial Disposal

Figure 1.20. Typically, the shuttle is first launched into a low circular earth orbit (150 to 500 kilometers above the earth). From this orbit, the tugs or upper stage(s) are launched to carry the waste package to its final destination. In some cases, the launch system can inject the waste to its final destination without subsequent course correction. In other cases, the waste tug will require subsequent mid-course corrections or propulsion.

1.6.5 Transmutation Elimination

Transmutation is the changing of one isotope into another by any means whatsoever. For waste management, transmutation results in a product isotope having a lower toxicity and/or a shorter half-life than its predecessor. Ideally, radioactive constituents in high-level waste could be eliminated by using nuclear processes themselves to achieve the transmutation. More practically, the transmutation process can accelerate the decay rate of radioactive waste by converting long-lived radioisotopes to other isotopes which have shorter decay times. If this can be achieved, the quantity of waste containing long-lived radionuclides could be reduced significantly and the time required for safely storing treated radioactive waste may be significantly shortened.

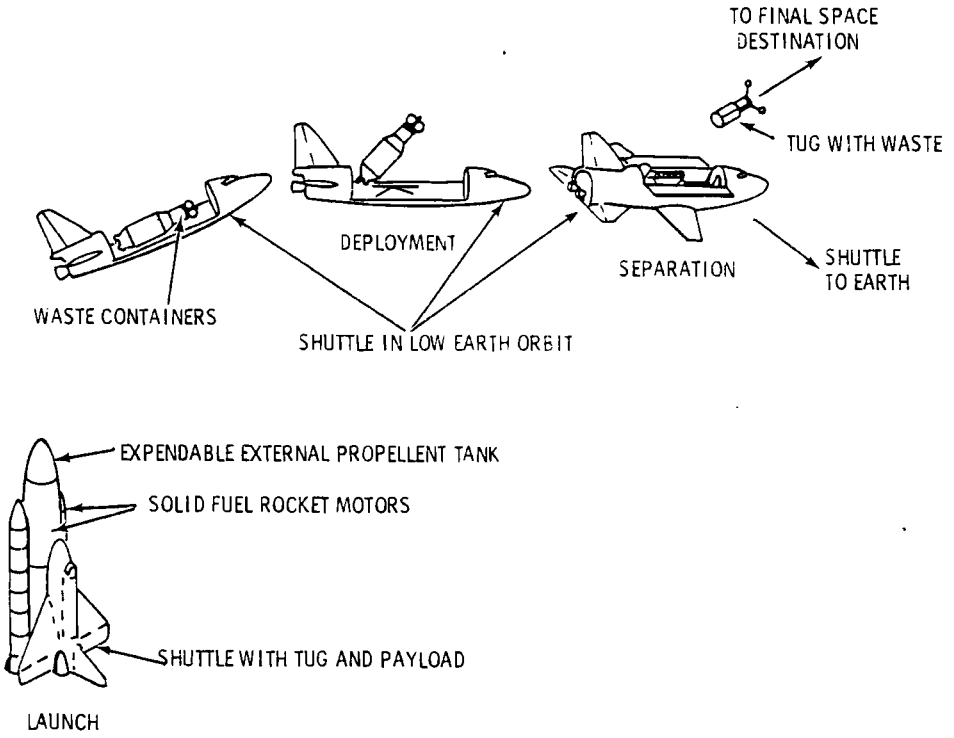

FIGURE 1.20. Shuttle Launch Deployment Sequence for Extraterrestrial Disposal

System requirements for managing high-level radioactive waste by transmutation are shown in Figure 1.21. The overall waste management system using fission reactors for waste actinides includes a period of interim aqueous waste storage to allow for decay and to permit improved partitioning; partitioning of the aqueous waste into an actinide waste stream and a short-lived residue; converting the actinides at the reprocessing plant to oxides; transporting the oxide to a facility for fabricating it into special recycle fuel forms; and transporting the actinide fuel form to a fission reactor for irradiation. The short-lived fraction must be disposed of by other means.

For the transmutation strategy using fusion reactors, the concept would be similar except that the aqueous waste stream would be partitioned into two or more streams containing waste actinides, possibly selected fission products, and a residual waste stream to be disposed of by other methods. The two waste streams for transmutation would be converted into solid fuel materials (probably oxide) at the reprocessing plant; the fuel materials would be transported to a facility for fabrication into special target elements; and the special targets would be transported to and inserted into the blanket of a fusion reactor for irradiation as

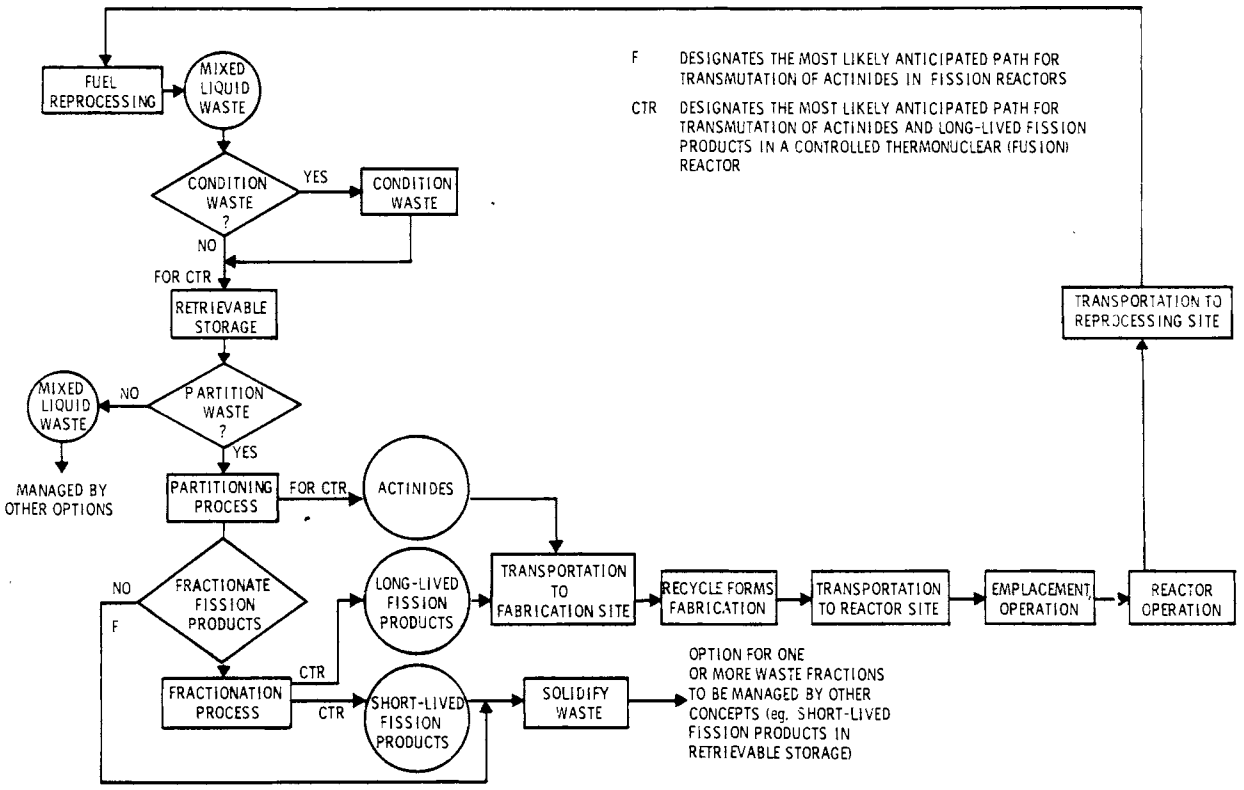

FIGURE 1.21. System Requirements for High-Level Radioactive Waste Management Using Transmutation

part of the reactor fuel cycle. Continued recycle of material which undergoes transmutation would also be a part of this section.

The waste streams not sent to transmutation must be disposed of by other means. In addition, the "heel" of untransmuted actinide waste at the termination of a nuclear plant era must be disposed of by other means.

The strategy envisioned for using transmutation in the management of high-level waste is shown in Figure 1.22, assuming a three-phase development scheme:

- Phase 1 converts long-lived actinides to short-lived fission products. This phase uses the normal nuclear fuel cycle of the fission reactor industry to retain all actinides in this fuel cycle and thereby convert a significant part of them into fission products by transmutation. The most significant modification to the fuel cycle is to partition the waste.
- Phase 2 involves temporary retrievable storage of fission products for ultimate use in Phase 3.
- Phase 3 transmutes in a fusion reactor the equilibrium inventory of long-lived fission products and actinides accumulated from the fission reactor cycle. This final phase results in the ultimate elimination of nearly all long-lived radioactive waste constituents.

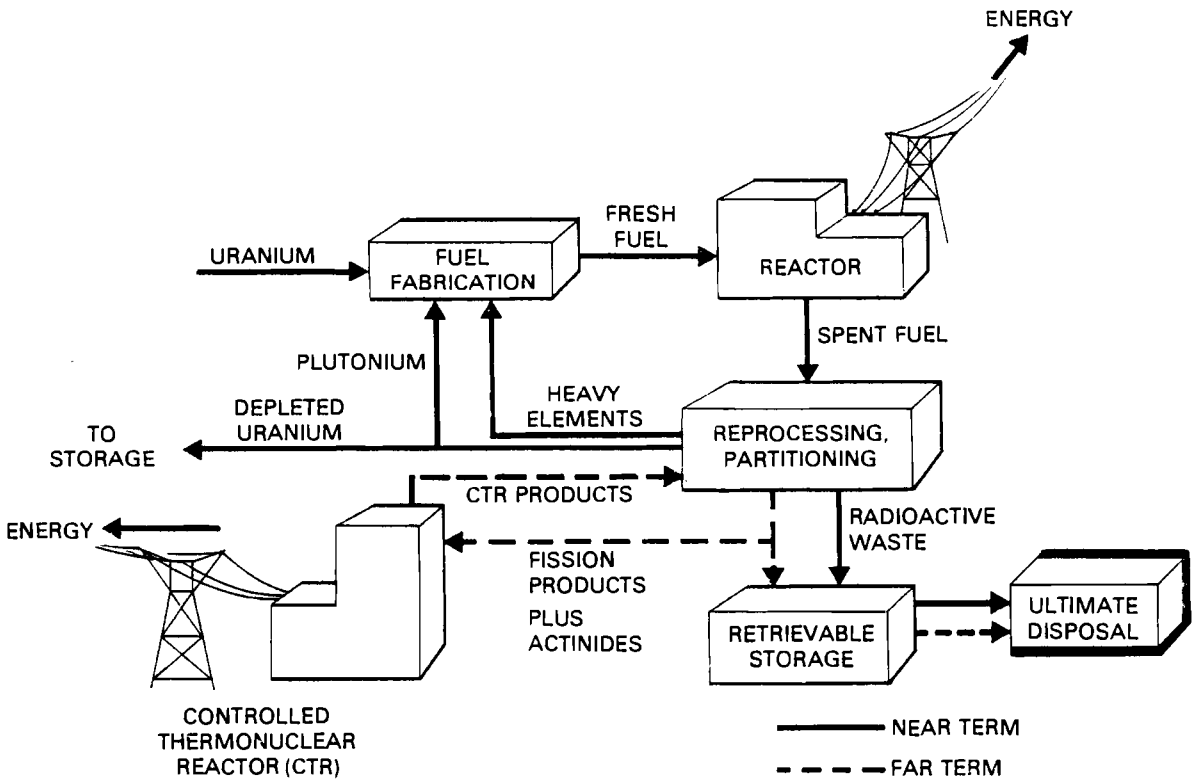

FIGURE 1.22. Transmutation Waste Management Strategy

The transmutation of certain fission products as well as actinides would require further separation of the waste to obtain additional transmutation process feed streams. In addition, fabrication of the target elements for transmutation in fusion reactors and the special fuel elements for transmutation in fission reactors will require special remote facilities because of the high dose rate of the materials handled.

1.7 TECHNICAL FEASIBILITY

The technical feasibility of the potential disposal concepts was determined in this study by responding to the following primary questions:

1) Can the disposal concept be implemented using today's technology? (This does not imply that additional development is unnecessary to adapt existing scientific and engineering technology to the implementation of these disposal concepts. It assumes that we have enough information to assess the overall development requirements.)

2) Can the disposal concept be implemented with future technology based upon current theory? (Is it theoretically possible?)

3) Can the disposal concept provide the potential for confining or eliminating the waste over the time period of concern? (Truly quantified answers to this point require very extensive study, and only qualitative indications were developed for this study.)

4) Does the concept have a favorable energy balance? (Is the energy consumed in the implementation of the disposal concept less than the electrical energy obtained from the nuclear fuel represented by the waste?)

The responses to these questions from this study are summarized in Table 1.9. To highlight the differences among the concepts, only the variations from the same previously described "reference" concept (geologic mined cavity) are shown. Also summarized in Table 1.9 are the inherent favorable and unfavorable characteristics of the concepts. In general, it can be seen that all concepts studied appear technically feasible (with some limitations) within the extent of this study, with the probable exception of transmutation using accelerators.

The information in Table 1.9 is discussed in the subsections which follow.

1.7.1 Geologic Disposal Concepts

All geologic concepts appear to be technically feasible. Cavities and holes could be made today with the possible exception of the very deep hole. A deep hole could probably be drilled today in areas with very low geothermal gradients, but a question remains as to whether the lower portion of the hole can be kept open at these depths during the time period required for emplacement of the waste. New technology is required for the moderately large holes needed at the great depth (16 kilometers or 10 miles) and for the high down-hole temperatures encountered at great depth.

Nuclear explosive technology is available, whereas chemical explosives appear impractical for exploded cavities. In either case, evaluation of the significance of fractures that will be produced by the detonation would be most difficult. It is not certain whether sufficient technology exists today for implementing the waste-rock melting concepts. Melting can certainly be accomplished, but the conduct of the molten mass and its effect on the surrounding media are not yet certain.

TABLE 1.9. Summary of Technical Feasibility for Alternative Waste Management Systems

Concept	Can It Be Implemented? With Today's Technology	Can It Be Implemented? Theoretically in Future	Does it Have Potential for Providing Adequate Safety?	Disposal Energy Consumed/ Electrical Energy in Original Fuel	General Characteristics Relative to Feasibility: Favorable	General Characteristics Relative to Feasibility: Unfavorable
"Reference" Concept (solid waste emplaced in mined cavity, no fluid cooling or melting.)	Yes	Yes	Yes	10^{-5}	Fair distance from man's environment Safety from storms, most of man's activities	Some potential for penetration by man in future Poor retrievability and monitoring Possible groundwater transport
Differences from Above Information are Listed Below						
Geologic Concepts						
1. Solid waste emplaced in mined cavity; no fluid cooling or melting	--	--	--	--	Ion-exchange of rocks as back-up(a)	--
2. Solid waste emplaced in mined cavity; initial water cooling; melting	--	--	--	10^{-6}	(a) --	Irreversible high temperature in rock
3. Solid waste emplaced in manmade structure in mined cavity; initial air cooling; no melting	--	--	--	10^{-6}	(a) Provides ready interim retrievability	Requires interim operation by man
4. Solid waste emplaced in manmade structure in mined cavity; initial water cooling; no melting	--	--	--	10^{-6}	(a) Provides ready interim retrievability	Requires interim operation by man
5. Liquid waste emplaced in mined cavity; initial reflux cooling; melting	--	--	--	10^{-6}	(a) No waste transportation	Irreversible high temperature in rock Liquid waste temporarily in repository
6. Liquid waste emplaced in exploded cavity; initial reflux cooling; melting	--	--	--	10^{-6}	(a) No waste transportation	Very poor retrievability and monitorability Irreversible high temperatures in rock Cracks in surrounding geology for waste transport Liquid waste temporarily in repository Explosive effects on surface activities
7. Solid waste emplaced in matrix of drill holes; no fluid cooling or melting	--	--	--	--	(a)	Very poor retrievability and monitorability Many penetrations to surface
8. Solid waste emplaced in deep holes; no fluid cooling; melting or nonmelting	No	--	--	--	(a) Large distance from man's environment	Very poor retrievability and monitorability Deep geology unknowns
9. Liquid waste emplaced in deep holes; initial reflux cooling, melting	No	--	--	--	(a) Large distance from man's environment No waste transportation	Very poor retrievability and monitorability Deep geology unknowns
10. Liquid waste emplaced by hydrofracture; in-place curing	--	--	--	10^{-8}	(a) No waste transportation	Limited favorable geology Significant heat transfer limits
Ice Sheet Concepts						
1. Self melt through ice	--	--	Uncertain	10^{-4}	Great distance from man Low temperature for cooling Possible international solution	Extended transport Severe operating conditions Very poor retrievability and monitorability Many technical unknowns
2. Anchored storage/disposal	--	--	Uncertain	10^{-4}		
3. Ice surface storage/disposal	--	--	Uncertain	10^{-4}		
Seabed Concepts						
1. Subduction zones and other deep sea trenches	No	--	Uncertain	--	Great distance from man Water for dilution Ion exchange of sediments as back-up Possible international solution	Extended sea transport Mobility of seawater Concentration by ecology Very poor retrievability and monitorability Many technical unknowns International considerations
2. Stable deep sea areas	--	--	--	--		
3. Rapid sedimentation	--	--	Uncertain	--		
Extraterrestrial Concepts						
1. Solar and earth orbits	--	--	--	--	Removal from earth Possible international solution No continuous potential for groundwater transport	Only partial waste removal Launch safety problems Very poor retrievability and monitorability International considerations
2. Solar impact	Difficult	--	--	10^{-4}		
3. Solar escape	--	--	--	10^{-4}		
Transmutation Concepts						
1. Fission reactors	--	--	--	10^{-3}	Elimination Improved resource use Monitorable, retrievable Possible international solution No continuous potential for groundwater transport	Only partial waste elimination Increased handling problems Subject to storms, man's activities
2. Fusion reactors	No	--	--	--		
3. Accelerators	No	No	Uncertain	?		
4. Nuclear explosives	Probably	--	Uncertain	?		

a. Ion exchange of soil-rocks as back-up applies to all the geologic concepts.

The technology for other related needs in geologic disposal systems is generally in-hand. These technologies include interim aqueous waste storage if desired, conversion to stable solid waste forms, interim solid waste storage if desired, transportation to the disposal site if needed, emplacement of the waste, and interim operation of the disposal facility as needed. Successful emplacement of an intermediate-level liquid waste-cement mixture using hydraulic fracturing techniques has been practiced by Oak Ridge National Laboratory since 1965.

Final sealing of the access holes is required for geologic concepts for the long time period of concern. Such high-integrity sealing, necessary to maintain long-term isolation of the waste from man's environment, has not been considered heretofore by industry. Existing sealing techniques must be tested (and improved if necessary) for radioactive waste disposal.

General heat transfer modeling technology is available for use in geologic systems, but the methodology must be modified for application to geologic waste disposal concepts.

The various geologic disposal schemes involve short-term operational, safety and retrievability differences. However, in the context of providing adequate long-term isolation, the major factors are in differences in the geologic settings relative to the different emplacement modes.

Key factors to avoid in siting are areas with: 1) potential for hydrologic transport; 2) usable groundwater; 3) seismic potential, including fault densities; 4) resource potential; and 5) significant population density.

Of the various geohydrologic factors considered in evaluating potential sites for disposal the most important is hydrologic isolation; this is to assure that the waste will be effectively contained within an acceptable radius of the emplacement zone. To achieve this degree of hydrologic isolation, the host rock for the waste should exhibit a very low permeability and the site should be virtually free of geologic faults.

A potential disposal site should be in an area of gentle relief to minimize any accelerated erosion or denudation that might occur because of natural climatic changes or changes brought about by the preparation for disposal operations. The most suitable geographic location for a disposal site is also one that is as far removed from major drainages, lakes, and oceans as possible and where the intrusion of man in a manner that will change the condition is minimal.

Areas considered generally unsuitable for waste disposal are those where seismic risk is high,[a] where possible sea-level rise or changes in drainage patterns[a] could inundate potential sites, where high topographic relief coincides with high fault densities[a] and/or unfavorable

a. Generalized maps of the conterminous United States showing these areas are included in Appendix B.

hydrologic conditions, where no suitable rock media are known to be present to reasonable depths, where a possible return of glacial or high rainfall climate will cause undesirable changes in the geology, where there is danger of exhumation by erosion, and where the area contains usable volumes of groundwater[a] or has high oil, gas, or other mineral potential.

In lieu of more comprehensive seismic risk studies and criteria for acceptable ground motions, this investigation considered that areas of seismic risk zone 3 are unsuitable for underground as well as surface facilities. Areas in seismic risk zone 2 and less are considered potentially suitable if zones of active faulting are avoided.

Sea-level rise as a result of future climatic changes could drastically alter the present-day hydrologic regime. A lack of firm factual data for predicting climatic change makes it necessary at this time to consider the possibility that large parts of the coastal areas and some inland areas of the United States could be inundated during the next million years. This consideration is a very conservative one, because future inundation of a disposal site by seawater may well have no effect on the integrity of the site and its waste contents. With this in mind, all potential sites for waste disposal that could be inundated by 60- to 150-meter sea level rises, especially those below the 60-meter level, should be reviewed critically.

Faults and fractures, along which there has been a relative displacement of the rocks, can either be conduits for flow of water between impermeable zones or be obstructions to flow of water in an aquifer. These faults are undesirable because they could serve as connections between burial sites and man's environment. Therefore, any site selected for disposal of waste should be virtually free of faults, especially in the disposal zone.

In any terrestrial concept for disposal of high-level waste, a conflict will arise between the use of the earth for disposal and for development of the resource potential that could be available in other forms such as geothermal energy, minerals, surface space and subsurface space.

The most suitable rock media for the various concepts considered appear to be[b] 1) intrusive igneous rocks[c] (e.g., granite) or crystalline metamorphic rocks[d] (e.g., quartzite) because of their low permeabilities and high mechanical strengths, 2) salt, either in stable domes or thick beds because of its

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a. Generalized maps of the conterminous United States showing these areas are included in Appendix B.
b. No order of preference was established in this study nor is it implied here. Much more information is available regarding disposal in salt than in these other rock media.
c. Intrusive igneous rocks are those formed by cooling and solidification of a molten rock mass that invaded the earth's crust but did not reach the surface.
d. Crystalline metamorphic is a general term used here for the more granular, coarse-grained rocks that have been changed in texture or composition by heat, pressure, or chemically active fluids after their formation.

low permeability and self-sealing property, and 3) tuff (welded volcanic ash) and shale[a] because of their very low permeabilities and high ion-exchange capacities. Sedimentary rocks other than shale and salt, and volcanic rocks, exclusive of tuff, are considered generally unsuitable for waste emplacement because of their potential for high permeabilities.

Areas appearing potentially suitable as waste repositories based on this study have not been defined. However, simple overlaying has been done of maps showing some geologic characteristics pertinent to waste disposal. These maps, shown as Figures 1.23 and 1.24, can be used as gross indicators of where to start looking for possible disposal sites. Excluded from the figures are areas of seismic risk zone 3 and areas which would be inundated by a rise in sea level of about 150 meters. Yet to be removed from consideration are areas such as those with high resource potential (including productive aquifers and areas of possible geothermal development), high population density, high fault density, and high topographic relief.

Potentially suitable media for the deep drill-hole method appear to be crystalline rocks, either intrusive igneous (e.g., granite) or metamorphic (e.g., quartzite). Possible areas, shown in Figure 1.23, include areas in the continental interior where the sedimentary cover over the crystalline rocks is generally thin.

Areas potentially suitable for consideration as cavity and matrix hole disposal sites are presented in Figure 1.24. The designated areas include essentially the same igneous and metamorphic rocks considered for the deep drill-hole, salt beds and stable salt domes, and granitic stocks in the Basin and Range area. Additionally, in the case of the mined cavity concepts, tuff and shale are potentially suitable formations for above-the-water-table emplacement in arid and semi-arid climates; and for the exploded cavity and matrix hole concepts, pending proof of hydrologic isolation, shale in some sedimentary basins below 2000 meters is a possibly suitable formation.

The sample risk evaluation in Section 1.5 indicated the high potential for geologic disposal to provide safety and isolation of waste from man. With proper site selection for geologic disposal in general, even in the event of a release, the surrounding rocks will still permit a high degree of protection to man's environment by sorption of radionuclides.

The major energy consumption in geologic disposal is in mining and drilling. This energy consumption is about 5 to 6 orders of magnitude lower than the electrical energy from the original nuclear fuel from which the waste was derived.

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a. Shale is rock composed of laminated layers of clay-like, fine-grained sediments.

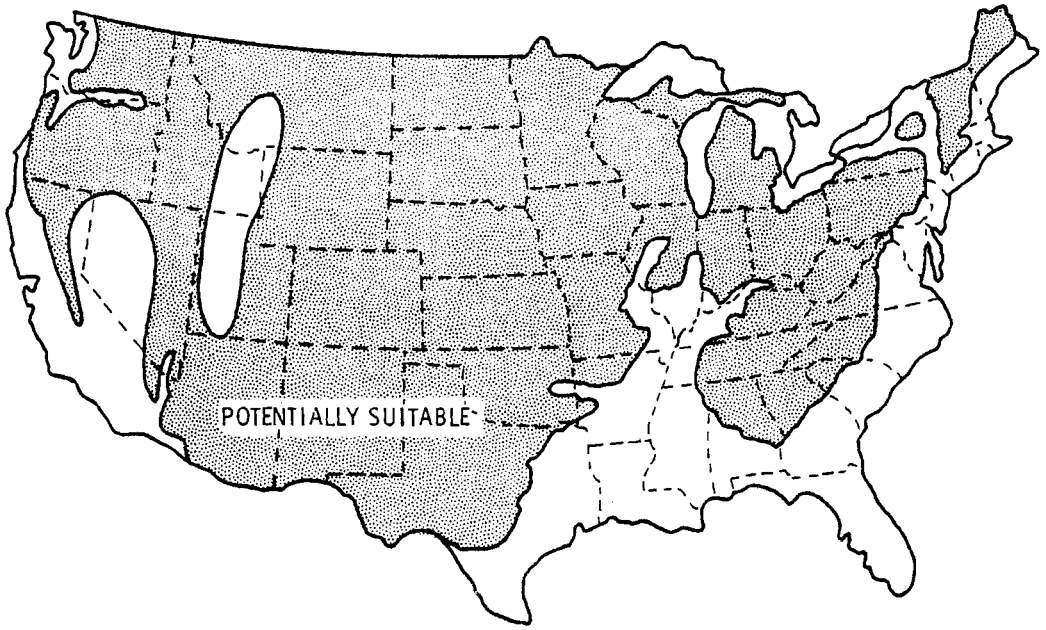

FIGURE 1.23. Potentially Suitable Areas for Geologic Disposal Sites Using the Deep Hole Concept

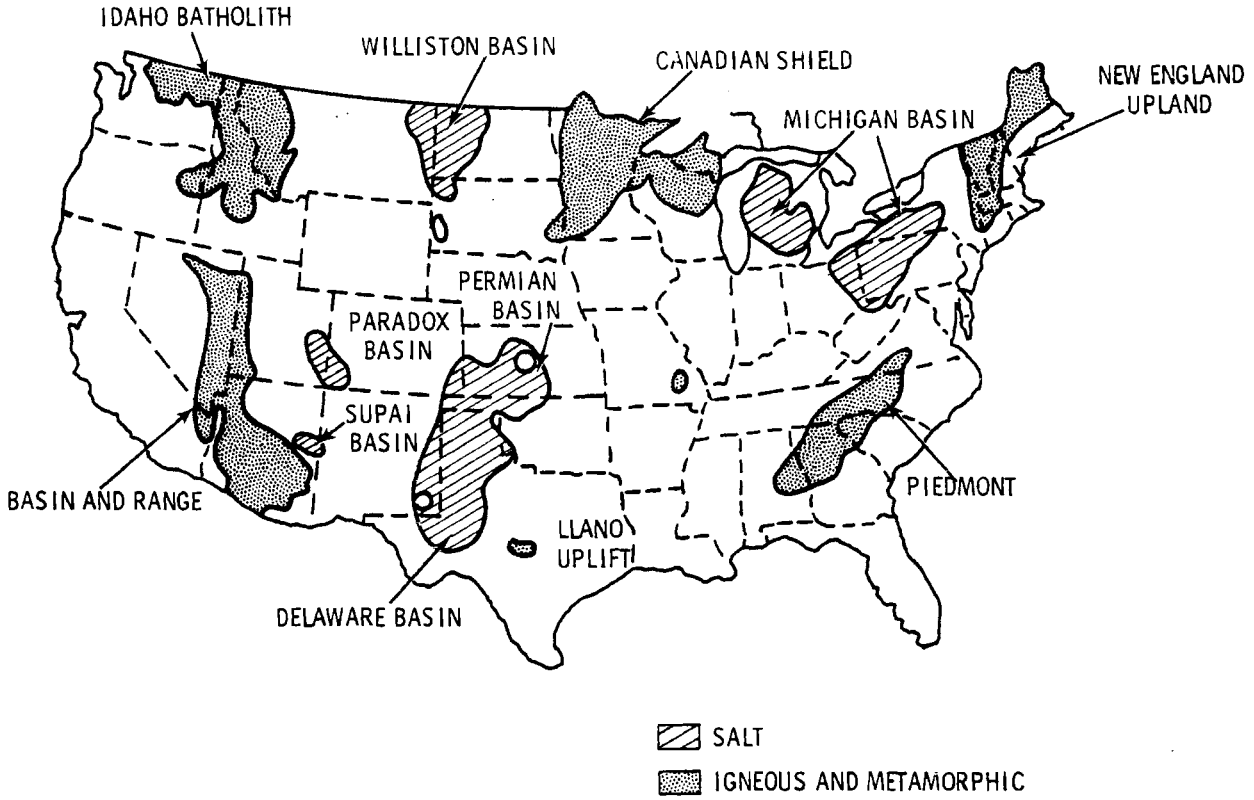

FIGURE 1.24. Potentially Suitable Areas for Geologic Disposal Sites Using the Cavity and Matrix Hole Concepts

Overall, disposal of radioactive waste in geologic formations has the potential of isolating the waste from man's environment for extended time periods (millions of years). Geologic environments exist which have been physically and chemically stable for such periods, are isolated from man's immediate environment, and can potentially provide effective barriers between waste and man's environment for the time periods required.

Generally favorable characteristics of geologic waste disposal are:

1) waste is reasonably distant from man's environment;

2) safety is provided from climatic phenomena such as surface storms and from man's destructive activities; and

3) significant backup isolation can be provided by favorable ion-exchange characteristics of many rocks and soils.

The primary unfavorable characteristics of geologic waste disposal are:

1) there is always some finite potential for man to inadvertently penetrate the disposal area at some time in the distant future;

2) groundwater is an ever present means for transporting waste constituents to man's environment;

3) for in-place melting concepts, localized melting and high rock temperatures cannot be reversed by man; and

4) retrievability and monitoring over long time periods is difficult.

1.7.2 Ice Sheet Concepts

The implementation of all ice sheet disposal concepts could be done with today's technology. The disposal system aspects of containerization, transportation, and emplacement can all be accomplished by modification of current technology. Final sealing of the waste would be performed by natural refreezing of the water around the waste in all concepts.

Major technical uncertainties exist as to the potential for ice sheets to provide long-term isolation. Relatively little is known about ice sheets with respect to history, movement, and conditions at depth. Subglacial lakes are known to exist but their number and extent are not well known. Projections regarding future conditions and even the continued existence of the ice sheet can be inferred only from highly speculative, theoretical, or limited knowledge.

A most important question is the prediction of the future existence of the ice sheets. Present knowledge of climatology is not sufficient to assure that an ice sheet will be present more than a thousand years or so in the future.

Another key question is the ice flow rate. If the ice flow rate at depth is 0.1 centimeter per day (a value hypothesized as being a minimum for a few select locations), it would take about 2,000,000 years for the ice in the center of a large ice

sheet (and an entrapped waste canister) to reach the edge of the ice sheet. If the ice flow rate is similar to measured values of surface flow rates toward the ocean (5 to 15 centimeters per day in Antarctica), a waste canister emplaced 1000 kilometers inland could reach the edge of the ice sheet in 20,000 years or less.

Other questions are unanswered such as whether the melt water surrounding the waste will travel quickly down through the ice to form a "pipe" for rapid communication of the waste to potential flowing water at the base of the ice sheet. In addition, the effects of the heat from the waste on the stability of the ice sheet is unknown.

Disposal sites would be selected with maximum travel distance to the ocean and minimum ice flow rates. These sites would be in the interior of the continent over ice-basin areas or possibly over "ice divides," where the underlying topography divides the ice flow into different directions and the time for ice (and waste) to flow to the ocean is maximized.

For emplacement of waste canisters within the ice, the hole depth for initial emplacement must be sufficiently great to assure that the interconnecting air spaces are sealed off to form bubbles. This placement is done to quickly remove the waste from surface exposure and to place it in the dense ice (0.8 gm/cm^3) where the meltdown trajectory would be expected to be more stable. The canister would melt through the 3000 to 4000 meters of ice in an estimated 5 to 10 years. The time estimated for the canister to reach its anchored depth in the anchored emplacement concept is 6 to 18 months. The anchors and also the surface storage facility would be covered slowly (2 to 10 cm/year) as the snow accumulated.

The major energy consumption in ice sheet disposal is for fuel needed for transportation. This energy consumption is about four orders of magnitude lower than the electrical energy from the original nuclear fuel from which the waste was derived.

Overall, disposal of radioactive waste in ice sheets is considered to have an uncertain potential for isolating waste from man's environment, depending largely on ice flow rates and lack of certainty that the ice sheet will remain in existence for 1000 to 1,000,000 years. Assuming the key questions can be answered favorably, disposal of radioactive waste in ice sheets could have the potential for isolating waste from man's environment for long time periods.

Generally favorable features offered by ice sheet waste disposal are:

1) waste can be deposited at great distance from man and his immediate environment;

2) a low temperature environment is provided for cooling the waste;

3) safety is provided from surface storms and man's destructive activities; and

4) a possible solution to the waste disposal problem is offered on an international basis.

The primary unfavorable features of ice sheet waste disposal are:

1) extended transport over sea and ice is required;

2) operation is performed under severe climatic conditions;

3) monitoring and retrievability of waste is difficult; and

4) international political factors must be accommodated.

1.7.3 Seabed Concepts

Implementation of the seabed disposal concepts in the stable deep sea areas or rapid sedimentation areas could be attained with today's technology. However, significant development of drilling and emplacement technology is required to implement disposal in the very deep sea areas of the trenches and the subduction zones. Final sealing of the disposal holes to maintain isolation for the long time periods of concern will need to be tested (and improved if necessary) for radioactive waste disposal.

Knowledge is limited about the seabed and overlying sediments with respect to history, movement, geology, and tectonic stability over extended time periods. Projections regarding future conditions can be inferred only from highly speculative, theoretical, or limited knowledge. The unconsolidated sediments on the sea floor are not currently considered adequate in total for long-time isolation of waste canisters, since the sediments are subject to slumping, erosion, and possibly liquefaction. These occurrences could expose waste canisters unless they are emplaced in the underlying basement rock. Sedimentation rates (from less than one to possibly ten meters per million years) in all seabed areas except large river delta areas would provide insufficient cover to assure waste isolation. Sedimentary cover, however, could provide an effective secondary barrier between waste in the basement rock and the ocean water. The high geologic instability of areas with high sedimentation rates precludes assurance of waste isolation unless waste is emplaced in the underlying dense seabed.

Because of their relative geologic stability, the stable deep areas are considered the preferred areas for seabed disposal, based upon present knowledge. Proper selection of sites in these areas could provide potential isolation of radioactive waste for very long time periods. These stable seabed areas are considered to be among the most stable geophysical features in the earth. Isolation of the waste would depend on the stability of the seabed and to some degree the integrity of the man-emplaced overlying sealant.

The major energy consumption in seabed disposal is for fuel needed for transportation and drilling. This energy consumed is about five orders of magnitude lower than the electrical energy obtained from the corresponding nuclear fuel.

Overall, disposal of radioactive waste in the seabed has the potential for isolating waste from man's environment for periods in the order of millions of years, depending upon confirmation of inferred information by future seabed exploration.

Generally favorable characteristics of seabed waste disposal are:

1) waste can be deposited at great distance from man and his environment;

2) unconsolidated sediments offer high retention capability for radionuclides in event of their release from the basement rock;

3) safety is provided from surface storms and man's destructive activities;

4) large volumes of water are available for dilution in event of release of waste constituents; and

5) a possible solution to the waste disposal problem is offered on an international basis.

The generally unfavorable characteristics of seabed waste disposal are:

1) extended transport and precise placement operations are required over the seas;

2) mobile seawater provides a ready mechanism for transport of released waste constituents;

3) plant and animal life in seawater offers potential means for reconcentration of released waste constituents;

4) knowledge of the seabed relative to waste disposal is inadequate; and

5) international political factors must be accommodated.

1.7.4 Extraterrestrial Concepts

The implementation of space disposal of transuranic waste could be achieved with current technology. This technology is considered to include the space shuttle and the space tug, which are advanced vehicles but which will use existing engineering technology.

Some consideration was given to potential advanced space propulsion systems such as solar sails, nuclear propulsion, ion propulsion, and acceleration of waste particles electrically from an orbiting platform. Advantages appear possible with most of these advanced schemes in regard to more flexibility in achieving destinations, larger payload, or improved flight economics. However, they are undefined and insufficiently advanced to permit the analysis required by this study.

Space trajectories considered include:

1) Solar system escape

2) Solar impact

3) A high-earth orbit on the order of 100,000 miles (160,000 kilometers)

4) A solar orbit other than that of the earth and planets.

Information on these destinations is shown in Table 1.10.

Solar system escape can be achieved directly by a single propulsion burn from the low-earth orbit with all propulsion and guidance provided by the launch vehicle. Solar system escape can be achieved with somewhat less energy expenditure by a properly designed swingby of Jupiter, using a single propulsion phase (tug) from low-earth orbit. However, either case requires multiple shuttles per waste package to supply the necessary sequential propulsion energy.

Direct solar impact with a single propulsion phase would require vehicles using advanced technology. Solar impact can be achieved by a swingby of Jupiter, using a single

TABLE 1.10. Summary of Potential Space Destinations

Destination	Delta-V, km/sec[a]	Advantages	Disadvantages
High-Earth orbit	4.11	Low Delta-V Launch any day Passive waste package Can be retrieved	Long-term container integrity required. Orbit lifetime not proven.
Solar orbits via:			
Single burn beyond Earth escape	3.65	Low Delta-V Launch any day Passive waste package	Long-term container integrity required. Earth re-encounter possible (may not be able to prove otherwise). Abort gap past Earth escape velocity.[b]
Circular solar orbit	4.11	Low Delta-V Launch any day	Long-term container integrity required. Orbit stability not proven. Abort gap past Earth escape velocity.[b]
Venus or Mars swingby	4.11	Low Delta-V	Long-term container integrity required. Limited launch opportunity (3 to 4 months every 19 to 24 months). Requires midcourse systems. Need space propulsion or have possibility of unplanned encounter.
Solar system escape:			
Direct	8.75	Launch any day Passive waste package Removed from solar system	High Delta-V Abort gap past Earth escape velocity.[b]
Via Jupiter swingby	7.01	Removed from solar system	High Delta-V. Limited launch opportunity (2 to 3 months every 13 months). Requires midcourse systems. Abort gap past Earth escape velocity.[b]
Solar impact:			
Direct	24.08	Package destroyed Launch any day Passive waste package	Extremely high Delta-V. Abort gap past Earth escape velocity.[b]
Via Jupiter swingby	7.62	Package destroyed	High Delta-V. Limited launch opportunity (1 to 2 months every 13 months). Requires midcourse guidance systems. Abort gap past Earth escape velocity.[b]

a. Delta-V is the incremental velocity required to leave a low-earth orbit and is a direct indication of the size and propulsion energy of the rockets required.

b. An abort gap is a short time period wherein a controlled abort of the mission cannot be accomplished if the flight is off-course.

tug phase from low-earth orbit. However, the complexities of course control in a swingby mission may make this mission impractical.

For high-earth orbit, the tug first places the payload into an elliptical orbit. Another tug places the payload into the final circular orbit. The stability of the high-earth orbit cannot currently be assured for times greater than a few thousand years. Furthermore, the orbiting destinations are currently believed to require that the capsule integrity be maintained for time periods approaching those of the need for isolation from man, because waste released in earth orbit could return to the earth.

Solar orbit possibilities include (1) those closely associated with the earth's orbit by injecting the waste to earth escape velocity or slightly beyond, (2) circular orbits slightly inside or outside the earth's orbit, achieved by additional propulsion after escaping the earth, and (3) solar orbits achievable by swingby of Mars or Venus. However, solar orbits, like high-earth orbits, cannot yet be assured stable enough so that the waste could not impact the earth before radioactive decay is complete.

Use of the moon as a repository was not analyzed in this study because of future scientific interest, future potential value, and space environmental considerations.

The destination considered most likely is direct solar system escape. About 190 kilograms of transuranic waste can be transported in each flight to direct solar system escape with the proposed space vehicles. This capacity provides for disposal of the transuranics from about 280 metric tons of spent LWR fuel in each flight.

A conceptual design of a high-integrity capsule has been developed for space disposal of waste transuranics. This spherical capsule, 1.5 meters in diameter, contains transuranic oxide particles inside individual coated tungsten spheres containing a void for buildup of helium from alpha particle decay; these spheres are within a solid aluminum matrix which also contains lithium hydride particles for slowing down the neutrons and boron particles to absorb neutrons. These capsules can be fabricated using current technology.

The safety aspects for space disposal include primarily safety during launch and control of the extraterrestrial destination of the waste constituents. The potential for an abort which could cause a release of radionuclides during any one space launching is moderately high, but relatively small amounts of waste constituents are associated with each launch, and package integrity is high even in an abort.

The major energy consumption in space disposal is for propelling the waste to its final destination. This energy consumption for disposal of transuranic waste is about 4 to 5 orders of magnitude less than the electrical energy from the original nuclear fuel, depending upon the final space destination.

Overall, extraterrestrial disposal has the potential for permanent removal of radioactive waste constituents from the earth, depending largely on incentives and improved knowledge of deep space travel.

Generally favorable features of space disposal are:

1) potential for complete removal of selected waste constituents from the earth;

2) safety is provided from earth's climatic phenomena, both short and long-term, and from man's destructive activities; and

3) a possible solution to the waste disposal problem is offered on an international basis.

Generally unfavorable features of space disposal are:

1) disposal of only part of the waste constituents appears to be economically feasible with present technology;

2) safety associated with multiple launches is questionable;

3) monitoring and retrievability of the waste constituents is very difficult; and

4) international political factors must be accommodated.

1.7.5 Transmutation Elimination Concepts

Elimination of a substantial fraction of the waste actinides via transmutation could be achieved by recycling in fission reactors. Elimination of larger fractions of waste actinides and selected fission products appears feasible by recycling in fusion reactors.

To establish the relative merits and specific technical feasibility of the transmutation approaches, special criteria were developed and applied which are unique to transmutation. These related to overall waste balance, specific transmutation rate, and total transmutation rate.

The results of the feasibility investigations are summarized in Table 1.11. The accelerator devices fail to meet the criteria for transmutation for almost all categories of radioactive waste. The possible exceptions are the use of a spallation neutron source for transmutation of

TABLE 1.11. Summary of Transmutation Device Feasibility

	Technically Feasible for Transmutation			
	Fission Products			Actinides
	Category 1[a]	Category 2[a]	Category 3[a]	Category 3
Accelerators				
• Electron Accelerator	No	No	No	No
• Proton Accelerator	No	No	No	No
• Spallation Accelerator	No	Possibly	Possibly	Yes
Nuclear Explosives	No	No	Possibly[a]	Yes
Fission Reactors	No	No	Possibly	Yes
Fusion Reactors	Possibly[b]	Possibly[b]	Yes	Yes

a. Category 1: Storage required for 100 years
Category 2: Storage required for 100-1000 years
Category 3: Storage required for 1000 years
b. Separated isotopes

long-lived fission products or actinides. The use of neutrons from a nuclear explosion does not appear technically feasible except for actinides or separated fission product isotopes. The use of fission and fusion reactors (when they exist) meet the selection criteria for transmutation of actinides. Fusion reactors also may transmute selected fission products.

The transmutation concept of continual recycle of actinides in fission reactors appears to have merit. Calculations by Claiborne at Oak Ridge National Laboratory, by Kubo and Rose at the Massachusetts Institute of Technology, and at PNL for this study indicate that significant reductions are possible in the cumulative toxicity index[(a)] of actinides. The calculations indicate that using existing separations efficiencies with recycling of actinides in light water power reactors could achieve an order of magnitude decrease in the short-term actinide toxicity index and about a factor of fifty decrease in the long-term toxicity index. These reduction factors may be significantly improved by achieving higher separations efficiencies, better optimization of the reactor irradiation, or by recycling in LMFBRs or HTGRs.

The calculations of the neutron-induced transmutation of actinides and fission products in the blankets of hypothetical Controlled Thermonuclear Reactors (CTRs or fusion reactors) have demonstrated that reductions of cumulative toxicity index of actinides by a factor of 10 or more below those achievable in fission reactors could be obtained in the high neutron flux levels proposed for CTRs. The limitations on efficiency of actinide transmutation in CTRs are primarily practical problems such as radiation damage to materials. These studies have also shown that large reductions in the total radioactive toxicity are possible for some fission product elements (e.g. 10^8 for I-129). For others, notably strontium and cesium, the degree of toxicity reduction is minimal (2 to 5 for Cs-137). The calculated values are also uncertain by a factor of about two because of uncertainty in nuclear reaction data for these elements. Thus, the projected transmutation of some fission product elements in CTRs may not be decided until improved estimates of rates are possible and the actual characteristics of a CTR have been established. All considerations of radionuclide transmutation in CTRs, of course, presuppose the successful accomplishment of controlled thermonuclear fusion.

The primary beneficial safety aspect of transmutation is the inventory reduction of most of the long-lived radionuclides. Safety considerations during the operational phase

a. Toxicity index is defined as the amount of air or water required to dilute the present amount of a given isotope to levels defined in the Code of Federal Regulations (10 CFR - Part 20) as the maximum permissible concentration. The toxicity index provides only an approximate comparison of radiological risk, since it does not allow for accumulation or reconcentration of a nuclide in environmental media, nor for the total impact of a number of nuclides. For limited comparisons, it is an acceptable alternative to dose calculations if used with caution.

are primarily concerned with the incremental burden of processing, handling, and transporting the transmutation materials. While the possibility for release of radionuclides during operation is relatively high, the amount of materials involved in a release should normally be small. For the long time periods the safety concerns are dictated by the means used for disposal of the untransmuted waste.

The energy consumption in transmutation is essentially that associated with increased enrichment for transmutation in Light Water Reactors, chemical partitioning and handling, and transportation costs. The energy consumed and the additional energy developed due to transmutation processes in the nuclear devices are considered to be essentially at the break-even point. The total incremental energy consumed from the processing and handling operations is three to four orders of magnitude less than the electrical energy from the original nuclear fuel. The added enrichment cost for Light Water Reactors would not be present if recycle were done in fast fission reactors.

Overall, elimination of a substantial fraction of actinides and selected fission products appears to be technically feasible by recycling in fission and fusion reactors.

Generally favorable features offered by transmutation processing are:

1) the inventory of actinides and certain fission products is reduced markedly;

2) improved use of resources from fission reactors is effected; and

3) the waste being transmuted is readily monitored and retrieved.

Generally unfavorable features offered by transmutation processing are:

1) elimination of only part of the radioactive waste constituents is feasible;

2) the waste constituents undergoing transmutation are subject to effects of all other nuclear materials in man's environment such as earth's storms and man's destructive activities;

3) significant additional handling and processing is required for the waste being transmuted; and

4) additional waste is formed in the processing and transmutation steps.

1.7.6 Waste Partitioning

The extraterrestrial and transmutation schemes require partitioning (separation) of actinides from the remaining waste constituents. The main extraterrestrial study case also requires further separation of the uranium from the remaining actinides; and if transmutation of selected fission products is done in a fusion reactor, these selected fission products must also be separated from the other waste streams.

Partitioning, if used, must result in a bulk fission product waste fraction which has very little of the actinides remaining so that this waste stream need be managed for only about 1000 years, and result in an actinide or transuranic fraction which has low enough fission product content to minimize interference with the transmutation or space disposal.

For the latter need, allowable fission product content in the actinide fraction for transmutation is estimated to be about 1% of the total waste fission products; and that for space disposal is in the range of 0.1 to 1% of the total waste fission products. This performance is considered to be technically feasible by extension of existing chemical separations technology.

For removal of actinides from the fission products, the separation requirements are not clear because the ultimate answer to the question of "at what radioactivity level can a material be considered as not radioactive" depends highly on the specific disposal technique and site. It is also complicated by the need for higher decontamination (separation) factors for some actinides than for others. The required separation factors can range from as low as 10 to as much as 10^6 to 10^8, depending upon assumptions and specific case conditions. The more likely case is somewhere in the middle of the range and is believed to be between 100 and 10,000.

An overview study was made of all chemical separations processes which might be applicable to partitioning of actinides from bulk liquid waste. The conclusions, summarized in Table 1.12, indicate that solvent extraction and ion exchange have the best capability for achieving the required separation factors. Other separations processes have uncertain capabilities, even for low decontamination factors. Also shown on the table is the need for analytical capability. The existing analytical technology is probably adequate for

TABLE 1.12. Partitioning Feasibility Study Conclusions: Adequacy of Existing Technology[a]

	Actinide Separation (DF)[b]		
	10-100	1,000-10,000	10^6-10^8
Solvent Extraction	Yes	Yes	Possibly
Ion Exchange	Yes	Possibly	No
Other Separation Techniques	Possibly	No	No
Analytical Capability	Yes	Possibly	No

a. Existing separations technology needs adaptation to the objectives of partitioning.

b. This study was concerned primarily with the adequacy of existing technology for obtaining adequate separation of actinide elements from the short-lived waste fraction. Adequate technology exists for obtaining needed purity of the separated actinide fraction.

low separation factors but is probably not adequate for higher separation factors.

The overview study also developed the following conclusions with respect to partitioning:

- Solids present in all high-level radioactive waste will complicate separations process development. Solids composed of large particle sizes may contain long-lived nuclides and have to be treated to remove them. Very small or colloidal solids may contain long-lived nuclides, particularly plutonium, and interfere with separations processes.
- A large amount of technology exists pertinent to the separations needed, but it has never been applied to this particular problem. Additional Research and Development is needed to adapt it to achieve the needed separation factors.
- To accomplish actinide element separation completely within a typical Purex reprocessing plant by process and equipment modification is not practical. Major process and equipment changes would be required.
- Because of potential radiation damage to solvents or ion-exchange media, there may be a processing incentive to include interim aqueous waste storage for improved partitioning.

Overall, it is concluded that partioning of the waste is feasible for low to modest separation factors and is uncertain for high separation factors.

1.8 RESEARCH, DEVELOPMENT, AND TIMING

All of the potential alternative concepts require Research and Development before they can be implemented. The time requirement to complete the Research and Development in all concepts is the primary controlling factor in the time that the concepts can be implemented. A summary of the estimated Research and Development needs and the estimated near-early time for implementation of the disposal concepts on a routine production basis is presented in Table 1.13. The Research and Development studies for all concepts are assumed to terminate upon successful completion of pilot-scale demonstrations.

A reference point for comparison of Research and Development costs is the Research and Development cost for nuclear reactors to date. The total cumulative Research and Development cost for nuclear reactors is on the order of $5 billion. The capital value of nuclear power reactors anticipated through the year 2000 and the value of the associated electricity may also be used for comparison. At $400/installed kilowatt, the capital cost of nuclear power reactors through the year 2000 is 5×10^{11} dollars ($500 billion); at 10 mills/kWhr$_e$, the value of nuclear electricity through the year 2000 is about $1000 billion.

1.8.1 Geologic Concepts

Research and Development requirements for the geologic concepts are primarily associated with the analysis and prediction of geological events and the definition of the effects resulting from the emplacement of waste in a geologic formation. In addition, significant drilling Research and Development is required for the deep-hole concepts, and significant thermal and chemical behavior studies are needed for the in-place melting concepts.

Some of the specific areas for study are:

1) Migration of radionuclides in geologic formations

2) Rock-waste chemical reactions

3) Rock mechanics of candidate geologic formations in the presence of waste

4) Sealing of access areas to disposal sites

5) All aspects of in-place fixation for certain concepts

6) Deep-hole drilling technology for deep-hole concepts

7) Deep geologic studies for deep-hole concepts

8) Improved survey and monitoring methods.

Major Research and Development problems are posed when considering disposal of an intermediate liquid phase and, in the melting concepts, assuring the behavior of a molten region.

Total Research and Development costs for the geologic concepts were estimated to range from $50 to $180 million, depending on the specific

TABLE 1.13. Estimated Research and Development Needs and Timing to Routine Operation

Concept	Research and Development: Major Activities	Total Cost, Millions of $	Total Time, years	Total Time for Operation, years[a]
Geologic Concepts				
1. Solid waste emplaced in mined cavity; no fluid cooling or melting	Basic geological, geophysical studies; site evaluation; emplacement systems development; thermal and radiation effects; containment/confinement integrity; instrumentation auxiliaries; rock sealing; demonstration	50	15	20-25
2. Solid waste emplaced in mined cavity; initial water cooling; melting	Same as 1 above; also, in-place conversion	90	20	25
3. Solid waste emplaced in man-made structure in mined cavity; initial air cooling; no melting	Same as 1 above	50	15	20-25
4. Solid waste emplaced in man-made structure in mined cavity; initial water cooling; no melting	Same as 1 above	50	15	20-25
5. Liquid waste emplaced in mined cavity; initial reflux cooling; melting	Same as 1 above; also, in-place conversion	160	20	25
6. Liquid waste emplaced in exploded cavity; initial reflux cooling; melting	Same as 1 above; also, in-place conversion	170	20	25
7. Solid waste emplaced in matrix of drill holes; no fluid cooling or melting	Same as 1 above	70	20	30
8. Solid waste emplaced in deep holes; no fluid cooling; melting or nonmelting	Same as 1 above; also, in-place conversion and deep hole drilling techniques	160	25	30-35
9. Liquid waste emplaced in deep holes; initial reflux cooling; melting	Same as 1 above; also, in-place conversion and deep hole drilling techniques	180	25	30-35
10. Liquid waste emplaced by hydrofracture; in-place curing	Same as 1 above; also, rock hydrofracture studies	50	10	15-20
Ice Sheet Concepts				
1. Self melt through ice 2. Anchored storage/disposal 3. Ice surface storage/disposal	Basic geological/geophysical studies; site evaluations; sea and ice transport; emplacement system development; instrumentation and auxiliaries; demonstration	600-1000[b]	25	30
Seabed Concepts				
1. Subduction zones and other deep sea trenches 2. Stable deep sea areas 3. Rapid sedimentation	Basic geological/geophysical studies; site evaluations; sea transport; drilling and sealing; emplacement system development; instrumentation and auxiliaries; demonstration	400-1000[b]	25	30
Extraterrestrial Concepts				
1. Solar and Earth Orbits 2. Solar impact[c] 3. Solar escape	Partitioning development; disposal priority; capsule design, testing; encapsulation development; flight vehicle, auxiliary development; testing; safety evaluation	200[c]	20	20
Transmutation Concepts				
1. Fission reactors	Partitioning development; neutronics data analysis and measurements; fuel development; safety evaluation; demonstration	130[d]	10-15	15
2. Fusion reactors[e]	--	--	--	--
3. Accelerators[f]	--	--	--	--

a. Includes Research and Development time.
b. Ice sheet and seabed costs are very difficult to estimate. The estimated ranges given are highly speculative. About four times the estimated costs shown here will be required for basic geological/geophysical and related earth science studies; the costs estimated in this table would be aimed specifically toward waste disposal.
c. Space Research and Development costs do not include costs for basic flight vehicle and auxiliaries development; these costs (in many millions of dollars), are assumed to be borne by NASA for other space flight activities. Costs include an estimated $100 million for space vehicle and trajectory development specific to waste disposal, and disposal of remaining waste fraction by the terrestrial concept with lowest Research and Development cost ($50 million). Costs and timing for solar impact were not estimated; these do not apply to solar impact.
d. Includes industrial participation estimated at 50 million dollars and disposal of remaining waste fraction by the terrestrial concept with the lowest Research and Development cost ($50 million).
e. Research and Development for fusion reactors was not evaluated. Requirements are dictated by advent and engineering of fusion reactors.
f. Research and Development for accelerator transmutation was not evaluated. Feasibility of concept is uncertain.

concepts.[a] Estimated time through full demonstration to beneficial occupancy of committed facilities for routine operation varies between 15 and 35 years.

1.8.2 Ice Sheet Concepts

Primary Research and Development needs for the ice sheet disposal of high-level waste are concerned with understanding and evaluating the factors affecting long-term containment and isolation of the wastes. Rates of movement within the ice sheet, its long-term stability, and physical conditions at the ice-bedrock interface are essentially unknown. Research in climatology would be necessary to permit estimates of the expected life of the ice sheet. To collect and evaluate data to assure long-term isolation would require tens of years of extensive effort in many fields of science.

Transportation of the waste from the edge of the continent to the disposal sites would require considerable development of both equipment and supply methods to establish a practical, highly safe system. Surface-effect vehicles offer the possibility of more rapid transport than conventional tracked vehicles but would require more development and testing to prove their usefulness under severe ice sheet conditions.

A pilot-scale demonstration would be needed to prove the effectiveness of meltdown and anchored emplacement concepts. Laboratory studies, transport, and embarkation port design and construction, concept demonstration and pilot-scale demonstration would require an estimated ten years concurrent with ice sheet studies.

Total Research and Development costs for ice sheet disposal concepts are most difficult to estimate but are expected to be in the range of $3 to $5 billion, and those specifically aimed toward waste disposal are expected to be in the $600 to $1000 million range. Research in the ice sheet areas is very expensive because of the high cost of logistics and supplies. Time requirements are estimated to be about 25 years for Research and Development before routine operation would be in effect.

More than three-fourths of the estimated Research and Development costs are for basic geological/geophysical studies of the ice sheet areas. The level of research effort would be several times that currently applied to these basic studies.

1.8.3 Seabed Concepts

Extensive geological/geophysical/oceanographic/biological studies would need to be conducted on the sea and seabed to determine more the location and specific features of suitable areas for waste disposal. Knowledge of the composition and physical characteristics of the sea floor material, deep currents and geologic stability is necessary to determine how

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a. The major Research and Development efforts expended to date on disposal of radioactive waste in mined cavities in geologic salt formations would likely result in significantly lower future costs for development of this concept.

successfully isolation of the waste could be maintained.

Present transportation systems and equipment could be modified to transport the waste. Establishing embarkation ports would be essentially a design problem but would require some research for site selection.

Waste canister materials resistant to corrosion during emplacement and able to accommodate the hydrostatic pressures would need to be developed. The thermal and radiation effects of the waste canisters on seabed material would need investigation, which could be performed, in part, in laboratories once seabed material had been obtained.

Drilling equipment capable of operating through 10 kilometers of water would need to be developed. Existing semi-submersible drilling platforms would need further development and modification for stable positioning and for firm docking of transport ships.

A pilot-scale demonstration would be needed to establish the viability of the waste management system and of the equipment, once developed.

Total Research and Development costs for seabed disposal concepts are quite difficult to estimate, but are expected to be in the range of $400 to $1000 million specifically for waste disposal, with a total of about $2 to $5 billion. Near-minimum time requirements are estimated to be 20 to 25 years. More than 75 percent of the total effort would be applied to geological/geophysical studies aimed at a basic knowledge of the seabed. The expenditure rate would be several times the current rate for seabed Research and Development studies.

1.8.4 Extraterrestrial Concepts

Research and Development items specific to extraterrestrial waste disposal include waste partitioning, waste capsule materials and form development, encapsulation process development, handling techniques, disposal trajectory studies, special instrumentation, and safety evaluations.

The estimated Research and Development cost of $50 million for space disposal of transuranic element waste includes all costs except those for the basic flight vehicles and their auxiliaries. Overall flight development costs, expected to be many millions of dollars, are assumed to be part of the space development program conducted by government agencies other than the Atomic Energy Commission. Costs for space vehicle and trajectory development specific to waste disposal are estimated by the Pacific Northwest Laboratory to be in the range of $100 million. An additional $50 million of Research and Development is assumed to be needed for terrestrial disposal of the waste fraction not sent to space. This cost is the minimum estimated for terrestrial disposal concepts. Thus the total direct Research and Development costs for space disposal are estimated at about $200 million.

The timing for routine operation of space disposal, estimated at about 20 years, is controlled largely by the schedule for development and

achievement of reliable operational status of the basic space shuttles and tugs by other government agencies.

1.8.5 Transmutation Elimination Concepts

It was assumed for this study that transmutation would be accomplished in commercially owned facilities and the Research and Development needs, costs, and timing for implementation were estimated on this basis.

The Research and Development needs to develop the fission reactor transmutation concept are estimated to require between 10 and 15 years (depending upon using either LWRs or LMFBRs) and cost 130 million dollars. The cost includes $3 to $5 million for partitioning, $50 million for terrestrial disposal of the waste fraction not transmuted and $75 million for actinide recycle engineering (assuming $20 million of government funding and $50 million of industrial funding).

The potential near-term feasibility of fission reactor transmutation of the actinides suggests major Research and Development emphasis in that area. Since the development of a viable fusion reactor remains to be proven, a modest analytical Research and Development effort is projected for studying transmutation in fusion reactors. No specific Research and Development effort is recommended for accelerator transmutation at this time. However, it may be worthwhile to consider a modest effort to better ascertain the accelerator requirements for transmutation in order to determine the breakthrough necessary in acceleration technology for this alternative to represent a technically feasible transmutation concept.

Specific Research and Development items for the fission reactor transmutation concept include development and evaluation of nuclear data, reactor and fuel cycle calculations, experimentation and evaluation, and evaluations of special fuel handling systems, waste management schemes, and safety evaluations.

1.8.6 Waste Partitioning

A Research and Development program was outlined to develop waste partitioning to the state of readiness for commercial application. The program is planned to obtain representative high-level waste and characterize it with respect to solids content and composition; to develop separations flowsheets through laboratory scale testing; to provide cost estimates on various separations processes for economic comparison; to select promising separations processes for pilot plant testing; to design, construct and operate pilot plant facilities for demonstration of processes and resolution of problems posed by large scale operation; and to develop and test analytical procedures as required for process control. The program is estimated to require about five years and cost $3 to $5 million, not including the cost of the pilot plant facility. (Pilot plant facilities exist which should be, with some modifications, usable for these studies.)

The AEC is currently embarked on a program of study of the partitioning of high-level radioactive waste.

1.9 WASTE MANAGEMENT COSTS

An analysis of waste management costs for each disposal concept was developed by taking into consideration all of the necessary components of a complete waste management system. The system cost includes, for example, any added spent fuel transport, interim liquid waste storage, waste solidification, interim solid waste storage, and transport of solid waste canisters to the disposal site or port of embarkation in the case of seabed or ice sheet concepts. The cost estimates are highly preliminary, based on limited concept definition, but are believed to be sufficiently detailed to establish the general magnitude and a relative comparison of disposal costs for each concept. The concept costs considered here include only the costs directly related to implementing each concept. They do not include Research and Development costs nor any estimated external or indirect societal costs.

Disposal costs were developed in terms of levelized unit charges--the single charge that could be assessed over the entire life of a project against each unit processed that would, regardless of fluctuations in processing rates and expenditure patterns, recover all operating expenses as well as the initial investment plus a specified rate of return on the investment. A 10% interest rate was employed. The final waste disposal facility was assumed to be a federal government operated facility, while all operations prior to this were assumed to be performed by a fuel reprocessor who must pay taxes on his profits.

Levelized unit charges were developed for each concept based on handling all of the waste generated by the nuclear power industry for a 25-year period starting in 1980. It was assumed that new facilities would be added at 10-year intervals with sufficient capacity to handle the next ten years of waste generation. The levelized charges are based on assumed payment at the time of fuel reprocessing when the waste is generated. When disposal operations are deferred several years after reprocessing, the payment is credited with interest up to the time the actual operation is carried out. The payment at the time of reprocessing is the discounted present worth at the time of reprocessing of the cost at the time the operation is carried out.

For partitioning, total costs of $10,000 to $20,000 per metric ton of irradiated fuel were estimated for relatively low separations requirements (actinide elements only, separation factors on the order of 100) depending on the purity of the long-lived fraction. If higher separation factors are required, separation costs would probably equal or exceed current total fuel reprocessing costs (about $30,000 per metric ton).

The resultant preliminary cost estimates for each of the disposal concepts are shown in Table 1.14. Estimates are shown for both the direct concept costs and for the waste management system costs. The direct concept costs are shown in terms of estimated total capital and operating expenditures for waste generated over

TABLE 1.14. Summary of Concept Cost Evaluations

Geological Concepts	Direct Concept Costs: Cumulative for 1980-2004 Period, Capital $ Millions	Direct Concept Costs: Cumulative for 1980-2004 Period, Operating $ Millions	Direct Concept Costs: Levelized Unit Charges[a] $/MT Reprocessed	Total Waste Management System Costs[d] Levelized Unit Charges[a] $/MT Reprocessed	Total Waste Management System Costs[d] Levelized Unit Charges[a] Mills/kW-hr
1. Solid waste emplaced in mined cavity; no fluid cooling or melting; granite.					
600 meters deep	1,100	300	3,700	12,000	0.046
1,500 meters deep	1,200	300	3,900	12,000	0.046
2. Solid waste emplaced in mined cavity; initial water cooling; melting; granite.	140	130	700	9,000	0.034
3. Solid waste emplaced in manmade structure in mined cavity; initial air cooling; no melting; granite.					
one tunnel	2,600	500	8,500	17,000	0.064
two tunnels	2,600	500	8,200	16,000	0.063
4. Solid waste emplaced in manmade structure in mined cavity; initial water cooling; no melting; granite.					
one tunnel	1,200	400	4,000	12,000	0.047
two tunnels	1,100	400	3,700	12,000	0.046
5. Liquid waste emplaced in mined cavity; initial reflux cooling; melting; granite.	110	140	1,400	6,400	0.024
6. Liquid waste emplaced in exploded cavity; initial reflux cooling; melting; granite.	100	140	1,300	6,300	0.024
7. Solid waste emplaced in matrix of drill holes; no fluid cooling or melting; granite.	640	140	2,100	10,000	0.039
8. Solid waste emplaced in deep holes; no fluid cooling; melting or nonmelting granite.	700	150	2,300	11,000	0.041
9. Liquid waste emplaced in deep holes; initial reflux cooling; melting; granite.	340	100	3,000	8,000	0.030
10. Liquid waste emplaced by hydrofracture; in-place curing; shale.	2,470	110	700	11,000	0.043
Ice Sheet Concepts					
1. Self melt through ice.	2,900	3,300	12,000	21,000	0.078
2. Anchored storage/disposal.	2,800	5,200	15,000	24,000	0.090
3. Ice surface storage/disposal.	2,900	2,800	12,000	20,000	0.077
Seabed Concepts					
1. Subduction zones - deep sea trenches.	1,300	1,700	8,000	17,000	0.063
2. Stable deep-sea areas.	1,300	1,700	8,000	17,000	0.063
3. Rapid sedimentation.	730	1,650	5,000	14,000	0.052
Extraterrestrial Concepts[b]					
1. Solar and earth orbits.	(c)	(c)	30,000	40,000	0.15
2. Solar escape.	(c)	(c)	80,000	90,000	0.34
Transmutation Concepts[b]					
1. Fission reactors.	(c)	(c)	28,000	38,000	0.15

a. Cost present worthed to time of reprocessing.
b. In the case of Transmutation and Extraterrestrial disposal concepts, the concept cost given in this table includes the cost of disposing actinides and transuraniums only. Additional costs of disposing of the remaining waste must be added to obtain total waste management costs. A representative cost for terrestrial disposal of the remaining waste fraction of $10,000/MT or 0.04 mills/kW-hr is added to the transmutation and extraterrestrial costs and listed in the last column to show a total waste management system cost.
c. Costs for Transmutation and Extraterrestrial disposal concepts were obtained somewhat differently than for terrestrial concepts. Comparable data for the headings shown are not available. Transmutation costs assume the use of commercially owned facilities.
d. System cost includes extra transport costs, interim liquid storage, partitioning, solidification, etc.

the 25-year period from 1980 to 2004 and in terms of levelized unit charges present worthed to the time of reprocessing. The present worthing somewhat obscures the relationship between capital and operating costs and the levelized unit charges because of differences in elapsed time from reprocessing to final disposal for some of the concepts. The waste management system costs include the costs of other essential waste handling components. Relative costs for different concepts are more realistically stated in terms of total system costs.

These estimates conclude that the levelized unit cost for the most expensive concept (extraterrestrial solar escape disposal) is less than five percent of current nuclear electric power costs; most concepts are in the range of 0.4 to 1.0 percent; and two concepts are in the range of 0.2 percent. Consequently, none of the disposal concepts is estimated to increase the cost of nuclear electric power by major amounts.

1.10 ENVIRONMENTAL CONSIDERATIONS

Exclusive of the possible dose consequences of radionuclide release from the waste, there were only a few specific cases in which any significant environmental effects were indicated. Environmental effects are estimated for disposal in the year 2010 for the waste accumulated in the U.S. through the year 2000.

Geologic concepts would commit typically about 130 square kilometers of land[a] but have little other impact. Some care would be required in disposing of the mining spoils of some 2.3 million cubic meters. There would be some small transportation impact resulting from an estimated 12,500 shipments to the disposal site by the year 2010.

The ecology of the ice sheet regions is fragile, and care would be required to ensure that the transportation and emplacement operations did not seriously disrupt it. The heat rejected by the nuclear waste would have a small but finite probability of accelerating ice sheet movement towards the sea. Such an event could have a profound effect on the entire world. In addition to overland trips to the embarkation point, the noise, possible oil spills, and disruption of the surface resulting from surface transport, air, and water support operations would cause most of the expected impact. Total ice sheet area used would be about 80,000 square kilometers. Up to ten trips per year would be required for over-ocean ship transport.

Seabed concepts would require the isolation of an area of some 2,000 square kilometers from other seabed activities. Some disruption of the ocean bottom environment can be anticipated during the drilling operations, but little disturbance of the marine ecology would be anticipated during other phases of the management operation. Truck or rail shipment would be required to the port of embarkation. An estimated 60 annual round trips to the drilling platform would be required for movement of personnel, small materials, and supplies. Up to ten trips per year would be required for transporting waste to the platform.

Extraterrestrial launches of transuranic elements entail some environmental impact. Probably the most severe of these is the noise level during launch and re-entry of the shuttle. Sonic booms with overpressures of about 0.014 atmospheres over the ocean and 0.001 atmospheres over land can be anticipated. The environmental effects from the launch operations will be only part of the total, since the remaining waste will have to be disposed of by some other method. The ground transportation impact

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a. The land use is generally controlled by the size of the "buffer" or zone of isolation around the actual disposal site. In this study, this zone was assumed to be 3.2 kilometers wide, which is in the range of 1.6 to 8 kilometers studied at ORNL for a bedded salt pilot plant repository.

will be considerably greater from the large launch components than from the "payload" capsules for the launches required each year. Ancther launch site comparable to the existing Kennedy Space Center will be required.

The incremental environmental impact of actinide transmutation in LWRs would be minimal. Most effects can be attributed to the additional load on the nuclear fuel cycle. Since more fissile material is required to transmute the actinide elements, more uranium must be mined, more enrichment and processing facilities are required, etc. As in the case of extraterrestrial disposal, additional environmental impacts would be involved in the disposal of the fission products. The transportation impact would be increased by a few percent in all phases of the fuel cycle. The fuel elements containing the actinides would require large shielded containers comparable to those used in the shipment of irradiated fuel.

1.11 POLICY CONFLICTS

Both national and international policies which might apply to the disposal of nuclear waste were examined. Although the results of these studies were not factored into the final program analysis, some interesting conclusions were reached.

The rules and regulations as established by the Atomic Energy Commission in 10 CFR 50 (Appendix F) have the most immediate national impact. These regulations state specifically that all high-level nuclear waste must be disposed of in solid form on federally owned and controlled land. This clearly affects all liquid waste/melting disposal concepts, all extraterrestrial and ice sheet concepts and, most probably, the seabed concepts. However, the AEC rules and regulations appear to be more easily modified than international treaties.

The Antarctic Treaty of 1959 is an international agreement to which the United States is a party. It specifically prohibits any disposal of radioactive waste material in the Antarctic. This would clearly affect all the ice sheet disposal concepts which envision the use of the Antarctic. This treaty is in effect until 1989. At that time any of the participants may suggest amendments. If these are not accepted within 2 years, any of the parties may withdraw.

If the Greenland ice sheet were considered as a waste repository, negotiations must be effected with Denmark.

The Nuclear Test Ban Treaty might affect the concepts using nuclear explosives. Any release of radioactive materials across international boundaries is prohibited. Although the treaty is of unlimited duration, any of the parties have the right to withdraw if their "supreme interests" have been jeopardized.

The Nonproliferation Treaty could conceivably impinge on any of the concepts since it provides for the safeguarding of all source and special fissionable materials. The treaty specifies that International Atomic Energy Agency safeguard standards must be observed in all peaceful nuclear activities whether within a state or under its control anywhere.

The Treaty on Outer Space of 1967 and the Convention on International Liability for Damage Caused by Space Objects of 1972 (not yet ratified by the U.S.) would affect all the extraterrestrial concepts. These treaties define the responsibilities of parties to the treaty in any space launch operations. They also define methods for fixing liabilities for damage caused by any space launch.

The seabed and ice sheet disposal concepts would most probably be impacted by the Convention on the High Seas and the Convention on the Continental Shelf of 1958. These treaties protect the high seas and the continental shelf respectively from pollution by radioactive waste. Additionally, the United States' Marine Protection, Research, and Sanctuaries Act of 1972 prohibits transportation and disposal at sea of radiological warfare agents and high-level radioactive waste.

1.12 PUBLIC RESPONSE

A method for the measurement of the major elements of public perception of risk associated with nuclear waste was developed as part of this study. From the recommendations of a specifically assembled task force of advisors on risk and public acceptance, seven major elements of perceived risk were identified: distance, population density, emplacement operations, stability, detectability of leaks, retrievability, and protective reaction in event of a release of waste.

A before-after research design was used in a preliminary pilot study based upon these seven elements of perceived risk. Two identical questionnaires were administered to 21 respondents from Battelle's Human Affairs Research Center in Seattle. In the pre-test only the barest of descriptive material included in the questionnaire was used as an information basis. In the post-test, respondents were asked the same questions after a videotape presentation of a 5-minute description of each disposal method. Five generic methods of nuclear waste disposal (geologic, ice sheet, seabed, high earth orbit, and surface retrievable storage) were used to illustrate a wide range of characteristics.

In both the pre-test and post-test sessions, respondents were asked to evaluate each of the five disposal methods with their perception of the seven elements of risk. They were asked to make a comprehensive judgment of the overall risk involved in each of the concepts. They were also asked to rank the relative importance of the elements of risk for each concept.

Although this experiment was administered to a small group and the results have limited significance, some of the results are interesting. Some of the judgments changed between the pre-test and post-test. After exposure to the information on the videotape, the respondents perceived geologic disposal as being safer with respect to the elements of distance and stability but as more dangerous with respect to retrievability and protective reaction. Similarly, the ice sheet disposal method was perceived as being more dangerous for all elements of risk after information was presented. The standard deviation of the responses was almost universally less in the post-test than in the pre-test. All of these results suggest that the respondents have objective risk attitudes which are subject to change with more detailed information.

High correlation factors were found in the correlation of importance of each risk element and perceived danger for each risk element.

Multiple regression analysis of the pilot survey results was inconclusive. However, it was concluded that this analytical technique can indirectly measure the respondents' attitudes. The technique could prove to be a useful approach towards measurement of public response to waste disposal concepts and perceived risk elements if the survey were administered

to larger and more representative groups. With such information based on in depth analysis, public attitudes could be factored into concept design. Favorable attitudes by the public on technically sound waste management practices is a most desirable objective.

1.13 SELECTED BIBLIOGRAPHY

Advisory Committee on the Biological Effects of Ionizing Radiations, The Effects on Populations of Exposure to Low Levels of Ionizing Radiations, National Academy of Sciences, National Research Council, Washington, D.C., 1972.

Bader, H., The Greenland Ice Sheet, U.S. Army Cold Regions Research and Engineering Laboratory, I-B2, September 1961.

Barnes, H., "Geologic and Hydrologic Background for Selecting Site of Pilot-plant Repository for Radioactive Waste," Bulletin of the Association of Engineering Geologists, vol. XI, no.1, 1974.

Bartlett, J. W., L. A. Bray, L. L. Burger, R. E. Burns, and J. L. Ryan, Feasibility Evaluation and R&D Program Plan for Transuranic Partitioning of High-Level Fuel Reprocessing Waste, USAEC Report BNWL-1776, Battelle, Pacific Northwest Laboratory, Richland, Washington, November 1973.

Battelle, Pacific Northwest Laboratory Staff, Program for the Management of Hazardous Wastes, Report to the Environmental Protection Agency, Office of Solid Waste Management Programs, Contract No. 68-01-0762, Richland, WA, July 1973.

Blomeke, J. O., C. W. McKee, and J. P. Nichols, Projections of Radioactive Wastes To Be Generated by the U.S. Nuclear Power Industry, USAEC Report ORNL-TM-3965, February 1974.

Boch, A. L., J. O. Blomeke, W. C. McClain and B. F. Bottenfield, Radioactive Waste Repository Project Annual Progress Report for Period Ending September 30, 1972, ORNL-4824, Oak Ridge National Laboratory, Oak Ridge, TN, December 1973.

Bostrum, R. C., and M. A. Sheriff, "Disposal of Waste Material in Tectonic Sinks, " Nature, vol. 228, October 10, 1970.

Brandt, C. T., Letter proposal to E. G. Struxness at Oak Ridge National Laboratory, Fenix & Scisson, Inc., November 1968.

Budd, W. F., "The Dynamics of Ice Masses," Australian National Antarctic Research Expeditions, ANARE Scientific Reports, Series A (IV) Glaciology, Pub. No. 108, Antarctic Div., Dept. of Supply, Melbourne, Australia, 1969.

Budd, W. F., D. Jenssen, and U. Radok, "Derived Physical Characteristics of the Antarctic Ice Sheet," Univ. of Melbourne, Australia, Meteorology Dept., Mark I, Pub. No. 18, 1971.

Claiborne, H. C., Neutron-Induced Transmutation of High-Level Radioactive Waste, ORNL-TM-3964, Oak Ridge National Laboratory, Oak Ridge, TN, December 1972.

Clark, G. A., of Marathon Oil Company, Findlay, Ohio, Letter proposal with enclosures sent to Dr. Frank K. Pittman, Division of Waste Management, AEC, Washington, D.C., November 27, 1972.

Code of Federal Regulations, Appendix F to 10 CFR 50, "Policy Related to the Siting of Commercial Fuel Reprocessing Plants and Related Waste Management Facilities," U.S. Government Printing Office, Washington, D.C., January 1, 1972.

Cohen, J. J., A. E. Lewis and R. L. Braun, Use of a Deep Nuclear Chimney for the In-Situ Incorporation of Nuclear Waste in Molten Silicate Rock, USAEC Report, UCRL 51044, May 1971.

Dahlman, R. C. and Y. Tanaka, Ecological-Environmental Assessments Related to Federal Repository, ORNL-TM-3619, Oak Ridge National Laboratory, Oak Ridge, TN, July 1973.

Denham, D. H., D. A. Baker, J. K. Soldat, and J. P. Corley, Radiological Evaluations for Advanced Waste Management Studies, USAEC Report BNWL-1764, Battelle, Pacific Northwest Laboratory, Richland, WA, September 1973.

Frye, J. E. et al., Disposal of Solid Radioactive Wastes in Bedded Salt Deposits, Report by the Committee on Radioactive Waste Management, National Academy of Sciences-National Research Council, November 1970.

Galley, J. E. et al., Committee on Geologic Aspects of Radioactive Waste Disposal, Report to the USAEC Division of Reactor Development and Technology, National Academy of Sciences-National Research Council Division of Earth Sciences, May 1966.

General Assembly, United Nations, Report of the United Nations Scientific Committee on the Effects of Atomic Radiation, Official Records: 27th Session, Suppl. No. 25 (A/8725), United Nations, New York, NY, 1972.

Gross, M. G., Oceanography, 2nd ed. Charles E. Merrill Publishing Company, Columbus, Ohio, 1971.

Heezen, B. C., "Turbidity Currents," The Sea, vol. 3, chapter 27, Interscience Publishers, John Wiley & Sons, New York, 1963.

Hess, H. H. et al., The Disposal of Radioactive Waste on Land, Report of the Committee on Waste Disposal of the Division of Earth Sciences, NAS-NRC Publication 519, September 1957.

Hughes, T., "Convection in the Antarctic Ice Sheet Leading to a Surge of the Ice Sheet and Possibly to a New Ice Age," Science, vol. 170, November 6, 1970.

Hyland, R. E. et al., Feasibility Study of Space Disposal of Nuclear Waste, NASA-AEC study group, NASA TM-X-2912, vol. 2.

Hyland, R. E. et al., Study of Extraterrestrial Disposal of Radioactive Wastes, Part II, "Preliminary Feasibility Screening Study of Extraterrestrial Disposal of Radioactive Wastes in Concentrations, Matrix Materials and Containers Designed for Storage on Earth," NASA-TM-X-68147, Lewis Research Center, Cleveland, Ohio, October 1972.

Koch, G. et al. Recovery of Transplutonium Elements from Fuel Reprocessing High-Level Waste Solutions, Report No. KFK-1651, November 1972.

Kubo, A. S., Technology Assessment of High-Level Nuclear Waste Management, ScD Thesis, Department of Nuclear Engineering, Massachusetts Institute of Technology, April 1973.

Kubo, A. S. and D. J. Rose, "On Disposal of Nuclear Waste," Science, December 21, 1973

Lakey, L. T. et al., ICPP Waste Calcining Facility Safety Analysis Report, USAEC Report IDO-14620, December 1963.

Larson, D. E., High-Level Liquid Radioactive Waste Management Program, USAEC Report ARH-2400, April 1972.

R. E. Leuze, R. D. Baybarz, and B. Weaver, "Application of Amine and Phosphonate Extractants to Transplutonium Element Production," Nucl. Sci. Eng., vol. 17, p. 252, 1963.

McCarthy, J. F. Jr. et al., Concepts for Space Disposal of Nuclear Waste, M.I.T., Graduate Student Summary, October 1972.

McElroy, J. L., K. J. Schneider, J. N. Hartley, J. E. Mendel, G. L. Richardson, R. W. McKee and A. G. Blasewitz, Waste Solidification Program Summary Report, Volume II, Evaluation of WSEP High-Level Waste Solidification Processes, USAEC Report BNWL-1667, Battelle, Pacific Northwest Laboratory, Richland, WA, July 1972.

Mellor, M., The Antarctic Ice Sheet, U.S. Army Cold Regions Research and Engineering Laboratory Report No. 1-B1, February 1961.

Mellor, M., Snow and Ice on the Earth's Surface, U.S. Army Cold Regions Research and Engineering Laboratory, II-C1, July 1964.

Menard, H. W., "The Deep Ocean Floor," Scientific American, vol. 221, no. 3, pp. 127-142, 1969.

Nye, J. F., "The Response of Glaciers and Ice Sheets to Seasonal and Climatic Changes," Proc. of the Royal Society, Series A, vol. 256, 1960.

Oak Ridge National Laboratory Staff, Pilot Plant Repository Group, Site Selection Factors for Bedded Salt Pilot Plant, USAEC Report ORNL-TM-4219, May 1973.

O'Keefe, D. R., Feasibility of Using an Orbiting Accelerator to Eject Radioactive Waste Products into Space, Gulf-RT-C12457, Interim Summary Report, July 1973.

Peppard, D. F., "Liquid-Liquid Extraction of Metal Ions," Advances in Inorganic Chemistry and Radiochemistry, vol. 7, H. J. Emeleus and A. G. Sharp, Editors, Academic Press, 1965.

Perona, J. J. et al., Design and Safety Considerations of Shipping Solidified High-Level Radioactive Wastes, USAEC Report, ORNL-TM-2971, December 1970.

Pettijohn, F. J., Sedimentary Rocks, Harper and Brothers, New York, 1957.

Reactor Handbook, Vol. II, Fuel Reprocessing - Section B, Aqueous Separation Processes, S. M. Stoller, R. B. Richards, Editors, Interscience, New York, 1961.

Ross, D. A., Introduction to Oceanography, Appleton-Century-Crofts, New York, 1970.

Routson, R. C., A Review of Studies on Soil-Waste Relationships on the Hanford Reservation from 1944 to 1967, BNWL-1464, March 1973.

Sagan, L. A. Editor, Human and Ecologic Effects of Nuclear Power, Charles C. Thomas, Springfield, Il, (in Publication).

Schneider, K. J., "Solidification and Disposal of High-Level Radioactive Wastes in the United States," A Critical Review, Reactor Technology, vol. 13, no. 4, Winter 1970-71.

Soldat, J. K., N. M. Robinson and D. A. Baker, Models and Computer Codes for Evaluating Environmental Radiation Doses, BNWL-1754, Battelle, Pacific Northwest Laboratory, Richland, Washington, June 1973.

United States Atomic Energy Commission, Office of Planning and Analysis, Nuclear Power 1973-2000, Report WASH-1139 (72), Washington, D.C., December 1, 1972.

Weertman, J., "Stability of Ice-Age Ice Sheets," Journal Geoph. Research, vol. 66, no. 11, November 1961.

Wheelwright, E. J., Ion Exchange: A Generic Nuclear Industry Process for the Recovery and Final Purification of Am, Cm, Pm, Sr, Pu, Np, Cs, Tc, Rh, and Pd, BNWL-SA-1945, October 1968.

Wolkenhauer, W. C., et al., Transmutation of High-Level Radioactive Waste with a Controlled Thermonuclear Reactor, USAEC Report, BNWL-1772, Battelle, Pacific Northwest Laboratory, Richland, WA, September 1973.

Zeller, E. J., D. F. Sanders and E. E. Angino, "Putting Radioactive Wastes on Ice," Bulletin of the Atomic Scientists, January 1973.

SECTION 2: BACKGROUND AND DATA BASE

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2.0 BACKGROUND AND DATA BASE

In the production of electrical power from nuclear energy, the nuclear processes which take place in the nuclear reactor result in the formation of radioactive fission products and actinide elements within the nuclear fuel rods. The irradiated or "spent" nuclear fuel is discharged from the reactor and then chemically processed in a nuclear fuel reprocessing plant to recover the significant amount of valuable "unspent" fissile and fertile materials for recycle through the nuclear fuel cycle. The bulk of the fission products, the smaller amount of "waste" transuranic elements and a fraction of the fuel materials are removed in highly concentrated form in an acid aqueous stream called high-level radioactive waste.

This high-level waste generates sufficient heat to require substantial cooling, it emits large amounts of potentially toxic ionizing radiation, and it must be carefully isolated or contained for at least thousands of years to prevent significant quantities of the more highly toxic radionuclides from entering man's environment.

Present Atomic Energy Commission (AEC) regulations require that the liquid high-level waste from fuel reprocessing 1) be converted to a stable solid material within 5 years after separation in the fuel reprocessing step, and 2) be encapsulated and shipped to a federal repository within 10 years of its production for long-term management by the AEC.[1]

Present AEC plans for long-term management of high-level waste call for 1) interim retrievable storage of solidified and encapsulated waste in man-made structures for up to about 100 years followed by 2) permanent disposal or elimination. For permanent disposal, the AEC, with advice and counsel of the National Academy of Sciences, is also actively sponsoring development of bedded salt geologic formations as offering potentially attractive features for long-term management of the waste. In addition, the AEC is sponsoring these studies investigating the feasibility of other potentially viable concepts for waste management.

In general, units used in this report are given in the metric system. A listing of the metric-English equivalents used commonly in this report is given in Table 2.1.

2.1 WASTE MANAGEMENT OPTIONS

Radioactive wastes are generated by essentially all segments of the fuel cycle. These include:

Waste Source	Forms	Radioactivity
Uranium Mills	Sludge	Low
Uranium Conversion	Solid	Low
Fuel Fabrication	Solid/Liquid	Low
Reactors	Solid/Liquid	Low to High
Fuel Reprocessing		
High Level	Solid/Liquid	High
Cladding	Solid	Low to High
Other	Solid/Liquid	Low
Miscellaneous	Solid/Liquid	Mostly Low

TABLE 2.1. Metric-English System Conversion Factors

To Convert	Into	Multiply By
calories, gram	Btu	3.9685×10^{-3}
centigrade	Farenheit	(C° x 9/5) + 32
centimeters	inches	0.3937
cubic meters	cubic feet	35.31
cubic meters	liter	1000.0
cubic meters	gallons (U.S.)	264.2
grams	pounds	2.205×10^{-3}
grams/liter	pounds/cubic feet	0.062427
hectares	acres	2.47
hectares	square kilometers	0.01
kilograms	pounds	2.205
kilometers	miles	0.6214
kilometers	feet	3,281
kilowatts	Btu/min	56.92
kilowatts	horsepower	1.341
kilowatt-hrs	Btu	3413
liters	cubic feet	0.03531
liters	gallons (U.S.)	0.2642
liters/min	cu.ft/sec	5.886×10^{-4}
meters	feet	3.281
meters/min	feet/min	3.2.81
millimeters	inches	0.03937
mills/kilowatts-hrs*	dollars/kilogram U*	277.2
newtons	pounds	0.2248
square centimeters	sq. inches	0.1550
square kilometers	acres	247.1
square kilometers	square miles	0.3861
square meters	square feet	10.76
tons (metric)	kilograms	1000
tons (metric)	pounds	2205
watts	Btu/hr	3.413
watts hours	Btu	3.413
watts hours	ergs	3.60×10^{10}
watts hours	foot-pounds	2,656
watts hours	kilogram-calories	0.8598
watts/cm^2-°C	Btu/(hr-sq ft-°F)	1760.6
(watts/cm^2)(°C/cm)	(Btu/hr-sq ft)(°F/ft)	57.8

* at 33,000 megawatt days (thermal)/ton(metric) U and 35% conversion efficiency, thermal to electrical.

The high-level waste from the reprocessing of nuclear fuel, since it contains essentially all of the fission products and a fraction of the fuel materials (i.e. uranium, plutonium and neutron-generated isotopes) is one of the more significant wastes from the standpoint of waste management.

This report deals principally with management of the high-level waste from reprocessing. Many of the considerations in handling this waste

are readily adaptable to other nuclear wastes and could be so applied in the future.

The long-term potential risk from release of nuclear wastes from fission reactors requires very careful development and implementation of a waste management system. The time periods involved, because of their length, challenge man's planning capabilities.

The two major protective devices in the management of nuclear waste are isolation and containment although substantial interaction can and does exist between these two factors. In this context, isolation is used to mean the factors which influence the time required for migration to man's environment. Typical factors could include distance (16-kilometer-hole), the ion-exchange capacity of the earth, the lack of water, etc. If waste is adequately isolated so that the migration times are greater than the time for radioactive decay, isolation alone provides adequate protection. Conversely, if adequate containment is provided by manmade barriers--again for the length of time for decay--the waste could be placed in many selected locations in man's environment. Here, the word barrier is used to include the matrix for the waste, e.g. silicate glasses, wrapping such as metallic sheets, and manmade containment such as a concrete building.

The waste management options explored in this report seek to utilize the maximum benefits from both isolation and containment although principal emphasis is on isolation.

Partitioning prior to disposal is a key element in some of the waste management systems. By dividing the high-level waste into two fractions, one in which the major content of radioactively toxic materials will diminish to very low levels in about a thousand years and the other, much smaller in weight, volume, and heat generation rate, but containing long-lived materials, a substantial increase may occur in the number of feasible waste management options.

Manmade artifacts, for example Chinese and Egyptian art objects, have existed and remained in good condition well in excess of 600 years. Modern man should be able to duplicate this performance and beneficially use containment to supplement isolation from the "short-lived" fraction of waste.

For the longer-lived actinide fraction of the waste, a combination of isolation and containment will be necessary. For these materials and in the broadest sense, only three options exist: elimination of the waste from man's environment by either beneficial transmutation; or extraterrestrial transport off the earth; or isolation from man's environment somewhere on earth. In this report, the word "disposal" is used in the context of a plan in which the intent is to permanently store in isolation, sometimes supplemented by manmade barriers to provide adequate protection for the periods of time required for effective removal of the hazard by decay. The word "storage" is used to mean a plan and operations which are dependent on routine and continuing

actions of man to maintain and provide the necessary containment barrier for the waste.

The waste management options under study are listed in Table 2.2. It will be noted that each major category involves several subsets.

The fission reactor waste management systems required for any concept are shown in Figure 2.1. This logic diagram indicates the potential routing of nuclear waste, starting with its presence in the discharged reactor fuel (the source of waste) to its final disposal or elimination step. Appropriate conditioning (fixation or solidification), retrievable storage, partitioning (removal of actinides) and fractionation (separation of different fission products) are

TABLE 2.2. Concepts Under Study for High-Level Radioactive Waste Management

A. PROCESSING

Partitioning[a]

B. DISPOSAL ON THE EARTH

Geologic	Seabed	Ice Sheet
Mined Cavity	Stable Deep Sea Floor	Ice Burial - Free Flow
Nuclear Cavity	Subduction Zones and Deep Trenches	Ice Burial - Anchored
Deep Hole	Rapid Sedimentation Areas	Ice Surface Facility
Drilled Hole Matrix		
Manmade Structures in Geologic Formations		

C. DISPOSAL OFF THE EARTH

Extraterrestrial

- Solar Impact
- Orbiting
- Solar Escape to Deep Space

D. ELIMINATION

Transmutation

- Accelerator
- Fission Reactor
- Nuclear Explosive
- Controlled Thermonuclear Reactor (Fusion Reactor)

a. Partitioning is separation of waste constituents into two fractions: one which contains the long-lived actinide elements and one which contains the fission product. Variations from this basic definition are also included in the study.

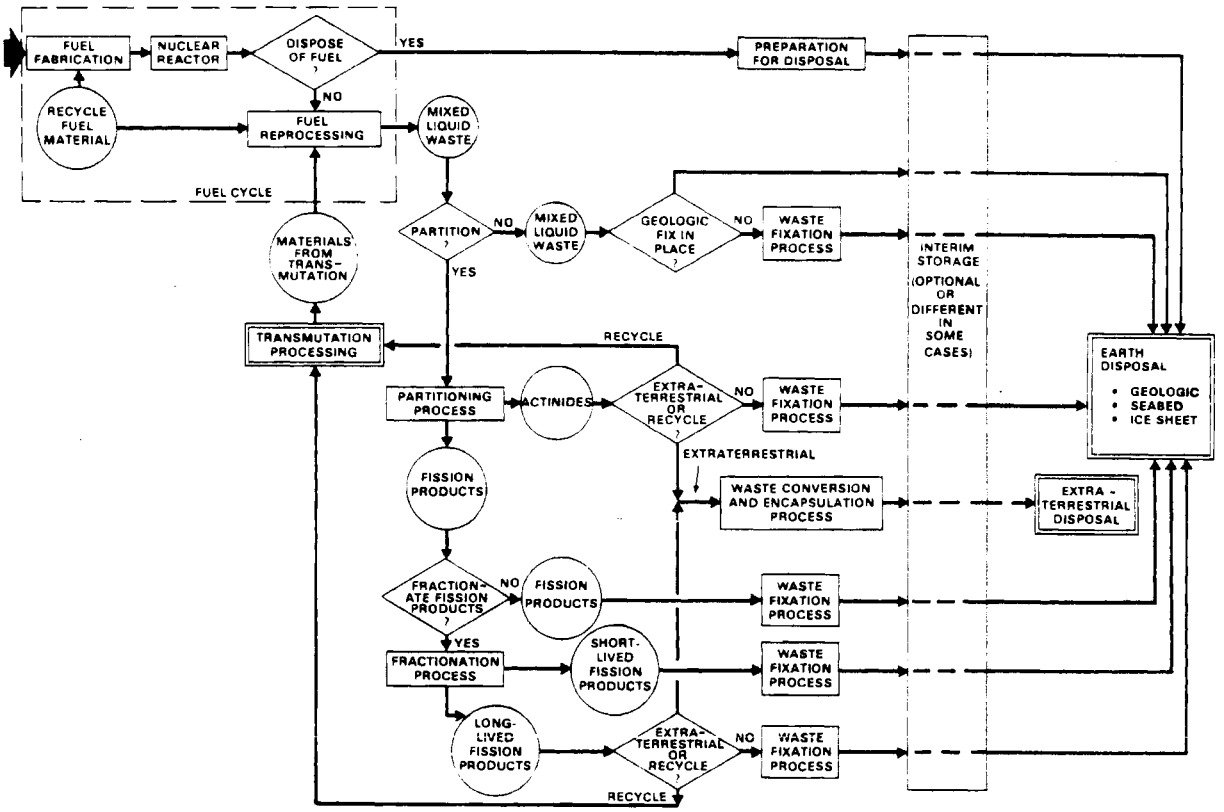

FIGURE 2.1. High-Level Waste Management Options

identified as processing steps where necessary to provide aging or modification to the physical or chemical forms of the waste.

2.2 POWER PROJECTIONS

Selected forecasts for installed electrical generating capacity for the United States are summarized in Figure 2.2. It is projected that by 1980 over 20 percent of the installed capacity will be generated by nuclear reactors, while by 1990 nuclear energy will be producing 40 percent of the total installed electrical capacity or 500,000 MW. Additional details of the nuclear electric power generating forecast are presented in Table 2.3 and Appendix 2.A.

The forecast for U.S. nuclear electric power generating capacity "is based on operating data through FY 1972,[7] the forecast of the AEC Office of Planning and Analysis from FY 1972 through FY 1988,[3] and results of a recent ORSAC case (Case 63),[4] thereafter."[2] Nuclear power generating predictions have been updated subsequent to the issuance of Reference 1.[a] However

a. Information cited from Reference 1 was taken from an unpublished draft. Certain values were changed in the published report, which reflects the updated projections.

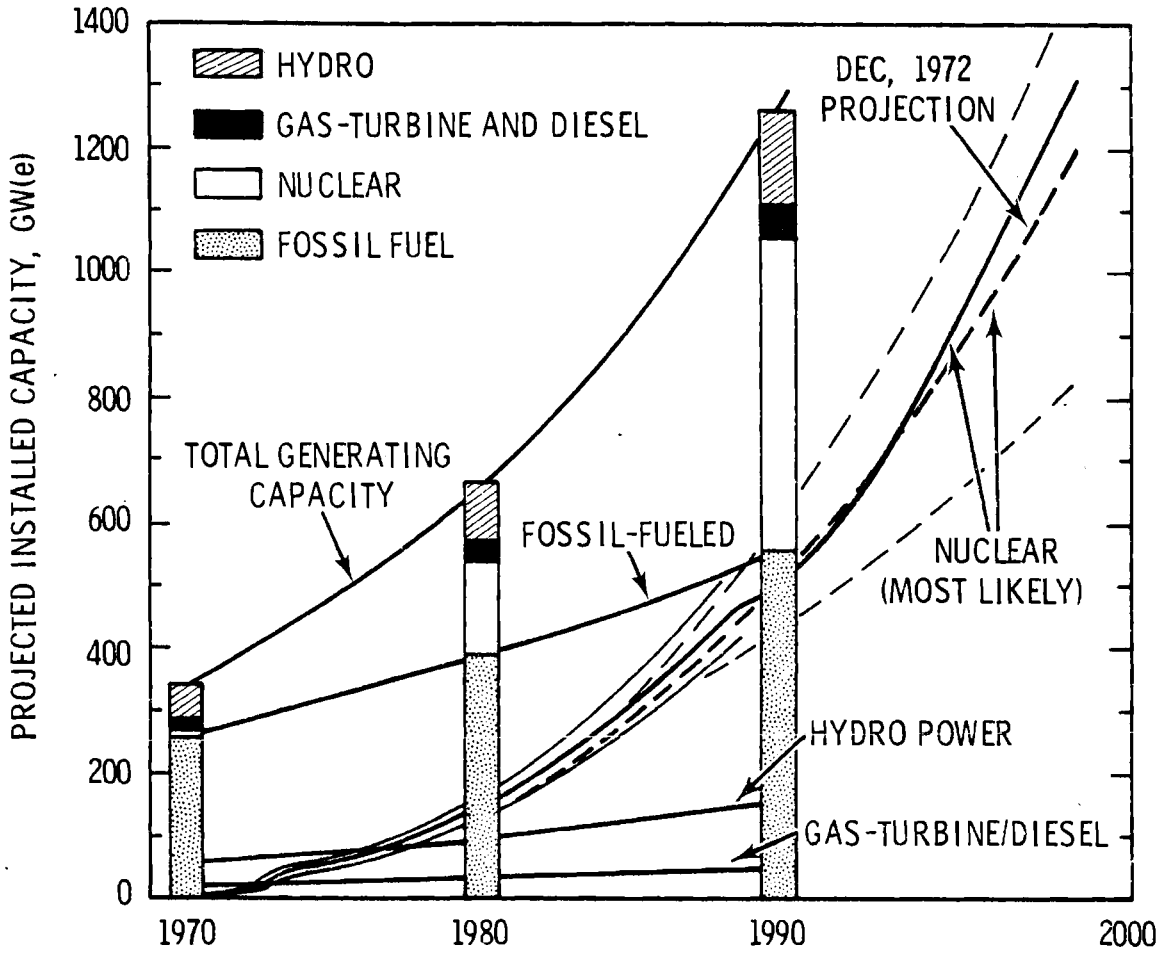

FIGURE 2.2. Projected Growth of Electrical Generating Capacity in the United States[2,5,6]

as shown in Figure 2.2, the results of these December 1972 "most likely" AEC projections are still within the probable range of Reference 2 and predict that ". . . U.S. nuclear generating capacity will grow to 1,200,000,000 kilowatts by the end of the century . . ."[5] Projections for the non-nuclear and total utility generating capacity were obtained from the 1970 National Power Survey (NPS) by the Federal Power Commission.[6]

The power projections form the bases for estimating the amount of nuclear fuel that will be irradiated in and discharged from nuclear reactors. High-level waste generation rates are then projected from estimates of the reprocessing rate of the discharged fuel.

TABLE 2.3. Forecast of U.S. Nuclear Electric Power Generating Capacity, GWe(net)[2]

Year	End of Calendar Year	End of Fiscal Year	Average in Fiscal Year				Additions to Average in Fiscal Year			
			LWR	HTGR	LMFBR	Total	LWR	HTGR	LMFBR	Total
1970	5.0[a]									
1971	8.1[a]	5.4[a]	5.2[a]			5.2	5.2			5.2
1972	17.4	10.8[a]	8.2[a]			8.2	3.0			3.0
1973	33.2	24.1[b]	17.5			17.5	9.3			9.3
1974	48.4	42.2[b]	33.2			33.2	15.7			15.7
1975	57.1	54.5[b]	48.4			48.4	15.2			15.2
1976	68.0	59.7[b]	57.1			57.1	8.7			8.7
1977	86.9	76.4[b]	68.0			68.0	10.9			10.9
1978	107.0	97.4[b]	86.9			86.9	18.9			18.9
1979	127.8	116.6[b]	107.0			107.0	20.1			20.1
1980	150.9	139.0[b]	126.8	1.0		127.8	19.8	1.0		20.8
1981	175.4	162.8[b]	146.9	4.0		150.9	20.1	3.0		23.1
1982	202.8	188.0[b]	166.4	9.0		175.4	19.5	5.0		24.5
1983	234.1	217.6[b]	186.8	16.0		202.8	20.4	7.0		27.4
1984	268.5	250.6[b]	208.1	26.0		234.1	21.3	10.0		31.3
1985	306.1	286.4[b]	229.5	39.0		268.5	21.4	13.0		34.4
1986	347.0	325.8[b]	250.1	56.0		306.1	20.6	17.0		37.6
1987	392.4	368.2[b]	268.0	76.0	3.0	347.0	17.9	20.0	3.0	40.9
1988	439.0	416.6[b]	285.4	99.0	8.0	392.4	17.4	23.0	5.0	45.4
1989	473.0	461.4	300.0	124.0	15.0	439.0	14.6	25.0	7.0	46.6
1990	510.0	484.6	300.0	149.0	24.0	473.0		25.0	9.0	34.0
1991	555.0	535.4	300.0	174.0	36.0	510.0		25.0	12.0	37.0
1992	606.0	574.6	300.0	199.0	56.0	555.0		25.0	20.0	45.0
1993	669.0	637.4	300.0	224.0	82.0	606.0		25.0	26.0	51.0
1994	746.0	700.6	300.0	249.0	120.0	669.0		25.0	38.0	63.0
1995	827.0	791.4	300.0	274.0	172.0	746.0		25.0	52.0	77.0
1996	913.0	862.6	300.0	299.0	228.0	827.0		25.0	56.0	81.0
1997	1004.0	963.4	300.0	324.0	289.0	913.0		25.0	61.0	86.0
1998	1101.0	1044.6	300.0	349.0	355.0	1004.0		25.0	66.0	91.0
1999	1201.0	1157.4	300.0	374.0	427.0	1101.0		25.0	72.0	97.0
2000	1302.8	1244.6	300.0	399.0	502.0	1201.0		25.0	75.0	100.0

a. Operating data from Nucleonics Week.[7]

b. Forecast from WASH-1139 (Rev. 1).[3]

2.3 REACTOR PLANTS

Pertinent nuclear reactor plant characteristics assumed for waste projections are reprinted in Table 2.4.[2] Characteristics for light water cooled reactors (LWR), which can be either pressurized water (PWR) or boiling water (BWR) units, are based on the 1000 MWe Diablo Canyon PWR plant. The fuels for the LWR plants are fissionable isotopes of uranium and plutonium (U-235 and Pu-239); plutonium recycle was assumed to begin in fiscal year 1979 in LWR plants.

TABLE 2.4. Nuclear Reactor Plant Characteristics[2]

	LWR-U	LWR-U, Pu[a]			HTGR[b]				A.I. Follow-on LMFBR[f]				G.E. Follow-on LMFBR[g]			
		U Fraction	Pu Fraction	Total	Th-U-233	U-235 Fresh Makeup	U-236 Recycled Makeup	Total	Core	Axial Blanket	Radial Blanket	Total	Core	Axial Blanket	Radial Blanket	Total
Electric Power, MWe(net)	1000	676	324	1000	-	-	-	1160	-	-	-	1002	-	-	-	1011
Thermal Power, MW	3077	2081	996	3077	-	-	-	3000	2219	107	74	2400	2081	195	141	2417
Ave. Specific Power,[b] MW/metric ton	37.5	37.5	37.5	37.5	-	-	-	30.69	116.1	8.1	4.7	50.18	155.6	13.0	8.5	53.76
Avg. Burnup, Mwd/metric ton	32,873	32,873	32,873	32,873	-	-	-	94,264	67,594	4739	7970	37,098	104,542	8725	9051	41,792
Refueling Interval, days[c]	365.25	365.25	365.25	365.25	365.25	365.25	365.25	365.25	364	364	364	364	385	385	385	385
Steady State Charge																
Th, kg	-	-	-	-	8434	-	-	8434	-	-	-	-	-	-	-	-
U-233, kg	-	-	-	-	217	-	-	217	-	-	-	-	-	-	-	-
U-235, kg	875.2	592.0	59.2	651.2	29.6	373.0	30.4	433	16	13	5	34	-	20	14	34
Total U, kg	27,350	18,500	8409	26,909	357.9	403.0	104.5	865.4	7890	6571	2702	17,163	5038	6884	4798	16,720
Fissile Pu, kg[d]	-	-	270.3	270.3	-	-	-	-	1196	-	-	1196	786	-	-	786
Total Pu, kg[e]	-	-	441.0	441.0	-	-	-	-	1662	-	-	1663	1093	-	-	1093
(U + Pu + Th), kg	27,350	18,500	8850	27,350	879.	403.0	104.5	9299.1	9553	6571	2702	18,826	6131	6884	4798	17,813
Steady State Discharge																
Th, kg	-	-	-	-	7819	-	-	7819	-	-	-	-	-	-	-	-
U-233, kg	-	-	-	-	219.3	-	-	219.3	-	-	-	-	-	-	-	-
U-235, kg	213.4	164.6	26.4	191.0	30.7	36.8	2.6	64.1	8	11	3	22	-	14	10	24
Total U, kg	26,137	17,679	8190	25,869	360.1	105.3	70.0	541.4	7255	6415	2543	16,213	4439	6580	4583	15,602
Fissile Pu, kg[d]	180.1	107.8	151.2	273.1	-	-	-	2.1	1143	133	119	1395	714	234	163	1111
Total Pu, kg[e]	264.9	172.4	273.1	445.5	-	-	-	10.0	1655	137	126	1918	1051	245	171	1467
(U + Pu + Th), kg	26,572	17,851	8463	26,315	8185	105.3	70.0	8370	8910	6552	2669	18,131	5490	6825	4754	17,069

a. PWR with self-sustaining Pu recycle.

b. Based upon full power and fuel charged.

c. At 80% load factor.

d. Pu-239 + Pu-241

e. Pu-238 + Pu-239 + Pu-240 + Pu-241 + Pu-242

f. A.I. plant representative of early units, F.Y.-87 through F.Y.-90.

g. G.E. plant typical of advanced units, i.e., beyond F.Y.-90.

The HTGR is a thermal converter plant based on the U-235 (highly enriched) /Th/U-233 fuel cycle that can produce more new fissile material (U-233 from fertile thorium) than conventional PWR plants but not as much as true breeder plants. The reactor is graphite-moderated and gas-cooled. "The model HTGR is based upon design studies of an 1160 MWe HTGR that uses annual refueling (at 80 percent capacity factor) of approximately one-fourth of the core."[2]

The LMFBR plants use fast (unmoderated) neutrons and liquid metal coolant and are designed to produce more fissile material than they consume. Fissionable plutonium will be the key fuel material for the LMFBR plants.

The United States utility industry commitment to nuclear power is approaching 2 x 10^8 kilowatts. Nuclear reactors built, being built, or planned are listed in Appendix 2A.

2.4 FUEL REPROCESSING AND HIGH-LEVEL WASTE

Irradiated enriched uranium LWR fuels typically contain about 30 percent of the original fissile uranium and the fissile plutonium that is produced by reactor irradiation. Chemical reprocessing is used to separate and recover these useful products from the fission products. In general the fission products and actinides other than uranium, plutonium and thorium are viewed as waste constituents. There is, however, also a small amount of unrecovered uranium, plutonium or thorium (commonly and hereafter called loss) in this high-level waste stream.

Existing or planned reprocessing flowsheets are based on a solvent extraction process. Aqueous acidic "feed" solutions, arising from the dissolution of irradiated fuels in nitric acid, are fed to the initial (first-cycle) solvent extraction contact. Here most of the nuclear fuel products are retained in an organic phase while the fission products, along with a small quantity of uranium, plutonium or thorium and generally all other actinide elements are discarded as aqueous acidic high level waste (aqueous first-cycle waste).

2.4.1 Liquid Waste

Typical constituents of high-level liquid waste from the reprocessing of irradiated fuels from LWR, LMFBR, and HTGR plants are shown in Table 2.5. This table was developed for aqueous acidic waste from first-cycle solvent extraction where in general, the addition of chemicals that could be troublesome in subsequent solidification processes is minimized.[2,8] Troublesome chemicals include those that result in volatilization, corrosion, segregation, creation of nondurable solid forms, or phase separation during solidification. In addition to first-cycle additives, troublesome chemicals can also result from the combination of other reprocessing plant waste with the first-cycle waste.

The concentrations for the aqueous first-cycle waste from LWR fuels are based on a chop-leach head-end method, followed by solvent extraction of irradiated fuels initially enriched with U-235. The zirconium-clad

TABLE 2.5. Typical Materials in High-Level Liquid Waste[2,8]

	Material[b]	Grams/MT from Reactor Type[a] LWR[c]	HTGR[d]	LMFBR[e]
Reprocessing Chemicals	Hydrogen	400	3,800	1,300
	Iron	1,100	1,500	26,200
	Nickel	100	400	3,300
	Chromium	200	300	6,900
	Silicon	--	200	--
	Lithium	--	200	--
	Boron	--	1,000	--
	Molybdenum	--	40	--
	Aluminum	--	6,400	--
	Copper	--	40	--
	Borate	--	--	98,000
	Nitrate	65,800	435,000	244,000
	Phosphate	900	--	--
	Sulfate	--	1,100	--
	Fluoride	--	1,900	--
	Sub-total	63,500	452,000	380,000
Fuel Product Losses[f,g]	Uranium	4,800	250	4,300
	Thorium	--	4,200	--
	Plutonium	40	1,000	500
	Sub-total	4,840	5,450	4,800
Transuranic Elements[g]	Neptunium	480	1,400	260
	Americium	140	30	1,250
	Curium	40	10	50
	Sub-total	660	1,440	1,560
Other Actinides[g]		<0.001	20	<0.001
Total Fission Products[h]		28,800	79,400	33,000
	TOTAL	103,000	538,000	419,000

a. Water content is not shown; all quantities are rounded.
b. Most constituents are present in soluble, ionic form.
c. U-235 enriched PWR, using 378 liters of aqueous waste per metric ton, 33000 MWd/MT exposure. (Integrated reactor power is expressed in megawatt-days [Mwd] per unit of fuel in metric tons [MT].)
d. Combined waste from separate reprocessing of "fresh" fuel and fertile particles, using 3,785 liters of aqueous waste per metric ton, 94,200 MWd/MT exposure.
e. Mixed core and blanket, with boron as soluble poison, 10% of cladding dissolved, 1,249 liters per metric ton, 37,100 MWd/MT average exposure.
f. 0.5% product loss to waste.
g. At time of reprocessing.
h. Volatile fission products (tritium, noble gases, iodine and bromine) excluded.

irradiated fuels are chopped into small sections that drop into a dissolver for dissolution by nitric acid. Only irradiated fuel constituents are dissolved, leaving a residue of leached and chopped metallic hulls. The resulting high-level waste is salt-free except for a small amount of corrosion products, waste fuel constituents, and product losses.

Reprocessing techniques for LMFBR fuels should be similar to those for LWR fuels. The waste constituents shown in Table 2.4 are based on solvent extraction reprocessing of a mixture of core (fuel) and blanket (fertile) materials and on the assumptions that 10 percent of the stainless steel cladding could dissolve during leaching and that boron is used as soluble poison for criticality control.

The waste constituents for HTGR plants shown in Table 2.4 are based on a combination of two of the three fission-product-contaminated waste streams that result from a reprocessing scheme currently under development.[2] In the proposed reprocessing scheme, irradiated "fuel" blocks are first crushed. The crushed graphite is then burned in a fluidized bed to expose the fertile and fissile particles, which are then separated by size difference. One fission-product-contaminated stream, solid "Uranium-235 Recycled Makeup" fuel particles, is depleted in fissile material to the extent that it is considered waste and will not be processed further. The remaining two streams, i.e., those that are combined, result from the separate first cycle solvent extraction of feeds obtained from the dissolution of "Uranium-235 Fresh Makeup" (nonrecycle) fuel and fertile particles. The "fresh" fissile particles are reprocessed to recover fuel for recycle while the contaminated fertile particles are processed to recover Uranium-233 and thorium. Recycle of both Uranium-233 and the partially burned Uranium-235 particles is assumed to begin in the third reload for each reactor.

2.4.2 Solidification of Liquid Waste

One of the major steps in many potential schemes for the management of aqueous first-cycle waste will be conversion to a solid prior to storage and transportation. An existing regulation requires that in the future this waste must be converted to a dry solid[a] and placed in a sealed container within 5 years after reprocessing.[1] The encapsulated solid is then to be transferred to a Federal repository within 10 years after reprocessing. The shipping cask is to meet the requirements of 10 CFR Part 71.[14] Four solidification processes have been developed in the United States to the point of radioactive demonstration on an engineering scale: spray solidification,

a. The dry solid is to be "chemically, thermally and radiolytically stable to the extent that the equilibrium pressure in the sealed container will not exceed the safe operating pressure for that container during the period of canning through a minimum of 90 days after receipt. . .at the Federal repository."

fluidized bed calcination, pot calcination and melting, and phosphate glass solidification.[9,10] In all four processes, heat is applied to drive off volatile constituents, primarily water and nitrates, resulting in either calcined solids or a melt that will cool to a monolithic solid. The latter generally requires the addition of about 70 mole percent of inert solids to incorporate the fission products into materials that are fusible at reasonably low temperatures (less than about 1200°C).[11]

Typical characteristics of the final solid waste forms from the four processes are shown in Table 2.6. The processes are described briefly below.[9,10]

- Spray Solidification. Atomized droplets fall through a heated chamber where flash evaporation results in oxide particles. Glass-making solid frit or phosphoric acid can be added to provide for melting and glass formation in an intermediate melter below the calciner or directly in the vessel that will serve as the waste canister. The molten glass or ceramic is cooled and solidified.
- Fluidized Bed Calcination. Liquid waste is atomized into a heated fluidized bed where the waste oxides are deposited on the inert granular bed particles. The resulting granular particles of waste calcine may be the final waste form or may be incorporated into crystalline or glassy matrices in a melting stage.

TABLE 2.6. Characteristics of Solidified High-Level Waste[9,11]

	Pot Calcine	Spray Phosphate Ceramic	Phosphate Glass	Borosilicate Glass[a]	Fluidized Bed Calcine
Form	Scale	Monolithic	Monolithic	Monolithic	Granular
Description	Calcine Cake, Friable	Ceramic Hard, Tough	Glass Hard, Brittle	Glass Hard, Brittle	Calcine, Mean Particle Diam. 100μ to 500μ
Bulk Density g/ml	1.2 to 1.4	2.7 to 3.3	2.7 to 3.0	3.0 to 3.5	1.0 to 1.7
Wt% Fission Product Oxides (Max.)	90	30	25	50	50
Thermal Conductivity, W/(m²) (°C/m)	0.3 to 0.4	1.0 to 1.4	0.8 to 1.2	1.0 to 1.4	0.2 to 0.4
Leachability in Cold water, g/cm²-Day	1.0 to 10^{-1}	10^{-3} to 10^{-5}	10^{-4} to 10^{-6}[b]	10^{-5} to 10^{-7}	1.0 to 10^{-1}

a. Produced by either spray or fluidized bed calcining followed by melting, or by in-canister vitrification processing.
b. Devitrified phosphate glass exhibits increased leachability (leach rates = 10^{-2} to 10^{-3} g/cm2-day).

- Pot Calcination. Liquid is continuously added to and boiled away in a processing vessel which also serves as the storage canister. When the canister is full of solids, the addition of aqueous waste is stopped and the temperature of the solid is raised and held at about 900°C to complete denitration and dehydration. Feed additives can be used to result in a glass rather than a calcine cake.
- Phosphate Glass Solidification. Liquid waste and phosphoric acid are mixed and concentrated to a thick slurry in an evaporator. The slurry is routed to a melter where dehydration and denitration are completed and the material is melted. The molten phosphate glass is then dropped into the canister where it cools and solidifies.

2.5 HIGH-LEVEL WASTE CHARACTERISTICS

Estimates of total quantities, radioactivity, and thermal power of the waste that will be accumulated through the year 2000 are reprinted in Table 2.7.[2] The waste volume accumulated through the year 2000 is based on a reprocessing load of 181,100 metric tons of irradiated fuel, about 70 percent of which is associated with LWR plants. This reprocessing load includes "some fuel with relatively low exposure as well as UO_2 - PuO_2 and UO_2 - ThO_2 scrap that is recycled from fabrication plants."[2] Radiation properties are based on 167,600 "equivalent" metric tons, for which it is assumed that all of the fuel has the rated steady-state and total integrated exposure. Reprocessing (product) losses are assumed to be 0.5%.

Additional information concerning radiation properties (radioactivity, thermal power, and toxicity indices) for the waste accumulated through the year 2000 and for decay times up to 10^9 years is summarized in Tables 2.8 and 2.9.[12] Toxicity indices are the base 10 logarithms for the quantity in cubic meters of air, for the inhalation hazard index, or of water, for the ingestion hazard index, required to dilute the radioactive material to the permissible concentrations shown in Appendix 2.B. These simplified indices provide an overview of the toxicity of wastes based solely on dilution with no allowance for reconcentration or retardation in the environment. Using these bases, fission products (primarily strontium) and transplutonium elements (primarily americium) are the controlling potential hazards in drinking water up to about 350 years and 2×10^4 years, respectively. Radioactivity from plutonium losses during reprocessing then becomes controlling until about 2×10^6 years. Finally, fission product I-129 becomes the controlling factor until about 6×10^7 years when it is supplanted by radioactivity remaining as the result of uranium losses during reprocessing.

The composition and radiation properties of fuel-reprocessing waste are given in detail in Appendices 2.C through 2.G for individual fission product and actinide nuclides for each of the reactor types previously described. These appendices are reproductions of part of the extensive output of the ORIGEN code, a versatile code that solves the equations of radiation growth and decay for large numbers of isotopes.[13]

TABLE 2.7. Characteristics of Solidified High-Level Waste Accumulated to Year 2000[2]

Fiscal Year	Accumulated Quantities							
	Radioactivity (MCi)		Thermal Power (MW)		Weight of Isotopes (Metric Tons)		Volume of Waste (10^3 liters)(c)	Volume of Waste (10^3 ft^3)(c)
	Actinides(a)	Fission Products	Actinides(a)	Fission Products	Actinides(a)	Fission Products(b)		
1972	0.72	153	0.0251	0.712	0.325	2.06	8	0.3
1973	1.36	302	0.0466	1.41	0.801	5.10	16	0.6
1974	3.89	850	0.133	3.95	2.26	14.4	41	1.4
1975	7.88	1,730	0.268	8.05	4.98	31.7	120	3
1976	13.5	2,990	0.458	13.8	9.32	59.3	145	5.1
1977	20.8	4,600	0.698	21.2	15.5	98.9	220	7.8
1978	29.7	6,530	0.990	30.0	23.8	152	319	11.3
1979	39.5	8,650	1.31	39.5	34.1	217	443	15.7
1980	79.3	11,000	2.68	49.9	47.0	296	595	21.
1981	154	14,400	5.26	65.0	64.6	400	791	28
1982	266	18,100	9.14	81.7	86.5	525	1022	36.1
1983	403	21,900	13.8	98.4	112	670	1287	45.5
1984	571	25,200	19.6	113	141	826	1570	55.4
1985	779	29,000	26.7	129	174	1,000	1897	67
1986	929	33,000	31.7	146	210	1,200	2266	80
1987	1,060	37,200	3,519	163	248	1,420	2675	94.5
1988	1,140	42,200	38.6	184	291	1,670	3143	111
1989	1,200	47,600	40.4	207	338	1,950	3670	130
1990	1,220	53,300	40.6	230	398	2,250	4254	150
1991	1,190	58,800	39.3	252	440	2,590	4877	172
1992	1,210	65,500	39.4	280	498	2,960	5568	197
1993	1,240	71,700	39.9	304	560	3,350	6304	223
1994	1,280	78,600	40.7	330	625	3,770	7103	251
1995	1,330	86,500	41.9	360	696	4,220	7975	282
1996	1,390	94,600	43.1	391	770	4,710	8918	315
1997	1,460	105,000	45.0	430	852	5,240	9954	352
1998	1,550	116,000	47.1	470	938	5,810	11073	391
1999	1,650	128,000	49.6	517	1,030	6,430	12296	434
2000	1,770	143,000	52.8	575	1,130(d)	7,120	13656	482

a. It is assumed that 0.5% of the U and Pu in LWR and LMFBR fuels, 0.5% of the U and Th in the HTGR fuel, and 100% of the other actinides in the fuels report to waste.
b. The weight of the fission products includes that of the noble gases.
c. Based on 56.6, 169.9, and 85.0 liter (2, 6, and 3 ft^3) per metric ton of heavy metal for LWR, HTGR, and LMFBR fuels, respectively.
d. Includes 839 MT of U, 71.2 MT of Th, and 52 MT of Pu.
e. Waste volumes based on reprocessing of 181,126 MT of fuel including 119,941 MT of enriched uranium fuel, 8130 MT of Pu recycle fuel, 22,297 MT of HTGR fuel, 4,606 MT of AI-LMFBR fuel and 26,152 MT of GE-LMFBR fuel.
f. Additional bases given in Table 2.8.

TABLE 2.8. Accumulated Reactor Plant Waste to Year 2000, Radioactivity, and Thermal Power

(Based on reprocessing of 167,602 MT irradiated fuel at rated exposure including 117,873 MT of enriched uranium fuel, 7,241 MT of Pu recycle fuel, 16,966 MT of HTGR fuel, 4,319 MT of AI-LMFBR fuel and 21,203 MT of GE-LMFBR fuel; fuel reprocessed after 150 days for LWR, after 90 days for LMFBR, and after 1 year for HTGR reactors; fuel segregated into fractions at year 2000; 0.5% fuel loss to waste. Radioactivity and thermal power of wastes from individual reactor types are presented in Appendices 2.C-2.G.

THERMAL POWER

WATTS FOR WASTE THROUGH YEAR 2000

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
STRONTIUM	9.52E+07	9.13E+07	7.31E+07	7.94E+06	4.13E+02	1.82E-03	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00
CESIUM	1.77E+08	1.53E+08	8.11E+07	9.81E+06	1.00E+03	4.11E+01	4.10E+01	4.02E+01	3.26E+01	4.09E+00	3.88E-09	.00E+00
SR+CS	2.73E+08	2.44E+08	1.54E+08	1.78E+07	1.41E+03	4.11E+01	4.10E+01	4.02E+01	3.26E+01	4.09E+00	3.88E-09	.00E+00
FP-SR-CS	2.96E+08	1.32E+08	7.00E+06	3.40E+05	1.23E+04	2.33E+03	2.07E+03	1.52E+03	1.12E+02	4.72E+00	8.97E-02	1.13E-17
KR85+I129	2.79E+06	2.62E+06	1.47E+06	4.63E+03	5.24E+00	5.24E+00	5.24E+00	5.22E+00	5.03E+00	3.49E+00	8.96E-02	1.13E-17
FISSION PROD.	5.68E+08	3.76E+08	1.61E+08	1.81E+07	1.37E+04	2.37E+03	2.11E+03	1.56E+03	1.45E+02	8.80E+00	8.97E-02	1.13E-17
U+TH WASTE	1.01E+04	1.01E+04	1.00E+04	9.36E+03	8.88E+03	8.86E+03	8.59E+03	6.37E+03	5.62E+02	1.95E+02	7.73E+01	5.76E+01
PU FUEL WASTE	1.19E+07	1.18E+07	1.12E+07	6.18E+06	1.23E+06	9.00E+05	3.62E+05	2.54E+04	4.18E+03	1.63E+03	1.24E+02	2.52E+00
TRANS PU	4.16E+07	3.31E+07	2.28E+07	3.04E+06	1.41E+06	8.13E+05	1.87E+05	2.09E+04	1.10E+04	6.20E+02	1.61E+01	6.30E+00
TOTAL WASTE	6.22E+08	4.20E+08	1.95E+08	2.73E+07	2.66E+06	1.72E+06	5.60E+05	5.42E+04	1.59E+04	2.45E+03	2.18E+02	6.64E+01

RADIOACTIVITY

CURIES FOR TOTAL WASTE THROUGH YEAR 2000
(PARENTS AND DAUGHTERS IN CHAINS ARE INCLUDED IN TOTALS)

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
STRONTIUM	2.64E+10	2.53E+10	2.03E+10	2.21E+09	1.15E+05	5.06E-01	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00
CESIUM	4.46E+10	4.16E+10	2.98E+10	3.70E+09	4.46E+05	8.46E+04	8.44E+04	8.27E+04	6.72E+04	8.41E+03	7.98E-06	.00E+00
SR+CS	7.10E+10	6.70E+10	5.01E+10	5.90E+09	5.60E+05	8.46E+04	8.44E+04	8.27E+04	6.72E+04	8.41E+03	7.98E-06	.00E+00
FP-SR-CS	7.11E+10	3.46E+10	2.44E+09	1.57E+08	9.32E+06	3.59E+06	3.38E+06	2.55E+06	3.80E+05	1.76E+04	1.37E+02	1.71E-14
KR85+I129	1.72E+09	1.61E+09	9.04E+08	2.85E+06	7.96E+03	7.96E+03	7.96E+03	7.93E+03	7.64E+03	5.30E+03	1.36E+02	1.71E-14
FISSION PROD.	1.42E+11	1.02E+11	5.25E+10	6.06E+09	9.88E+06	3.67E+06	3.46E+06	2.63E+06	4.47E+05	2.60E+04	1.37E+02	1.71E-14
U+TH WASTE	7.58E+05	7.65E+05	7.58E+05	5.77E+05	4.47E+05	4.43E+05	4.30E+05	3.22E+05	2.89E+04	9.10E+03	4.75E+03	3.73E+03
PU FUEL WASTE	5.69E+08	5.57E+08	4.63E+08	1.73E+08	1.93E+07	8.52E+06	3.33E+06	1.34E+06	1.19E+05	1.81E+03	4.12E+02	1.53E+02
TRANS PU	1.25E+09	1.02E+09	7.30E+08	1.54E+08	7.44E+07	3.87E+07	6.00E+06	1.13E+06	6.92E+05	3.86E+04	9.55E+02	3.83E+02
TOTAL WASTE	1.44E+11	1.03E+11	5.37E+10	6.39E+09	1.04E+08	5.13E+07	1.32E+07	5.41E+06	1.29E+06	7.55E+04	6.25E+03	4.27E+03

TABLE 2.9. Toxicity Indices of Accumulated Plant Waste to Year 2000

(Based on reprocessing of 167,602 MT irradiated fuel at rated exposure including 117,873 MT of enriched uranium fuel, 7,241 MT of Pu recycle fuel, 16,966 MT of HTGR fuel, 4,319 MT of AI-LMFBR fuel and 21,203 MT of GE-LMFBR fuel; fuel reprocessed after 150 days for LWR, after 90 days for LMFBR, and after 1 year for HTGR reactors; fuel segregated into fractions at year 2000; 0.5% fuel loss to waste.) Toxicity indices of waste from individual reactor types are presented in Appendices 2.C-2.G.

INGESTION TOXICITY

THE INGESTION TOXICITY INDEX IS THE BASE 10 LOGARITHM OF THE CUBIC METERS OF WATER TO DILUTE TO RCG

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
STRONTIUM	16.64	16.63	16.53	15.57	11.28	5.53	*****	*****	*****	*****	*****	*****
CESIUM	15.24	15.18	14.88	13.97	9.99	8.53	8.93	8.92	8.83	7.92	-1.10	*****
SR+CS	16.66	16.64	16.54	15.58	11.30	8.53	8.93	8.92	8.83	7.92	-1.10	*****
FP-SR-CS	15.45	15.11	13.50	12.01	11.21	11.17	11.17	11.16	11.11	10.95	9.36	-6.54
KR85+I129	11.12	11.12	11.12	11.12	11.12	11.12	11.12	11.12	11.11	10.95	9.36	-6.54
FISSION PROD.	16.68	16.65	16.54	15.58	11.36	11.18	11.17	11.16	11.11	10.95	9.36	-6.54
U-TH FUEL WASTE	11.92	11.92	11.92	11.92	11.92	11.92	11.91	11.80	10.77	10.04	10.03	9.97
PU FUEL WASTE	13.84	13.83	13.81	13.55	12.91	12.80	12.73	12.60	11.50	8.40	7.96	7.57
TRANS PU	14.19	14.15	14.01	13.32	13.02	12.77	12.13	11.34	11.09	9.83	8.35	7.96
TOTAL WASTE	16.68	16.66	16.54	15.58	13.30	13.12	12.89	12.69	11.80	11.03	10.12	9.98

***** TOXICITY INDEX IS LESS THAN -10
RCG IS RADIONUCLIDE CONCENTRATION GUIDE BASED UPON 10 CFR 20

INHALATION TOXICITY

THE INHALATION TOXICITY INDEX IS THE BASE 10 LOGARITHM OF THE CUBIC METERS OF AIR TO DILUTE TO RCG

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
STRONTIUM	20.64	20.63	20.53	19.57	15.28	9.93	*****	*****	*****	*****	*****	*****
CESIUM	19.75	19.70	19.48	18.57	14.59	13.45	13.45	13.44	13.35	12.45	3.42	*****
SR+CS	20.69	20.67	20.57	19.61	15.36	13.45	13.45	13.44	13.35	12.45	3.42	*****
FP-SR-CS	20.17	19.86	18.76	17.25	15.70	15.34	15.31	15.22	14.75	14.43	12.83	-3.07
KR85+I129	15.79	15.76	15.53	14.61	14.60	14.60	14.60	14.60	14.58	14.42	12.83	-3.07
FISSION PROD.	20.81	20.74	20.57	19.61	15.87	15.34	15.32	15.23	14.77	14.43	12.83	-3.07
U-TH FUEL WASTE	17.79	17.79	17.79	17.73	17.68	17.68	17.67	17.54	16.39	15.73	15.62	15.51
PU FUEL WASTE	21.69	21.69	21.66	21.36	20.25	19.84	19.47	18.35	17.16	15.37	15.03	14.65
TRANS PU	21.52	21.50	21.37	20.67	20.38	20.17	19.72	18.87	18.49	17.22	15.43	15.05
TOTAL WASTE	21.95	21.93	21.86	21.44	20.62	20.34	19.92	19.00	18.51	17.24	15.90	15.68

***** TOXICITY INDEX IS LESS THAN -10
RCG IS RADIONUCLIDE CONCENTRATION GUIDE BASED UPON 10 CFR 20

REFERENCES

1. Code of Federal Regulations, Appendix F to 10 CFR 50, "Policy Related Waste Management Facilities," U.S. Government Printing Office, Washington, D.C., p. 268, January 1, 1972.

2. J. A. Blomeke, W. C. McKee and J. P. Nichols, Projections of Radioactive Wastes to be Generated by the U.S. Nuclear Power Industry, USAEC Report ORNL-TM-3965, Oak Ridge National Laboratory, Oak Ridge, TN, February 1974.

3. Office of Planning and Analysis, USAEC, The Growth of Nuclear Power, 1972-1985, Report WASH-1139 (Rev. 1), Washington, D.C., December 1971.

4. F. G. Welfare et al., The Oak Ridge Systems Analysis Code (ORSAC) Users' Manual, USAEC Report ORNL-TM-3223, Oak Ridge National Laboratory, Oak Ridge, TN, June 1971.

5. Office of Planning and Analysis, USAEC, Nuclear Power 1973-2000, Report WASH-1139 (72), Washington, D.C., December 1, 1972.

6. Federal Power Commission, The 1970 National Power Survey, Part I, U.S. Government Printing Office, Washington, DC, p. I-1-17, December 1971.

7. Nucleonics Week, January 1970 through July 1972.

8. A. M. Platt, Editor, Quarterly Progress Report, Research and Development Activities, Waste Fixation Program, July through November 1972, USAEC Report BNWL-1699, Battelle, Pacific Northwest Laboratory, Richland WA, p. 9.

9. J. L. McElroy et al., Waste Solidification Program Summary Report, Volume II, Evaluation of WSEP High Level Waste Solidification Processes, USAEC Report BNWL-1667, Battelle, Pacific Northwest Laboratory, Richland, WA, July 1972.

10. L. T. Lakey et al., ICPP Waste Calcining Facility Safety Analysis Report, USAEC Report LDO-14620, December 1963.

11. K. J. Schneider, "Radioactive Waste from Nuclear Power in the U.S.A.," presented at the AIME Environmental Quality Conference, Washington, DC, June 7-9, 1971.

12. G. Jansen, Personal Communication (Letter, Summaries of Reactor Wastes for AWMM Program Report) Battelle, Pacific Northwest Laboratory, Richland, WA, March 5, 1973.

13. M. J. Bell, ORIGEN - The ORNL Isotope Generation and Depletion Code, USAEC Report, ORNL-4628, Oak Ridge National Laboratory, Oak Ridge, TN, May 1973.

14. Code of Federal Regulations, 10 CFR 71, "Packaging of Radioactive Material for Transport," U.S. Government Printing Office, Washington, DC, p. 300, January 1, 1972.

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3.0 EVALUATION METHODOLOGY

Background

The management of high-level waste is a complex problem. Man's decision in this matter can impact not only the environment of his own generation but also that of thousands of generations in the future. A number of concepts have been proposed for disposal and control of this waste. These vary from relatively simple processes such as pouring the waste into a hole in the ground to very advanced techniques such as rocketing the waste out of the solar system.

The detailed analyses of even the simplest sounding of concepts are frequently as complex as those for the more advanced systems, particularly in the conceptual stage. Before an evaluation can be made, a description of the concept is required which includes, in many cases, a description of a generic site. Some of the concepts may present the potential capability to handle a broad range of waste as generated, whereas other concepts require special treatment or handling such as a waste solidification step, special waste partitioning, or extended interim storage.

With the large number of disposal concepts to be considered, each requiring a substantial research and development effort, some order of priority must be established so that those concepts with the greatest potential for solving the problem can be addressed first. To establish the methodology for such an overall evaluation, the following elements have been considered.

- Technical Feasibility
- Safety
- Research and Development Requirements
- Timing
- Costs
- Policy
- Environmental Considerations
- Public Attitudes

With the outcome of each of these elements being described in completely different units, obviously, simply adding up the performance level by element would not lead to the best concept selection. Instead, the technique being developed is one of overcoming the performance hurdles of those listed. For instance, the technical feasibility hurdle (the hurdle examined first) would be of the "yes-no" type, where "yes" is required before analysis of other requirements would be undertaken. In this study, the only hurdle used for rejection of potential concepts is that of technical feasibility. (Only a few concepts were rejected; i.e., some transmutation and space disposal variations.) Information on the other factors was developed for the technically feasible concepts and is presented in this report, but has not been used for any ranking of concepts. The ordering of the performance hurdles has not been developed in this study.

Figure 3.1 graphically illustrates the relationship between elements for this study.

The waste management concepts are first developed to the detail needed to describe them for overall evaluations, and in general were studied on a systematic, generic basis. Concepts were generally developed on the reference basis of having the capability to handle the waste from a plant which reprocesses 5 metric tons/day (1825 MT/yr) of spent nuclear fuel. This reference capacity need was then scaled up as a function of time to accommodate the total need for the U.S. nuclear economy through the year 2000.

Once the technical feasibility of a concept was established, the technology needs were assessed, and research and development needs (scope, time, and dollars) were estimated. Although not done in this study, final analyses could reject concepts whose research and development budget would represent a significant fraction of the potential benefits in nuclear power, or whose research and development time requirements may be excessive. From the research and development time needs, the total time for implementation of each concept on a routine basis was estimated.

An overview was performed of system safety for each concept. A sample quantitative safety analysis was performed for one generic type of geologic disposal concept to develop and test the safety analysis methodology. For total safety analysis, detailed and quantitative studies would be needed. The absolute risk of a selected alternative must be acceptably low. An analysis of system cost was made for each concept. In a final analysis, a priority order for research would be

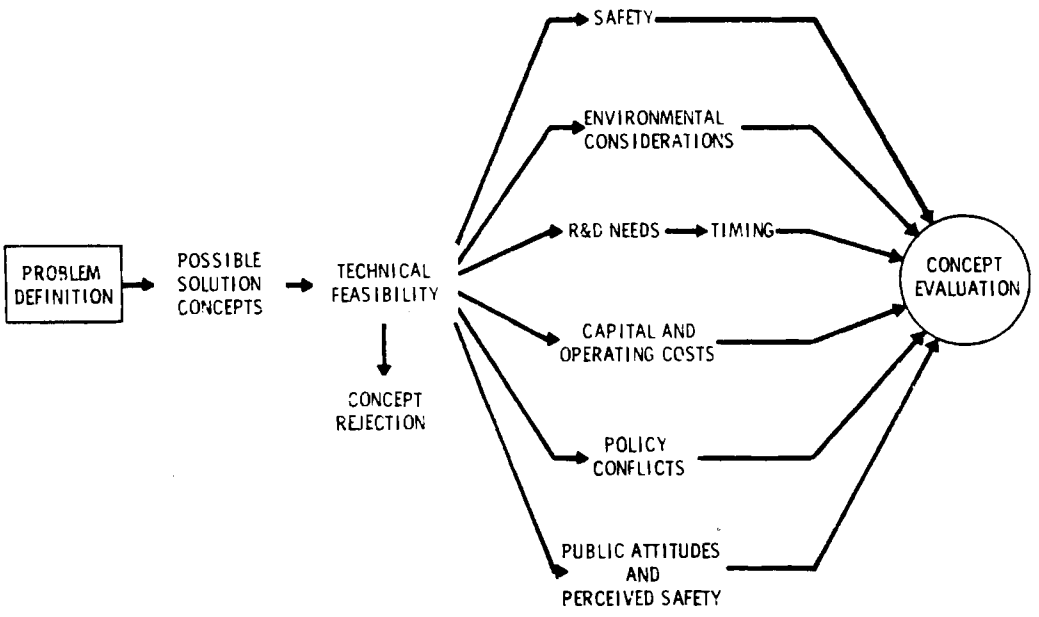


FIGURE 3.1. Relationships Among Evaluation Factors

established for those systems with lowest cost which meet the safety and other requirements. In the context of these studies, such costs were only important if they would result in major changes in the nuclear fuel cycle and hence alter the nuclear waste management system.

As is discussed in the cost analysis (Section 3.2), societal costs (such as occupational disability payments) have not been included. Eventually these costs should be calculated for the entire nuclear fuel cycle and all other energy alternatives.

Implementation of some of the concepts being considered would conflict with present policies--such as disposal of radioactive materials in the ocean. This policy and similar policies which are either parts of the Federal Code of Regulations or international agreements are identified so that the problems involved with changing such policies can be balanced against the safety and economic potentials of a particular waste management concept. The environmental considerations, aside from the potential release of radioactive materials, are not expected to control concept selection but will be important factors in detailed site selection. General considerations such as land area or water used are listed for evaluation.

The final area for evaluation is the public attitude toward a given waste management scheme. Obviously, this is a complicated subject and most difficult to evaluate. An initial study of methodology was designed to identify those aspects of the waste management program that might be deemed most important by the general public. With future analysis-in-depth, the information on public attitudes could be factored into concept design. Eventually public information programs could utilize the same data. In the final analysis, the public's acceptance of a technically sound waste management system is an important goal.

The objective of this study is to develop information on and methodology to evaluate technical feasibility, research and development requirements, timing, safety, and costs of various waste disposal alternatives. Each of these items is addressed in more detail in the latter sections of this report. The specific contributions to the overall evaluation are the following.

Technical Feasibility

Each alternative for waste management is analyzed on the basis of its technical feasibility and the current status of technology. This analysis is based on four primary considerations. The first level of assessment considers the feasibility of the method's confining or eliminating the waste over the required time period in light of presently available data. The second assessment considers the feasibility of implementing the method with today's technology. The third assessment considers the theoretical potential of implementing the disposal method with technology which is believed to be capable of development. The fourth considers the energy balance involved in the process (i.e., any system which requires more energy to dispose of the fission products

than was generated in the original fission event is clearly eliminated). This factor as well as the next two are discussed in detail under each concept, but not in this section.

Research and Development Requirements

The major deficiencies in technology or problem areas identified under Technical Feasibility which must be solved by research and development are analyzed. The scope of the research and development needs is developed and estimates are made of the time period and the research and development expenditure needs.

Timing

The purpose of this element is the identification of the earliest reasonable date when a given alternative could be in operation. This estimate cannot be exact: therefore, a time range is typically given.

Costs

The levelized capital and operating costs of the waste management alternatives are estimated and summed. The costs of any waste partitioning or other processing requirements, shipping, and interim storage requirements are included in the waste management system cost. For this purpose, an existing computer model has been modified which will calculate the cost of each of the concepts.

Policy Conflicts

Potential conflicts with existing international or national policies are listed. Any aspect of a waste management option which is in conflict with existing policy was not considered a constraint in the development of waste management concepts. Only after the incentives to change policy are established can change be considered.

The remaining elements for overall evaluation are dealt with in a manner which is less result-oriented, but rather with the emphasis placed primarily on methodology to be applied for more detailed concept evaluations and comparisons at a later time. A summary of the objectives and technical approach for each of the remaining evaluation elements follows.

Safety

Features of each concept which relate to its safe use are identified and cursorily assessed. A committee of national experts of safety analysis and public attitudes was convened to review study methodology. This committee advised on the techniques to be used, the data sources, and the data to be developed to allow the calculation of the risk to the populace of each alternative. A summary of the committee meetings and its recommendations are presented in Appendix A. The methodology developed is that of calculating on a probabilistic basis the risk in terms of radiation dose to man using analyses of failure modes and pathways of radionuclides into and through man's environment to man.

Environmental Considerations

The unusual nonradiological effects of each concept on the environment is assessed briefly. Data are developed on such effects as land use, water use, and effects on biota. These data are assembled in a summary format similar to the one used for the environmental statements for

nuclear reactors. The impact of radionuclide releases is covered under the safety element.

Public Attitudes

The safety-public attitude committee described above included experts in social psychology. These experts identified elements of the concepts which it believed would be of major concern to the public. A preliminary in-house test survey was conducted using a video tape describing the waste management options to test the methodology.

3.1 SAFETY

The management of nuclear wastes requires isolation and/or containment until the waste, through radioactive decay, becomes stable and less hazardous. The time required for this process ranges from thousands to perhaps millions of years. Thus, the safety of waste management concepts must be evaluated in a geological time frame. Structures have been constructed by man which have lasted thousands of years but never hundreds of thousands. The probability of climate change, change in the flow of rivers, and even meteorite impact must be considered.

Evaluation of the methods for maintaining isolation from the world population for such a period of time can be best handled on a probabilistic basis. The potential failure of a waste management system is measured in terms of the potential release of radioactive material to the human environment. Such releases could ultimately result in radiation exposure to the then existing population.

Figure 3.2 illustrates the interrelationship between the waste disposal concept, the failure mode and probability and the potential dose to people in the immediate region of release if failure occurs. The definition of each concept implies a generic site, for example, ice sheet

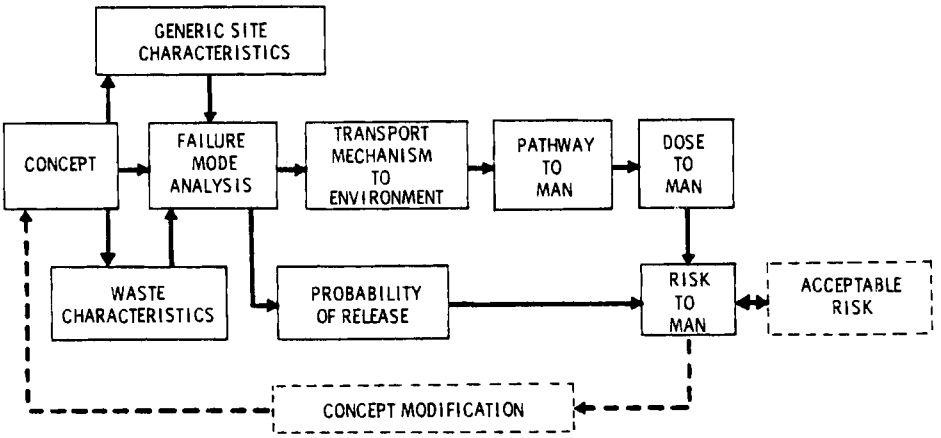


FIGURE 3.2. Interrelationships Among Pathway, Probability and Risk

disposal, and defines the location, surrounding geology, and population density. The characteristics of the waste must be defined to allow quantification of system failures. The next step required in the evaluation process is the preparation of a complete fault tree analysis which will have two outcomes--one to describe the most likely sequence of failure events leading to release of radioactive materials to man's environment, and the second to provide the probability of these sequences taking place. The next step follows the most likely sequences through the physical and chemical processes required to release the waste constituents into man's environment. The generic site defines the media (salt, shale, granite, air, water, etc.) through which radionuclides must move. Finally, based on the population as indicated by the generic site and the calculated release rate, the dose to the surrounding population can be estimated. By multiplying the probability of the event taking place times the cost if it takes place, the probabilistic risk to man can be determined. By comparing each of these doses with safety criteria (not developed in this study), it can be determined whether or not the risk to man exceeds acceptable criteria. If the risk level is unacceptably high, the concept could be rejected or changes could be made in the concept to improve the level of risk. If the risk for a concept meets all criteria, the concept would be considered to have met the safety requirements. Of course, concepts in which the risk is substantially lower than the measurement criteria would be rated as most favorable.

Development of suitable safety criteria are most important in a final evaluation of waste management practices. Development of such criteria were beyond the scope of this study, but the following three basic criteria for safety evaluation are proposed as representative of major safety criteria:

(1) On a probabilistic basis, the risk to the world population should represent only a minor increase in the total risk presently assumed by the operation of nuclear power plants. For example, if an annual integrated dose of 50 man-rem exposure from chronic release is experienced from the average power plant, the dose contribution from probabilistic releases from the annual waste production of the plant should preferably be no more than a fraction of the chronic release from the plant.

(2) The risk to man may exist substantially longer than the use of fission reactors as a power source. Thus, a comparison with other involuntary risks with small or zero benefit is also required. For example, being struck by lightning or being hit by a falling aircraft are involuntary risks with little benefit to those exposed to the risk. Such risks result in about one death per million population per year. Comparison of risk from waste management would require conversion of radiation dose to deaths to establish a criterion. Several such conversions have been postulated but remain controversial.

(3) A third criterion would deal with the immediate effects near the point of release. It would require that the dose to population in the immediate area not present the population any serious immediate risks. This may allow, however, that some protective reaction from a release of waste constituents be implemented; for example the population in the affected area might be evacuated or restricted, or the water supplies may be relocated, etc. It is assumed that evacuation may be required if the exposure received by the population exceeded some maximum individual dose rate which could not be decreased through curtailed operation.

The basic problem with this analytical technique is that the values used to describe probabilities of fault tree events, the actual rates of movement through the media to release, and even the population distribution around the release from a plant 10,000 years in the future are obviously in question. Probability distributions are attempted for assignment to some of the numbers used in this analysis. It is believed that this numerical evaluation will result in the probability of release being unacceptably high for a small fraction of the conditions. However, the quantitative analysis will determine the information needed to better refine our knowledge of the safety.

The next two sections of this report describe methodology development for failure mode analysis (fault tree) and population dose calculations with sample application to one of the many waste management options.

3.1.1 Failure Mode Analysis

Assessment of the safety of each waste disposal concept requires a knowledge of the potential for release of waste constituents to man's environment and mechanisms of release probabilities and pathways through the environment which can result in radiological exposure to man. Failure mode analysis discussed in this section is a tool for identifying the release mechanisms and providing for estimating the probabilities of their occurrence. Section 3.1.3 discusses the methods for evaluating consequences of these releases by evaluating possible exposure pathways to man.

Many techniques exist for identifying mechanisms for release of radionuclides and their associated probabilities of occurrence. These range from intuition to sophisticated analytical techniques. This section discusses the methods for identifying release mechanisms and then determines those techniques which have greatest application to assessing the safety of waste disposal concepts.

To be shown workable, an analytical method must be applied to some actual cases. The following subsections explain the method used in this study and then apply it to a hypothetical geologic disposal concept. The depth of the analysis is detailed enough to show any potential limitations of the method. At the same time, the analysis is preliminary and highly qualitative, and the results should not be used to draw quantitative conclusions. To fully determine the relative risk to the environs of a given disposal concept would require

more detailed study, including iteration with concept design.

3.1.1.1 General Rationale for Failure Mode Analysis

The development of even a preliminary failure analysis requires several preparatory steps. The first step is to identify hazardous conditions inherent within a system and determine the significance of any potential accidents. This is frequently called a Preliminary Hazards Analysis. This analysis 1) identifies potential safety problems and provides methods to cope with them, 2) outlines undefined areas requiring guidance or review, and 3) describes technical risks or problems in design. This information is generally summarized for each generic waste disposal concept in later sections of this report.

The information derived from this safety analysis of potential hazards can be used as a basis in more powerful tools for analysis which both identify and quantify system failures both in terms of effects and probability of occurrence. The Failure Modes and Effects Analysis,[1] the Decision Tree,[2] and the Top Level Fault Tree[3] all fall in this class of tools for analysis. In this section, a preliminary Top Level Fault Tree is used for each generic class of concepts to show the interaction of various possible component failures required for a release to occur.

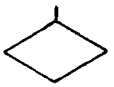
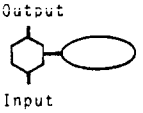
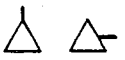
3.1.1.2 Fault Tree Analysis Methodology

The fault tree analysis technique was developed in the 1960's in the aerospace industry to identify design deficiencies before actual space flight of the equipment. Basically the procedure is to assume a failure and work backwards to identify component failures which could cause or contribute to the failure. The terminology and symbolism used to describe this progression back to a component is shown in Table 3.1.

A fault tree should be related to individual components for which failure data are available. For instance, in an electronic circuit the basic failure might occur in a resistor. In practice, fault trees seldom are developed to that degree. What occurs instead is development of fault trees in terms of basic system modules. Using the electronic example, one would carry the possible failure back through the fault tree only to the amplifier which contained the resistor. Such a fault tree is called a Top Level Fault Tree since it usually identifies only large systems which could result in a failure.

The methodology used in fault tree analysis applied to waste management involves postulation of a release of waste materials and then examination of the series of component failures which must have occurred to cause the release. This form of inductive reasoning is thought to be much more inclusive than beginning with an initiating event and working toward a release, (i.e., constructing accident scenarios). At the same time, quantification of the release requires specifications of an ordered sequence of failures or accident scenarios. In this analysis, a fault tree is

TABLE 3.1. Fault Tree Symbolism

Symbol	Meaning and Use
	"AND" logic gate. The simultaneous occurrence of inputs is required to cause an output.
	"OR" logic gate. The occurrence of any one of the inputs will result in an output.
	Fault event that results from the logical operation of two or more fault events. It is always the output from a logic gate.
	Basic fault event. It requires no further development. Data regarding frequency and mode of failure can be derived empirically.
	Inferred fault event. Any failure except a primary failure which is not developed further due to lack of information, time or money or due to the low probability of occurrence. It can also be used where other analyses give sufficient information to indicate that further analysis would be redundant.
	Inhibit gate. The condition specified in the oval is required for an input fault event to result in an output event. This condition is frequently a design limit which will not transmit a failure until the design limits have been exceeded.
	Transfer symbol denoting that failure also impacts on other branches of fault tree. A line at the apex of the triangle represents a "transfer in." A line in the side represents a "transfer out." A number is placed in the triangle to identify transfer locations.

used as the basis for estimating the total release probability from the system of interest. Then the fault tree is broken down into all the possible failure sequences which contribute to the release. In effect, all the accident scenarios will be obtained from the fault tree. Since the inductive processes, such as fault tree analysis, in theory allow for a more thorough analysis of failure probabilities, it follows that the accident scenarios obtained from a fault tree should be more complete than the alternative method of trying to imagine all the accident scenarios. Thus in this analysis the fault tree will be used to obtain a list of failure sequences or scenarios and will be the basis for estimating a probability of release from each failure sequence in the fault tree. The probability must then be combined with the consequences of a release to calculate the risk for a particular failure sequence.

In this section, a generic geologic disposal fault tree is developed. The availability of information to permit analysis of the fault tree is assessed. The methodology is described by developing one path through the fault tree in detail.

3.1.1.3 Use of Fault Tree Analysis for Evaluating Waste Disposal Concepts

The application of the fault tree analysis to evaluate the safety of waste disposal concepts will be divided into four sections. The first section will present the generic fault tree for the geologic disposal concepts. This will be followed by a section discussing the availability of data for the basic failure events in the fault tree. Then using these preliminary data, one branch in the tree will be analyzed to show how the basic failure events must interact to result in a release of waste constituents. These three sections are required in any evaluation. The fourth section will be an identification of basic failure events which have been identified for other disposal concepts such as seabed, ice, and extra-terrestrial disposal.

3.1.1.4 Generalized Geologic Disposal Fault Tree

The generalized geologic fault tree is shown in Figures 3.3 through 3.10. Any continuation (transfer) of failure modes which are not on the figure being described have a figure reference number below the triangle to show where further development of that branch can be found.

Figure 3.3 shows the top of the fault tree. Any failure sequence must pass through these top events. On the left side of the tree are found the segments which relate to

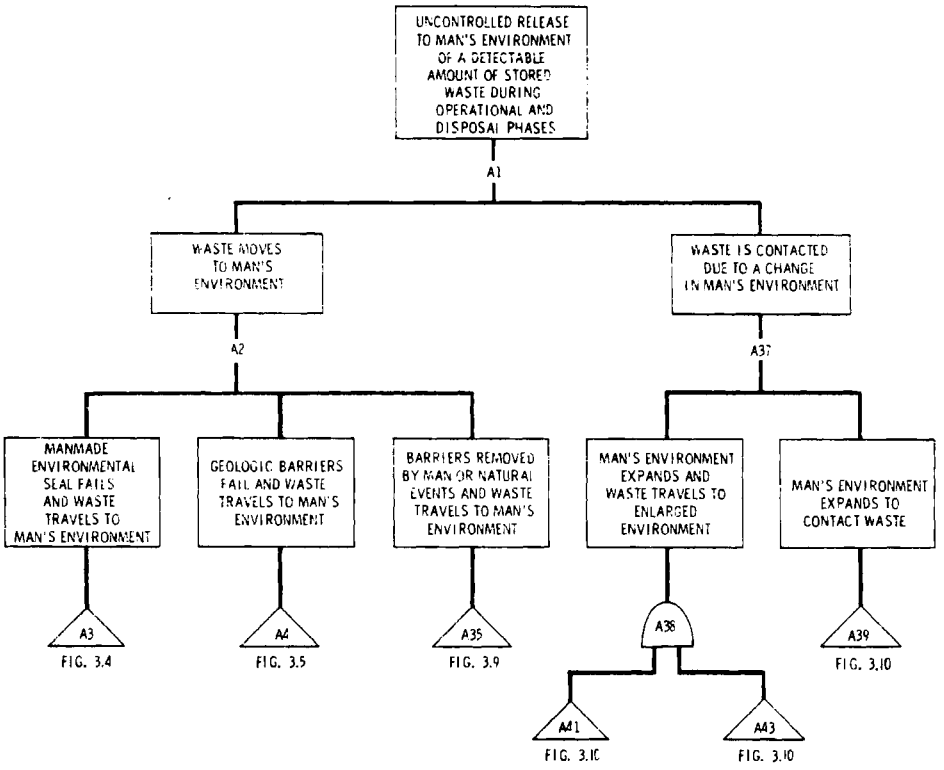


FIGURE 3.3. Geologic Disposal Fault Tree

the waste moving to man's present environment. On the right, man's environment expands and contacts the waste. Three basic modes for waste to move to man's present environment are shown. The first, denoted by A3, is initiated by a seal failure which allows migration if forces exist to move the waste. The second, A4, is initiated by a failure of the geologic barriers separating the waste from man's environment. Once again, forces must exist for the waste to move through the ruptured barrier. The final method envisioned for the waste to be released is a physical removal of natural or manmade barriers. On the right hand side of the diagram, the waste is contacted due to a change in man's environment in only two ways. The first is the case where man's environment expands to contact the waste. The other is a combination of waste migration and man's environment expanding to contact the waste which has moved to a new location.

In Figure 3.4 is shown the fault tree sequence for the seal failure. Below the top event on this page are two failures which must occur simultaneously to result in a release. The seal has to fail and active transport mechanisms must exist to induce flow through the failed shaft. The first failure element is developed on Figure 3.4 of the fault tree and the second failure element is developed on Figure 3.6.

Release by rupture of the shaft seal requires two conditions to exist. As shown on Figure 3.4, the shaft seal must be ruptured and the rupture must be either not detected or improperly repaired. The other branch in the shaft seal failure considers the possibility that the shaft was never properly closed. Below these failure events, the basic failure events for which data should be obtainable are shown. Figure 3.5 develops the fault tree for geologic barrier failure. Basically the barrier is envisioned to fail by three modes. It can fail from stresses above the design envelope envisioned for the disposal concept. It can fail as a result of an undected flaw, or for those concepts using a cavity, the cavity could collapse from a physical instability. In each case, forces to induce migration of waste must exist.

Those failures which are the result of stresses beyond the design envelope include barrier failures which are the result of testing or monitoring followed by improper sealing of the test holes. Also included are the large natural forces and also cavity pressurization. The geologic failure from stresses within design limits considers the possibility of an undetected flaw and also any unexpected natural deterioration of the barrier. The flaw could exist from tests on barrier integrity, the tests might not detect the flaw, or the barrier could lose its integrity if water enters the region. It is envisioned that the barrier might contain soluble minerals which dissolve if water enters the region from a climatic change.

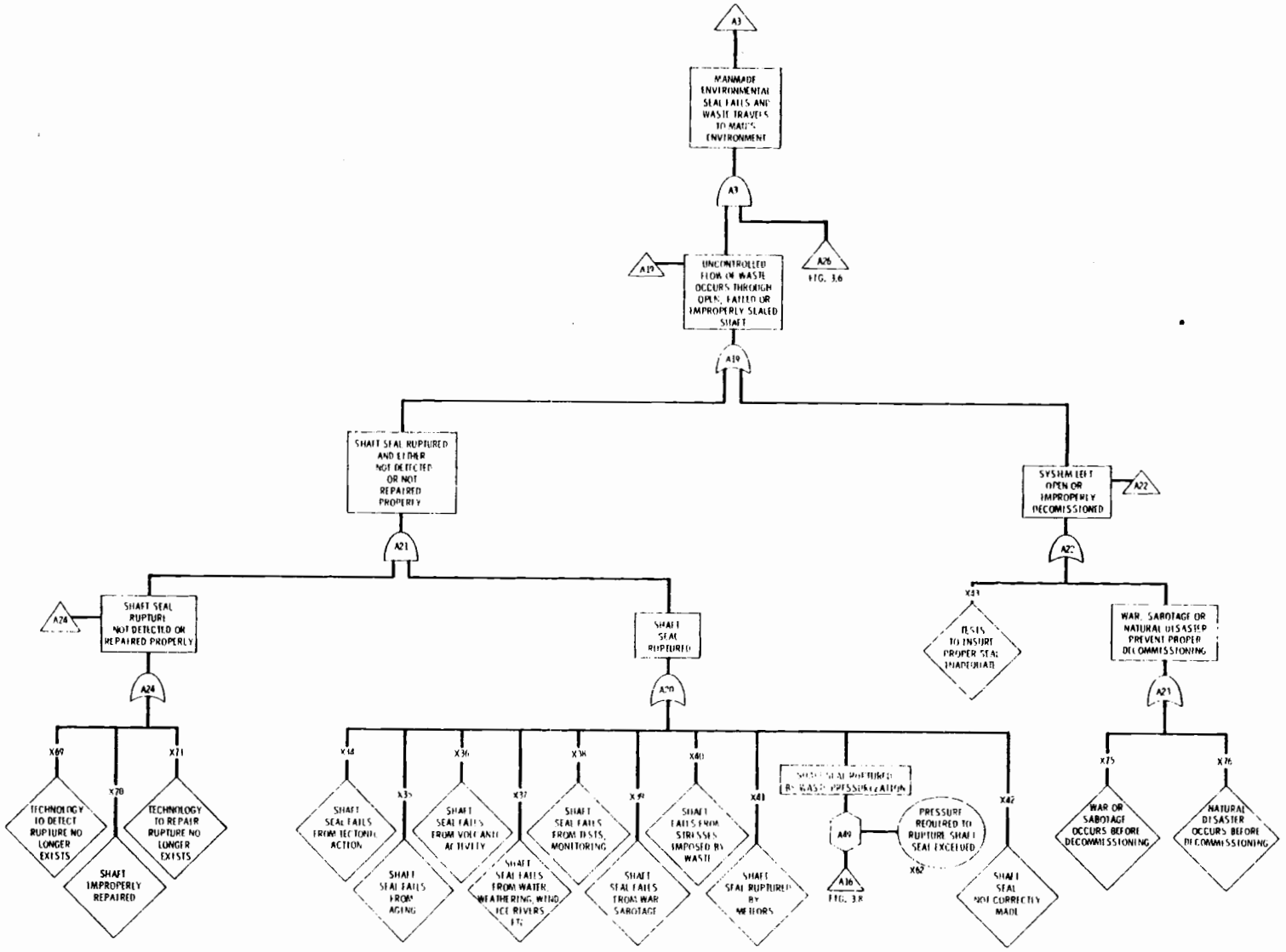


FIGURE 3.4. Geologic Disposal Fault Tree (Cont'd)

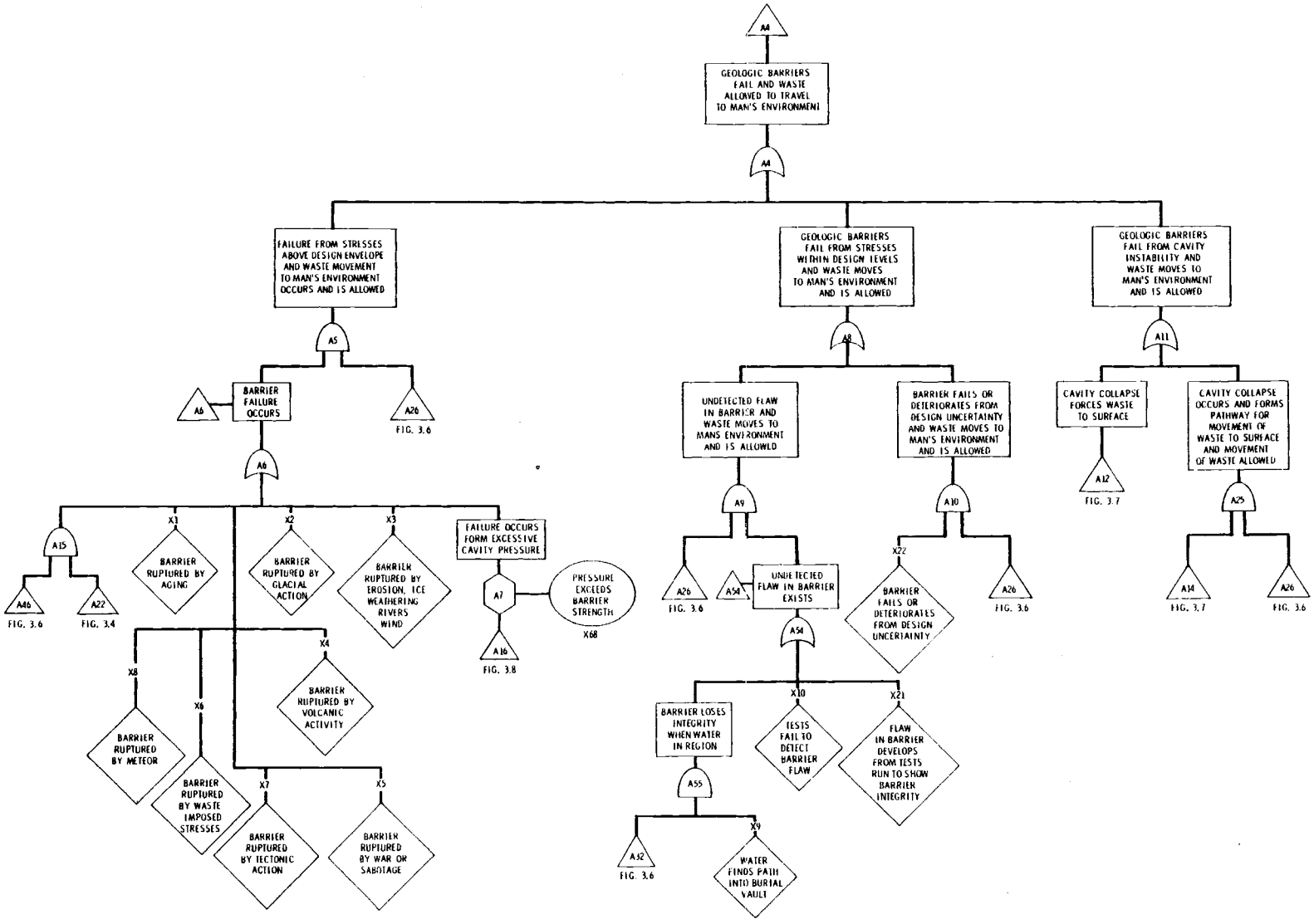


FIGURE 3.5. Geologic Disposal Fault Tree (Cont'd)

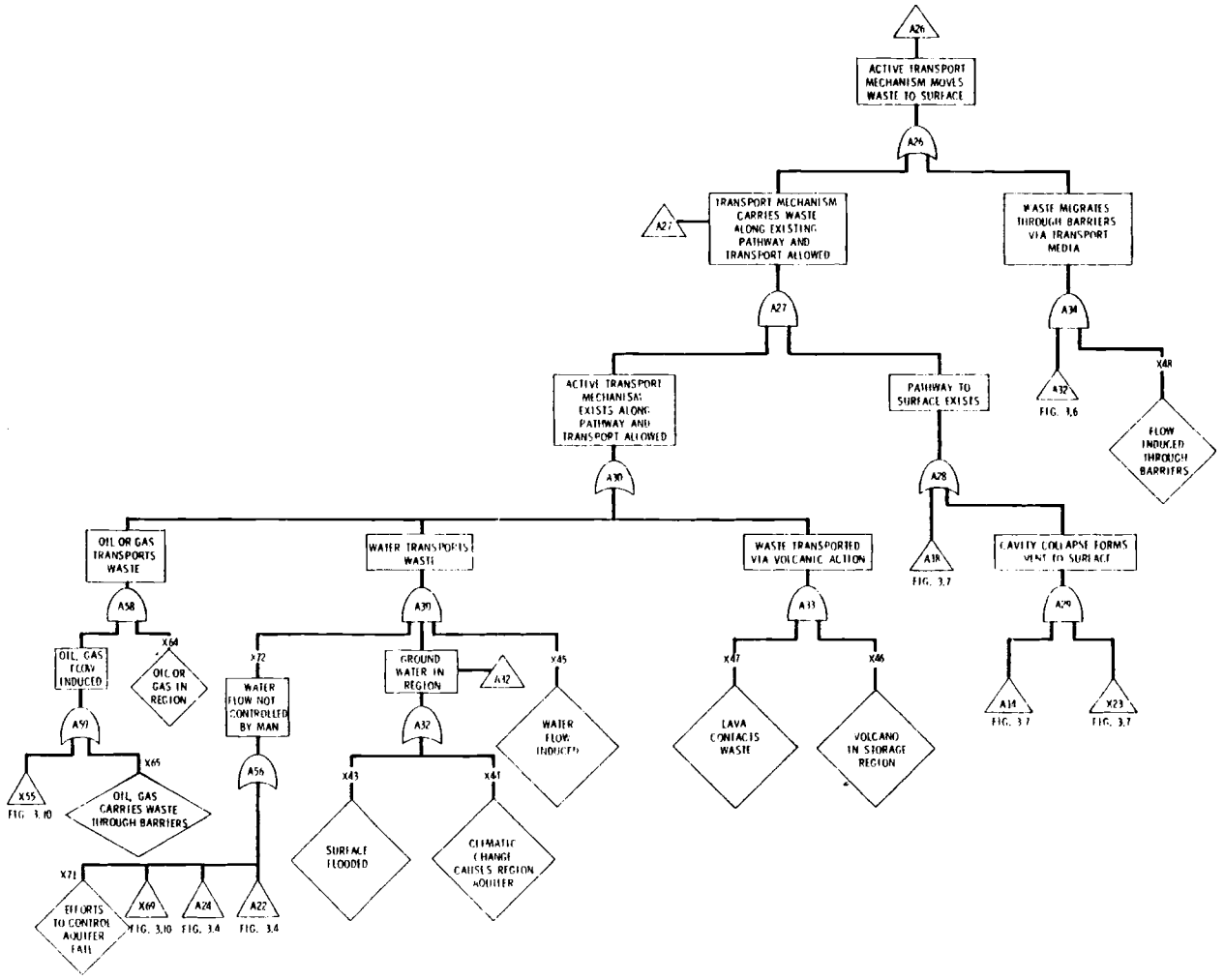


FIGURE 3.6. Geologic Disposal Fault Tree (Cont'd)

The cavity failure branch of the fault tree is divided into two segments. The cavity can collapse and force waste to the surface or the cavity collapse can occur and form a pathway for subsequent waste movement to the surface. These two failures transfer into other parts of the fault tree.

Figure 3.6 develops migration of the waste via an active transport mechanism. In one case, the waste is transported through the existing barriers, which are considered to be slightly permeable. In the other case, the waste is transported through an existing pathway. The transport media considered are oil, water, and molten rock through volcanos. Oil refers to the naturally occurring hydrocarbons found in geologic formations.

Figure 3.7 develops the cavity collapse failure events. These are differentiated from the barrier failure in the fault tree. The mining of material from a geologic formation can cause physical stresses over and above those naturally present in the geologic formation. The cavity collapse branch considers the stresses imposed by the existence of a cavity. The failure events are quite similar to those considered for barrier failure and shaft seal failure.

Figure 3.8 looks at the ways in which the waste environment can become pressurized. If the waste is molten, no other media are required for waste to move to the surface if sufficient pressurization exists.

Figure 3.9 looks at the ways the barrier might be stripped off the storage vault. Figure 3.10 looks at the ways man's environment might expand into the waste.

3.1.1.5 Data Availability for Basic Failure Events in the Fault Tree

The past section has identified 77 basic failure events which could interact to release waste from its geologic disposal location. This section will look at the availability of failure rate data for these events both now, in 1000 years and in 1,000,000 years.

Table 3.2 gives a listing of the 77 basic failure events. The following paragraphs will look at each element and address the following questions: Is it possible to predict failure thresholds either through analysis or testing? Is it possible to develop a good data base for predicting the frequency of the event? Is the failure of that element of potential importance relative to safety?

In some cases, the basic failure elements can produce a common system failure mode such as a barrier failure or a cavity collapse. An attempt will be made to discuss such related failure elements as a group.

Barrier Failure Occurs (Failure Elements 1 through 8)

Eight basic failure elements and two secondary failure events are postulated to cause barrier failure. The eight basic failure elements are barrier failure by aging, glacial action, erosion by ice, wind, rivers, volcanic activity, war or sabotage.

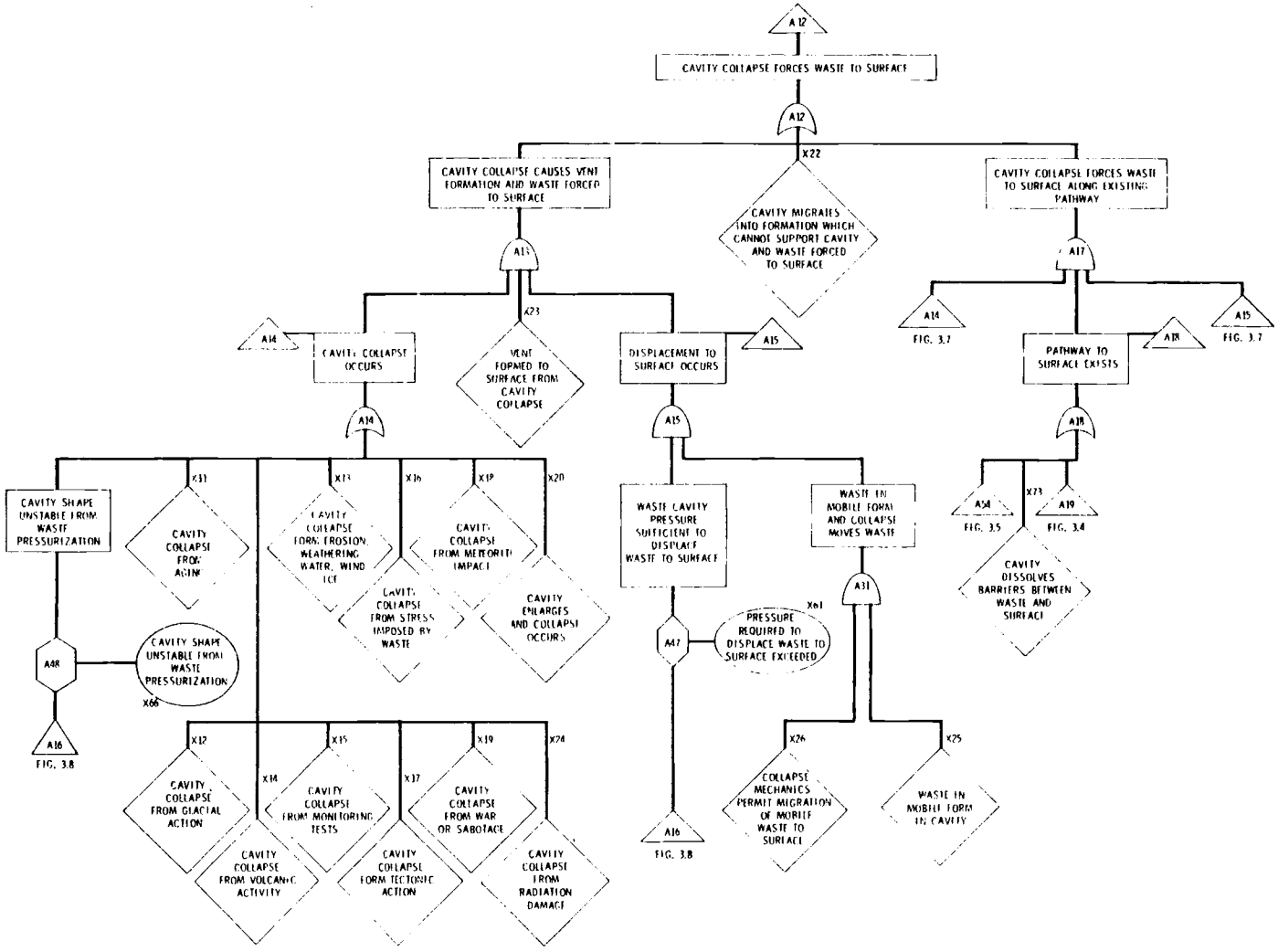


FIGURE 3.7. Geologic Disposal Fault Tree (Cont'd)

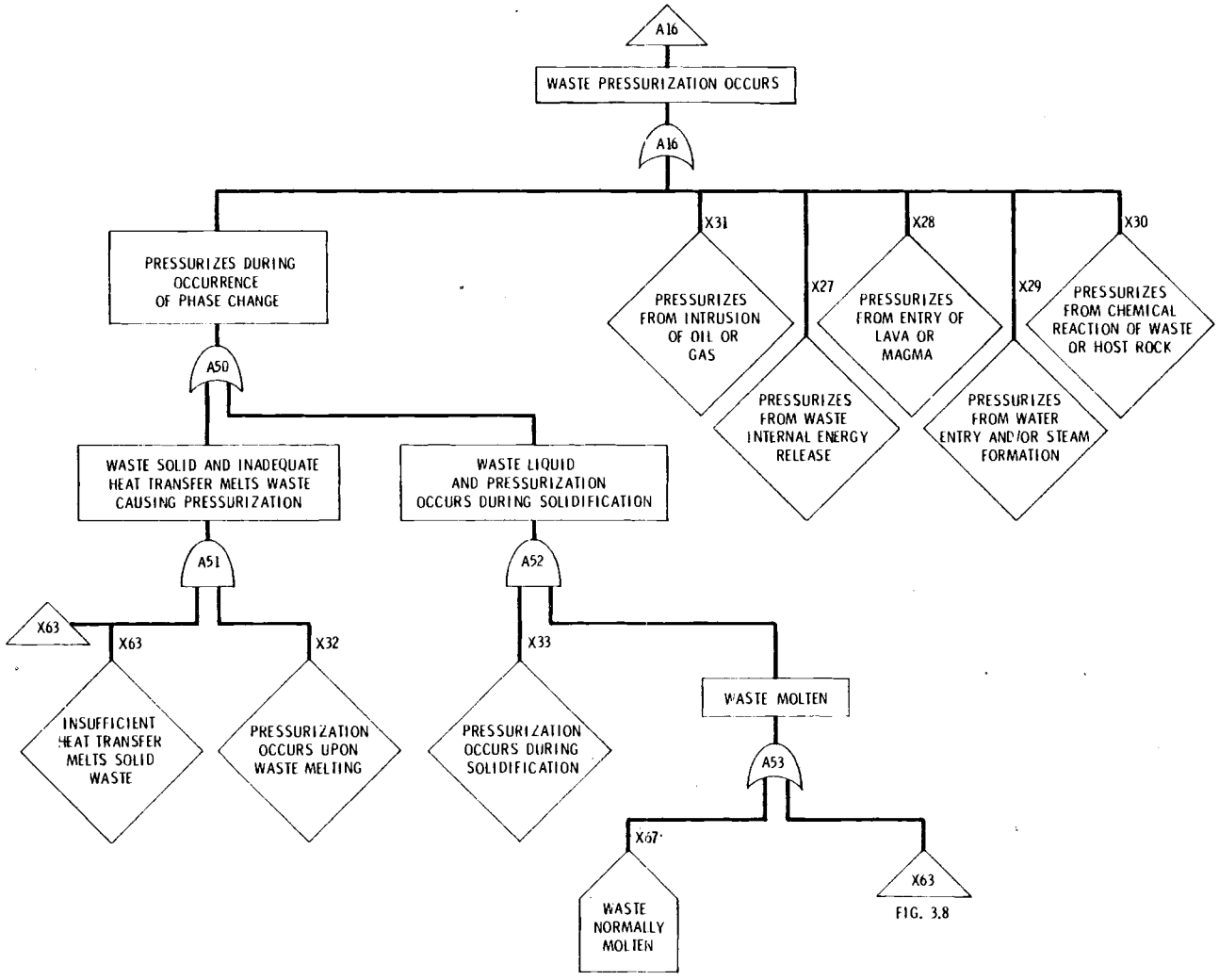


FIG. 3.8

FIGURE 3.8. Geologic Disposal Fault Tree (Cont'd)

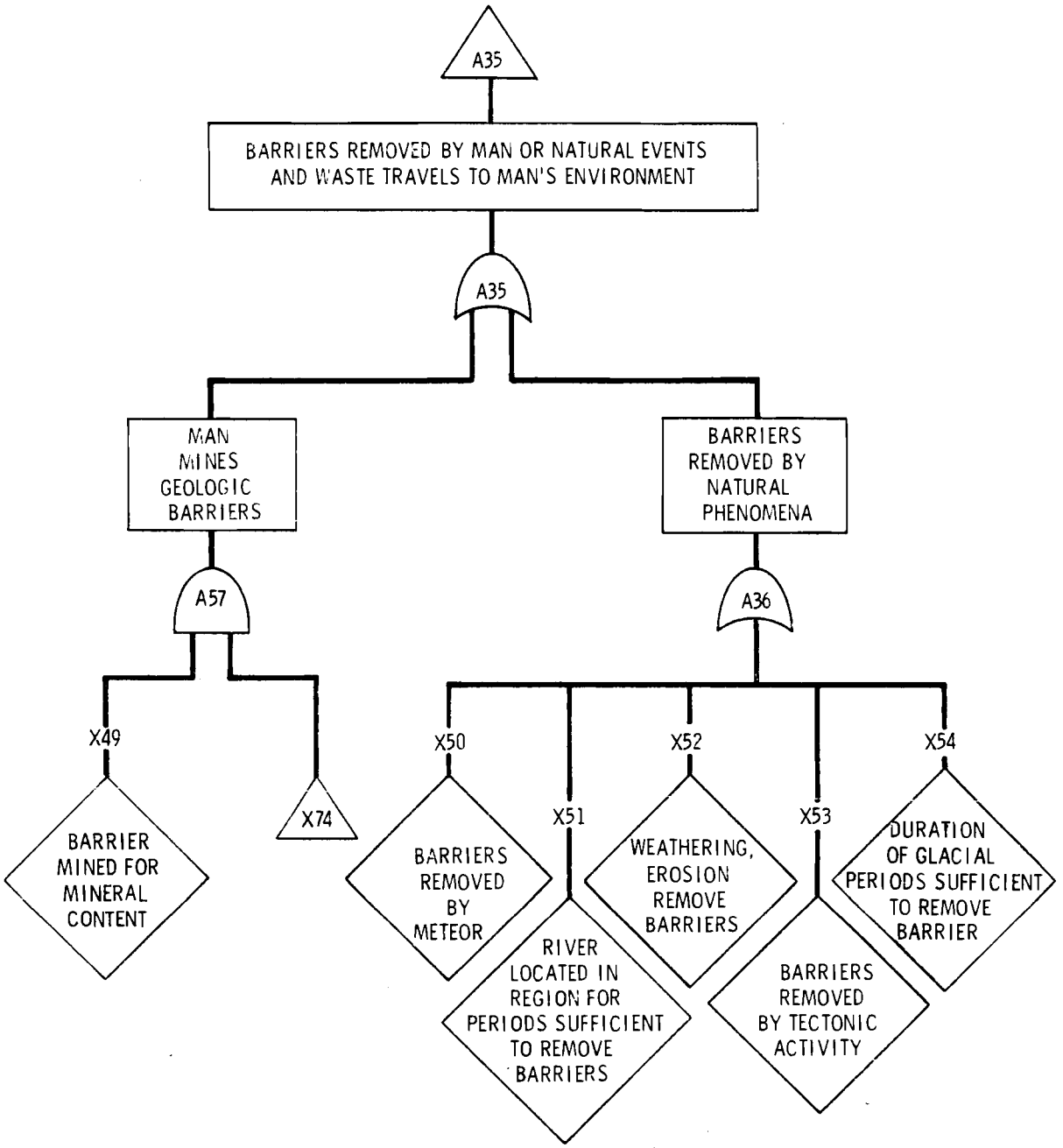


FIGURE 3.9. Geologic Disposal Fault Tree (Cont'd)

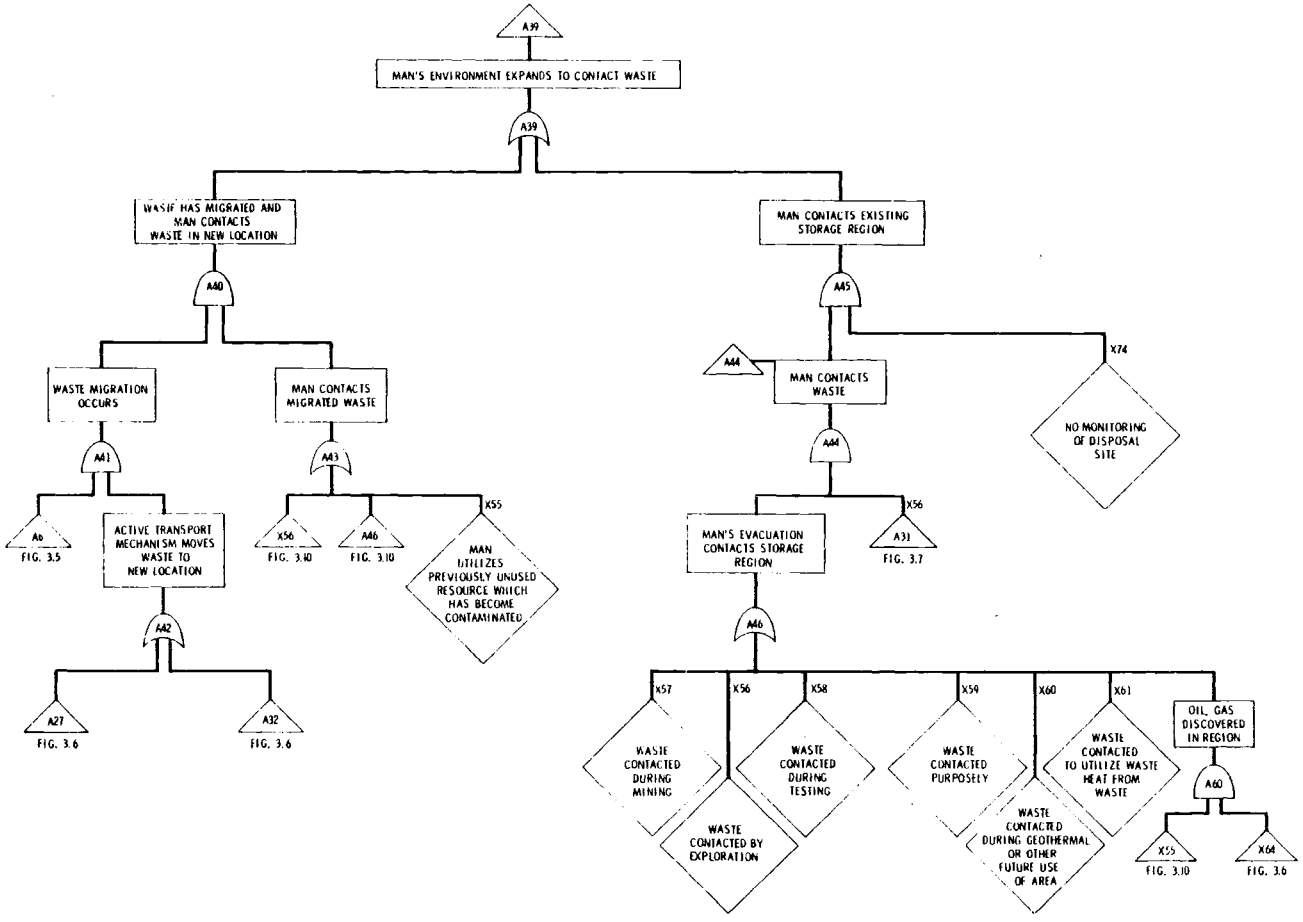


FIGURE 3.10. Geologic Disposal Fault Tree (Cont'd)

TABLE 3.2. Basic Geologic Disposal Failure Events Identified by Fault Tree Analysis

Failure Event No.	Description of Failure Element
1	Barrier Ruptured by Aging
2	Barrier Ruptured by Glacial Action
3	Barrier Ruptured by Erosion from Ice, Wind, Weathering, Rivers, etc.
4	Barrier Ruptured by Volcanic Activity
5	Barrier Ruptured by War, Sabotage
6	Barrier Ruptured by Waste-Imposed Stresses
7	Barrier Ruptured by Tectonic Activity
8	Barrier Ruptured by Meteor
9	Water Finds Path into Burial Vault
10	Barrier Contains Undetected Flaw
11	Cavity Collapse from Aging
12	Cavity Collapse from Glacial Action During Ice Ages
13	Cavity Collapse from Erosion, Weathering, Wind, Water, Ice
14	Cavity Collapse from Volcanic Activity
15	Cavity Collapse from Monitoring, Tests
16	Cavity Collapse from Stress Imposed by Waste
17	Cavity Collapse from Tectonic Action
18	Cavity Collapse from Meteorite Impact
19	Cavity Collapse from War or Sabotage
20	Cavity Enlarges and Collapse Occurs
21	Flaw in Barrier Develops from Tests To Snow Barrier Integrity
22	Cavity Migrates into Formation Which Cannot Support Cavity and Waste Forced to Surface
23	Vent Formed to Surface from Cavity Collapse
24	Cavity Collapse from Radiation Damage
25	Waste in Mobile Form in Cavity
26	Collapse of Cavity Permits Migration of Mobile Waste to Surface
27	Pressurization from Internal Energy Release
28	Pressurization from Entry of Lava in Magma
29	Pressurization from Water Entry and/or Steam Formation
30	Pressurization from Chemical Reaction of Waste or Host Rock
31	Pressurization from Intrusion of Oil or Gas
32	Pressurization Occurs upon Waste Melting
33	Pressurization Occurs upon Waste Solidification
34	Shaft Seal Fails from Tectonic Events
35	Shaft Seal Fails from Aging
36	Shaft Seal Fails from Volcanic Activity
37	Shaft Seal Fails from Water, Ice, Weathering, Wind, Rivers, etc.
38	Shaft Seal Fails from Tests, Monitoring
39	Shaft Seal Fails from War or Sabotage
40	Shaft Seal Fails from Stresses Imposed by Waste
41	Shaft Seal Ruptured by Meteors
42	Shaft Seal Not Correctly Made
43	Surface Flooded
44	Climatic Change Causes Aquifer in Region
45	Water Flow Is Induced
46	Volcano in Disposal Region
47	Lava Contacts Waste
48	Flow Induced Through Barrier
49	Barrier Mined for Mineral Content
50	Barriers Removed by Meteor
51	River Located in Region for Periods Sufficient to Remove Barrier
52	Weathering Erosion Removes Barrier
53	Barrier Removed by Tectonic Activity
54	Duration of Glacial Periods Sufficient to Remove Barrier
55	Region Strata Thought To Contain Valuable Resource
56	Waste Contacted by Exploration
57	Waste Contacted During Mining
58	Waste Contacted During Testing
59	Waste Contacted Purposely
60	Waste Contacted During Geothermal or Other Future Use of Region
61	Pressure Required to Displace Waste to Surface Exceeded
62	Cavity Pressure Exceeds Shaft Seal Strength
63	Insufficient Heat Transfer Melts Solid Waste
64	Oil or Gas in Region
65	Oil or Gas Transfer Waste Through Barrier
66	Cavity Shape Unstable from Waste Pressuraization
67	Waste Disposal as Liquid
68	Pressure Exceeds Barrier Strength
69	Technology To Detect Rupture No Longer Exists
70	Shaft Seal Improperly Repaired
71	Technology To Repair Rupture No Longer Exists
72	Barrier Fails or Deteriorated from Design Uncertainty
73	Cavity Dissolves Barrier Between Waste and Surface
74	No Monitoring of Disposal Site
75	War or Sabotage Occurs Before Decommissioning
76	Natural Disaster Occurs Before Decommissioning
77	Efforts To Control Aquifer Fail

waste-imposed stresses or meteors. The two secondary failures are excess pressure buildup in the disposal vault and barrier failure from monitoring, exploration, etc., followed by improper repair.

Barrier Ruptured by Aging (Failure Element 1). Aging could cause the barrier to lose integrity with time. The change in properties of barrier materials caused by aging can be specified quite well. By factoring the aging properties of the barrier into the analysis, the failure by aging should not be a controlling failure element.

Barrier Ruptured by Waste-Imposed Stresses (6). This variable should be fully analyzable as part of the design of a disposal concept. At the burial depths under consideration, the barrier/waste system should eventually reach isostatic equilibrium, and plastic behavior of the barrier should minimize stress concentrations. This variable should not be an important contribution to concept safety.

Barrier Ruptured by War or Sabotage (5). It is possible to analytically estimate the consequences of waging a nuclear war above the disposal site. Analyses have shown a 1000 megaton nuclear explosion at the ground surface would be required to rupture a barrier to a depth of 1000 meters. The detonation of such a weapon at the ground surface would not maximize destruction at the surface, which is a primary aim of nuclear war. Thus war should not have an important influence on barrier failure rates. Sabotage is somewhat different from war. However it is difficult to envision an act of sabotage which could result in the rupture of a 1000-meter thick barrier and have immediate major detrimental effects to the population.

Barrier Ruptured by Glacial Action During Ice Ages (2-3). Ice or ice-dammed lakes several kilometers deep can build up over land surfaces. The deep rock strata below these overburdens normally are sufficiently plastic to deform without rupturing. It should be possible to show by calculation that the barriers will not be stressed to levels approaching failure even if the ice loading is not uniform. In addition, waste would not be emplaced such that erosion by glaciers would be expected to expose the waste. Thus this variable is not expected to be an important contributor to waste release.

Barrier Ruptured by Meteorite Impact (8). The effects of a meteorite impact on the barriers above a disposal vault can be analyzed with the same tools used for the cratering effects of nuclear explosions. Gera and Jacobs[4] have projected the probability of a meteorite forming a 400-meter deep cavity in the disposal site can be expected at a frequency of $10^{-12}/km^2$-year. Thus, meteors are not expected to be the controlling waste release mechanism.

Volcanic Activity (4). Analytical models to predict the effects of nearby volcanos on barrier integrity are not yet available. However, based on present knowledge of strata behavior adjacent to volcanos, the probable effect on the barrier could be developed. In particular, the amount and

the extent of barrier rupture caused by magma flows in the region could be specified. However, disposal sites would not be placed adjacent to known volcanos. In terms of barrier rupture, the effects of volcanic activity in a region are probably less important than other tectonic activity. Barrier Ruptured by Tectonic Activity (7). Tectonic activity is expected to impose significant forces on the barriers. Therefore this variable is one of the most important of the eight basic events. Vertical faulting in the disposal region could either expose the waste or bury it much deeper than it was originally buried. At the present time it is not possible to predict where future faulting will occur, although potential failure points for the barrier could be calculated. The probability that a region will be tectonically active in the near future (less than 1000 years) can be estimated by the frequency of earthquakes.

In the million year time frame, it is much more difficult to predict with certainty where active tectonics will occur, although areas which have not been active for many millions of years would not normally be expected to become active during the next million years. The U.S. National Atlas[5] compares tectonic activity associated with mountain building to atmospheric storms. "Fold belts commonly form a mountainous terrain. They are formed by orogeneses which are, in effect, storms within the crust of the earth. But whereas atmospheric storms come and go within a few hours or days, the crustal storms endure for many millions of years because of the much greater rigidity of the materials involved. To be more exact, each fold belt was created during stormy periods of geologic time--a succession of orogenic storms following on and reinforcing each other, the whole constituting an orogenic cycle . . . . The causes of these orogenic storms are poorly understood. Nevertheless their manifestations are plain--the folding and faulting of the near-surface strata, the flowage, recrystallization and metamorphosis of the parts beneath, and the emplacement of bodies of granite and other plutonic rocks into the deepest layers."

The motion of the near-surface strata during orogenic cycles gives some indication of the forces involved during such motion. The discussion of geologic history in the National Atlas refers to the following crustal measurements. "In the latest Devonion or Early Mississippian time (about 350 million years ago) a disturbance called the Antler orogeny produced eastward thrusting and folding in a northeast-tending band across central Nevada and probably across western Idaho and eastern Washington . . . . Eugeosynclinal deposits of the western Nevada region were displaced by faulting at least 55 miles and perhaps as much as 90 miles eastward over miogeosynclinal deposits and a mountain belt possibly 500 miles long was produced."

The National Atlas refers to the Sierra Nevada in California as one of the westernmost fault-block mountains

uplifted about 4000 meters in modern times along a fault on the eastern site.

If forces such as those described in the past paragraph become active in the disposal region, geologic barrier integrity is difficult to assure. Through careful analysis and by following future developments in plate tectonics, it may be possible to find areas where the stability is expected to be acceptable for the next million years. Future developments in plate tectonics studies will increase the knowledge of plate stability and then increase the assurance that suitable disposal sites will be found with long-term stability.

Water Finds Path into Burial Vault (9).

As presently envisioned, the burial site would not be located in an environment with active aquifers. The question of leak tightness if water did become present around the site must be considered. For geologic formations which are not water soluble, it may be possible to design tests which show that a disposal site is watertight. Another approach is to accept the probability that the barriers above the vault may not be watertight and calculate the effects. The following discussion gives a basis for how such a failure probability might be developed.

The following facts relative to water entry into active mines were obtained. From the period 1893-1944 a total of 26 mines (for metal ores and nonmetal ores) experienced accidents by flooding.[6] Based on these data and those in Reference 8, the probability of experiencing an inrush of water, assuming an occurrence of five flooding accidents in 10 years, is on the order of 10^{-5}/km-year. For geologic disposal in competent rock, this value could be used as a rough estimate of the probability that a kilometer-long mine tunnel will contain an undetected flaw which would allow waste entry if water were present in the region. Since water is probably the most likely transport mechanism for waste, this failure event appears to have high importance. Good failure rate data should be obtainable.

Barrier Contains Undetected Flaw (10).

The potential consequences of this failure event could be large or small depending on the form of the waste and the type of defect. Without completely excavating the geologic barrier to the repository, it is difficult to assure that the barriers do not contain an undetected flaw which might eventually develop into a pathway for communication between the disposal vault and the surface. For the mine shaft, the value of 10^{-5}/km-yr for the water entry is probably a reasonable estimate for this failure element.

For large underground reservoirs containing boiling waste solutions or molten rock/waste mixes, there is really no similar experience from which to estimate barrier failure probabilities. The closest relevant experience would be the gas storage reservoirs normally either in salt cavities or abandoned mines. At the present time there are 600 storage reservoirs for natural gas storage.[7] Based on the projected growth curve,[8]

it is estimated that there have been 8600 cavity-years of experience with cavities used to store natural gas. At least two reservoirs have leaked. One is referred to on page 349 of Reference 10 and the other was a reservoir in Elk City, Oklahoma.[9] From these data, the probability of barrier failure for these systems is estimated to be on the order of 10^{-3}/cavity-yr.

Cavity Collapse (11-19). Cavity collapse failures very closely parallel the geologic barrier failure modes discussed previously, but with a slight shift of emphasis. Previous concerns were for those facets which could breach the barrier irrespective of the presence of waste. In these cases, the decreased capability of the geologic barrier to maintain integrity due to the presence of the cavity or the waste is of concern. If the cavity is not completely full or contains liquid (as aqueous or molten phases), the arch above the waste may be incapable of resisting forces imposed on the barrier. These forces should be active only during the period the cavity structure is distinct from the geologic barrier. Thus it tends to be of concern only during the operational period rather than for a million years. Through mechanical analyses, the failure thresholds should be identifiable, and the probabilities of failure should be similar to those developed for the geologic barrier failures.

Cavity Enlarges and Collapse Occurs (20). Analyatical models to predict the stability of openings in competent rock have been developed. These can be applied to the design of the tunnels. The safety factors employed in the design can be set high enough that cavity failure of the tunnels would not be the controlling variable during site operations. For long-term stability, plastic flow would eventually close the opening and the site would approach isostatic equilibrium. At that point cavity failure would be nonexistent.

For the deep hole or large underground reservoir concepts, the potential for cavity collapse from structural instability exists. Since no holes have been drilled deeper than 9 kilometers, the stability of a 16-kilometer-deep hole can be analyzed only in theory. The frequency of collapse either from creep or rock bursts can be expected to be quite high. Although presently existing theories could be applied to deep-hole stability, ultimately the results would have to be verified experimentally.

The stability of an underground reservoir containing molten waste or boiling aqueous waste is not known. However, failure rate data on solution-mined salt cavities would appear to be somewhat relevant. The following data relative to solution mining has been found. Since 1940, the total volume of salt removed by solid and solution mining is approximately 136 million cubic meters, based on the amount of salt mined.[10] Solution mining makes up 60 percent of the total, and the average cavity size has a volume of about 28,000 cubic meters.[8] Thus there are about 3000 solution cavities, and as discussed under failure element 9 about

600 are being used for storage of hydrocarbons. For the 600 storage cavities, the total number of cavity years of experience was 8600; thus one might expect total cavity years experience with all cavities to be about 50,000 cavity-years. There have been two leaks, discussed under failure element 9, and there have been two other cases of significant cavity subsidence for cavities which were not storing hydrocarbons.[11,12] Thus the number of significant cavity collapses is roughly estimated to occur at a frequency of 10^{-4}/cavity-yr.

This failure element is important for the liquid waste emplacement concepts. Since rock temperatures rise with depth, the salt reservoir experience may be relevant for boiling wastes. In current experience, the molten rock case really has no parallels other than underground nuclear explosions and probably has a higher cavity collapse failure rate than conventionally excavated cavities. Thus it is believed that failure probabilities for boiling waste can be obtained, but the case of molten rock would require much greater study.

Barrier Ruptured by Tests (21). The analysis of the effects of the testing program on the geologic barrier integrity should be relatively amenable to evaluation with present analytical tools. The urge to drill many test holes through the barrier should be resisted from the standpoint of contributing to failure.

Cavity Migrates into Region Which Cannot Support Cavity and Waste Forced to Surface (22). This branch of the fault tree has not yet been developed. In general, however, the geologic barrier above the site is expected to have a lateral extent that is great enough to prevent circumventing the barrier.

Vent Formed to Surface from Cavity Collapse (23). There are numerous documented cases where tunnels in mines have collapsed and the collapse propagates vertically upward to the surface with time. Analytical models of cavity stability should be able to predict this behavior and geologic formations where the barrier has this characteristic should be avoided.

No data on frequency of occurrence was obtained, although it should be possible to construct some relevant data from the more than 400,000[13] kilometers of mine tunnels dug in the last 10 yeras. The probability for this failure should be below that given for failure element 9, i.e., less than 10^{-5}/km-yr.

Cavity Collapse from Radiation Damage (24). This failure element should be amenable to evaluation in the laboratory. With such evaluation and proper design, this variable should not be significant.

Waste in Mobile Form in Cavity (25). The probability of this failure element is set at 1 for the concepts where the waste in a fluid form can be displaced by the collapse of the roof or the application of flowing media. Examples of mobile wastes are gases, molten waste, liquids containing dissolved waste or solid suspensions, or very finely divided powders which could be entrained in a gas stream.

For the solid waste disposal concepts the waste will initially be in canisters. Analytical and experimental studies are currently being carried out to investigate changes in waste properties with age. This information can be used to evaluate the possibility that the waste will become mobile if placed in a flowing gas or liquid. This failure element may have significance for safety analysis.

Collapse of Cavity Permits Migration of Mobile Waste to Surface (26). Simulation of the mechanics of an underground opening should describe the possibility of mobile waste being displaced to the surface for the type of collapses considered in items 11 through 24. In the absence of these calculations, the probability that mobile waste is displaced directly to the surface is unknown.

This failure mode should be considered for those disposal cases where the waste is in a mobile form. Analytical studies should probably be followed by model tests to show behavior of the waste during simulated collapse mechanisms.

Waste Pressurization Occurs (27 through 33). In the fault tree, seven mechanisms which could cause waste pressurization have been identified. The waste could become pressurized by an interal energy release, intrusion of lava or magma, water entry, chemical reaction, intrusion of oil or gas, melting, or solidification of melt. Each of these potential mechanisms will be discussed individually.

Pressurization from Internal Energy Releases. Internal energy can be in a variety of forms. The largest energy form is nuclear. Because of the dilution by the fission products and the glass, nuclear criticality of the actinide elements should not be possible. The assessment of nuclear criticality can be made by a relatively straightforward calculation for any possible waste matrix. Such calculations should be made to verify present consensus. Chemical energy release stored in the cavity is another potentially disruptive mechanism. The radiolytic decomposition of materials present in the disposal vault should be considered. The data required to make such a calculation is being developed. Finally, the expected lack of buildup of stored energy in the waste form needs to be confirmed for the cases to be examined. It is expected that the amount of internal energy potentially stored in the waste would be incapable of doing significant damage to the disposal vault or to geologic barriers between the vault and man if it is released.

Pressurization from the Intrusion of Lava or Magma. The potential pressures associated with the intrusion of lava or magma are much larger than any internal pressures from the waste.

Pressurization from Water Intrusion. Water is capable of changing thermal energy into mechanical energy via vaporization. Pressurization will occur when the temperature of the waste corresponds to a saturation pressure above the isostatic pressure

of the disposal vault. The potential for obtaining these temperatures and pressures should be verified for each disposal concept.

Chemical Reaction of Waste or Host Rock. Laboratory experiments should verify that no significant pressurization would result from chemical reactions (including decomposition) in a properly designed system for waste burial.

Intrusion of Oil or Gas. Gas or oil in underground systems is typically at very high pressure. If hydrocarbons accumulated in the disposal site, relieving the pressure by venting could cause the waste to migrate either by entrainment or by dissolution of the waste.

Pressurization Occurs upon Waste Melting. The plastic flow of the surrounding media should relieve any pressurization which might occur during melting. This can easily be verified to show that no catastrophic release occurs.

Pressurization Occurs upon Waste Solidification. It has been postulated that some catastrophic eruptions have occurred as a result of magma solidification and the pressure build-up caused by the inverse solubility of water. It is believed that this mechanism can be verified experimentally. It could be important for in-place melting concepts.

Shaft Seal Failures (33 through 42). The phenomena which can cause shaft seal failures are similar to the phenomena causing geologic barrier or cavity failures. However the shaft seal involves the additional complexity of having a boundary between the barrier and the synthetic seal. Thus discontinuity can be a point of stress concentration. In addition, the behavior of man-emplaced seals for thousands of years has not yet been verified.

Based on data in the Statistical Abstracts,[10] there are over 500,000 producing oil wells in this country. There is probably at least an equal number of abandoned wells. All have seals between the well casing and the underground strata. The statistics on seal failures may be available, but no known research has been done on this point to date. However, Associated Press accounts in the past year have related at least two instances of shaft seals leaking. In one case oil was coming from a well in the front lawn of a residence in Southern California. The well had been capped several decades ago. The other case was a new well in Traverse City, Michigan. These are just two of significance. There are probably more that have not been reported. Thus the probability of a seal failure by conventional techniques is more frequent than 10^{-5}/well-yr.

The above statistics are for shaft seal failures which could be attributed to an improper seal or seal degradation. Seals are also very susceptible to failures as a result of earth movement (failure element 32). It is highly unlikely that a shaft could withstand an earthquake with an intensity of IX on the Modified Mercalli scale. The breaking of underground pipes is a design criterion used to define areas where an earthquake has struck an area with an

intensity of at least IX. Algermissen[14] has estimated the seismic risk in the various regions of the country (presented in Section 4 of this report). Gutenberg and Richter[15] have summarized the seismicity of the entire earth for the 1904-1952 time period. Of particular interest to this study are reports by S. A. Bollinger[16] and a book by Wiegel.[17] Bollinger states, "The great Charleston, South Carolina earthquake of August 31, 1886 provides an example of a major United States earthquake outside the Pacific coast region. No prior severe shocks were known to have occurred in this region since its settlement by the English in 1670." Because of this long aseismic history, the 1886 event is often cited as an example that no region is completely safe from earthquake hazard. The estimated magnitude of this earthquake was 7.7 on the Richter scale.

On the Modified Mercalli scale this earthquake had a maximum intensity of X, and a region of about 8,000 square kilometers experienced damage in excess of IX on the Modified Mercalli scale. In this 8,000 square kilometers, buildings were shifted off foundations, cracked, thrown out of plumb, and ground was cracked and underground pipes broken. For this report, an intensity of IX is used as the basis for calculating the probability of an earthquake at a waste disposal facility. The use of this intensity is not meant to indicate that the earthquake will result in a waste release; it is used as a point of reference. More severe earthquakes will have a lower probability of occurrence.

Bollinger shows that the probability of an earthquake striking a region of 8000 square kilometers along the east coast is about 0.005/year. Assuming the east coast consists of 22×10^6 square kilometers, then the risk of an earthquake at any point on the east coast is approximately $0.005 \times 8000/2 \times 10^6$. Thus the probability of an earthquake at some generic eastern site would be approximately 2×10^{-5}/year.

In California, the probability of a Richter magnitude 7.5 earthquake is 0.076/year.[14] This would result in an intensity of greater than IX on the Modified Mercalli scale over about 5,000 square kilometers. The probability of an earthquake with a magnitude greater than 8.0 is 0.021, and 20,000 square kilometers can be expected to experience heavy damage. The probability of a magnitude 8.5 earthquake is estimated to be 0.006/year. Approximately 36,000 square kilometers can be expected to experience heavy damage from this earthquake. Thus the probability of an earthquake in this magnitude range occurring at a random point in California (390,000 square kilometers) is:

$$p = \left[0.006 \times 36{,}000 + (0.015)(20{,}000) + (0.055)(5{,}000)\right] / 390{,}000$$

$$= 0.002/\text{year}.$$

This calculation shows that some regions of the country experience risk from earthquakes which is at least 1000 times more likely than

many regions of the country. In like manner, there are probably some regions which can be shown to have the expected frequency of earthquakes to be 10^{-8} or less for the next few thousand years and perhaps longer. Thus for some regions, the natural events can be more controlling than seal failures from degradation. It should be possible, through more in depth analysis to obtain better failure numbers. The shaft seal is a fundamental element in the waste disposal site safety evaluations.

Surface Flooded (43). Extensive studies have been made for surface flood potential in some areas. The potential is very site specific. A disposal location would be selected so that the region would not be inundated by surface floods. This failure element is more concerned with the potential that the normal runoff patterns could be modified by weather changes or damming and subsequent lake formation. Some of the potential reasons for lake formation could be landslides, tectonic activity, volcanic activity, meteorite impact, or climatic changes such as the onset of another glacial age. Man could also dam up the runoff although it is assumed that the disposal site will not be upstream of a location where man would want to build a dam.

Detailed studies as to the potential likelihood of surface flooding can be carried out for specific sites. During the operational phase of geologic waste disposal, a crater from a meteor could be considered as a potential mechanism for forming a lake directly above a disposal vault. Based on this assumption, the probability of a lake 1 square kilometer in surface area would be estimated to occur with a frequency of approximately 10^{-10}/year. After 1,000,000 years, the possibility of a surface region being flooded could be approximated by assuming that the flooding of land area occupied by lakes and rivers is a random variable. On the average, 2 percent of the land area within the contiguous U.S. is under water.[5] The average land fraction under water in the western and semi-arid states is about 0.5 percent.[5] Using this logic, 0.01 could be used as a rough expected frequency that a site would be inundated after 1,000,000 years. After 1000 years, an intermediate number on the order of 10^{-6}/year might be used in the absence of any site analysis.

The numbers developed in the last paragraph are very preliminary ones based on a very limited amount of data and in the absence of any site selection. Better numbers can be developed for a particular site. As long as the site is not located in a region with significant tectonic activity, the probability of surface flooding can be estimated with reasonable accuracy.

Climatic Change Causes Aquifer in Region (44). The potential for a region to contain an aquifer, if water was added to a drainage basin, is an important variable since aquifers are able to leach and transport immobilized waste or transport mobile waste. In addition aquifers are

quite common. Even though a region contains no currently actively flowing subsurface water, it cannot be concluded that the potential for underground aquifers in the region does not exist. Unfortunately, underground flow of water is not well defined even in regions with active aquifers. The knowledge about the potential for active aquifers in regions with no present underground water systems is very scarce. For individual sites some estimate could be made of the probability that existing dry underground flow channels will become recharged or that new channels will be formed where none exist today.

No studies on the extent of underground water systems have been done in this analysis. However, it is recognized that the extent of underground water courses is several times the extent of surface areas inundated by lakes or rivers. Therefore, in this study the probability of having an underground aquifer in the disposal region was set an order of magnitude above the probability of surface flooding in any time period studied.

As with the surface flooding failure element, it is important to recognize that tectonic activity can drastically alter water flow through underground formations. However, if the disposal site is in a region of projected tectonic stability, it should be possible to obtain a reasonable estimate for the frequency, duration and extent of aquifers in the region. Much more effort will be required to develop the data on underground aquifers to the certitude that surface flooding data can be developed. However, the potential for aquifers is one of the most critical failure elements.

Water Flow Induced (45). Active leaching of waste from the disposal site requires flowing water. Thus water which comes into a formation and is stagnant will not do any significant leaching.

Water flow through the disposal formation can be induced either by internal or external forces. The accumulated heat from decay can act as a driving force. The gradual sloping of the strata in the disposal site can be a driving force, as can be the difference in elevation of supply and discharge points.

Since natural processes for removing water from underground basins containing no exit are very slow, the absence of water could be an indication that any new aquifers formed in the region may be active. Thus for conservatism in this analysis, it is assumed that any water in the disposal region will be flowing. It should be recognized that for some sites the natural resistance to water movement may be an important safety feature.

Volcano in Disposal Region (46). Since volcanos accompany active crustal movement, volcanic activity in the disposal region can be analyzed at the same time tectonic activity of the region is investigated. This variable will always be less probable than the tectonic activity. As an example, in the western United States, which has undergone recent tectonic upheaval, the World Atlas[5] denotes 17 volcanic cones and 12 caldera.

Using a figure of 10 square kilometers for a caldera and 1 square kilometer for the cone of a typical volcano, results in a volcanic land area of about 140 square kilometers. The western U.S. has an area of approximately 2.5×10^6 square kilometers. Thus the probability of a volcano existing in the western U.S. is about 4 orders of magnitude below the probability of tectonic activity. This ratio is used in this report to obtain the probability of volcanic action, given the probability of tectonic activity in the region.

The preceding analysis was a very cursory study of volcanos. The diameters of volcanic cones and calderas can be determined more precisely, but it may be very difficult to predict volcano frequency with any greater accuracy. Since volcanic activity occurs in active tectonic areas, identifying areas of future tectonic instability is important for this failure element.

Lava Contacts Waste (47). This failure element is a statement that is conditional on the last failure element. Even though the volcano is in the disposal region, the molten rock coming to the surface must transport the waste. In this analysis, credit for this safety feature was not taken. It was assumed that if a volcano strikes the region the waste is transported to the surface.

Flow Induced Through Barriers (48). It is possible, given enough force, to have flows of water, steam, oil or gas containing waste penetrate a geologic barrier. Because of the lower permeability of most rocks at greater depths, this variable should generally become less important with increasing depth of waste disposal.

Barrier Mined for Mineral Content (49). To date no studies have been done to estimate the potential value of the barrier as a future resource. Such studies can be made to verify that enough of the barrier material exists in the world to satisfy man's expected future needs for any element present in the barrier, assuming present-day knowledge.

With proper site selection this failure element should not be a major contributing factor influencing the probability that waste will be released.

Barrier Removed by Meteor (50). Analyses indicate that the probability of a meteor capable of completely removing a barrier 1 kilometer thick above a 1 km^2 disposal site is about 10^{-14}/km^2-year. This size meteor is actually the most singularly disruptive failure mechanism. Only the Deep Bay Crater in Canada[18] approaches an impact of this size in North America.

River of Sufficient Size in Region Erodes Barrier (51). The erosive power of rivers is sufficient to remove any barrier. However, three conditions are needed: 1) the river has to be in the region long enough, 2) the flow has to be large enough, and 3) there has to be enough elevation for the river to erode the barrier to the disposal vault.

For the probability of rivers eroding barriers, a rough estimate was made here using the Grand Canyon of the Colorado as a model of a river which could erode a barrier.

Gera and Jacobs[4] estimate the erosion rate of the Colorado River to be 80 cm/1000 years. If the average rate of denudation (weathering) of the highlands is added in, the rate of erosion relative to the original land elevation would be 1 m/1000 years or 1 kilometer in a million years. Thus if a river like the Colorado were located above a disposal site 1 kilometer in depth, it would erode the barrier in 1 million years.

Based on the data by Cole and Wise,[19] the Colorado River is an average western river. Of the 16 rivers with average annual flows in excess of 28 m^3/sec, the Colorado, discharging about 280 m^3/sec ranks eighth from the top. The largest, the Columbia, with an annual average discharge of 2800 m^3/sec, would probably be capable of greater erosion rates for the flow over similar strata.

This information shows that in most cases rivers have very little potential for removing a barrier at a properly selected site in periods which are significantly less than one million years. After a million years it is likely that some of the originally favorable characteristics, such as remoteness from lakes and rivers, may no longer exist. Based on this unknown, it is assumed that at that time there is a 50 percent probability that a river of sufficient flow to erode the barrier will be located in the region. Since approximately 0.5 percent of the western land area is under water, a large fraction of which is associated with rivers, the probability of the barrier's being eroded away after a million years will be taken as the probability of the site being under a river (0.005) times the probability that the river will be large enough to erode the barrier (0.5). Thus the probability of failure by water erosion after 10^6 years is taken as 0.003.

Weathering Erosion Removes Barrier (52). Information given in the above discussion on river erosion shows that wind erosion (denudation) occurs probably at less than one-fifth the rate of water erosion. Thus weathering is not expected to be of major concern for periods less than several million years.

Barrier Removed by Tectonic Activity (53). This failure element parallels 7 but looks at the potential for barrier removal by tectonic action. No complete study has been made for this failure element. Fault measurement indicates that barrier removal by tectonic activity is much less likely than barrier rupture by tectonic activity. Assuming a strike-slip type fault is active in the area, maximum expected relative vertical displacement in one tectonic movement is about 10 meters.[20] Thus it would take 100 large earth movements before waste 1000 meters deep would be exposed along the fault line. Since tectonic activity is currently plotted using a random distribution, it can be said that the probability of barrier removal by tectonic activity is at least 2 orders of magnitude lower than the probability of barrier rupture. In addition, since even the most rapid faults move less than

4 cm/yr,[4] barrier removal would not be complete for 25,000 years at the earliest.

Duration of Glacial Periods Sufficient to Remove Barrier (54). Gera and Jacobs[4] list five factors which affect the rate of glacial erosion: 1) the rate of glacier movement, 2) thickness of ice, 3) amount and physical character of the drift constituting the glacier base, 4) erodibility of the geological materials beneath the glacier area, and 5) topography. These authors refer to a report by Corbel[21] which estimates that glacial erosion is, on the average, four times more effective than fluvial erosion. If only maximum erosion rates are considered, we find rates due to glacial erosion are 25 times greater than those due to torrential erosion.

Like stream erosion, glacial erosion is not expected to be an important failure mechanism for the first few thousand years. However, given the right set of conditions, the barrier 1000 meters thick could easily be eroded away by glacial activity in the region. Gera and Jacobs refer[21] to the Sogne Fjord in Norway, which has been eroded for a total apparent depth of 2400 meters if we consider the valley depth above and below sea level. This erosion has taken place within the last million years.

The above discussion assumes the existence of glaciers in the region. Based on the glacial geology maps shown in the National Atlas, past active glaciers covered essentially all the land mass above the 47th parallel in North America. Glacial activity is only partial from there to the 36th parallel. Below that parallel, significant glacial activity has not been detected. Thus the location of the site and the potential for severe periods of glaciation has an important bearing on whether this failure element has to be evaluated in detail.

The probability of barrier removal by glaciers for the first 10,000 years or so should be extremely low. At that point, depending on the site, glacial removal of the barrier might be expected to be as much as an order of magnitude more probable than barrier removal by water erosion.

Region Strata Thought To Contain Valuable Resource (55). This failure element is similar to element 49. The expected mineral resource value of the region around the disposal site should be determined. Then based on projected future needs and the probable availability from other sources, the potential value of the region should preferably be projected as being low. This failure element is of concern and as a result should be studied for candidate sites.

Waste Contacted by Man's Future Activity (56 through 60). There are five known future activities of man which could potentially move the waste into man's environment. These are mining, exploration, testing, sabotage, and geothermal utilization of heat in surrounding strata or other use of the region. All these failure elements assume that man is allowed to operate freely in the region.

These five elements are very subjective. As such, they probably can

never be quantified exactly for a failure probability. At the same time, it seems apparent that it is important to control man's activities in the region. In this case, the concepts which have the greatest intrinsic safety should be preferred. Then intrinsic safety could be further augmented by administrative restrictions.

One approach to analysis of this element would be to document the amount of exploring for natural resources done in the region. Then ask, "Does the site appear to have attractive features for some other resource development?" Once these scenarios have been evaluated, estimate the possible effects if the disposal site had been located there some years ago. This type of approach, however, does not account for man's future advancement which could be highly significant.

In the final analysis, a failure probability for each event must be specified as part of the analysis.

In the absence of any detailed site evaluation, the following rough estimate might be used. In 1972, an estimated 29,510 wells were drilled for gas or oil in the United States.(22) Of these, 8357 were wildcat wells, i.e., drilled in a virgin region. Only those wells should be considered in the analysis. If they were assumed to be randomly drilled around the country, the probability of the hole being drilled in a 65 square kilometer disposal area in the United States is 8357 holes x 65 km^2/hole/ 9,171,372 km^2 of area in the United States = 0.059/year. An additional factor is the fraction of the 65 square kilometer disposal area occupied by canisters or mine tunnels. For the reference concept of solid waste emplaced in a mined cavity, the actual disposal area is 0.4 square kilometers or approximately 0.70 percent of the disposal site. Thus the probability of man violating the integrity of site disposal vault by locating a wildcat well in the region is 0.059 x 0.0070 or 4 x 10^{-4}/year. A better estimate could be developed for a specific site with known characteristics.

Pressure Required To Displace Waste to Surface Exceeded (61). The pressure buildup in the waste from most external forces will be sufficient to move the waste to the surface if the waste is mobile and a pathway to the surface exists. Pressure buildup from forces internal to the waste may not be sufficient to displace waste to the surface. However, in the absence of detailed analysis, it is conservatively assumed here that any pressure buildup is great enough to displace mobile waste to the surface along an existing pathway.

Cavity Pressure Exceeds Shaft Seal Strength (62). This failure element compares the pressure buildup in the disposal vault from all circumstances against the strength of the shaft seal. It is not expected that the shaft seal will fail from excess pressure in the disposal vault. A calculation is needed to verify this belief.

Insufficient Heat Transfer Melts Solid Waste (63). Through adequate testing and pilot plant studies the capability of the disposal site to

dissipate the decay heat can be demonstrated. Calculations should then be made to show what conditions are required to melt the waste. Based on knowledge of the disposal site characteristics, it should then be possible to show that undesired waste melting cannot occur.

Oil or Gas in Region (64). It is remotely possible that oil or gas could collect in the burial region. It could be collecting there just because of the nature of the burial formation or because the decay heat releases the oil or gas. During core sampling at the site, it should be possible to show that the burial vault will not collect significant amounts of oil or gas.

Oil or Gas Transfers Waste Through Barrier (65). The geologic barriers above the burial vault should normally be very impermeable to water (failure element 48) and for the same reasons it should be impermeable to oil or gas. In addition, waste is much less soluble in hydrocarbons than in water. Therefore, this flow path is not expected to have major importance. Analysis or testing should verify this conclusion.

Cavity Shape Unstable from Pressurization (66). It could be expected that cavity pressure greatly exceeding the isostatic pressure in the rock could cause fracturing of the surrounding rock and possible collapse. No information on this failure mechanism has been obtained, and relevant experience may not be available. At the same time, based on the underground nuclear explosion experience, which may not be relevant, cracking of surrounding rock does lead to cavity instability. In almost all cases surface subsidence has occurred. This failure element must be studied in more detail if conditions which result in high cavity pressures can be postulated.

Waste Disposal as Liquid (67). This failure element is used only as a signal in the analysis to distinguish between disposal concepts which emplace waste in liquid phases and those which have no liquid phases during disposal.

Pressure Exceeds Barrier Strength (68). This element is similar to failure element 66. The designer of any disposal concept must be able to demonstrate that pressures approaching the barrier strength cannot be exceeded under any conditions during the disposal operation.

Inability of Future Technolgies To Repair Failures (69 through 71). These three failure elements consider the inability of future generations to correct failures which would result in a release if they went uncorrected. These are: the Seal Improperly Repaired, Technology to Detect Rupture No Longer Exists, and Technology To Repair Rupture No Longer Exists.

Like failure elements 56 through 60, these elements can probably never be quantified in terms of a precise probability. The best that could ever be expected would be to demonstrate the importance or unimportance of these failure elements. A disposal concept that places little reliance on man is probably desirable. Thus if a barrier leaks and

the leak seals itself because of the type of material surrounding the waste, this concept is more desirable than one requiring that man seal the leak.

Barrier Fails or Ruptures from Design Uncertainty (72). This element is very similar to failure element 6. Design uncertainties should not play an important role in the safety of the disposal concept. In order to show that this failure element is not important, analyses based on the most unfavorable set of conditions must show that design uncertainties play no important role in possible system failure.

Cavity Dissolves Barriers Between Waste and Surface (73). This failure element is applicable only to liquid waste emplacement concepts. It is similar to failure element 72 but has been separated out because it is a failure element which is not common to all concepts. Cavity migration with time must be considered and understood in the design. Tests must show that the cavity action is understood before any liquid waste forms are injected into an underground reservoir.

Administrative Error Allows Man To Operate Freely in Region (74). As discussed under failure elements 56 through 60 and 69 through 71, this element is primarily a signal to show how much man is relied on to assure the safety of a given disposal concept. The analysis should be performed both with and without administrative control.

War or Sabotage Occurs Before Decommissioning (75). Once the facility is decommissioned, the disposal site safety is not expected to be compromised (see elements 5, 19 and 38). However, wars can occur prior to decommissioning and potentially compromise safety. The effects of war during operation can be analyzed, and it may be possible, based on history, to look at the frequency of general warfare. The variability is expected to be great. The following analysis presents an approach which might be employed to examine the potential for war in the region.

The last generation (35 years) will be taken as an example to look at the fraction of the land area on the earth which has experienced warfare. The last world war was fought over most of Europe, about one-tenth of Africa and perhaps one-third of China. In addition, wars have broken out in Korea, Vietnam, Israel and several other countries since that time. For all practical purposes, World War II statistics indicate that a large fraction of the total land area was affected by warfare. From the standpoint of failure, the duration of the war is considered less important than the fact that war broke out. If increases in man's sophistication to destroy other men are neglected, then the following formula can be used to obtain the annual probability of a war being fought in the disposal area, based on statistics from the last generation:

$$P_w = \frac{A_e + (A_a/10) + (A_c/3)}{35\ A_l} = 0.002$$

$$\cong 10^{-3}$$

where

A_e = the area of Europe - 4,934,940 square kilometers,

A_a = the area of Africa - 30,312,076 square kilometers,

A_c = the area of China - 3,746,453 square kilometers, and

A_l = total land area earth - 135, 745,940 square kilometers.

The disruption from a war could last several years, but in most cases active fighting in a region lasts only a few months. In most cases, it could be expected that man would return to maintain the disposal facility.

The subject of sabotage is a very complex field which has not been researched as part of this analysis. As with war, good probability estimates for acts of sabotage would be very difficult to obtain. Saboteurs can be agents of foreign countries or for internal activist groups, or a saboteur can be acting as an individual, perhaps as a disgruntled employee. The external and internal agents are highly influenced by the political climate that exists at that time. Since the political future can not be predicted, the probability for sabotage can not be firmly set. Concepts which are least susceptible to sabotage are probably the most favored.

At the same time it is valuable to have a rough estimate of the sabotage frequency just to place the failure element in perspective.

The airplane hijackings of the late 1960's and early 1970's will be taken as an example of the extent of sabotage during periods of political unrest. In 1969, 40 out of 5.4×10^6 flights were hijacked.[23] Since an average of 26 people were on a flight,[24] one out of 3.5 million individuals who flew on airlines during 1969 was a saboteur. Thus the probability of hiring a saboteur in a waste disposal facility, assuming no effective screening of personnel, is 3×10^{-7}. This assumes no effect of the degree of unrest in the country. If the plant employs 100 people during operation and one during monitoring, then the probability of having a saboteur on the staff may be on the order of 3×10^{-5} and 3×10^{-7} during any year for the operational and disposal phases respectively.

Natural Disaster Occurs in Region Before Decommissioning (76). A natural disaster can be disruptive to the normal operation of a facility. If a natural disaster occurs in a region, personnel may be killed, work activity could be temporarily halted, and supplies of needed materials delayed. For facilities which need a sizable operating staff to maintain safe conditions at all times, the effects of natural disasters could be important.

In the U.S. the probability of being killed by a natural disaster is 10^{-6}/year.[25] This implies that about 200 individuals die in natural disasters each year. In many cases, it is one serious event which kills the majority of these 200 people. Thus there is about one natural disaster each year. It would be extremely disruptive only if the 200 were killed in the area where most of the laborers lived and worked. This

would typically be within an 8- to 30-kilometer radius of the facility (about 806 square kilometers). Therefore the probability of a natural disaster occurring in a region could be roughly approximated by:

$$p = \frac{(1 \text{ disaster/year}) \times 800 \text{ km}^2}{9.1 \times 10^6 \text{ km}^2}$$

$$= 10^{-4}/\text{year}.$$

The operator of a facility should investigate the possibility of such a disruption in service. Facilities which do not need significant control by man are preferred. Historically, the total duration of disruption accompanying a natural disaster does not exceed one month.

Efforts to Control Aquifer Fail (77). At present man has not demonstrated major ability to control underground aquifers. Therefore, in this study this failure element is assumed to be failed. If the ability to control aquifers is demonstrated in the future, this part of the fault tree should be modified to reflect the improved technology.

3.1.1.6 Assessment of the Applicability of Fault Trees in Geologic Waste Disposal Safety Considerations

The previous sections of this report showed the application of fault tree analysis to waste disposal safety considerations. This technique identified 77 basic failure elements and numerous interactions between elements to show how a release of waste constituents might occur.

For the fault tree to be fully utilized each failure event must be amenable to analysis. Each must have a predictable failure threshold, and it must be possible either to obtain a reasonable data base for predicting the frequency of the event or else to show that the failure event is not an important safety consideration.

Of the 77 failure events in the example studied, over 60 are believed to have predictable failure thresholds; thus it should be possible to develop data base for predicting probabilities. They are fully amenable to analysis.

Of the remaining 17 failure events, the majority were associated with man's future activities. Although man's future activities can never be exactly quantified, the importance of man's presence can be bracketed by first assuming the site is not actively administered and alternatively by assuming that man is actively controlling activities in the area. Thus the degree of reliance placed on man's presence in the region can be roughly quantified. It is believed that disposal concepts which place minimum reliance on man's presence can be found. Thus, for those concepts the final criterion is met; i.e., the failure events associated with man's activity are not an important safety consideration.

The remaining failure events were associated with future tectonic activity. Areas of high tectonic activity may not be readily amenable to analysis because the forces involved are potentially large, they may not be

well known, and they are particularly difficult to quantify. However, areas of high tectonic stability are available, and disposal in these locations should be amenable to fault tree analysis.

3.1.1.7 Sample Waste Release Probability Estimate

The next step of analysis is to follow each release sequence through its pathway to man's environment and ultimately to man. One release sequence, obtained from the geologic fault tree developed previously, is followed here. The numbers presented in this analysis are based on very limited data. Thus they serve primarily to demonstrate the safety evaluation method.

The example waste release sequence considers the release of waste to man's environment by water. This is considered to be one of the more likely release sequences.

The release sequence starts with the premise of "Water Transports Waste" and requires the following three conditions: "Groundwater in Region," "Water Flow Is Induced" and "Water Flow Not Controlled by Man." All three conditions must occur together before a release of waste constituents can take place. Based on present tunneling experience, the probability that an undetected flaw in a barrier exists which will allow water entry in a region where there is no detectable aquifer is estimated to occur at a rate of once in 100,000 kilometers of tunnel length. Thus the failure element "Water Finds Path into Burial Vault" is estimated to occur at a rate of 10^{-5}/km of tunnel constructed for geologic disposal. This and the following numbers are order of magnitude estimates. For the concept of solid waste emplaced in a mined cavity, 90 kilometers of tunnels will be used in the year 2000; thus the probability of a defect allowing water entry is expected to be once in every one thousand mines (or 10^{-3}) with 90 kilometers of tunnel.

Conditions which could cause an aquifer in the region in the next year were estimated to be once in one billion (10^{-9}). After one million years, the probability of an active aquifer in the region is taken to be much greater or 10^{-1} to 10^{-2}. At the 1000-year period, an intermediate number was used. It was assumed that man would not be able to control the aquifer and the aquifer would be flowing; thus the failure elements "Water Flow Is Induced" and "Efforts to Control Aquifer Fail" were assigned probabilities of one.

Table 3.3 summarizes the sample failure event probabilities and the resultant cumulative probabilities obtained by multiplying the individual probabilities in each vertical column. The ranges of probabilities given reflect uncertainty in the above data.

The table summarizes a release probability estimate from one sample failure sequence. To estimate the overall safety, all significant paths must be analyzed and the probabilities times the respective consequences must be summed.

TABLE 3.3. Sample Components of Release Sequence Probabilities for Geologic Disposal

Failure Event	Probability of Waste Release During Operational Period	During 1,000 Years	During 1,000,000 Years
Climatic Change Causes Aquifer in Region	10^{-10} to 10^{-8}	10^{-6} to 10^{-4}	10^{-2} to 10^{-1}
Water Finds Path into Burial Vault	10^{-4} to 10^{-2}	10^{-4} to 10^{-2}	10^{-4} to 10^{-2}
Water Flow Can Not Be Controlled by Man	1	1	1
Water Flow Is Induced	1	1	1
Cumulative Release Probability in the Time Given	10^{-14} to 10^{-10}	10^{-10} to 10^{-6}	10^{-6} to 10^{-3}

3.1.1.8 Application of Fault Trees to Other Disposal Concepts

Preliminary failure modes were identified for seabed, ice sheet and extraterrestrial disposal concepts, and are given in Tables 3.4, 3.5 and 3.6, respectively. Fault tree analysis can be applied to these disposal concepts in the same manner as to the geologic concepts.

The preliminary analysis pointed out how relatively little data are available to assess the seabed and ice sheet environments. For example, in the seabed environment, very little information is known about the long-term behavior of ocean sediments. In like manner, there is little experience with drilling, placement and sealing of waste canisters in the seabed. Thus its apparent safety is uncertain, chiefly because of lack of detailed knowledge about it. The same is true of the ice sheet environment except that more known mechanisms for release of waste can be identified.

For the extraterrestrial disposal concepts, NASA has accumulated experience with manned space flights as a basis for estimating the safety which can be achieved. Failures on the launch pad, by burnup in the atmosphere, or meltdown after loss on the earth's surface are the failure elements of greatest concern and can be estimated with improved confidence as the number of launches accumulates.

TABLE 3.4. Basic Failure Elements for Ice Sheet Disposal Concepts

Number	Failure Element Description
1.	Melt Stream Containing Waste Exposed to Wind Erosion
2.	Manmade Climatic Change Occurs
3.	Natural Climatic Change Occurs
4.	Waste Lost During Transport and Not Recovered
5.	Canister Fails in Ocean Environment
6.	Canister Fails from Ice Pressure
7.	Canister Fails from Waste Interaction
8.	Canister Fails from Suspension System Forces
9.	Canister Suspension System Fails from Normal Wearout
10.	Canister Suspension System Fails from Natural or Manmade Forces
11.	Canister Suspension System Fails from Waste Interaction
12.	Man Relocates Canister
13.	Calculational Uncertainty in Canister Motion Relative to Ice
14.	Actual Ice Flow Faster than Calculational Estimate
15.	Waste Interaction Speeds Ice Flow
16.	Effects of Volcanic Eruption Speeds Ice Flow
17.	Man's Activity Speeds Ice Flow
18.	Tectonic Action Modifies Ice Flow
19.	Man's Activity Produces Melt Stream
20.	Volcano Produces Melt Stream
21	Waste Interaction Produces Waste Stream

Conditional Failure Incidents

1.	Fraction of Climatic Changes Which Produce Melt Stream
2.	Fraction of Climatic Changes Which Could Move Canisters
3.	Fraction of Streams Made by Man Which Could Move Canisters
4.	Fraction of Climatic Changes Which Could Accelerate Ice Motion
5.	Fraction of Climatic Changes Which Would Make Area Habitable
6.	Melt Water Present Around Canister at Time of Failure

TABLE 3.5. Basic Failure Elements for Seabed Disposal Concepts

Number	Failure Element Description
1.	Volcano in Storage Area
2.	Aquifer in Storage Area
3.	Canister Failure Rate in Aquifer
4.	Canister Failure Rate in Ocean
5.	Change in Site Depth Occurs
6.	Energy Release Occurs
7.	Waste Improperly Stored
8.	Entire Waste Shipment Lost
9.	Gas Accumulates in Failed Canister
10.	Barrier Damaged by Waste Compaction
11.	Barrier Damaged by Man's Activity
12.	Barrier Erodes from Current
13.	Barrier Damaged by Tectonic Activity
14.	Barrier Damaged by Irradiation/Temperature
15.	Barrier Damaged by Landslide
16.	Barrier Damaged by Pressure Buildup
17.	Waste Dislodged by Man's Activity
18.	Waste Dislodged by Waste Expansion
19.	Waste Dislodged by Landslide
20.	Waste Dislodged by Tectonic Activity
21.	Waste Dislodged by Erosion
22.	Waste Dislodged by Barrier Disintegration
23.	Canister Fails from Placement Operation
24.	Canister Not Recoverable after Placement
25.	Canister Lost During Shipment Not Recovered
26.	Return of Canisters Not Detected

Conditional Failure Incidents

1.	Area Affected by Volcano
2.	Magnitude of Climatic Change Required
3.	Internal Energy Release Required To Disperse Waste
4.	Internal Energy Release Required To Damage Barrier
5.	Internal Energy Release Required To Dislodge Waste
6.	Failure Mode Fraction Favorable to Flotation
7.	Gas Formation Rate Required To Float Capsule

TABLE 3.6. Basic Failure Elements for Extraterrestrial Disposal Concepts

Failure Element Number	Description
1.	Capsule Ruptured During Ascent from Shuttle Explosion
2.	Accident Occurs on Launch Pad
3.	Release Occurs During Emergency Return
4.	Capsule Not Recoverable as a Result of Accident in Earth Orbit
5.	Accident Occurs After Earth Orbit Achieved
6.	Capsule Fails Before Recovery
7.	Capsule Not Recoverable Following Reentry
8.	Capsule Fails from Design or Fabrication Defect
9.	Shield Damaged by Accident Causing Reentry Failure
10.	Uncertainty in Behavior of Capsule in Final Trajectory Results in Return
11.	Capsule Survives Reentry But Criticality Occurs on Water Immersion
12.	Capsule Fails in Atmosphere from Accident Damage
13.	Shield Fails upon Reentry from Waste Interaction
14.	Shield Ruptured from Meteorite Bombardment
15.	Guidance System Fails During Powered Ascent
16.	Crew Unable To Overcome Guidance System Failure in Powered Ascent
17.	Rocket Failure Occurs During Final Mission Phase
18.	Attempts To Adjust Final Trajectory Fail
19.	Launch Pad Accident Generates Fireball
20.	Launch Pad Accident Generates Propellant Fire
21.	Launch Pad Accident Generates Fragments
22.	Launch Pad Accident Generates Blast Overpressure
23.	Launch Pad Accident Causes Capsule To Impact Ground
24.	Emergency Landing from Aborted Flight Fails
25.	Propellant Fire from Emergency Crash Landing Causes Capsule Failure
26.	Tug Crew Unable To Dump Propellant Prior to Emergency Landing
27.	Emergency Crash Landing Generated Fragments Cause Capsule Failure
28.	Emergency Crash Landing Impacts Unyielding Surface and Causes Capsule Failure
Conditional Failure Propagation	
1.	Thermal Design Limit of Capsule to Fireball Exceeded
2.	Thermal Design Limit of Capsule to Propellant Fire Exceeded
3.	Strength Limit of Capsule to Fragments Exceeded
4.	Strength Limit of Capsule to Blast Overpressure Exceeded
5.	Strength Limit of Capsule to Ground Impact Exceeded

3.1.2 Transport Mechanisms

All disposal concepts under study provide substantial containment or isolation barriers to initially separate the constituents of nuclear waste from man's environment. A failure or degeneration of these barriers is required before transport to man's environment can be initiated. However, a barrier failure does not necessarily result in release of waste materials into man's immediate environment where exposure takes place; transport mechanisms are required.

The primary transport mechanisms are naturally occurring water and air. In most cases, transport by water will be through soils and/or rock with extensive chemical interaction (ion exchange) taking place. The quantities, rate, and timing of radioisotopes entering man's environment will depend on a host of parameters such as the rate of release of radioisotopes at the source (i.e., solubility of waste in groundwater), the flow rate of the water, the distance travelled to reach man's environment, the efficiency of ion exchange, chemical species, etc.

Transport by air could be achieved as a result of either a single or a two-step process. In the first, an accident could both directly expose the waste to air and fracture it to such an extent that air currents would resuspend and transport material. In the two-stage process, it is postulated that naturally occurring water would transport the radioisotopes to a water (or earth)-air interface. Resuspension and transport could then occur from the residues of evaporation.

Quantification of the decontamination factors (i.e., radioisotope adsorption and holdup time) in the transport process requires an accurate model of the geologic system.

Sample transport decontamination factors were calculated for an aquifer 16 kilometers in length flowing at 30 cm/day in typical western soil. This calculation (discussed in Section 3.1.3) assumed that an aquifer penetrated a failed barrier in a geologic disposal site. Dose reduction factors were in the range of 10^5 to 10^6; that is, the calculated doses to man with soil retention were 5 to 6 orders of magnitude lower than those without soil retention. The significance of this calculation is that for properly sited disposal concepts, the earth itself can provide major safety factors.

3.1.3 Radiological Evaluations

3.1.3.1 Introduction

The high-level solid wastes which are the focus of the Advanced Waste Management Methods Study involve complex inventories of radionuclides and potential pathways of radiation exposure. Adequate risk evaluations of waste disposal concepts should therefore include estimates of radiation doses which might be received by humans if releases of such materials should occur to man's immediate environment. In addition, the evaluations may indicate incentives for additional radionuclide separations in high-level waste (waste partitioning) to reduce any eventual radiation exposures.

Radiological evaluation is, as discussed earlier, only one step in the overall safety evaluation of waste management concepts. Each proposed concept for disposal of radioactive waste may have several potential modes of release of radioactive materials to man's immediate environment, each of which in turn has associated probabilities of occurrence, as assessed in the failure mode analysis. Taking into account the effects of storage period and transport mechanisms on the radionuclide inventory released, an exposure pathway analysis and consequent radiation dose calculation can be made. The combination of consequences as measured by the calculated doses and the probability of occurrence defines the overall risk. Assessment of this risk against selected criteria may indicate the need for modification of the original concept.

3.1.3.2 Radiation Dose Criteria

It has been common practice to use tables of Maximum Permissible Concentrations (MPC) or Radiation Concentration Guides (RCG) for radionuclides in air, water, and foodstuffs as measures of significance for radiological evaluations. Various hazard or toxicity indices based on these tables have been proposed for comparisons of radiological significance. Such shortcuts may be permissible if only pathways and nuclides with a common critical organ (the body organ receiving the largest fraction of the appropriate dose criterion from a given exposure) are involved. However, where a number of radionuclides and multiple pathways of exposure are involved, the most appropriate assessment and comparison can be made only by calculating the total radiation doses to the potential critical organs.

An evaluation chart (Table 3.7) shows the hierarchy of criteria (or standards) and their interrelationships. The basic standards are in terms of radiation dose to individuals or population groups. The various factors for which data bases or assumptions are required to translate release rates to doses are shown in the second column. Secondary and tertiary standards may be derived, using standard assumptions, for application at prior steps in the evaluation chain. However, the relative importance of any specific group of nuclides and exposure pathway(s) can best be determined by dose calculations.

Recommended limits on the radiation doses received by individuals and population groups have been published by the International Commission on Radiological Protection,[26] the National Council on Radiation Protection and Measurements,[27] and the Federal Radiation Council.*[28,29] The Atomic Energy Commission dose limits both for licensees given in Chapter 20, Title 10, Code of Federal Regulations,[30] and for its own operations in AEC Manual Chapter 0524[31] are derived from the latter. Although the published criteria given by these bodies differ somewhat in detail, many of the same concepts are common to all.

TABLE 3.7. Evaluation Chart - Radiation Standards

	STEP	FACTORS	EVALUATION	STANDARDS
A.	Release	Concentration, Rate of Release	Measurement of Effluent: Gas, Liquid	Release Guides
B.	Dispersion, Reconcentration	Meteorology, Biology, Hydrology, Physical and Chemical Forms, Concentration and Discrimination Factors	Measurement of Environmental Media: Air, Water, Foods	MPC_w, MPC_a, Concentration Guides
C.	Intake	Air, Water, Food } { Concentration, Consumption Rate	Diet Surveys, Studies of Uses of Environs	Intake Ranges - FRC Maximum Permissible Rate of Intake -ICRP Reduction Factors for Gaseous Concentrations - 10CFR50
D.	Retention	Percent Uptake, Biological Half-Life, Distribution in Body	Bioassay, Whole-Body Counting	Maximum permissible Body Burden - ICRP
E.	Dose	Body Dimension, Quality Factor, Dose Equivalency Factors, Rads/μCi	Dose Calculation for: Maximum Individual, Population Average, Adult, Child	10CFR20 FRC Reports NCRP Reports ICRP Reports

*Functions now absorbed by the Environmental Protection Agency.

Although recommendations of the ICRP and the NCRP were developed primarily for occupational radiation exposure, they were later modified and applied to nonoccupational exposures of populations. All of these recommended limits are based upon controlling the radiation dose to the individual, whether a radiation worker or a member of the general public. All derived concentration limits are ultimately based on limiting radionuclide intake and direct exposure, so as not to exceed some prescribed dose limit. Inherent is a principle of long standing in radiation protection work--that all unnecessary radiation exposure should be avoided. In recent terminology, radiation exposure should be kept as low as technically and economically practicable.

Applicable radiation dose criteria consider not only potential effects on the health of individuals, but also the potential genetic burden for the population as a whole. As a result, the ICRP and NCRP have in the past included a recommendation that the general public should not receive more than 5 rem per 30 years (the mean age of childbearing) from manmade sources other than medical, with the dose delivered at a fairly uniform rate. Recent publications discuss the probabilistic health and mortality risk from low-level chronic radiation exposure to the general public,[32,33] for which the appropriate measure of risk is the accumulated dose to the entire population. Since the radiosensitivity of the various parts of the body differs, the dose to each organ should be calculated separately and compared to a dose criterion for that organ. Further, whole body dose[a] must be calculated separately and compared to a whole body dose criterion.

Little guidance is available on limiting doses to the public from accidents which result in long-term chronic exposure. The Federal Radiation Council did publish guidance for action levels based on projected doses from Sr-89, Sr-90, I-131 and Cs-137 released to the environment from accidents.[34,35] These so-called Protective Action Guides were defined as projected doses at which corrective actions should be instituted to significantly reduce the potential doses to the public. Such Protective Action Guides do not seem applicable in the current situation where a postulated accident sequence of low probability could result in long-term chronic exposure of the public in a manner which could probably be effectively controlled after the fact.

In essence then, it appears that at this time the only radiation dose guides which can prudently be applied to long-term waste management situations are those recommended for normal operations of nuclear facilities.

The current trend in regulatory guidance for radiation protection in

a. It is sometimes overlooked that the whole body dose is not the sum of doses to individual body organs; it has a significance of its own, although basically related to effects on the blood-forming and gonadal tissues.

the United States is to provide numerical definitions of "as low as practical" radiation doses for specific nuclear activities. Such a definition for long-term radioactive waste management would require reconsideration of the listed dose criteria, as would the allocation of a population dose increment specifically to waste management activities. Even though these or other considerations might result in significantly lower numerical dose standards, the relative acceptability of the alternative waste disposal concepts is unlikely to change.

Consideration was also given to the possible translation of radiation dose to increased mortality and genetic effects, using the recent BEIR[33] or UNSCEAR[32] reports as a basis. It was the decision of the working group not to attempt such a conversion at this time. Again, such attempted conversions would not be likely to affect the relative acceptability of alternate waste disposal concepts.

The following maximum dose criteria for waste disposal concept comparisons were, therefore, derived primarily from NCRP recommendations, and secondarily from Chapter 20, Title 10, Code of Federal Regulations and FRC recommendations. The presentation of these criteria does not imply that any such doses are planned nor that they are necessarily acceptable if practicable measures can be taken to reduce the probability of their occurrence.

TABLE 3.8. Maximum Dose Criteria Used for Advanced Waste Management Concept Evaluation - mrem/year

	Maximum Individual	Population Average
Whole Body	500	170
All Other Organs	1,500	500

3.1.3.3 Dose Calculation Model

The complex ways in which radionuclides may be transferred from one environmental component to another are illustrated in Figure 3.11, showing a flow diagram for the calculation of radiation dose to various organs of the body which could result from the release of a single radionuclide to the air or to a water supply. Each sign (X) in the diagram indicates multiplication by the following specific factor required for the calculation.

Figure 3.11 is taken from reference (36), which includes a description of a computational dose model developed and used for calculation of radiation doses to a regional population in the year 2000 from nuclear power. Extensive use of the model has been made in assisting the Atomic Energy Commission's Office of Regulation to prepare Environmental Statements for nuclear power reactors. The integrated model requires extended time usage of a large digital computer, but for many nuclides a

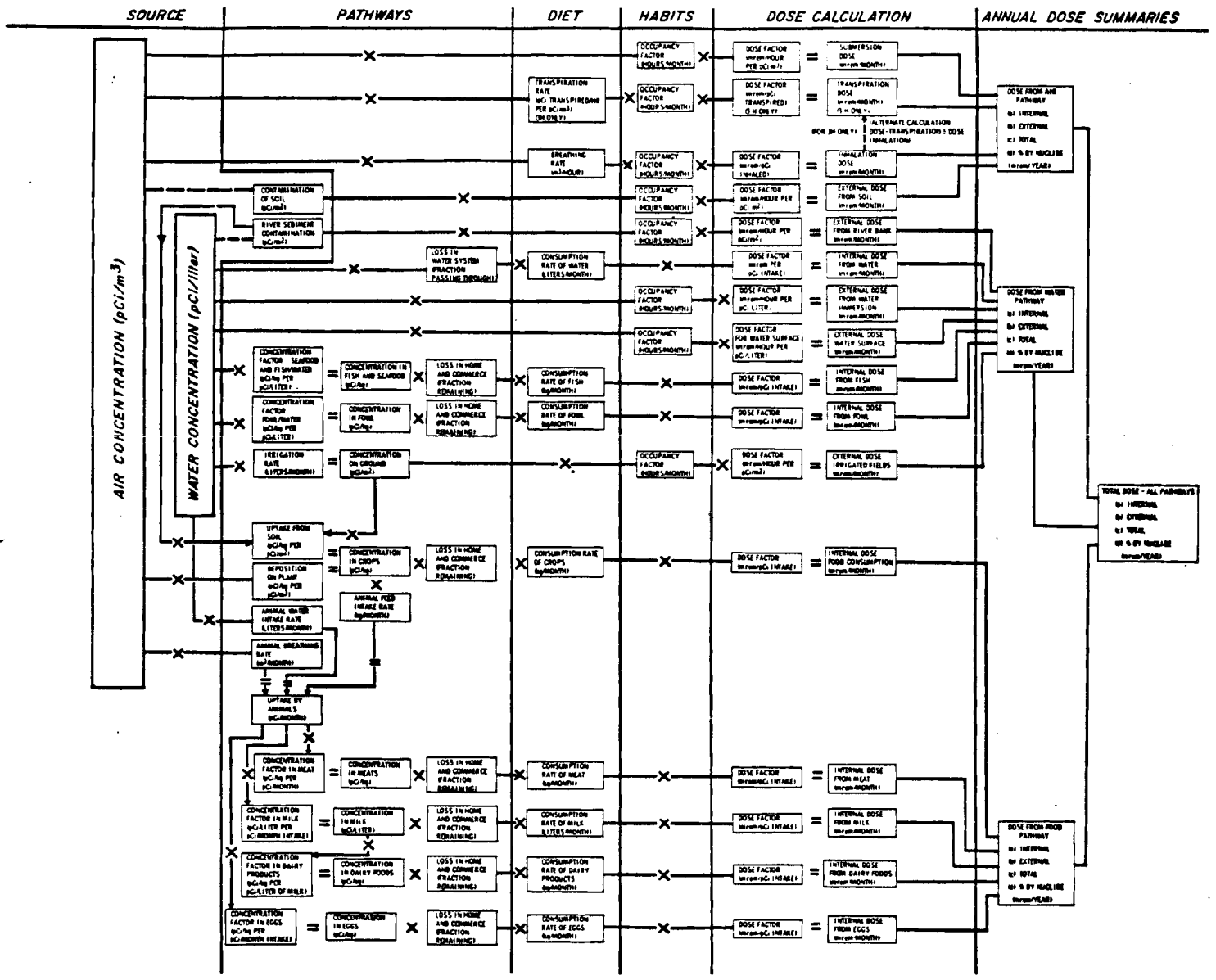


FIGURE 3.11. Radiation Dose Calculation Matrix(36)

much simplified calculation is adequate. Therefore, a group of relatively short programs[37] has been developed to permit separate dose calculations for each of the major pathways, including a marine environment. These smaller programs not only permit ready manipulation of the input parameters but also solution with a simple computer language on a time-shared computer with limited data storage capability. A typical small program for calculation of doses from consumption of foods from farms irrigated with radionuclide-bearing water is given in Appendix 3.A, with lists of the factors used in all of these programs in Appendices 3.B and 3.C.

Input data that must be provided for each computation are the dilution volume for water releases and the release rates of specific radionuclides to air and water. Joint frequency tables of wind direction and speed versus atmospheric stability category and sector distribution of population should also be specified, as well as any significant exposure quantities not already included.

Output tabulations from the several pathway calculations give radiation dose to the whole body and other critical organs for both the maximum individual and the exposed population for the distribution specified. Also given is the percentage contribution of each nuclide to each dose. Contributions for all pathways may also be summed with similar percentage distribution by nuclide and by pathway. Both annual doses and the total doses for a continuous 50-year exposure are given. Examples of dose summaries are shown in Tables 3.15 through 3.18 of this report.

The dose-pathway models are under continual review and development, including parameter changes as warranted. One improvement in progress is the inclusion of doses to other organs of the body following the slow removal from the lungs of inhaled insoluble materials (120-day biological half-life as per the ICRP). Other potential refinements in the overall model include use of the newer lung model developed by an ICRP Task Group,[38] but not yet officially adopted by the ICRP.

3.1.3.4 Exposure Pathway Analysis

Application of an exposure pathway model based on today's culture, food, and recreational habits, to periods of one thousand to one million years in the future obviously involves predicting the unpredictable. However, if the earth is still occupied by human beings at the more remote periods, one can assume that they will be breathing air, drinking water, and consuming foodstuffs from their environment.

The radiological evaluation concept--applicable in general to any nuclear installation including operating plants as well as waste storage facilities--involves the solution of an exposure pathway matrix (Figure 3.11) for each of the nuclides which may be released from the installation. Typical dose calculations include the internal pathways of inhalation and consumption of drinking

water, fish, milk and fresh leafy vegetables, as well as the external pathways of air submersion and standing on contaminated land (from irrigation, shoreline deposition, or airborne fallout).

Doses are calculated for individuals (in mrem) and for the population (in man-rem), typically within an 80-kilometer radius of the assumed release point, based on one and on 50 years of continuous exposure. The 50-year dose factor (factor by which the annual dose from a given nuclide may be multiplied to obtain the 50-year total dose) is shown in Figure 3.12 as a function of τ, the effective half-life in a particular body organ. The total external and internal dose is calculated for each of several organs (lungs, GI-LLI, bone, thyroid, liver). Internal dose factors are those used for adults by the ICRP,[39,40] as is the exposure period of 50 years. External dose factors have been calculated using the respective radionuclide decay schemes given in the Table of Isotopes.[41]

The dose to an individual is calculated for a person whose dietary and living habits as well as his geographic location with respect to the potential release will tend to maximize his radiation dose. Intake rates and exposure periods, used both for individuals and the regional population, are given in Table 3.9, and are based in large part on diet surveys and questionnaires used in Hanford studies.[42]

For airborne releases, the individual doses are calculated for the location where the annual average atmospheric concentration would be the greatest. No allowance is made in the air submersion or inhalation

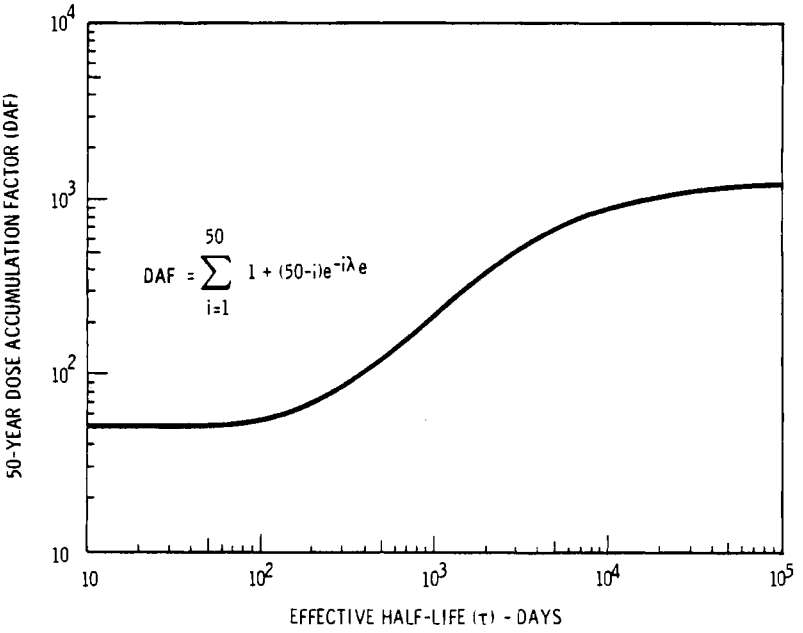


FIGURE 3.12. Fifty-Year/Annual Dose Ratios

TABLE 3.9. Annual Intake and Exposure Assumptions for Radiological Dose Calculations

Pathway	Individual	Population
Inhalation/Air Submersion	8760 hr	8760 hr
Drinking Water	730 liters	440 liters/person
Shoreline Recreation	500 hr	10 hr/person
Swimming and Boating	200 hr	5 hr/person
Fresh Leafy Vegetables[a]	36 kg	8 kg/person
Root Vegetables	180 kg	120 kg/person
Other Vegetables and Fruits	410 kg	100 kg/person
Fresh Whole Milk[b]	280 liters	140 liters/person
Meat and Poultry	98 kg	48 kg/person
Eggs	30 kg	20 kg/person
Fish	18 kg	2.4 kg/person
Grains	100 kg	90 kg/person

a. Six months of local vegetables consumed by individual; three months of local vegetables consumed by persons of population.
b. Nine months of grazing on contaminated pasture.

dose calculations for cloud depletion of radioactivity by deposition or precipitation scavenging. However, deposition velocities estimated from the data of Watson[43] are used for calculating resultant concentrations on crops, land, or water.

Most airborne materials are assumed to be insoluble particulates for the inhalation pathway while all materials taken in via the ingestion pathway (fresh leafy vegetables, milk, fish, drinking water) are assumed to be soluble in the body. No allowance is made in the model itself for removal of waterborne nuclides by ion exchange or absorption in soil or sediments, or by filtration at a water treatment plant. The latter assumptions undoubtedly introduce a large measure of conservatism in the dose estimates and, when warranted, inclusion of such removal factors can be made by adjusting the source term.

The fractions of radionuclides ingested by the cow that are secreted per liter in milk are based on those listed by Y. G. Ng et al.,[44] but the referenced values are divided by two, since the authors state that their values represent the upper range of literature values and that their value for iodine is twice the average value.[44] The concentration factors used for radionuclides in fish and other aquatic organisms were taken from Thompson et al.,[45] and Freke.[46]

The concentrations of radionuclides in poultry (and eggs), meat animals, and waterfowl have generally been found not to result in significant doses to man. The dose calculations, therefore, do not include these foodstuffs.

Other assumptions used for calculation of concentrations are listed in Table 3.10.[47]

TABLE 3.10. Assumptions and Quantities Used in Calculating Radionuclide Concentrations

CROPS

- Deposition velocities: Iodine - 1×10^{-2} m/sec
  Other Nuclides - 8×10^{-4} m/sec
- Irrigation rate - 110 liters/m^2/month
- Initial retention on crops from irrigation water or fallout - 25% of total deposition.
- Weathering half-life for radionuclides on crops - 14 days.
- Accumulation period of radionuclides on crops (before harvesting): Leafy vegetables - 90 days; pasture grass - 30 days.
- Crop yields: Leafy vegetables - 1 kg/m^2; pasture grass - 1.3 kg/m^2.
- Radionuclide accumulation in the root zone - 25 years.
- Mass of soil in root zone - 224 kg/m^2.
- Plant uptake factors from soil used for irrigation mode only.

MILK

- Water consumption of cow - 50 liters/day.
- Forage consumption of cow - 55 kg/day.
- Inhalation by the cow - insignificant for transfer of radionuclides to milk.

SHORELINE

- Accumulation period of radionuclides in shoreline silt - 1 year.
- Semi-infinite plane source (shoreline).
- Shoreline dose rate - gamma only at 1 meter above surface.
- Ground roughness factor - 0.5.

3.1.3.5 Example of Dose Calculations

To illustrate the methodology and typical computational outputs, a hypothetical geologic disposal case was used. No attempt was made to treat a specific disposal site, but typical parameters for an arid low-population region were assumed as needed. Similar calculations for other disposal concepts were made to a degree needed to assure applicable methodology; however, even less information was available for specific site, release modes, and needed parameters for dose calculations for these other concepts.

Initial Source Term

Key to the calculation of radiological effects is the quantity of radioactive material including its

composition and its rate of release. For the examples discussed here, all of the nuclear waste generated through the year 2000 was assumed to be contained at a single location. The radionuclide inventory, including fission products, transuranic nuclides generated in reactor fuels, cladding wastes, and 0.5% fuel loss, was generated by the ORIGEN Program.[48] This inventory--based on total equivalent fuel processed of 167,000 metric tons through the year 2000, with a mixture of reactor and fuel types--includes 60 nuclides expected to be present in the high-level wastes after periods ranging from 100 to 1,000,000 years. The inventories for all nuclides with mass numbers greater than 75 are based on Oak Ridge data, while those for mass numbers below 75 were calculated by Battelle-Northwest personnel. Tritium from fission and C-14 from impurities in the fuel were not included in the waste inventory (see Appendix 3.D). Ni-59 and Ni-63 were included as cladding impurities, even though such material may not be included as part of the high-level waste.

Geologic Disposal - Soil Retention, Fractionation and Dose Calculation

The effective retention and fractionation of radionuclides in soil columns have been thoroughly demonstrated and documented [for example, reference (49)]. Although the effectiveness is highly dependent upon the ion-exchange capacity of the soil involved, as well as other characteristics of the soil and solution, the potentially overruling importance of the phenomenon makes it desirable to include it in the dose calculation. To exemplify the dose calculation and output details, a single disposal site with initial release of waste from the waste canister to groundwater at 100 years after separation was used. Eventual release to a river, with a flow rate of 280 cubic meters per second (10,000 cubic feet per second) and providing drinking water, irrigation, and recreation to a population of 150,000 was assumed.

The rate of release of the waste inventory to groundwater was assumed to be 0.3% per year of the total waste. As shown in Table 3.11, the 0.3% per year is typical of solid shapes, such as spheres, cubes or right circular cylinders, with a characteristic dimension of 10 centimeters and a leach rate of 10^{-4} g/cm^2/day (borosilicate glass, for example). Incorporation of the waste in larger monolithic solids (characteristic dimension of 100 cm) with improved resistance (10^{-6} gm/cm^2/day) to leaching or corrosion, could reduce release rates a thousandfold. Conversely, changes which result in waste properties with high leach rates or smaller characteristic dimensions could result in increased release rates.

Estimated distribution coefficients (Kd) and retardation factors Vi/Vw for movement of selected radioactive elements through a typical western desert soil in contact with typical nonsaline groundwater were as given

TABLE 3.11. Percent of Waste Dissolved per Year as a Function of Leach Rate and Waste Solid Characteristic Dimension

LEACH RATE	Percent Dissolved per Year DIAMETER - cm				
$g/cm^2/day$	0.01	0.1	1.0	10.	100.
1E-09	0.37E-02	0.37E-03	0.39E-04	0.45E-05	
1E-08	0.37E-01	0.37E-02	0.37E-03	0.39E-04	0.45E-05
1E-07	0.36E-00	0.37E-01	0.37E-02	0.37E-03	0.39E-04
1E-06	0.36E+01	0.36E-00	0.37E-01	0.37E-02	0.37E-03
1E-05	0.32E+02	0.36E+01	0.36E-00	0.37E-01	0.37E-02
1E-04	0.10E+03	0.32E+02	0.36E+01	0.36E-00	0.37E-01
1E-03	0.14E+06	0.10E+03	0.32E+02	0.36E+01	0.36E-00
1E-02	0.18E+09	0.14E+06	0.10E+03	0.32E+02	0.36E+01
1E-01	0.18E+12	0.18E+09	0.14E+06	0.10E+03	0.32E+02
1E-00	0.18E+15	0.18E+12	0.18E+09	0.14E+06	0.10E+03

Note: Density of waste mass is $\sim$ 3 g/cm^3

in Table 3.12. Table 3.13 gives the selected composition of the "typical nonsaline groundwater." The typical soil selected was a sand of moderate cation-exchange capacity (about 5 milliequivalents per 100 grams) to sandy loam containing about 1 milligram of free $CaCO_3$ per gram of soil and soil pH of 7.0-8.2. An aquifer through the soil of 16 kilometers in length (from disposal site to a river) with an average groundwater flow rate of 30 centimeters per day was also assumed.

Several simplifying assumptions were made in the calculations for transport from the waste repository to the river. An axial dispersion coefficient of 0.008 cm^2/min was assumed, but transverse dispersion (typically 0.001 cm^2/min), which causes plume spreading and lower exit concentrations, was ignored. A continuous flow of water was assumed, with the absence of regions unsaturated in water in the flow path. The solid surface-to-liquid volume ratios in the flow path were relatively high, being characteristic of soil rather than rock formations. Tracer level distribution coefficients for radionuclide adsorption were used in the calculations. Macroscopic concentrations of ions in solution such as from the bulk quantities of fission products in the repository or from a bedded salt formation could reduce the travel times to the river. The migration rates of daughters in decay chains were treated by semi-intuitive engineering estimates.

The remoteness of a repository in a geologic formation is due to its adsorptive properties, which cause a

TABLE 3.12. Estimated Distribution Coefficients in a Typical Desert Soil

Atomic No.	Element	Kd (ml/g)[a]	Vi/Vw[b]
1	Tritium	0	1
4	Beryllium	75	3×10^{-3}
6	Carbon	2	1×10^{-1}
11	Sodium	10	2×10^{-2}
17	Chlorine	0	1
18	Argon	0	1
19	Potassium	35	6×10^{-3}
20	Calcium	15	1×10^{-2}
26	Iron	150	3×10^{-4}
27	Cobalt	75	3×10^{-3}
28	Nickel	80	3×10^{-3}
34	Selenium	20	1×10^{-2}
36	Krypton	0	1
37	Rubidium	125	2×10^{-3}
38	Strontium	20	1×10^{-2}
39	Yttrium	2,000	1×10^{-4}
40	Zirconium	2,000	1×10^{-4}
41	Niobium	2,000	1×10^{-4}
42	Molybdenum	5	4×10^{-2}
43	Technetium	0	1
46	Palladium	250	9×10^{-4}
48	Cadmium	2,000	1×10^{-4}
50	Tin	250	9×10^{-4}
51	Antinomy	15	1×10^{-2}
53	Iodine	0	1
55	Cesium	200	1×10^{-3}
61	Promethium	600	4×10^{-4}
62	Samarium	600	4×10^{-4}
63	Europium	600	4×10^{-4}
67	Holmium	600	4×10^{-4}
81	Thallium	2	1×10^{-1}
82	Lead	4,000	6×10^{-5}
83	Bismuth	10	2×10^{-2}
84	Polonium	25	9×10^{-3}
85	Astatine	0	1
86	Radon	0	1
87	Francium	200	1×10^{-3}
88	Radium	100	2×10^{-3}
89	Actinium	1,000	2×10^{-4}
90	Thorium	15,000	2×10^{-5}
91	Proactinium	4,000	2×10^{-5}
92	Uranium	3,000	6×10^{-5}
93	Neptunium	15	7×10^{-2}
94	Plutonium	2,000	1×10^{-4}
95	Americium	2,000	1×10^{-4}
96	Curium	600	1×10^{-4}
97	Berkelium	700	3×10^{-4}

(a) Equilibrium distribution coefficients between water and soil.
(b) Relative transport rate of elements in assumed soil to that in water.

TABLE 3.13. Estimated Composition of Groundwater Below a Typical Arid Area

	Concentration/ppm						
pH	$SO_4^=$	NO_3^-	Cl^-	HCO_3^-	Na^+	K^+	Ca^{++}	Mg^{++}
6.8-8.2	15	1	8	125	20	5	25	5

delay in the radionuclide discharge to man's environment after a leaching incident. This results in a lower discharge rate because of radioactive decay. The formation also separates the radionuclides into chromatographic bands, so that each discharge peaks at a different time and the doses are not additive. Axial dispersion of the water in the aquifer also can reduce exit radionuclide concentrations by a hundredfold by spreading the chromatographic bands. Thus the discharge rate from the aquifer is not necessarily proportional to the leach rate at the repository. Finally, the daughters in a decay chain do not discharge in discrete chromatographic bands but are spread out over hundreds of thousands of years, greatly reducing their discharge concentration and making them less significant as dose factors. All of these effects are highly dependent on the chemical and hydrologic properties of the flow path, which can vary widely with formation type or from site to site in a given formation.

Using methods given in Reference (50), a mathematical model was derived and programmed for computer solution. Arrival time at the river, time of maximum concentration entering the river, and duration of release into the river were calculated for the more important dose contributors. Figure 3.13 and Table 3.14 give partial results of these calculations, made at periods selected for peak concentrations of those contributors. The results are tabulated in Tables 3.15 through 3.18.

From Tables 3.16 through 3.18 it can be seen that both the annual and 50 year doses to the Maximum Individual and the population result in most instances from only a few radionuclides. The particular nuclides change with time after separation. For example, at 100 years, Tc-99 predominates for all organ dose except the thyroid where the dose is primarily from I-129. At 1,000 years, Se-79 and Np-237 are the principal contributors to the dose, and at 10,000 years the Sn-126 and Cs-135 are the major dose contributors. At 100,000 years Zr-93, Sn-126, Cs-137 and the U-233 chain are the most important radionuclides. The U-234 chain becomes important at 1,000,000 years and greater for all organs listed except for the GI-LLI dose, where the Zr-93 is still contributing a measurable fraction of the dose.

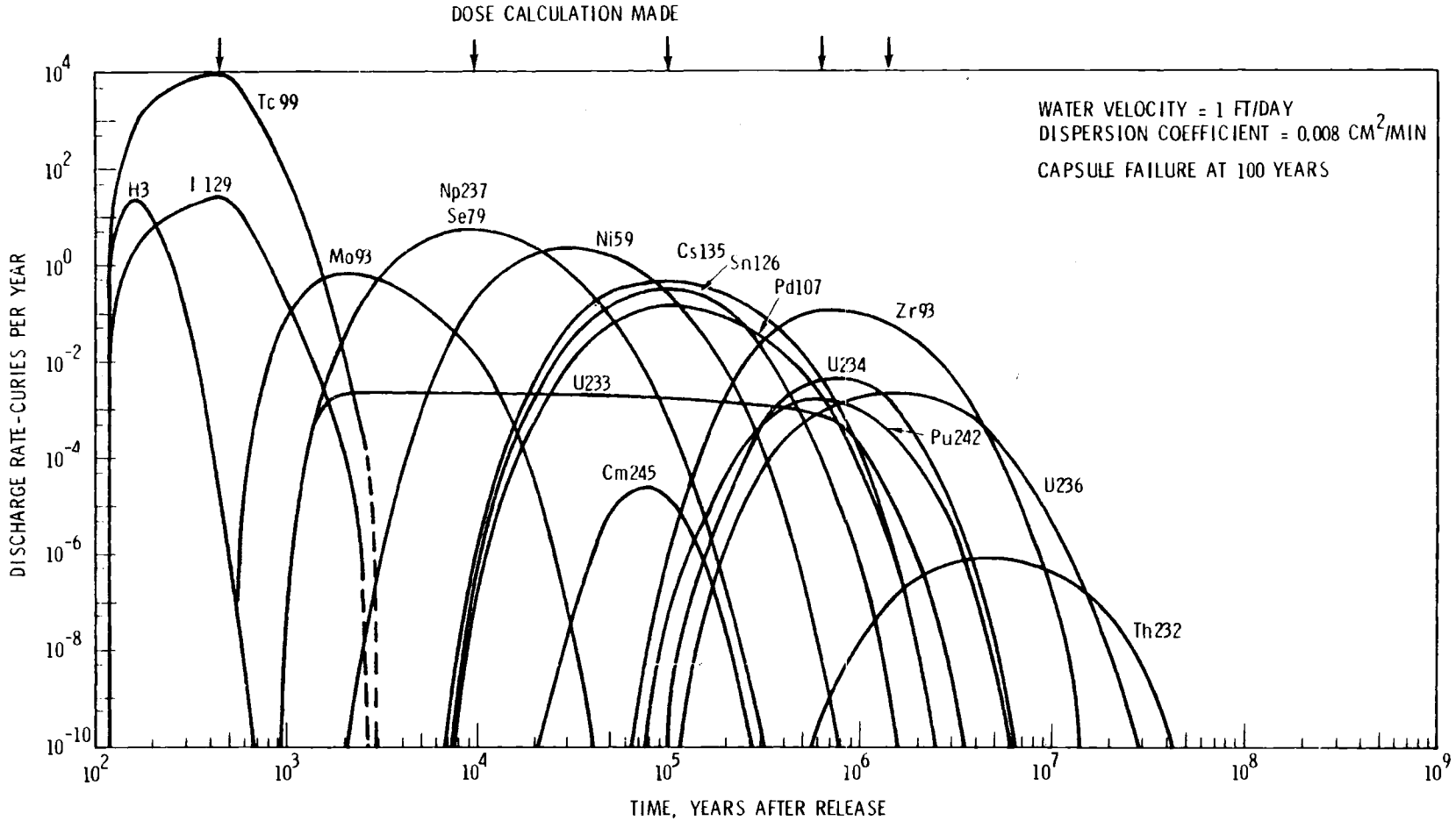


FIGURE 3.13. Selected Radionuclide Discharge from an Aquifer with Soil Retention

TABLE 3.14. Arrival Times and Peak Discharge Rates of Selected Radionuclides from Aquifer with Soil Retention

Release Rate - 0.3% per year
Mean Flow Rate - 30 cm per day
Distance to River - 16 km

Major Nuclide	Inventory at 100 Years - Ci	Time of Peak Discharge - Years	Discharge Rate Ci/Yr	Other Nuclides
^{99}Tc	2,800,000	480	7,800	
^{129}I	8,000		24	
^{79}Se	97,000	9,400	4.7	
^{237}Np	73,000		4.5	
			0.23	^{14}C
			0.07x7	^{59}Ni
^{135}Cs	85,000	94,000	0.44	
			0.34	^{59}Ni
			0.32	^{126}Sn
^{242}Pu		620,000	1.5×10^{-3}	
			1.1×10^{-1}	^{93}Zr
			4.1×10^{-3}	^{135}Cs
			3.9×10^{-3}	^{234}U
			2.0×10^{-3}	^{107}Pd
			4.5×10^{-4}	^{233}U
			1.6×10^{-4}	^{126}Sn
			1.0×10^{-5}	^{229}Th
			6×10^{-5}	^{231}Pa
			4×10^{-5}	^{230}Th
^{236}U	6,200	1,300,000	2.3×10^{-3}	
			7.2×10^{-2}	^{210}Pb
			2.0×10^{-3}	^{93}Zr
			1.2×10^{-3}	^{242}Pa
			5.0×10^{-4}	^{234}U
			4.5×10^{-4}	^{226}Ra
			9.1×10^{-5}	^{238}U
			2.2×10^{-5}	^{233}U
			1.0×10^{-5}	^{230}Th
			8.4×10^{-6}	^{235}U
			6.2×10^{-6}	^{107}Pd
			6.1×10^{-6}	^{126}Sn

TABLE 3.15. Annual Radiation Dose to a Maximum Individual from Hypothetical Fractionated Discharge to Surface Water, with Initial Release to Groundwater 100 Years After Disposal

Source Release Rate - 0.3% per year

Time After Initial Release (Years)	480	9,400	94,000	620,000	1,300,000
A. WHOLE BODY - Dose Criterion 500 mrem					
Total Annual Dose - mrem	0.44	0.24	0.12	0.0002	0.0012
Dose Contribution by Nuclide					
^{79}Se	-	0.02	-	-	-
^{99}Tc	0.40	-	-	-	-
$^{126}Sn+D$	-	-	0.11	0.00005	-
^{129}I	0.04	-	-	-	-
^{135}Cs	-	-	0.01	0.00009	-
^{233}U Chain	-	-	-	0.00004	-
^{234}U Chain	-	-	-	0.00001	0.0012
$^{237}Np+D$	-	0.22	-	-	-
Others(a)	0.005	0.002	0.001	0.00001	<0.00001
B. GI (LLI) TRACT - Dose Criterion 1500 mrem					
Total Annual Dose - mrem	49.	0.3	0.15	0.0005	0.0004
Dose Contribution by Nuclide					
^{79}Se	-	0.02	-	-	-
$^{93}Zr+D$	-	-	-	0.0002	0.0001
^{99}Tc	49.	-	-	-	-
$^{126}Sn+D$	-	-	0.15	0.0001	-
^{233}U Chain	-	-	-	0.0001	-
^{234}U Chain	-	-	-	-	0.0002
$^{237}Np+D$	-	0.28	-	-	-
Others(a)	<0.5	0.01	0.01	0.0001	0.0001
C. THYROID - Dose Criterion 1500 mrem					
Total Annual Dose - mrem	38.	0.22	0.10	0.0001	0.0001
Dose Contribution by Nuclide					
$^{126}Sn+D$	-	-	0.10	0.00005	-
^{129}I	38.	-	-	-	-
^{233}U Chain	-	-	-	0.00004	-
^{234}U Chain	-	-	-	-	0.0001
$^{237}Np+D$	-	0.22	-	-	-
Others(a)	0.01	0.002	0.001	0.00001	<0.00001
D. BONE - Dose Criterion 1500 mrem					
Total Annual Dose - mrem	1.0	0.25	0.28	0.0005	0.003
Dose Contribution by Nuclide					
^{99}Tc	1.0	-	-	-	-
$^{126}Sn+D$	-	-	0.25	0.0001	-
^{135}Cs	-	-	0.03	0.0003	-
^{233}U Chain	-	-	-	0.0001	-
^{234}U Chain	-	-	-	-	0.003
$^{237}Np+D$	-	0.24	-	-	-
Others(a)	<0.1	0.01	<0.01	<0.0001	<0.0001
E. LIVER - Dose Criterion 1500 mrem					
Total Annual Dose - mrem	1.5	0.34	0.13	0.0004	0.0006
Dose Contribution by Nuclide					
^{79}Se	-	0.11	-	-	-
^{99}Tc	1.5	-	-	-	-
$^{126}Sn+D$	-	-	0.10	0.0001	-
^{135}Cs	-	-	0.03	0.0003	-
^{234}U Chain	-	-	-	-	0.0006
$^{237}Np+D$	-	0.23	-	-	-
Others(a)	0.01	0.01	0.01	0.0001	0.0001

(a) May include small contributions from nuclides for which a (-) is shown.

TABLE 3.16. Annual Radiation Dose to Assumed Population from Hypothetical Fractionated Discharge to Surface Water, with Initial Release to Groundwater 100 Years After Disposal

Source Release Rate - 0.3% per year

Time After Initial Release (Years)	480	9,400	94,000	620,000	1,300,000
A. WHOLE BODY - Dose Criteria 25,000 man-rem					
Total Annual Dose - man-rem	29.	2.0	0.67	0.0026	0.053
Dose Contribution by Nuclide					
^{59}Ni	-	-	0.03	-	-
^{79}Se	-	1.2	-	-	-
^{99}Tc	27.	-	-	-	-
^{126}Sn+D	-	-	0.40	0.0002	-
^{129}I	2.	-	-	-	-
^{135}Cs	-	-	0.24	0.0022	-
^{233}U Chain	-	-	-	0.0002	-
^{234}U Chain	-	-	-	-	0.053
^{237}Np+D	-	0.7	-	-	-
Others(a)	0.3	0.1	0.01	0.0001	0.001
B. GI (LLI) TRACT					
Total Annual Dose - man-rem	3,200	5.6	1.4	0.013	0.010
Dose Contribution by Nuclide					
^{79}Se	-	1.5	-	-	-
^{93}Zr+D	-	-	-	0.006	0.004
^{99}Tc	3,200	-	-	-	-
^{107}Pd	-	-	0.1	0.001	-
^{126}Sn+D	-	-	1.3	0.001	-
^{233}U Chain	-	-	-	0.001	-
^{234}U Chain	-	-	-	0.002	0.005
^{236}U	-	-	-	-	0.001
^{237}Np+D	-	4.0	-	-	-
^{242}Pu	-	-	-	0.001	-
Others(a)	30	0.1	0.1	0.001	<0.001
C. THYROID					
Total Annual Dose - man-rem	2,400	0.71	0.32	0.0003	0.0004
Dose Contribution by Nuclide					
^{14}C	-	0.04	-	-	-
^{126}Sn+D	-	-	0.32	0.0001	-
^{129}I	2,400	-	-	-	-
^{233}U Chain	-	-	-	0.0001	-
^{234}U Chain	-	-	-	-	0.0004
^{237}Np+D	-	0.66	-	-	-
Others(a)	20	0.01	0.003	0.0001	<0.0001
D. BONE					
Total Annual Dose man-rem	68.	2.3	4.3	0.008	0.12
Dose Contribution by Nuclide					
^{14}C	-	0.2	-	-	-
^{59}Ni	-	0.1	0.2	-	-
^{99}Tc	68.	-	-	-	-
^{126}Sn+D	-	-	3.5	0.002	-
^{135}Cs	-	-	0.6	0.005	-
^{234}U Chain	-	-	-	-	0.12
^{237}Np+D	-	1.8	-	-	-
Others(a)	1.	0.2	0.04	0.001	<0.001
E. LIVER					
Total Annual Dose - man-rem	100	8.3	1.1	0.006	0.019
Dose Contribution by Nuclide					
^{59}Ni	-	-	0.1	-	-
^{79}Se	-	7.4	-	-	-
^{99}Tc	99.	-	-	-	-
^{126}Sn+D	-	-	0.4	-	-
^{135}Cs	-	-	0.6	0.005	-
^{234}U Chain	-	-	-	-	0.019
^{237}Np+D	-	0.7	-	-	-
Others(a)	1.	0.2	0.1	0.001	<0.001

(a) May include small contribution from nuclides for which a (-) is shown.

TABLE 3.17 Fifty-Year Radiation Dose to a Maximum Individual from Hypothetical Fractionated Discharge to Surface Water, with Initial Release to Groundwater 100 Years After Disposal

Source Release Rate - 0.3% per year

Time After Initial Release (Years)	480	9,400	94,000	620,000	1,300,000
A. WHOLE BODY - Dose Criterion 25,000 mrem					
Total Dose - mrem	1.2	0.65	0.30	0.0005	0.01
Dose Contribution by Nuclide					
^{79}Se	-	0.05	-	-	-
^{99}Tc	1.1	-	-	-	-
$^{126}Sn+D$	-	-	0.27	0.0001	-
^{129}I	0.1	-	-	-	-
^{135}Cs	-	-	0.02	0.0002	-
^{233}U Chain	-	-	-	0.0001	-
^{234}U Chain	-	-	-	-	0.01
$^{237}Np+D$	-	0.60	-	-	-
Others(a)	<0.01	<0.01	0.01	0.0001	<0.0001
B. BONE - Dose Criterion 75,000 mrem					
Total Dose - mrem	2.6	1.8	0.75	0.002	0.10
Dose Contribution by Nuclide					
^{59}Ni	-	-	0.02	-	-
^{99}Tc	2.5	-	-	-	-
$^{126}Sn+D$	-	-	0.65	0.0004	-
^{129}I	0.05	-	-	-	-
^{135}Cs	-	-	0.08	0.0008	-
^{233}U Chain	-	-	-	0.0005	-
^{234}U Chain	-	-	-	-	0.10
$^{237}Np+D$	-	1.8	-	-	-
^{242}Pu	-	-	-	0.0002	-
Others(a)	<0.05	<0.05	<0.01	0.0001	<0.001
C. LIVER - Dose Criterion 75,000 mrem					
Time After Initial Release (Years)	480	9,400	94,000	620,000	1,300,000
Total Dose - mrem	3.8	0.95	0.35	0.001	0.008
Dose Contribution by Nuclide					
^{79}Se	-	0.28	-	-	-
^{99}Tc	3.8	-	-	-	-
$^{126}Sn+D$	-	-	0.27	0.0001	-
^{135}Cs	-	-	0.08	0.0007	-
^{233}U Chain	-	-	-	0.0001	-
^{234}U Chain	-	-	-	-	0.008
$^{237}Np+D$	-	0.67	-	-	-
Others(a)	<0.1	<0.01	<0.01	0.0001	<0.0001

(a) May include small contributions from nuclides for which a (-) is shown.

TABLE 3.18. Fifty-Year Radiation Dose to Assumed Population from Hypothetical Fractionated Discharge to Surface Water, with Initial Release to Groundwater 100 Years After Disposal

Source Release Rate - 0.3% per year

WHOLE BODY - Dose Criterion 1,300,000 man-rem

Time After Initial Release (Years)	480	9,400	94,000	620,000	1,300,000
Total Dose - man-rem	1,500	160	38	0.16	10
Dose Contribution by Nuclide					
^{59}Ni	-	3	5	-	-
^{79}Se	-	61	-	-	-
^{99}Tc	1360	-	-	-	-
$^{126}Sn+D$	-	-	20	0.010	-
^{129}I	130	-	-	-	-
^{135}Cs	-	-	13	0.12	-
$^{231}Pa+D$	-	-	-	0.003	-
^{233}U Chain	-	-	-	0.017	-
^{234}U Chain	-	-	-	-	10
$^{237}Np+D$	-	95	-	-	-
^{242}Pu	-	-	-	0.005	-
Others(a)	10	2	<0.3	0.005	<0.1

(a) May include small contributions from nuclides for which a (-) is shown.

Interpretation of Dose Tables

As discussed in Section 3.1.2.2, a dose criterion is shown in each table where appropriate. However, since the cases are hypothetical, the only conclusions that should be drawn concern critical nuclides, prevailing exposure modes, and relative importance of the several parameters.

Although many nuclides contribute to the calculated doses, only those contributing more than 1% of the total organ dose are shown in each table. For nuclides with only one or two daughters, and when the half-life of the daughter nuclide(s) is shorter than the parent's, only the parent (with the notation +D) is listed, e.g., Zr-93+D, Sn-126+D, Am-243+D. Decay chains are listed separately when the half-life of the daughter(s) is greater (by a factor of 10 or more) than the parent's. Thus, Pu-239, Pu-240, and Am-241 are shown separately from their longer-lived daughters U-235, U-236, and Np-237, respectively. Since the uranium isotopes are generally much longer-lived than any of their daughters, they are listed as a chain (e.g., U-233 Chain), indicating that the dose from the parent and all daughters was included in the calculation.

Calculated whole body doses are shown in all dose tables, but doses are shown only for those other organs of the body believed to be potentially critical organs, considering

the mixture of radionuclides and the modes of exposure. The model provides dose calculations in every case for whole body, gastrointestinal tract, bone, lungs, liver, and thyroid. Other body organs, such as the skin or kidney, may be added if warranted.

Other Concepts

Test calculations were tried for other disposal concepts, using the same computational model but with different assumptions as to mode of release and exposure pathways.

Geologic Disposal - Atmospheric Release: For atmospheric releases from a geologic disposal site, a population distribution and time-averaged meteorological data are required by geographic sector. Two population distributions with an 80-kilometer (50-mile) radius were used, one a typical urban population[51] of 1.5 million people that has been used in environmental impact studies for the Office of Regulation, and the other a rural population of 170,000 people. A different set of meteorological parameters was used with each population case. Meteorological data from an actual midwestern reactor site were used for the urban case, while the Hanford tower meteorological data were used as being typical for an arid western region.

Population and meteorological parameters for each case are listed in Appendices 3.E and 3.F.

The point of release in each case was assumed to be at the center of the grid. The test case assumed no retention on soil, but a smaller fraction released. No specific release mechanism was postulated.

For the test case for both an individual and the total population, inhalation would be the dominant pathway and the lung the critical organ. By far the most significant nuclides for release after 100 years storage would be Sr-90 and Ce-137, the americium after 1,000 years and uranium daughters (including those derived from plutonium and americium) at 100,000 years and longer periods. It is interesting to note further that the calculated doses for the 100-year storage are generally at least three orders of magnitude greater than the values for longer storage periods.

Ice Sheet Disposal: Dose calculations were tested for radionuclides released from an ice-sheet disposal site into the ocean off the coast of Greenland. It was assumed that a failure of the disposal system would release 0.3% per year of the total inventory available into the Greenland current of 8×10^6 m^3/sec[52] and that complete mixing would occur rapidly in the ocean.

The pathway to man was assumed to be nearly all via fish consumption. An Eskimo consuming 100 kg/yr of fish caught in these waters was considered to represent an individual receiving the maximum dose. A population dose was estimated assuming that the total fish catch from the North Sea in 1965, 3.2×10^9 kilograms[53] was consumed by a human population of 150,000,000 people, and that all these fish had lived in the waters contaminated by the radionuclide release. Consumption weight was taken as half the live weight.

For this hypothetical case; individual doses would be comparable with those from a geologic disposal site release to a river. Population doses would not be comparable, however, since the size of the exposed population for the ice sheet calculation could be 1,000 times the exposed population for a ground disposal case. The release rate of 0.3% per year may not be realistic, but was used to provide a comparison.

Seabed Disposal: As a test, emplacement in the North Pacific Ocean was assumed, with similar release modes to the open ocean. Exposure of people would presumably be almost entirely via the pelagic fishery, but with a larger potential population. Calculated doses for this hypothetical case and critical nuclides would be very similar to the Ice Sheet case.

These dose calculations are highly dependent on the assumed rates of release to the ocean from beneath the ice sheet or seabed and rate of dilution by the ocean. The example chosen is a very simple pathway; other sea disposal concepts, especially near shorelines in more temperate zones, would involve much more complex pathways and significantly higher individual doses.

Extraterrestrial Disposal: As an example only, dose consequences were estimated for hypothetical reinsertion of a waste capsule into the earth's stratosphere after 100 years in earth orbit (or the equivalent, burnup during orbital insertion after 100 years' storage). Complete disposal in one hemisphere was assumed with a 1-year half-life in the stratosphere before transfer to the troposphere. The dose pathways are very similar to those for a direct atmospheric release case, but with a uniform exposure to the hemispheric population instead of a non-uniform exposure emanating from a point source.

The dose to the average individual from a stratospheric burnup after 100 years' storage in earth orbit would be much lower than those calculated from an atmospheric release from a point ground disposal source.

For the ice sheet, seabed sites, and extraterrestrial disposal, the political impact of even small doses on a global scale must of necessity be considered in the overall concept evaluation. In addition, evaluations of these concepts should take into account the fact that, where global dispersion mechanisms are involved, nuclear waste disposal for all countries rather than a single country may involve radiation doses considerably higher than those calculated from the single waste inventory considered here.

Transmutation: Dose calculations have not been made specifically for a transmutation case. For the residual wastes therefrom, the methods used here would be applicable. Other standardized methods exist for the safety evaluation of other steps in the transmutation cycle such as reactor accidents.

Extrapolation of Results

It must be re-emphasized that the calculated doses shown here are valid only for the parameters chosen. As studies provide more specific characterization of site parameters, fault-tree end points, release rates,

and partitioning of nuclides by natural processes, more realistic dose estimates can be made.

Once dose calculations are made for a hypothetical or normalized case, however, ready extrapolation can be made for different values of some parameters. Table 3.19 indicates which of these parameters may be linearly extrapolated ("Yes") and which would require additional dose calculations ("No"). For example, Table 3.15 shows annual radiation doses to a maximum individual. A relatively small whole body dose of 0.4 mrem is calculated, almost all from Tc-99. If via a partitioning process, 90 percent of the Tc-99 were removed from the waste before disposal, one would properly estimate the whole body dose to the same individual as being reduced to less than 0.1 mrem/year. If other radioactivity-containing food sources, on the other hand, were introduced into this individual's diet, it would be necessary to go back to the dose model to calculate the resultant change in dose received.

3.1.4 Risk to Man

The sample calculations of probability given in Table 3.3 can be multiplied by doses such as those shown in Tables 3.15 and 3.16 to obtain a hypothetical risk of radiation dose to man from the disposal concept. The maximum measure of risk to an individual from the given failure mechanisms and pathways would then be in the range of 10^{-14} to 10^{-10} mrem/year to the whole body during the operational period, 10^{-10} to 10^{-6} mrem/year at 1,000 years after disposal, and 10^{-6} to 10^{-3} mrem/year at 1,000,000 years after disposal.

TABLE 3.19. Linearity of Dose Calculations with Various Parameters

Parameter	Dose Linearity
Weight fraction or activity density in waste - individual nuclide	Yes, for dose contribution from that nuclide.
Release rate - bulk waste	Yes
Fractional removal - individual nuclide	Yes, for dose contribution from that nuclide.
Stream flow for dilution	Yes
Fraction of population using stream	Yes
Air, food, or water intake rates or exposure period	Yes, for contribution from individual pathways. No, for total doses calculated.
Population size - no change in sector distribution	Yes, for population dose only. (No change for individual doses).
Population - change in sector distribution	No
Meteorological parameters	No
Marine versus freshwater environment	No

Similarly, the risk to the affected large population group would be less than 10^{-8}, 10^{-4}, and 10^{-1} man-rem/year during the same respective three time periods.

The previous sections demonstrate the methodology for calculating the probabilistic risk to man from radioactive waste disposal. For actual application of risk calculations, analyses will be required for specific concepts, sites, and operations. In addition, the risks from all major mechanisms and pathways must be summed to obtain the total calculated measure of risk.

An alternative measure of risk would be derived from estimation of harmful effects (deaths or illness) on people from the calculated radiation dose increments associated with each disposal concept. Recent studies sponsored by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)[32] and by the U.S. Environmental Protection Agency (BEIR)[33] address what is known and what is assumed concerning the radiation dose/radiation effects of chain low-level radiation exposures. Considering the large uncertainties in the derived conversions and the problem of making equivalent conversions for radiation doses to different organs of the body, we have chosen not to attempt estimates of harmful effects for these concept comparison studies.

Attempts have been made by others to place a dollar value on estimates of increased harmful effects on people to provide a more direct method of comparisons than the above. Such a procedure involves not only still larger uncertainties, but the basic philosophical question of equating dollars to human lives, and is not being considered for these studies.

3.2 CONCEPT COST ANALYSIS

This section describes the cost evaluation methodology and the disposal concept costs developed to evaluate various waste disposal options on a consistent basis from the perspective of total waste management systems. The cost evaluations were achieved by performing the following tasks in the order shown:

1. The assumptions required to develop uniform cost bases for alternative disposal concepts were defined.
2. A waste disposal cost model suitable for analysis of the alternative disposal concepts was developed.
3. Cost estimates for each alternative concept were developed using 1973 dollar values.
4. Total system costs for each concept were developed by including all disposal-related operations that precede the final disposal process; for example, any added spent fuel transport required, interim liquid waste storage, partitioning, solidification, interim solid storage, etc.
5. A summary of the various cost elements for each disposal concept, from the perspective of a total waste management system evaluation, was prepared.

The information developed for each of these tasks is discussed in the sections that follow.

The concept costs considered here include only the costs directly re-

lated to implementing each specific concept. The costs do not include, for example, the Research and Development costs required to bring the concept feasibility status to the point of practical application. Nor do the costs include the consideration of possible costs to society that might result from occupational or population radiation exposure or costs that might result from particular environmental impacts. These are costs that should be considered in the final selection process, but they may not all be easily expressed in consistent monetary units and can be considered separately from the direct costs of implementation. Where they are considered, it is important that all implications be identified and that the full societal costs be born by each concept.

It should be emphasized that the cost estimates developed in this study are of necessity preliminary and amenable to further optimization within each concept. The results identify the general magnitude of disposal costs for each concept and point out the important cost components. These results will provide a basis for future more detailed design and cost evaluation studies that will permit them to focus on the most significant cost components and on the most promising concepts.

It is worth noting at the outset here that although they require very large expenditures, even the most costly of these waste disposal concepts would have only a minor impact on electric power generating costs. With the present search for reliable and environmentally sound energy sources, it may be possible to justify costs significantly greater than those considered here. In the following discussion, the waste disposal concepts are evaluated on the basis of costs for disposal of waste generated over the 25-year period from 1980 through 2004. Assuming nuclear power generating costs would average 10 mills/kW-hr, the total cost for nuclear power generated over this period would approach $\$10^6$ million. When the large costs of the waste disposal concepts are viewed from the perspective of total generating costs they are not at all unreasonable.

3.2.1 General Assumptions and Definitions of Waste Disposal Concepts

To provide a basis for cost comparisons, a reference design was defined for each disposal concept. The reference design assumptions were not necessarily optimum but are believed to be reasonable. Further studies are needed to optimize any concept. The general assumptions applying to each reference design were as follows:

1. The reference plant facility for each disposal concept is sized to handle the high-level waste from a plant reprocessing LWR fuel operating at 5 metric tons a day or 1,825 metric tons a year over a 25-year lifetime. Total fuel processed during the 25 years is 45,625 MT.

2. Fuel exposure is assumed to be 33,000 MWd/MT.

3. Approximately 210 liters (7.5 cubic feet) of high-level liquid waste are generated for every metric ton of spent fuel reprocessed at 33,000 MWd/MT.

4. Solidified waste is assumed to be a borosilicate glass type with a volume of 56.6 liters (2 cubic feet) of waste glass per metric ton of fuel reprocessed.

5. Dimensions of solidified waste canisters are 30.5 centimeters (12 inches) in inside diameter by 3.05 meters (10 feet) long. The solidified waste fills 2.44 meters (8 feet) of the canister. The amount of solid waste contained in a canister is 180 liters, or 6.28 cubic feet. The canisters are made of 1.27 centimeter thick (0.5 inches) mild steel, unless otherwise specified for a specific disposal concept.

6. The number of canisters required to handle the waste generated over the 25-year life of the 5 MT/day reprocessing plant is 14,522. The maximum disposal rate is 20 canisters/week.

7. Heat generated per canister at the time of waste solidification, 5 years after reprocessing, is 3.39 kilowatts.

8. High-level liquid waste is available for treatment and ultimate disposal immediately after production in the fuel reprocessing operation.

9. If not disposed of as liquid, the high-level waste is solidified after 5 years of interim liquid storage.

10. High-level solid waste is stored for 5 years and is not available for disposal until 10 years after waste generation at the reprocessing plant.

11. Where concepts require waste partitioning, the partitioning is done 5 years after reprocessing.

The various basic concepts that have been evaluated can be classified as follows:

Geologic	10 concepts (with some variations)
Seabed	3 concepts
Ice Sheet	3 concepts
Transmutation	1 concept
Extraterrestrial	2 concepts

Detailed descriptions of each concept are given in Sections 4 through 8 in this report.

3.2.2 Waste Management Cost Model

Before discussion of the economic model used for the comparative cost calculations in these studies, it should be noted that there is concern that economic analysis techniques alone probably do not adequately measure the differences between waste management systems which involve commitments over very long periods of time. Techniques of modern economic analysis were developed to handle problems concerned with a relatively short period of years, say 10 to perhaps 50 years, compared to hundreds of years for some waste management systems. Obligations more than a few years in the future become insignificant in present worth analyses. For example, the present worth of a continuing series of uniform annual costs with a 10% discount rate reaches 75% of its ultimate present value in 15 years, 90% in 25 years, and 99% in 50 years. Even though one concept may have obligations extending over centuries while another may terminate any obligations at the 50th year, present-worth economics may differentiate very little between

these two systems if they have similar expenditure patterns for the first 50 years. Thus the requirement of some waste management concepts for future generations to accept commitments imposed by an earlier generation is a factor that must be set apart and judged separately from the economic analysis.

In this analysis, waste disposal concepts are compared on the basis of levelized total unit costs. The levelized total unit cost or charge is the single charge that could be assessed over the entire life of a project against each unit processed that would, regardless of fluctuations in processing rates and expenditure patterns, recover all operating expenses as well as the initial investment plus a specified interest rate of return on the investment. The calculation procedure involves a modification of the discounted cash flow procedure widely employed to determine return on investment. The interest rate of return is the interest rate that results in the discounted net-cash-flow equalling zero over the economic life of the project. Likewise, the levelized total unit cost or charge is the charge for the service that results in the net cash flow equalling zero for a specified rate of return over the economic life of the project.

It is the single charge that satisfies the following relationship:

Sum of Present Worth Income =
Sum of Present Worth Expenditures

$$\sum^{n} f_n(\text{Income})_n = \sum^{n} f_n(\text{Expenditures})_n \qquad (1)$$

where:

f_n = present worth factor for the nth year.

Levelized unit charges were developed for each ultimate disposal concept based on handling all the waste generated by the nuclear power industry for a 25-year period starting in 1980, which is undoubtedly earlier than any of the final disposal concepts could be activated. The 25-year period 1980-2004 provides a reasonably long period over which waste disposal requirements can be projected with a relatively high confidence level. Use of these projected requirements permits comparison of disposal costs on a sufficiently large and realistic scale to permit any advantages of scale to be reflected in the cost comparisons. An existing computer program was modified to handle the levelized charge calculations for each final disposal concept.

The final waste disposal facility is assumed to be a federal government operated facility. To take advantage of the economies of large-scale operations, it was assumed that only one facility would be in operation at any specific time. This would not always be an advantage, particularly for the liquid waste disposal concepts; but in that case the scaling advantage is slight and multiple sites would not appreciably affect the cost estimates. No chemical processing would be done at the government disposal facility. All operations prior to this are assumed to be carried out by a fuel reprocessor as an integral part of his profit-making enterprise.

In some cases it was convenient to visualize the capacity of the disposal facility in terms of total waste disposal capacity rather than in terms of processing rate. For example, the reference plant size of 5 MT/D with a life of 25 years has a lifetime capacity for 45,625 metric tons of fuel or 14,522 standard canisters of solidified waste. For a facility of this size the amount of contained waste material is the same whether it is filled in 10 years or 25. Operating costs during the period of filling would, of course, vary according to the rate of filling.

It would be possible to build one large facility to accept all the waste to be generated over the entire 25-year period. However, near-term capital requirements would be unreasonably large. For this analysis it was assumed that a new disposal facility would be built every 10 years (either at the same or a new site) with a capacity for the next 10 years of waste. This period is referred to as the look-ahead period: whenever a new facility is needed, a look ahead at the next 10 years of disposal requirements determines the size of the new facility.

Since the disposal facility capacity requirements for these calculations do not conform to the reference plant capacity used for conceptual design of the waste disposal systems, it was necessary to develop scaling factors for both capital and operating costs to adjust reference plant costs to costs for the required plant size. The scaling factors were developed by obtaining cost estimates for facilities having ten times the capacity of the reference plant as well as the reference plant itself. The following relationship was used to calculate the scaling factors:

$$\left(\frac{P_2}{P_1}\right)^S = \left(\frac{C_2}{C_1}\right) \qquad (2)$$

where:

P_1 = Capacity of Plant No. 1

P_2 = Capacity of Plant No. 2

C_1 = Cost for Plant No. 1

C_2 = Cost for Plant No. 2

S = Scaling factor.

Scaling factors were estimated for both capital costs and variable operating costs. In the case of capital costs, capacity was expressed as total waste storage capacity and cost in terms of total dollars. In the case of variable operating costs, capacity was expressed in terms of metric tons-equivalent per year and costs in terms of dollars per metric ton-equivalent.

A learning function was also applied to reflect the probability that costs for new technology such as extraterrestrial disposal would be reduced with time faster than costs for old technology such as hard rock mining. The following equation illustrates the learning relationships:

$$C_n' = C_n \left(\frac{T_o}{T_n}\right)^g \qquad (3)$$

where:

C_n = Cost without learning effect

C_n' = Cost with learning adjustment

T_o = Years of technology experience at the time the first plant is built

T_n = Years of technology experience at the time n when plant under consideration is built

g = Learning coefficient = 0.32.

The learning coefficient of 0.32 results in a 20% reduction in cost for every doubling in years of accumulated experience.

The following equations illustrate how the combined effects of scaling and learning were applied:

$$C_n'' = C_R \left(\frac{P_n}{P_R}\right)^S \times \left(\frac{T_o}{T_n}\right)^g \qquad (4)$$

$$O_n = \left[VO_R \left(\frac{P_n}{P_R}\right)^S \times \left(\frac{T_o}{T_n}\right)^g\right] \times T_n + FO_n \times N_n \qquad (5)$$

where:

C_n'' = Capital cost of plant started up in year n

C_R = Capital cost of reference plant

P_n = Capacity of plant started up in year n

P_R = Capacity of reference plant

T_o = Years of technology experience at time the first plant is built

T_n = Years of technology experience at year n

O_n = Total annual operating cost in year n, $/year

VO_R = Variable operating cost for reference plant, $/MT equivalent

T_n = Throughput in year n

FO_R = Fixed annual operating cost for reference plant, $/year

N_n = Number of plants in operation in year n.

An interest rate of 10% was used for all present worth and levelized cost (charge) calculations whether operated by private business or government. The difference in levelized charges between private business and government operations shows up in the additional cost of income taxes required from the private business operation. A 10% interest rate is consistent with recommendations by the Office of Management and Budget (OMB)[54] for evaluating U.S. Government projects and is also a reasonable approximation of the long-term return on investment that a private fuel reprocessor could expect for his operations. (Over the long-term, fuel reprocessing is anticipated to be a relatively low risk venture because plant investments will not be made until substantial reprocessing commitments are in hand.)

The calculations just described determine the charges that would be required at the time the disposal operation is carried out. In cases where the disposal operation takes place 5 to 10 years after fuel reprocessing (when the waste is first generated), the disposal costs are

further discounted to the time of fuel reprocessing. This is discussed again in relation to total system costs in Section 3.2.4.

3.2.3 Estimation of Capital and Operating Costs

With the assistance from the Vitro Engineering Division of Automation Industries, Inc., estimates of capital and operating costs, based on the reference design, were developed for each terrestrial disposal concept. The concepts evaluated are described in summary form in Table 3.20. The capital and operating cost estimate details for each concept are discussed by generic group in the subsections that follow. It should be kept in mind that these costs relate to the final disposal concept and do not include all the necessary related waste management operations. These other related operations are discussed in Section 3.2.4, and their effects on total waste management costs are presented in Section 3.2.5.

3.2.3.1 Geologic Concepts

The cost estimates for the geologic concepts plus some subordinate variations are shown in further detail in Table 3.21. All together ten geologic concepts have been considered. To show the effect of important variations of the basic concept, two separate cases are shown for three of the concepts. The capital costs are subdivided into 1) surface operating facilities, 2) excavating and drilling costs, 3) underground operating facilities, and 4) cooling facilities when required. Operating costs are subdivided into 1) personnel costs, 2) maintenance, and 3) utilities, contingencies and miscellaneous costs. Scaling factors are also shown. No scaling effects are indicated for the capital costs, and only a modest 0.8 scaling factor is shown for the operating costs. The total industry costs for disposal of waste over the 25-year period, 1980 through 2004, comprise the final item in this table. The total industry cost is shown in terms of both total undiscounted cost and the levelized unit charge.

Two cases for disposal of solid waste canisters in mined cavities are shown. The first case, G-1, calls for disposal in a 600 meter (2,000 foot) deep cavity mined in granite rock using direct conduction cooling to the rock. The second case shows that the effect of increasing the mine depth to 1,520 meters (5,000 feet) is a relatively modest increase in the levelized unit charge of 6 percent ($9,600/MT increased to $10,000/MT). Thus with respect to cost there appears to be considerable flexibility in the choice of disposal depth since the effect of depth on overall cost is small.

Consideration was also given to the effect of geologic media on mining costs. Mining costs in shale would be substantially greater than in granite while mining costs in salt formations would be substantially less than in granite. The following unit excavating costs illustrate these differences:

Shale	$98/m^3	$75/yd^3
Granite	$65/m^3	$50/yd^3
Salt	$33/m^3	$25/yd^3

TABLE 3.20. Summary Description of Disposal Concepts

Case	Disposal Concept Description
	GEOLOGIC CONCEPTS (See Section 4)
G-1	Direct Conduction Cooling to Rock, Solid Waste in Mined Cavity - 600 m (2000 ft) in granite, no rock-waste interactions.
G-2	Direct Conduction Cooling, Solid Waste in Mined Cavity - 1500 m (5000 ft) in granite, no rock-waste interactions.
G-3	Air Convection Cooling, Solid Waste in Mined Cavity - 1500 m (5000 ft) in granite, 5.5 km x 9.1 m diameter tunnel (3.4 mile x 30 ft), conduction cooling after 100 years.
G-4	Air Convection Cooling, Solid Waste in Mined Cavity - 1500 m (5000 ft) in granite, 884 m x 21.3 m (2900 linear ft x 70 ft) diameter tunnel (conduction cooling after 100 years), and 4.5 km x 4.6 m (2.8 mile x 15 ft) diameter tunnel.
G-5	Boiling Water Cooling, Solid Waste in Mined Cavity - 1500 m (5000 ft) in granite, 5.5 km x 9.1 m (3.4 mile x 30 ft) diameter tunnel (direct conduction cooling to rock after 100 years).
G-6	Boiling Water Cooling, Solid Waste in Mined Cavity - 1500 m (5000 ft) in granite, 884 m x 21.3 m (2900 linear ft x 70 ft) diameter tunnel (conduction cooling after 100 years), and 4.5 km x 4.6 m (2.8 mile x 15 ft) diameter tunnel.
G-7	Rock-Waste Melting, Solid Waste in Mined Cavity in granite 13,000 m^3 (17,000 yd^3) cavity.
G-8	Solid Waste in Matrix of Drilled Holes, no rock-waste interaction, bottom 900 m (3000 ft) of 4600 m (15,000 ft) deep hole, in granite with overlying sedimentary rock.
G-9	Solid Waste in Deep-Drilled Holes (6), 15,000 m (50,000 ft) deep, with rock-waste melting, bottom 7000 m (25,000 ft) of 15,000 m (50,000 ft) filled, top 3000 m (10,000 ft) sedimentary and bottom 12,000 m (40,000 ft) granite.
G-10	Liquid Waste in Deep-Drilled Holes (3), other description same as in G-9.
G-11	Liquid Waste in Mined Cavity - 1500 m (5000 ft) deep, rock-waste melting, in granite, cavity size: 3300 m^3 (5000 yd^3).
G-12	Liquid Waste in Exploded (Nuclear) Cavity - 1500 m (5000 ft) deep in granite.
G-13	Hydrofracturing in Shale, liquid waste to well as a cement grout-slurry.
	ICE SHEET (See Section 5)
IC-1	Ice Burial - Melt-Down or free Flow
IC-2	Ice Burial - Anchored Storage in Ice
IC-3	Ice Surface - Shielded Storage Facility
	SEABED (see Section 6)
SB-1	Subduction Zones and Other Deep Sea Trenches
SB-2	Stable Deep-Sea Floor
SB-3	High Sedimentation Rate Areas (Shallow Ocean)
	EXTRATERRESTRIAL (See Section 8)
E-1	Solar or High Earth Orbit
E-2	Solar System Escape
	TRANSMUTATION (See Section 9)
T-1	Actinides in Fission Reactors

TABLE 3.21. Summary Cost Data for Geologic Disposal Concepts

	Conduction Cooling in Mined Cavity		Air Cooling in Mined Cavity		Boiling Water Cooling in Mined Cavity		Other Solid Waste Concepts			Liquid Waste Concepts			
	G-1 Granite 600 m	G-2 Granite 1500 m	G-3 Granite One-Tunnel	G-4 Granite Two-Tunnel	G-5 Granite One-Tunnel	G-6 Granite Two-Tunnel	G-7 Granite Rock-Waste Melting	G-8 Matrix of Drilled Holes	G-9 Deep Drilled Holes	G-10 Deep Drilled Holes	G-11 Mined Cavity	G-12 Exploded Cavity	G-13 Hydro Fracturing
Reference Plant Capital Costs ($ million)													
1. Surface operating facilities	6	6	6	6	6	6		6	6	3	3	3	5
2. Excavating shafts and tunnels, drilling holes, casings, etc.	185	205	480	480	130	135	23	129	150	75	6	7	10
3. Underground operating facilities	38	38	4	4	4	4	--	--	--	--	--	--	--
4. Cooling facilities when required	--	--	60	60	100	95	--	--	--	2	13	13	--
TOTAL CAPITAL COSTS (rounded)	230	250	550	550	240	240	29	140	160	80	22	23	15
Reference Plant Operating Costs ($ million/year)													
1. Personnel	1.2	1.2	1.6	1.6	1.6	1.6	1.2	1.2	1.3	0.8	0.8	0.8	0.7
2. Maintenance	1.3	1.3	2.1	2.1	1.7	1.7	--	0.2	0.2	0.2	0.5	0.5	0.2
3. Utilities, Contingencies and Miscellaneous	0.3	0.3	0.4	0.4	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
TOTAL OPERATING COSTS (rounded)	2.8	2.8	4.0	4.0	3.6	3.6	1.4	1.5	1.6	1.1	1.4	1.4	1.0
Scaling Factors													
1. Capital Costs	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2. Operating Costs	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1.0
Total Industry Disposal Costs for Waste Generated Over the 25-Year Period (1980 through 2004)													
1. Total Direct Costs Excluding Interest Costs													
a) Capital Facility Costs ($ million)	1,100	1,200	2,600	2,600	1,200	1,100	140	640	700	340	110	100	70
b) Operating Costs ($ million)	300	360	500	500	400	400	130	140	150	100	140	140	110
TOTAL (a + b) ($ million)	1,400	1,500	3,100	3,100	1,600	1,500	270	780	850	440	250	240	180
2. Levelized Unit Charge for Final Disposal at Time of Disposal													
($/MT of Fuel Reprocessed)	9,600	10,000	22,000	21,000	10,000	9,600	1,800	5,500	6,000	3,000	1,400	1,300	1,100
3. Levelized Unit Charge for Final Disposal Discounted to Time of Reprocessing	3,700	3,900	8,500	8,200	4,000	3,700	700	2,100	2,300	3,000	1,400	1,300	700

However, because comparison of disposal costs in different geologic media requires analysis of relative heat removal capabilities as well as mining costs, few conclusions can be based on mining costs alone.

The next two cases, G-3 and G-4, show the costs for disposal of solid waste canisters in 1,500 meters deep mined cavities with air convection cooling for the first 100 years, after which time natural granite-conduction cooling would be relied on. Blowers are required to start the convection circulation but, once started, the circulation will be maintained by natural convection. In case G-3, the disposal cavity is a 5.5 kilometers long by 9.1 meters (3.4 mile long by 30 feet) diameter tunnel which provides adequate spacing for natural rock-conduction cooling of the canisters after 100 years. In case G-4, a shorter (880 meters or 2,900 feet), larger diameter (21.3 meters or 70 feet) tunnel is used for the first 100 years of air convection cooling, after which a 4.5 kilometer (2.8 mile) long small diameter (4.6 meters or 15 feet) tunnel is excavated to provide adequate spacing for rock-conduction cooling. After 100 years, the canisters are moved to this tunnel for final disposal. The thought was that this variation could reduce excavation costs; however, the effect is small. Total excavation costs are reduced an insignificant amount. Of the $480 million excavation cost in case G-4, $19 million is deferred 100 years and in terms of present worth is effectively eliminated. The effect on the levelized unit charge is only a 4% reduction from $22,000/MT to $21,000/MT. The controlling cost in either case is the $400 million required for 40 2.1 meters (7-foot-diameter) cooling air shafts.

Cases G-5 and G-6 are similar to G-3 and G-4 except that water is supplied to the disposal cavity where it boils and the radioactive-decay heat is removed as latent vaporization heat with the steam. Steam is condensed at the surface and the condensate returned to the disposal cavity. Once the process is started, natural forces will maintain the cooling system action. This system is much less expensive than the air convection system because the diameter of the cooling shafts is only 0.5 meter (20 inches) compared to 2.1 meters (7 feet) and 40 shafts cost only $60 million rather than $400 million. However, a requirement for an expensive pressure vessel in the disposal tunnel (about $50 million) offsets some of the advantage. In the two-tunnel concept (case G-6) the total cost is the same as for the one-tunnel concept. The levelized unit charges are $10,000/MT for the one-tunnel concept and $9,600/MT for the two-tunnel concept. Either case appears to have a substantial cost advantage over the air-cooled concept.

Case G-7 is identified as the rock-waste melting concept. It calls for mining out a 1,500-meters deep (5,000-foot) cavity with double lining into which the waste canisters are dumped into a random array. During the period of filling, temperature control is maintained by supplying water to

the cavity. The water boils off and keeps the cavity at the boiling water temperature. After filling, the shaft is closed and the decay heat causes the waste and some of the surrounding rocks to form a conglomerate melt. After many years, the mixture then slowly solidifies again. This is a remarkably inexpensive concept. Capital cost is estimated at $29 million and the 25-year levelized charge is estimated at $1,800/MT.

Case G-8, shown next in the table, is identified as a matrix of drilled holes. Solid waste canisters are lowered into the drilled holes. Heat is removed by natural conduction of the rock. The concept is simple but the drilling costs are substantial--much less, however, than the mined cavity concepts G-1 through G-6. Total capital is $140 million and the 25-year levelized charge is estimated at $5,500/MT.

Case G-9 is similar to G-8, but the holes are 16,400 meters (50,000 feet) deep compared to 4,900 meters (15,000 feet) in G-9 and rock-waste melting is permitted. Total capital cost is $160 million (based on $25 million per hole) and the 25-year levelized charge is $6,000/MT.

The next four cases, G-10, G-11, G-12 and G-13, involve emplacement of liquid waste with in-place conversion to solid. Case G-10, liquid in 16,400 meters deep (50,000 foot) drilled holes, is similar to G-9, but the liquid waste form reduces the number of required holes from six to three, and this reduction accounts for the difference in capital costs, $75 million for G-10 compared to $150 million for G-9 (based on $25 million per hole). The 25-year levelized charge for G-10 is $3,000/MT or one-half the charge for G-9.

Cases G-11 and G-12 are similar and their costs are similar even though the method of construction is quite different. Case G-11 calls for deposition of liquid waste in a 1,600-meters (5,000-feet) deep-mined and lined cavity while case G-12 calls for deposition of liquid waste in an unlined cavity formed by a 1,600-meters deep (5,000-feet) underground nuclear explosion. The two cases are both very inexpensive concepts. Capital costs are essentially identical, $22 million and $23 million, as are the 25-year levelized charges, $1400/MT and $1300/MT.

Case G-15 is the simplest and least expensive of all the concepts. Identified as the hydrofracturing concept, it requires thirty 15-centimeter (6-inch) diameter wells approximately 1,000 meters (3,300 feet) deep to handle the waste from an 1,825 MT/year plant over its 25-year life. This concept requires a liquid storage period for cooling prior to injection which is an additional cost other liquid waste disposal concepts do not have to support. The liquid waste is accumulated for 5 years and diluted to meet heat-generation limits, mixed in 300,000-liter (80,000 gallon) batches with a dry cement formulation to form a type of grout-slurry and pumped under pressure into the well. The mixture forces its way into preformed fractures and solidifies.

Prior to the waste slurry injection, the well is prepared for the injection by cutting the casing at a predetermined point and starting a fracture with high-pressure water. Capital cost is $15 million and levelized charges are $1,100/MT.

3.2.3.2 Ice Sheet Concepts

Three ice sheet disposal concepts were evaluated assuming disposal in Antarctica. A summary breakdown of cost estimates for the reference plant size is shown by major components in Table 3.22. A major portion of the costs relate to transport facilities required because of the remote and hostile environment and climate and the short 2 to 3 month working season for ocean transport. Capital costs are subdivided into 1) port facilities, 2) sea transport vessels, 3) support and maintenance facilities at the Antarctic base camp, 4) monitoring equipment, 5) shipping casks, 6) surface transport vehicles for over-ice transport, 7) refueling and support facilities for surface transport vehicles, and 8) either drilling rigs or surface storage facilities. Operating costs include 1) port facility operations, 2) transport vessel operation, 3) surface transport vehicle operations, and 4) drilling and support operations. Table 3.22 also shows the total undiscounted costs for the 25-year period, 1980 to 2004, as well as the levelized unit charges for the same period.

The three concepts have very nearly identical costs. This is because most of the cost is concerned with just getting the waste canisters to the final disposal site. Relatively small differences in drilling or final storage facility operation are the only differences. Case IC-1, identified as the melt-down or free flow concept as the name implies, requires only that shallow holes be drilled to drop the waste canister into after which it melts down to a final place near the base of the ice sheet. Case IC-2, identified as anchored disposal in ice, requires anchor plates and chains at the surface tied to each waste canister so that it hangs suspended in a melt pool below the ice sheet. Case IC-3 provides for a shielded storage facility at the surface. Because of the cold climate, the waste canisters are easily maintained at a safe temperature without cooling and elaborate monitoring equipment.

There are no advantages for large scale operation with the exception of the port facility, which is adequate for the entire 25-year period. Otherwise, each 1,825 MT/day production increment requires duplication of all all of the facilities in Table 3.22. This results because of the short working season. The conceptual ship is the same as the one in the deep seabed concepts, but here it can make only one trip per year where three trips per year appear feasible in the seabed cases.

The levelized unit charges range from $29,000/MT for the shielded storage concept (IC-3) to $39,000/MT for the anchored storage concept (IC-2) with an intermediate value of $31,000/MT for the melt-down concept (IC-1).

TABLE 3.22. Summary Cost Data for Ice Sheet Disposal Concepts

	IC-1 Melt-down or Free Flow	IC-2 Anchored Disposal in Ice	IC-3 Shielded Storage at Surface
Reference Plant Capital Costs ($ million)			
1. Port of Embarkation	20	20	20
2. Sea Transport Vessel	100	100	100
3. Drill Holes (rigs)	12	12	--
4. Storage facility with crane and cell shielding	--	--	20
5. Monitoring Equipment	3	3	3
6. Shipping Casks (300)	45	45	45
7. Surface Transport Vehicles	53	53	53
8. Support Maintenance and in Transit Facilities	5	5	5
9. Support and Refueling Facilities for Surface Transport Vehicles	50	50	50
TOTAL CAPITAL COSTS (rounded)	290	290	300
Reference Plant Operating Costs ($ million/yr)			
1. Port Operations	1.0	1.0	1.0
2. Sea Vessel Operations	8.1	8.1	8.1
3. Surface Transport Vehicles Including Support Facilities	10.5	10.5	10.5
4. Holding Chain and Bearing Pad	--	15.0	--
5. Drilling and Support Maintenance Operations	7.0	7.0	3.5
TOTAL OPERATING COSTS (rounded)	27	42	23
Scaling Factors:			
Capital Costs	1.0	1.0	1.0
Operating Costs	1.0	1.0	1.0
Total Industry Disposal Costs for Wastes Generated Over 25 Years (1980-2004)			
1. Total Direct Costs Excluding Interest Costs ($ million)			
(a) Capital Facility Costs	2,700	2,700	2,800
(b) Operating Costs	3,300	5,200	2,800
(c) TOTAL (rounded)	6,000	8,000	5,500
2. Levelized Unit Charge ($/MT of Fuel Reprocessed rounded)			
(a) At Time of Disposal	31,000	39,000	29,000
(b) At Time of Reprocessing (discounted for 10 year delay)	12,000	15,000	11,000

3.2.3.3 Seabed Concepts

Three seabed disposal concepts have been evaluated. A summary breakdown of the cost estimates for the reference plant size is shown by major components in Table 3.23. Capital costs are subdivided into 1) port facilities, 2) sea transport vessels, 3) sea drilling platform, 4) drill pipe and casing, 5) monitoring equipment, and 6) shipping casks. Operating costs are subdivided by 1) port facility operations, 2) transport vessel operation, 3) sea platform operations, and 4) drilling, support and maintenance operations. Total undiscounted costs for the 25-year period, from 1980 through 2004, as well as the levelized unit charges for the same period are also shown.

TABLE 3.23. Summary Cost Data for Seabed Disposal Concepts

	SB-1 Subduction Zones and Other Deep Ocean Trenches	SB-2 Stable Deep Sea Floor	SB-3 High Sedimentation Rate Areas
Reference Plant Capital Costs ($ Million)			
1. Port of Embarkation	20	20	20
2. Sea Transport Vessel	100	100	50
3. Sea Drilling Platform	300	300	50
4. Drill Pipe and Casing	5	5	5
5. Monitoring Equipment	3	3	3
6. Shipping Cask (300)	45	45	45
Total Capital Costs (rounded)	470	470	170
Reference Plant Operating Costs ($ Million per year)			
1. Port Operation	1	1	1
2. Sea Vessel Operation	8	8	2
3. Sea Platform Operation	8	8	8
4. Drilling and Support Maintenance Operation	7	7	7
Total Operating Costs (rounded)	24	24	18
Scaling Factors (Capital and Operation)			
1. Sea Vessel	0.6	0.6	0.6
2. Sea Platform	0.4	0.4	0.7
3. Drilling and Maintenance Operations	1.0	1.0	1.0
Total Industry Disposal Costs for Wastes Generated Over 25 years, 1980-2004 ($ Million)			
1. Total Direct Cost Excluding Interest Costs			
Capital Facility Cost	1,300	1,300	730
Operating Cost	1,700	1,700	1,650
TOTAL (rounded)	3,000	3,000	2,400
2. Levelized Unit Charge (rounded) ($/MT of Fuel Reprocessed)			
a) At Time of Disposal	20,000	20,000	14,000
b) At Time of Reprocessing (Discounted for 10 Year Delay)	8,000	8,000	5,000

Two deep ocean disposal concepts have been defined. They differ in the location and in the nature of the seabed, but in terms of costs there are no definable differences in either capital or operating costs at this conceptual stage of development. The major capital item is the deep sea platform at $300 million. However, it is estimated that this same platform could handle the waste from up to five 1,825 MT/year reprocessing plants. The next largest item is $100 million for the ship to transport the waste from the port to the sea platform. Here, again, a single ship could serve more than one plant. Up to three trips per year with 600 canisters per trip appears feasible. A single port facility at $20 million could handle the entire waste production through the year 2004. Special shipping casks costing $45 million are required but can be used for up to 1,800 canisters per year. Thus, even though initial costs are high, substantial savings occur as the scale of operations increase. The 25-year levelized unit charges are $20,000/MT.

A single shallow ocean (high sedimentation rate area) disposal concept was defined and evaluated. Costs are reduced substantially compared to the deep ocean concepts. The drilling platform costs $50 million and can handle up to 1,200 canisters per year. Transport vessels costing $50 million can move 1,500 canisters per year. Port facility and cask costs are identical to the deep ocean requirement at $20 million and $45 million respectively. The 25-year levelized unit charges are $14,000/MT.

3.2.3.4 Extraterrestrial Elimination Concepts

The reference case for extraterrestrial waste disposal, as envisioned, is not a complete disposal concept. Because of the high unit costs for space transportation, this concept is currently considered to be applicable primarily to the long-lived radionuclides in waste. This concept provides for removal of the transuranium elements from the waste, and removing them from the earth's environment by sending them into space, either to a solar or high earth orbit or completely out of our solar system. For the reference case, the bulk of the fission product waste must be disposed of through some waste disposal concept whose cost may not be significantly affected by the removal of the transuranium elements. Thus the cost of this system must be weighed against the value of any risk reduction to future generations.

Costs for extraterrestrial disposal consist of three main components: 1) a partitioning process to separate the transuranium elements from the rest of the high-level waste, 2) an encapsulation process to prepare the separated elements for space flight, and (3) the space flight itself.

Because the unit costs for space flight are enormous, early considerations of the extraterrestrial or space disposal concept indicated that the relatively low risk associated with the uranium and thorium reprocessing "waste loss" component of the actinide elements may not justify

including them in the disposal package. Based on experience with actinide and fission product separation processes and the scale of operations required for a partitioning operation associated with the reference 1,825 MT/year fuel reprocessing elements the following estimates from Section 7 were developed as representative of the magnitude of charges that would be assessed for the partitioning required here:

(a) Separate the transuranium (actinide) elements, excluding uranium and thorium, from the bulk of the waste along with 1% of the short-lived radionuclides as contaminants: $15,000/MT of fuel.

(b) Same, but reduce short-lived radionuclide contamination to 0.1%: $20,000/MT of fuel.

Because the difference in cost between these two estimates is so small in comparison to the reduction in the weight of shielding required, only the latter case is used in this analysis. (Reducing short-lived radionuclides from 1.0 to 0.1% permits an approximate 60% increase in quantity of transuranium elements in each flight.)

To achieve a reasonable plant size, encapsulation costs were based on a plant encapsulating the actinides (less uranium and thorium) from two 1,825 MT/year reprocessing plants. Based on known costs for similar facilities, the following encapsulation estimates were developed:

Capital Cost	$40 million
Annual Operating Cost	$2.4 million/yr

Assuming that 10% of the capital facilities would require replacement at 10-year intervals while the balance of the facility would have a 25-year life, an annual levelized cost for encapsulation was calculated as $3,000/MT of fuel. In addition, $1,000/MT of fuel was added for a required heat shield, bringing the total estimated encapsulation charge to $4,000/MT of fuel.

Two space disposal concepts are considered in this cost analysis: ET-1, a solar or a high earth orbit (which have essentially identical costs), and ET-2, escape from solar system. Estimates of the launch and flight costs were obtained through the NASA Lewis Research Center and based on the Kennedy Space Center as a reference launch facility. Estimated costs for and capabilities of space flights from Kennedy Space Center are shown in Table 3.24. A minimum of $4 million is estimated to be required for new facilities for receipt, inspection and storage of waste packages. Launch and flight costs are estimated at $25,000/MT of fuel for the high earth orbit system and $110,000/MT for escape from the solar system. This estimate does not include the cost of new facilities, $1.7 million per launch per year, required when present capability of the Kennedy Space Center is exceeded. However, these costs appear relatively small compared to the space flight itself.

These cost estimates assume that the Kennedy Space Center could be

TABLE 3.24. Estimated Costs and Limitations of Space Flights from Kennedy Space Center for Extraterrestrial Elimination of Transuranic Wastes from LWR Fuels

	Solar or High Earth Orbit	Escape From Solar System
Minimum New Facilities Required, $	4×10^6	4×10^6
Launch and Flight Costs		
Each Mission, $	15×10^6	30×10^6
$ Per MT of Fuel	25×10^3	110×10^3
$ Per Kg of Actinides	35×10^3	150×10^3
Number of Flights Required Each Year		
1980 Waste Generation Rate	4	16
2004 Waste Generation Rate	30	140
Total Launches Required for Waste Generated From 1980 Through 2004	380	1,800
Maximum Launches Per Year With Existing Facilities	20	20
Estimated Cost of New KSC Facilities Required Beyond 20 Launches Per year,		
$ Per Launch Per Year	1.7×10^6	1.7×10^6

diverted entirely to waste disposal use, and this may not be realistic. If an entirely new launch facility were required the costs would be much higher.

Total estimated costs for the extraterrestrial concepts are summarized in Table 3.25. This shows total costs as $50,000/MT for the orbit destinations and $130,000/MT for the solar system escape. It seems very likely that significant additional new launch facility costs would be required if serious efforts were made to schedule actual launches from the Kennedy Space Center on a continuing basis. It should be remembered also that the cost for this disposal system takes care of only the actinides (other than uranium and thorium) and that costs for final disposal by some other method must still be added to this for disposal of the bulk of the fission product waste.

TABLE 3.25. Cost Summary for Extraterrestrial Elimination of Transuranium Waste from LWR Fuel

	High Earth Orbit	Escape from Solar System
Partitioning, $/MT	20,000	20,000
Encapsulation, $/MT	4,000	4,000
Space Flight, $/MT	25,000	110,000
Total Cost, $/MT (rounded)	50,000	135,000
Mills/kW-hr	0.19	0.50
Total Cost Discounted, 5 Years to Time of Reprocessing		
$/MT	30,000	80,000
Mills/kW-hr	0.11	0.30

3.2.3.5 Transmutation Elimination Concept

The reference transmutation concept, like the extraterrestrial concept, is not a complete disposal concept. This concept provides for the removal from the waste of the very long-lived actinide elements, including the uranium and thorium, and recycling them back through successive irradiation cycles in fission reactors until this material is converted (except for a small nonrecoverable process loss to the fission product waste) to short-lived fission products. The bulk of the fission-product waste must still be disposed of through some waste disposal concept whose cost may not be significantly affected by removal of the actinides. The cost for this system must be weighed against the value of any risk reduction to future generations.

Costs for the transmutation concept (T-1) consist of 1) cost for a partitioning process to separate the actinides from the bulk of the fission product waste, 2) the incremental fuel fabrication cost for including the recycled actinides as a nuclear power fuel component and 3) the incremental fuel enrichment cost required to compensate for the neutronic effect of the actinide recycle. Although the case was not calculated for transmutation in a Fast Breeder Reactor, the net costs are not expected to be materially different. The cost of partitioning will be the same; the cost of fabrication may be slightly higher since smaller diameter pins would be required; and the penalty for enrichment might be somewhat less. Transmutation in a Controlled Thermonuclear Reactor may have some promise because of favorable neutronics. It did not seem prudent, though, to consider costs of an unproven technology such as the Controlled Thermonuclear Reactor (CTR or fusion reactor) for the treatment of the nuclear waste.

The partitioning process for the reference transmutation concept is less complex and hence less costly than for the reference extraterrestrial concept, which required separation of the uranium and thorium from the other actinides. From experience with actinide and fission product separation processes and the scale of operations required for an 1,825 MT/year fuel reprocessing plant, it was estimated that the actinide elements could be separated from the bulk of the waste with a residual contamination level of 1% of the short-lived radioisotopes for $10,000/MT of fuel.

Based on assumed requirements for remote fabrication and previous experience with cost estimates for various plutonium fuel fabrication concepts, it was estimated that the fabrication cost for power reactor fuel containing the recycled actinides would be increased on the order of $200/kg of contained uranium. It is not necessary, however, to spread the recycled actinides throughout all of the fuel. Preliminary burnup calculations have shown that a feasible, although probably not optimum, procedure would involve loading all of the recycled actinides into 10% of

the fuel. This would reduce the average fabrication penalty to $20/kg of total fuel.

To compensate for the neutronic effect of the recycled actinides, the fuel enrichment (U-235 content) would have to be increased. The preliminary burnup calculations have shown that this increased enrichment would be equivalent to $15/kg of fuel based on current enriched uranium costs.

The total estimated costs for this transmutation concept are summarized in Table 3.26. The cost of disposal of the bulk of the fission product waste by some other final disposal method must also be added to this cost.

TABLE 3.26. Cost Summary for Transmutation Elimination of Actinide

Partitioning, $/MT	10,000
Incremental Fuel Fabrication, $/MT	20,000
Incremental Fuel Enrichment, $/MT	15,000
Total Cost, $/MT	45,000
Mills/kW-hr	0.17
Total Cost Discounted 5 Years to Time of Reprocessing	
$/MT	28,000
Mills/kW-hr	0.11

3.2.4 Other Components of Total System Costs

Several intervening processes (between the waste production and the final disposal step) are essential components of some waste disposal systems. A set of standardized charges (costs) for these operations was developed based on the processes, being an integral part of a 5 MT/day fuel reprocessing plant operation. Depending on the requirements of each concept, several, all or none of these processes may be included in a waste disposal system. These process components are as follows:

a) Additional spent fuel transport costs for remote fuel reprocessing plant location.

b) Interim liquid waste storage.

c) Waste solidification.

d) Interim solid waste storage.

e) Rail transport of solid waste to disposal site or port of embarkation.

The basis for the process charges for these components is discussed in the following subsections.

3.2.4.1 Additional Spent Fuel Transport Costs

In the disposal concepts based on waste in the liquid form, such as pumping the waste to deep drilled holes or a deep exploded cavity, it is assumed that the reprocessing plant would have to be located at the disposal site since transport of liquid waste would be impractical and unsafe. This could result in locating the plant at a site other than one with optimum distance from the power reactors it is serving. Although there is obviously no single correct distance, it was estimated from geographical considerations of possible disposal sites relative to reactor sites and desirable reprocessing plant locations that this increased distance could be on the order of 1,300 kilometers (800 miles)

or a 2,600 kilometer (1,600-mile) round trip distance for the shipping casks.

Spent fuel shipping costs, developed as part of a study of all fuel cycle costs in WASH-1099,[55] were estimated to be $4,000/MT for a 3,200-kilometer (2,000-mile) round trip distance. This estimate includes cask costs, freight handling, and insurance costs based on 1967 values. This estimate was adjusted to a 1973 base by escalating at 7% per year and then directly ratioed for a 2,600-kilometer (1,600-mile) round trip. The resulting estimate for the incremental cost was $5,000/MT. Because of the variables and uncertainties in this estimate, it should be considered only as an order of magnitude estimate.

3.2.4.2 Interim Liquid Waste Storage

Interim liquid waste storage costs were recently updated and evaluated in a Battelle, Pacific Northwest Laboratory study, BNWL-1667,[56] concerned with an overall evaluation of high-level waste solidification processes. The optimum storage tank size for a 1,370 MT/year plant (5 MT/day at 75% operating efficiency) was found to be 1,060 cubic meters (280,000 gallons) for a 5-year interim storage period. Four tanks including one spare were required. Summarized capital and operating costs follow:

Service facilities, building, stack, filters, cooling tower, etc.	$ 5,000,000
Four tanks (including spare) plus cooling costs	13,000,000
Pumps, piping and heat exchangers, design and contingencies	14,000,000
Total Capital Cost	$32,000,000
Annual Operating Costs	$ 1,250,000

These costs were escalated 7% to bring them from a 1972 to a 1973 base and multiplied by the ratio of 1825/1375 to adjust to the reference plant size for this study. Annual levelized storage charges were then calculated using Equation (4) and the ground rules for this study, that is, an 1,825 MT/year plant, a 25-year life and a 10% return on investment. The resulting storage charge was $5,500/MT.

3.2.4.3 Waste Solidification

The same study, BNWL-1667, was utilized to develop the waste solidification charges. Costs for facilities to solidify waste into borosilicate glass from a 1,370 MT/year plant are summarized below:

Process Cells	7.0×10^6
Equipment	2.6×10^6
Total Initial Capital	9.6×10^6
Annual Operating Costs Excluding Container Costs	$1.1 million

The process cells were assumed to last the life of the plant, while the equipment was assumed to require replacement at 10-year intervals. These costs were escalated 7% to bring them to a 1973 base year, and the levelized operating charge was calculated using Equation (4) and the ground rules for this study. The resulting solidification charge was $2,300/MT. The cost for waste canisters must be added to this.

For the standard 1.3-centimeter-thick (0.5 inches) carbon steel canisters suitable for the geologic concepts, canister costs were estimated at $500/canister or $170/MT (based on 3 MT-equivalent of solidified waste in a canister). For the seabed and ice sheet concepts, a 3.8-centimeter-thick (1 1/2 inches) carbon steel canister was required. Canister cost in this case was estimated at $2,000/container or $700/MT.

3.2.4.4 Interim Solid Waste Storage

The same waste solidification study, BNWL-1667,[56] was also the source of cost data for interim solid waste storage charges. Here, however, a case had not been prepared that exactly matched requirements for the ground rules of this study, and it was necessary to interpolate from closely matching cases. The storage facility consists of stainless steel-lined storage canals and facilities for submerged water cooling and monitoring the waste canisters. Costs for a facility to store the solidified waste from a 1,370 MT/year plant for 5 years following 5 years of liquid waste storage were found to be as follows:

Capital Cost	$7.8 million
Annual Operating Cost	$0.5 million/yr

These estimates were also escalated 7% and levelized operating costs calculated using Equation (4). The resulting solid waste storage cost was $1,500/MT.

3.2.4.5 Rail Transport of Solid Waste

Rail transport of the solid waste will be required between the interim storage site and the final disposal site or to the port of embarkation if seabed or ice sheet disposal is utilized. A 1,000-mile shipping distance or 2,000-mile round trip for the cask is assumed to be representative of this requirement. Shipping charges for an assumed 2,000-mile round trip by railroad were calculated in BNWL-1667[56] for a number of waste container sizes. The case most closely matching the assumed conditions for this study called for a 95-ton cask holding nine 12-inch-diameter containers. For solidified waste at 56.6 liters (2 cubic feet) per metric ton, shipping charges are estimated at $750/MT. This cost includes shipping cask amortization, handling costs, freight costs, taxes, and insurance.

3.2.4.6 Discounted Unit Charges

The unit charges just discussed are based on levelized costs at the

time the operation is performed. Except for the incremental spent-fuel shipping and liquid waste storage, all of the operations are delayed 5 to 10 years after fuel reprocessing. It can be assumed that payment is required at the time of fuel reprocessing when the waste is generated. For the deferred operations, the payment can be credited with interest up to the time the actual operation is carried out. Thus the payment required at the time of reprocessing is the discounted present-worth of the cost at the time the operation is carried out.

The unit charges for each of the operations just discussed as well as the discounted charges required at the time of reprocessing are summarized in Table 3.27.

3.2.5 Total Waste Management System Costs

Having obtained the levelized unit charges for all of the components in the waste disposal system, it is then possible to add the component costs to obtain the total system costs. In this final summation, all costs are defined in terms of charges to be assessed at the time of fuel reprocessing (the discounted present worth charges).

3.2.5.1 Geologic System Costs

The total system costs for the geologic concepts are shown in Table 3.28. Relative differences between the different disposal concepts are reduced by addition of the other system charges. In the solid waste systems, the differences are further reduced by the effect of discounting

TABLE 3.27. Unit Charges for Waste Management Operations Prior to Final Disposal

	Operational Component	Unit Cost of Operation in $/MT of Fuel Reprocessed at the Time of the Operation	Number of Years Between Operation and Reprocessing	Discount Factor at 10% Per Year	Discounted Unit Cost of Operation at the Time of Reprocessing
1	Incremental Charge for Transporting Spent-Fuel from Reactor to Special Reprocessing Plant Site	5,000	0	1.0	5,000
2	Charge for Interim Liquid Storage for 5 Years	5,500	0	1.0	5,500
3	Charge for Solidification of Waste into Borosilicate Glass	2,300	5	0.62	1,400
4	Container Cost:				
	For Geologic Concepts	170	5	0.62	100
	For Sea and Ice Concepts	700	5	0.62	400
5	Charge for Interim Solid Storage for 5 Years	1,500	5	0.62	900
6	Charge for Rail Transportation of Solid Waste Containers from Reprocessing Plant Site to Disposal Facility Site or Port of Embarkation	750	10	0.39	300

Note: Partitioning could also be considered a waste management operation prior to final disposal but in this analysis has been considered as part of the cost of the concepts it relates to, i.e., extraterrestrial and transmutation.

TABLE 3.28. Total System Cost Summary for Geologic Concepts, $/MT (Based on Charges Assessed at Time of Reprocessing)

	Operational Component	Conduction Cooling in Mined Cavity G-1 Granite 610 m	Conduction Cooling in Mined Cavity G-2 Granite 1520 m	Air Cooling in Mined Cavity G-3 Granite One-Tunnel	Air Cooling in Mined Cavity G-4 Granite Two-Tunnel	Boiling Water Cooling in Mined Cavity G-5 Granite One-Tunnel	Boiling Water Cooling in Mined Cavity G-6 Granite Two-Tunnel	Other Solid Waste Concepts G-7 Granite Rock-Waste Melting	Other Solid Waste Concepts G-8 Matrix of Drilled Holes	Other Solid Waste Concepts G-9 Deep Drilled Holes	Liquid Waste Concepts G-10 Deep Drilled Holes	Liquid Waste Concepts G-11 Mined Cavity	Liquid Waste Concepts G-12 Exploded Cavity	Liquid Waste Concepts G-13 Hydro-Fracture
1	Incremental Charge of Transporting Spent-Fuel from Reactor to Special Reprocessing Plant Site	--	--	--	--	--	--	--	--	--	5,000	5,000	5,000	
2	Charge for Interim Liquid Storage for 5 Years	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600	--	--	--	5,400
3	Charge for Solidification of Waste into Borosilicate Glass	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	--	--	--	--
4	Container Cost	100	100	100	100	100	100	100	100	100	--	--	--	--
5	Charge for Interim Solid Storage for 5 Years	900	900	900	900	900	900	900	900	900	--	--	--	--
6	Charge for Rail Transportation of Solid Waste Containers from Reprocessing Plant Site to Disposal Facility Site	300	300	300	300	300	300	300	300	300	--	--	--	--
7	Levelized Unit Charge for Final Disposal	3,700	3,900	8,500	8,200	4,000	3,700	700	2,100	2,300	3,000	1,400	1,300	500
8	TOTAL SYSTEM UNIT CHARGES (Rounded)													
	$/MT	12,000	12,000	17,000	16,000	12,000	12,000	9,000	10,300	11,000	8,900	6,400	6,300	11,000
	10^{-3} mills/kW-hr	46	46	64	63	46	46	34	39	41	30	24	24	42

the final waste disposal charges which take place 10 years after reprocessing.

Except for possibly a) the rock-waste melting concept (G-7) and the liquid disposal concepts (G-10, G-11, and G-12), which appear to be inherently less costly than the other concepts, and b) the air-cooled concepts (G-3 and G-4), which appear to be inherently more costly, the differences in total system costs are not significant. The cost advantage of the hydrofracturing concept (G-14) is lost due to the liquid waste storage cost it must support.

It should be emphasized again at this point that none of these systems is optimized and that greater differences could show up in a thorough optimization analysis. For example, interim liquid storage costs are a large component of the total cost. These can be reduced by reducing or eliminating interim liquid storage, but the solidified waste container diameter may have to be reduced (to meet solid waste temperature limits). This, in turn, affects solidification costs, interim solid storage costs, shipping costs, and final disposal costs. Furthermore, the time period between processing and disposal operations affects the discounted costs. None of the component costs is independent and none can be optimized independently. All are interdependent and optimization requires consideration of the entire system. Substantial advantages might show up for specific concepts with a thorough optimization analysis that would not otherwise be apparent.

3.2.5.2 Ice Sheet and Seabed System Costs

The total system costs for the ice sheet and seabed concepts are shown in Table 3.29. For the ice sheet concept, the limited working season magnifies the transport difficulties and costs. The shallow seabed concept (high sedimentation areas) has the lowest cost, but costs for all of

TABLE 3.29. Total System Cost Summary for Ice Sheet and Seabed Concepts, $/MT (Based on Charges Assessed at Time of Reprocessing)

	Operational Component	Ice Sheet Concepts			Seabed Concepts		
		IC-1 Meltdown or Free Flow	IC-2 Anchored Storage in Ice	IC-3 Shielded Storage at Surface	SB-1 Subduction Zone and Other Deep Ocean Trenches	SB-2 Stable Deep Sea Floor	SB-3 High Sedimentation Rate Areas
1	Incremental Charge of Transporting Spent-Fuel from Reactor to Special Reprocessing Plant Site	--	--	--	--	--	--
2	Charge for Interim Liquid Storage for 5 Years	5,500	5,500	5,500	5,500	5,500	5,500
3	Charge for Solidification of Waste into Borosilicate Glass	1,400	1,400	1,400	1,400	1,400	1,400
4	Container Cost	400	400	400	400	400	400
5	Charge for Interim Solid Storage for 5 Years	900	900	900	900	900	900
6	Charge for Rail Transportation of Solid Waste Containers from Reprocessing Plant Site to Port of Embarkation	300	300	300	300	300	300
7	Levelized Unit Charge for Final Disposal Over 25 Years of Operation	12,000	15,000	11,000	8,000	8,000	5,000
8	TOTAL SYSTEM UNIT CHARGES (Rounded)						
	$/MT	21,000	24,000	20,000	17,000	17,000	14,000
	10^{-3} mills/kW-hr	78	90	75	63	63	52

the ice sheet and seabed concepts are high. A major part of the cost in either of these concepts is for transport facilities.

3.2.5.3 Extraterrestrial and Transmutation System Costs

Separate total waste management system costs for extraterrestrial and transmutation elimination concepts are not developed here because they are not complete disposal concepts as envisioned in the reference concepts analyzed here. These concepts for elimination of the long-lived radionuclides could be added to any disposal system that provides for at least 5 years of interim liquid storage. The extraterrestrial or transmutation costs would add directly to the disposal cost.

3.3 POLICY CONSIDERATIONS

An examination was made of the written national and international policies which might apply to the disposal of nuclear wastes. The purpose was to determine how the various disposal methods would impinge on existing policy, although policy, national and international, was not a constraint in this study.

A number of regulations, treaties, conventions, and declarations apply to one or more of the potential nuclear waste concepts. The rules and regulations established by the AEC in

10 CFR 50 (Appendix F) apply most immediately to the question. The rules state that interim storage of liquid high-level waste may be done for up to 5 years before conversion to approved solid waste forms. The disposal of the waste, in solid form, on federally owned and controlled land within 10 years after reprocessing of the fuel is stated as policy in this regulation. Obviously, any concept which disposed of waste in any location not "owned and controlled by the Federal Government" would be in conflict. The shipment or disposal of high-level nuclear waste in liquid form is also forbidden by 10 CFR 50 (Appendix F).[57] The restriction on storage of liquid waste for more than 5 years could affect the concepts involving the direct disposal of liquid wastes underground.

Amendments to AEC policies such as those discussed above are probably more easily executed than are those to international treaties which might apply. In the case of the federal codes, the cognizant agency can unilaterally declare a policy change as long as it falls within the limits of the enabling legislation--in this case the Atomic Energy Act of 1954 as amended. In practice, these changes are usually commented on by industry and other agencies. Notices of rule changes are published in the Federal Register, and they automatically become law after a specified time period.

The United States Marine Protection, Research, and Sanctuaries Act became effective in 1973. The act specifically prohibits the United States from transporting and disposal at sea of high-level radioactive waste and radiological warfare agents. This act would affect seabed and ice sheet disposal concepts.

The United States is bound by a number of international agreements which would affect some disposal methods directly or indirectly. For example, this country is a signatory to the Antarctic Treaty of 1959 and is bound by its terms. Part 1 of Article V of this treaty states: "Any nuclear explosions in Antarctica and the disposal there of radioactive waste material shall be prohibited." While this treaty may be amended (Part 2 of Article V and Article IX allude to such amendments), under its present terms any of the ice disposal methods in Antarctica would clearly be prohibited. Considering the complexity of the international negotiations required to amend treaties, it is apparent that the treaties and conventions which will be discussed in the following paragraphs are potentially more restrictive than the national ones contained in 10 CFR 50.

The Antarctic Treaty has already been mentioned. It prohibits nuclear explosions and/or nuclear waste disposal in the area south of 60° South Latitude, including all ice shelves. Article XII of the treaty provides that it may be modified or amended at any time by unanimous consent of the contracting parties. Part 2 of Article XII provides that after the treaty has been in effect for 30 years (i.e., 1989) any of the contracting parties (whose representatives are entitled to participate in

the meetings) may request a conference to review the operation of the treaty. At that time the treaty may be modified or amended by a majority of the contracting parties represented at the conference. If such modification is not ratified within 2 years, any of the parties may withdraw.

Article I of The Nuclear Test Ban Treaty, to which the United States is a party, prohibits any nuclear explosion "in any other environment if such explosion causes radioactive debris to be present outside territorial limits of the State under whose jurisdiction or control such explosion is conducted." While the nuclear cavity concept calls for a deeply buried, fully contained, nuclear explosion, there is always a finite probability of venting. Any crossing of an international boundary by vented radioactivity would be a violation of this treaty.

The Nuclear Test Ban Treaty may be amended if a majority of the parties approve and all of the Original Parties (U.S., Great Britain, Northern Ireland and USSR) also approve. The treaty is of unlimited duration although any party has "the right to withdraw from the Treaty if it decides that extraordinary events, related to the subject matter of this Treaty, have jeopardized the supreme interests of its country."

The Nonproliferation Treaty, to which the U.S. is a party, could conceivably affect any ultimate disposal concept. The basic objective of the treaty is the limitation of nuclear weapons through the effective control of the flow of source and special nuclear materials.

Article III of the treaty states in part: "Procedures for the safeguards required by this article shall be followed with respect to source or special nuclear material whether it is being produced, processed or used in any principal nuclear facility or is outside any such facility. The safeguards required by this article shall be applied to all source or special fissionable material in all peaceful nuclear activities within the territory of such State, under its jurisdiction, or carried out under its control anywhere." While mixed fission products and actinide elements might be considered outside the scope of this treaty on the technical basis of cost and risk of separation of the fissionable materials, any concept dealing with separated actinide or transuranic element disposal would almost certainly fall under the agreements of this treaty. It would seem, then, that those procedures and operations would have to conform to IAEA safeguards. Likewise, they would be subject to the appropriate international inspection and observation.

Any amendment to the treaty must be approved by a majority of all parties to the treaty and by all nuclear weapon states party to the treaty. Twenty-five years after the treaty is in force a conference is to be held to decide whether it should be extended indefinitely or renewed for a fixed time period. This decision will be made by a majority of the parties to the treaty. Each party to

the treaty has the right to withdraw if it decides that extraordinary events have "jeopardized the supreme interests of its country."

Any of the extraterrestrial disposal concepts would come under the provisions of the Treaty on Outer Space, which was ratified by the U.S. in 1967.

Article VII of this treaty provides that "Each State Party to the Treaty that launches or procures the launching of an object into outer space, including the moon and other celestial bodies, and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space, including the moon and other celestial bodies." Any launch operations or mission aborts could entail international liabilities under this treaty. An orbit degradation which caused a capsule to eventually return to earth might also be subject to these provisions.

Liability for damage from any of the space concepts could be incurred under the terms of the 1972 United Nations Convention on International Liability for Damage Caused by Space Objects. The United States has not yet ratified this treaty, which defines in some detail the responsibilities of countries launching objects into space. For example, Article XII of the Convention specifies "...such reparation in respect of the damage as will restore the person, natural or juridical, state or international organization on whose behalf the claim is presented to the condition which would have existed if the damage had not occurred." While this convention will not materially extend the liability already accepted under the Treaty on Outer Space it will, if ratified, mean acceptance of a precise method for defining, assessing, and paying for space-related damages.

Any of the sea or ice disposal concepts could, conceivably, come under the restrictions of the 1958 Convention on the Continental Shelf. This convention provides for the protection of seabed and subsoil submarine areas adjacent to continental coasts and those of islands.

Article 5.1 of the convention states in part that "...the exploitation of its natural resources must not result in any unjustifiable interference with navigation, fishing or the conservation of the living resources of the sea..." Article 5.7 provides that: "The coastal State is obliged to undertake, in the safety zones, all appropriate measures for the protection of the living resources of the sea from harmful agents."

The same concepts would also be affected by the Convention on the High Seas. As defined in this convention, "high seas" are all parts of the sea not included in territorial or internal waters of a state.

Article 25.1 of the Convention provides that "Every State shall take measures to prevent pollution of the seas from the dumping of radioactive

waste, taking into account any standards and regulations which may be formulated by the competent international organizations."

Any leakage from any of the ocean disposal concepts would clearly be in violation of this convention. It is possible that any radioactivity which reached the ocean from an ice disposal site might also be deemed in violation.

Any contracting party to the convention can request a revision 5 years after it has entered into force. The request for revision is considered by the General Assembly of the United Nations.

In summary, there are a number of national and international regulations on the disposal of nuclear wastes. Some of these policies would, in present form, affect some disposal concepts. While the international policies can be modified or abrogated, it is probably simpler to make changes in national policy.

3.4 ENVIRONMENTAL CONSIDERATIONS

This section presents an overview of the key potential nonradiological environmental impacts of selected waste disposal concepts (geologic, ice sheet, seabed, space, transmutation) on a generic basis. Additional information is presented in the appropriate portions of Sections 4, 5, 6, 8 and 9.

The primary environmental impact of concern in the disposal of nuclear waste is that associated with the potential release of radionuclides. This subject is considered significant enough that it is treated separately in this report (see Section 3.1) and hence is excluded from consideration in this section.

The details of the environmental impact of various waste disposal options are highly dependent on the specific site selected. Without these details it is still possible, though, to make some generic statements about the relative impact of each of the possible disposal concepts. The conclusions which follow are based on disposal of waste formed through the year 2000. This in turn is based on integration of the number of the reference cases of disposal of the waste from a plant reprocessing 5 MT/day of LWR-uranium fuel (which yields a total of 14,500 "standard" canisters over a 25-year period). The reader should remember, though, that by the year 2000 the industry will have grown to the point where at least 7,500 canisters per year of solidified high-level waste will have to be managed. This is about 13 times the quantity from one reference 5 MT/day plant. The environmental analysis is given for the five basic types of disposal concept. While there are variations in the impacts to be expected within a basic concept, these are usually negligible.

3.4.1 Geologic Disposal Concepts

Land. All of the geologic concepts are based on the principle of isolating the combined actinides and fission products underground in a stable geologic formation. Protection from disruption, both intentional and accidental, from the surface is provided by enclosing the

disposal site within a reservation. Further protection is afforded by providing a buffer zone between the actual disposal area and the perimeter of the reservation. Although it is possible that some existing nuclear or non-nuclear reservation might be used for these purposes, for the sake of this analysis it was assumed that new land must be committed for this purpose. For the assumed buffer zone of 3.2 kilometers (2 miles) around the area, the total land use would be on the order of 65 square kilometers (25 mi^2). By way of contrast, the 50 typical reactors which this reference reprocessing plant would service would have a total combined land use of about 130 square kilometers (50 mi^2). It is not anticipated that any non-nuclear uses of this land would be allowed.

Water. Water consumption would be negligible except in the limited concept variation which utilizes water cooling. In this concept, water is used as a secondary cooling medium in conjunction with air cooling. In this case, the evaporative consumption of water would be about 76 cubic meters per hour. Very little, if any, waste water would be discharged from these disposal concepts.

The mining operations could potentially affect nearby waterways. Since a dry area would generally be sought, this possibility is remote. Since some 1.2 million cubic meters of mine waste must be disposed of, this could present a serious problem in the case of water-soluble rocks such as salt. Most rocks are orders of magnitude less soluble than salt, and the resultant potential for contamination of water would be proportionately lower.

Air. The pollution of air by any compounds other than radioisotopes is not likely during the operational phase. Although an air-cooling concept might utilize some 2.3 million standard cubic meters per hour of air, no chemicals would be added. The air would be carefully treated by more than one stage of highly efficient filters.

During the mining operation and disposal of mine "tailing" wastes, some dust contamination of the air could be expected.

Ecologic Impact. Even though a large land area would be involved, a relatively small portion of this would be disturbed on the surface. The only serious impacts on the terrestrial ecology would result from construction of the surface handling facility, roads, and the spoil area. The specific flora and fauna affected would be highly dependent on the area selected. Aquatic ecology should not be affected inasmuch as water usage and discharges will be small and highly treated.

Aesthetic Impact. The aesthetic impact will be confined to the surface unloading facility and the road/rail transportation systems. This assumes that mine tailings will be disposed of with a minimum aesthetic impact. Since this will be in the center of an isolated reservation, the visual impact should be very small. Acoustic impact, with the exception of the transportation, will be nil.

Transportation Impact. There will be some transportation impact--either truck or rail. If shipments containing six waste canisters each in casks weighing 50 metric tons are taken as typical, shipments will increase from about 100 per year to about 1250 per year in the year 2010 for the total waste management system. Each shipment entails a trip into the disposal site and a return trip with the empty casks to the reprocessing plant.

3.4.2 Ice Sheet Disposal Concepts

Land. The commitment of land in this concept entails a port of embarkation facility as discussed above, a staging area (including an airport) at the edge of the ice, six support stations en route to the disposal area and a 13,000 square kilometer disposal site. The disposal area is large because the canisters need to be deposited singly on 1.5-kilometer centers. The separation is required to minimize the possibility of the creation of a large water mass under the ice sheet. Such a continuous water body (created by the heat load of the radionuclides) might trigger the movement of the metastable ice sheet. Such a movement could generate more water through friction-pressure effects and could change the rate of movement of the ice from its present rate (generally, a few centimeters per year in areas of likely disposal sites) by at least two orders of magnitude. Such a shift could have catastrophic environmental effects. If the Antarctic ice sheet slid into the ocean, the ocean level would rise about 30 meters over a period of a few hundred years. The loss in life and property around the world would be immense. The change in the world's weather would also be profound.

If the ice is considered as land, the most serious pollution impact will be the accidental spills of fuel. The surface transport vehicles used to transport the waste across the ice cap consume some 18,000 liters of fuel per round trip. There are over 300 round trips required per year, hence a consumption of over 5 million liters per year. This fuel will have to be dropped by the equivalent of Hercules C-130 cargo planes. The probability of airplane crashes and/or rupture of fuel bladders during fuel drops is moderately high.

Water. The consumption of water would be primarily restricted to support for the operating personnel--some 300 people. The waste disposal operation itself requires no cooling water.

Pollution of the Antarctic Ocean and the water beneath the ice shelf could result from the oil spills discussed above. Such spills would penetrate the surface snow and the firn* and reach the underlying ice. Depending on where the spill occurred, the oil could be expected to reach the sea in anywhere from a few tens to millions of years. The magnitude of such spills and the diffuseness of the spill by the time it reaches the ocean are such that this should not be a major problem.

* Compacted snow of density 0.5 to 0.8 g/cm^3.

Air. The major impact on the air will arise from the combustion products of the surface vehicles and the support aircraft. Likewise, a considerable amount of fuel will be consumed in heating the facilities. While this is a large effect compared to present use in the area, it probably would not have a major impact on the air quality of locations such as Greenland or Antarctica. Serious consideration should be given, though, to the potential impact on the weather patterns of the southern hemisphere, for much of that weather is generated in the Antarctic. Similar effects on the Northern hemisphere could possibly result from waste disposal in Greenland. There is a distinct possibility that the combustion products could have an effect on weather patterns.

In this environmental factor, as well as the others, it should be remembered that the calculations quoted here are based on the disposal of wastes from one 5 MT/day reprocessing plant. It should be remembered that by the year 2000 there may be 8 to 10 plants of this size in operation. If an ice sheet is used for nuclear waste disposal, it will likely be used as an international repository. The cumulative impact of the total world's nuclear waste plus the projected increases of waste in the year 2000 that are manyfold larger than the reference capacity used in this study, then, would be several orders of magnitude greater than indicated by the numbers presented herein.

Ecologic Impact. The ecology of the ice sheet areas is extremely fragile. It can be compared in many respects to the tundra areas of the Arctic region. There are simple plants (mostly lichens and mosses) which grow within 450 kilometers of the South Pole.[58] Due to the cold, dry weather, animal and plant life is limited to a few hearty species. Most of the flora and fauna are concentrated in the dry valleys and on the coasts of the ice sheets. To minimize their disruption, these areas should be avoided as much as possible.

3.4.3 Seabed Disposal Concepts

Land. The above sea-level land use involved in the various sea disposal concepts will be confined to a dockside transfer and loading facility. This will entail less than 1 square kilometer.

If the sea floor is considered "land," the commitment to this concept is much higher. An estimate has been made of 930 square kilometers for the area which should be set aside. This is based on 100 canisters per hole and holes on 1.5-kilometer centers. This is larger than the corresponding geologic disposal site to allow for uncertainties in navigation and in control of location and direction of holes drilled deep in the ocean.

Water. No consumptive use of water is foreseen in this concept. During the drilling operations some mud would be displaced on the ocean floor. Heat dissipation to the ocean would be so diffuse at the disposal site as to be negligible. The impact of a shipboard accident is discussed below under "ecologic impact."

Air. No impacts on the air are foreseen. There is a remote possibility of hitting gas reservoirs during the drilling operation. These could cause air pollution problems until capped off.

Ecologic Impact. The ecologic impact should be small. Although the ocean-bottom environment will be disturbed during the drilling operation, the total effect on the aquatic ecology will be small. The productive near-surface zones should be essentially undisturbed by normal operation.

In the case of an accidental sinking of a transport ship there would be a possible release of oil. Depending on the disposal area, this could affect both fish and bird life. While the oil release from such an accident would be significant, it would be small compared to an oil tanker sinking.

Another potential cause of damage could come from inadvertently striking oil or gas in the drilling operation. The probability of this occurring should be reduced to a negligible value by prior exploration of the site. Moreover, the probability of finding oil or gas reservoirs at the 6,100-meter depths of the deep sea concepts is thought to be highly unlikely. The pressures at these depths and the geologic nature of the formations under consideration militate against such reservoirs. The nature of the ocean floors, on the other hand, are not yet thoroughly understood, and the possibility of such a pollution source should be considered at this time. Such an occurrence would have a serious impact until it was capped.

Aesthetic Impact. The aesthetic impact will be negligible since only a modest transfer facility will be involved on shore. Noise levels will be low. The drilling and emplacement operations will be at sea with negligible effects.

Transportation Impact. Truck or rail shipment will be required to the port of embarkation. These will be essentially the same as those described previously for geologic disposal concepts. One round trip per year of the ocean-going vessel will be required. An estimated one round trip/month is required for a ship to supply the drilling platform. Similarly, an estimated one round trip/week is required for movement of personnel and small materials.

The noise of surface and air support vehicles could disrupt the mating cycle of the birds and animals. Likewise, the activity around supply bases could have a disturbing effect. Such effects could be minimized by avoiding nesting or feeding areas.

Aesthetic Impact. Due to the extreme remoteness of the area, the visual and aural impact on man would be nil.

Transportation Impact. Most of the effects on the ecology discussed above would be a result of the transportation operation. The noise, oil spills, and disruption of the surface resulting from the surface transport vehicles, and from air, water, and

land support operations would cause most of the expected impact.

3.4.4 Extraterrestrial Disposal

Land. The land use for extraterrestrial disposal is a combination of the land allocated to the launch site and that devoted to the disposition of the separated fission products. The latter disposal may be assumed to be the same as for the mixed fission products and actinide elements discussed above under the heading "geologic." While the land used for geologic disposal can be considered as permanently committed, that used for the launch facility is committed only for the duration of the disposal operation--50 to 100 years. If it is assumed that the launchings would be from Kennedy Space Center and that this land is already committed to space uses, one can argue that no additional land need be allocated to the transuranic element disposal by space launch. This probably would not hold for an expanded launch program of 120 or more launches per year. At that time additional land would have to be committed.

The planning of the Kennedy Space Center is such that maximum joint use of the land is enjoyed. For example, the Bureau of Sport Fisheries and Wildlife under agreement with the Kennedy Space Center manages all property, except launch facilities. There are also plans to turn over part of the reservation to the National Park Service for a National Seashore Park which might be incompatible with waste launching.

Water. The water supply for the Kennedy Space Center is withdrawn from the underlying aquifers. Water usage at the Kennedy Space Center is estimated for 1980 to be about 3.4 million liters/day (0.9 million gallons per day). Of this total about 57% is estimated to percolate back into the water table: the remainder, 1.5 million liters/day is consumptively used. Kennedy Space Center recognizes the danger of overpumping.[59] If water is withdrawn too rapidly along the coastal plains, there is a distinct possibility of salt inundation due to inflow of ocean water. This is guarded against by pumping from a multitude of wells. There are also a number of standby wells for use in an emergency.

Aside from the consumptive use impact, there is the potential for pollution of surface waters. This would arise from an aborted mission in which propellant or oxidizer was released. The use of a spill pond at launch pads guards against pollution from such accidents. In a spill of 20,000 liters (5,300 gallons) of propellant during the loading of Apollo/Saturn 505 in May 1969, all the material was caught in a spill pond and turned over to the Air Force for disposal.[59]

Air. Each launch will release a significant weight of combustion products into the air. While these quantities are small compared to the combustion productions from a large power plant (where many thousands of metric tons of combustion products are produced annually), it must be

remembered that they represent products from a single launch. For 100 launches per year the potential pollution could be significant. Of particular concern, would likely be the potential for high hydrogen chloride concentrations.

Ecologic Impact. Except for the effect of noise on birds and animals, the major impacts on the ecology have already been encountered during construction of the Kennedy Space Center. Although the noise level will be high [overpressures as high as 0.014 atmospheres (30 pounds per square foot) occur during the shuttle ascent[59]] during launch, booster descent, and orbiter descent from orbit, these periods total only a few minutes per launch. Although the net effect on wildlife is unknown, it is qualitatively no different than that which has been withstood since the opening of the Kennedy Space Center.

Aesthetic Impact. The visual impact on the community will be small since the launch facilities are in a large exclusion area. During the few minutes of each launch operation the degree of visual impact is high.

The aural impact is potentially more serious. During the launch operation the maximum safe 115 decibel noise level is estimated to occur outside of the 5-kilometer radius.[59] While the entire land area in this noise contour is located within the control zone, there is a much larger population exposed to nuisance level noise. In addition, there is the nuisance problem of sonic booms. These arise from shuttle ascent, return of the booster, and re-entry of the shuttle. The most severe sonic boom results from the pitchover maneuver during shuttle ascent. Overpressures as great as 0.014 atmospheres can be expected 60 kilometers (33 miles) downrange.[59] This area will be over water; but this is considered a very serious sonic boom (all persons surveyed found sonic booms above 0.0014 atmospheres highly objectionable; plaster, windows, etc. are damaged above 0.0014 atmospheres). During re-entry of the shuttle, the sonic boom may occur over land. The maximum overpressure is expected to be about 0.001 atmospheres between 19 and 185 kilometers from the landing site, depending on flight path and maneuvers. The width of the area impinged by the sonic boom is a maximum of 170 kilometers at a distance of 185 kilometers from the landing site.

Transportation Impact. The ground transportation impact would be considerably greater from the large launch components than from the "payload" capsules carrying transuranium elements of waste. In the reference case, 50 to 260 launches are required in the year 2010. In considering this aspect of environmental impact, as in all others, it should be remembered that only the disposal of transuranium elements is being considered here. If this disposal method is used, all of the environmental impacts discussed under one of the terrestrial disposal concepts (i.e., geologic, or seabed, or ice sheet) will also be incurred for disposal of the remaining waste constituents.

3.4.5 Transmutation

Land. Transmutation of actinide elements in Light Water Reactors should require little or no additional land commitment over and above that needed for the reactors already planned and their supporting fuel cycle services. The basic version of this concept disposes of only transuranium elements; hence in considering environmental impacts one must add those to be expected from the disposal of the remaining waste constituents. These are discussed in Section 3.4.1. The total extra land affected is only about 4 hectares (0.04 km^2).

Water. The additional impact on water supplies will be minimal. Most of these can be expected from the added fuel cycle load. As discussed in detail in Section 9, 474 additional metric tons per year of U_3O_8 will be required. If this is extracted from ore containing 0.5% uranium, approximately 95,000 MT of ore must be mined and milled each year. These ancillary operations will have a much greater impact than the transmutation process itself.

Air Impact. The fuel cycle support operations will have a much greater impact on the air quality than will the reactor irradiations. Dust from mining, milling, and transportation operations are likely to be the chief offenders.

Ecologic Impact. The incremental ecologic impact from the added fuel cycle activities is expected to be very small. The impact from geologic disposal of the remaining bulk wastes discussed earlier would also apply to this case.

Aesthetic Impact. With the exception of the added facilities needed for fuel cycle support and disposal of the remaining waste, there should be no aesthetic impact.

Transportation Impact. The transportation impact will be increased somewhat in all phases of the fuel cycle. The fuel elements containing the actinides will require large shielded containers comparable to those used in the shipment of irradiated fuel.

3.5 PUBLIC ATTITUDES AND PERCEPTION OF RISK

Public attitudes regarding nuclear waste disposal in particular and nuclear power in general are obviously of enormous importance. Large scale projects simply cannot proceed without some degree of public acceptance and favorable attitudes on the part of key decision makers who are responsive to public feelings.

The decisions are often highly technical, and scientific evidence has been highly deterministic of these decisions--so deterministic as to leave little room for public attitudes to affect the decision making process. In these circumstances, policy makers have traditionally proceeded far down the road toward a final decision before public attitudes are directly sought. The most common form of public input in this process is the public hearing where "interveners" have an opportunity to express their views. The very term "interveners" suggests that a decision is nearly final and the only

course open to those wishing to modify the decision is agressive confrontation. Intervention in this classic sense has been a very valuable process and has changed decisions in some instances. However, intervention in the form of public confrontation is not the only way, or necessarily even the best way, of obtaining truly useful public input on nuclear decisions or of providing useful information to the public.

Public input in a variety of forms and at several stages of the decision process--generation of alternative solutions, evaluation of alternative solutions and choice among alternative solutions--might very well improve the quality of nuclear power decisions. In any case, decisions, once reached, with the benefit of informed public input would almost certainly be easier to implement. Wider and earlier participation in the decision process can prevent "last resort" situations from developing.

Social science methodology designed to measure beliefs, attitudes and values has been in use for many years. Any of a score of leading texts and reference works will list hundreds of references to attitude measurement (see for instance, Insko and Schopler[60] for an integrated treatment of experimental approaches to attitude measurement and change, Lindzey and Aronson, Vol. 2[61] and Runkel and McGrath[62] for research design and field research methodology of attitude measurement, Rappaport and Summers[63] for research methodology on human judgment and social interaction, and Lindzey and Aronson, Vol. 5[61] for applications of attitude measurement in applied research settings). A variety of methods are available to measure attitudes directly and also to infer attitudes indirectly. However, these methods have rarely been applied to the measurement of attitudes about as complex an issue as the perception of risks associated with nuclear waste disposal. This particular issue is difficult for the following reasons:

1. Many members of the general public have already formed opinions based on information from the news media, and much of this information is sketchy, value laden and inconsistent.

2. The particular issue of alternative methods of nuclear waste disposal is imbedded in a confusing array of related questions involving the genuineness of the energy crisis, the need for or desirability of more energy, the relative desirability of alternative sources of additional energy, the risks associated with aspects of the nuclear fuel cycle not directly related to waste disposal, the credibility of technical information about nuclear power (whether emanating from the AEC or elsewhere), concern for the environment, and even attitudes about the desirability of population growth.

3. Perceptions of risk tend to arouse emotion, altering judgmental processes. This makes reliable measurement more difficult.

4. The nature of the subject matter is highly technical, and the information base on which citizen attitudes are formed is very heterogenous. Some respondents have virtually no information while others are quite

knowledgeable. The information base of those who have no information on which to form an opinion must be raised somewhat to permit informed judgments and avoid superficial responses. However, the information presented must be very carefully balanced to avoid determining the results. Information, where little existed before, is highly deterministic of one's responses.

3.5.1 Pilot Study Description

Because of these difficulties in applying the attitude measurement methods to waste disposal concepts and because of a very limited research budget, it was decided to conduct a brief pilot study with the objective of testing several aspects of available methodology for appropriateness. The methodology and experience gained can be applied to later studies where the objective should be to actually measure public acceptance of nuclear waste management alternatives. The objective of this brief study was, therefore, development of methodology. The results of the present pilot study should not be interpreted as measuring public attitudes toward nuclear waste alternatives. The reasons for this will become clear as the study is described. The information is described in appreciable detail to illustrate the methodology.

Five generic methods of nuclear waste disposal were selected for study. They were chosen to illustrate a wide variety of problems. The disposal methods were: geologic disposal, ice sheet disposal, seabed disposal, space disposal in a high-earth orbit, and retrievable storage on the earth's surface. Discussions with technical and social science experts plus logical analysis led to identification of seven elements of risk associated with each of the five disposal methods. The seven elements of risk and their definitions are as follows:

Distance - How far from the nearest person is the material (how deep in the earth, how high in orbit)?

Population Density - Aside from emplacement distance, how far from population centers is the disposal site?

Emplacement Operations - What is the nature of the transportation needed to get the material to the disposal site? What is the stage of the development of the emplacement technology? How likely are mishaps during the transportation and emplacement operations?

Stability - Once disposed/stored, how would the waste be affected by such phenomena as earthquakes, volcanos, hurricanes or floods?

Detectability - If there is any dispersal of the radioactivity, how well can it be detected?

Retrievability - Once the material is in its final disposal/storage location, how easily can it be recovered for further treatment or for emergency procedures?

Protective Reaction - If nuclear waste escaped into man's environment, how effectively could the population be protected?

These risk elements were chosen to be as independent from each other as possible.

Because of the controversial nature of the subject matter and the need to pretest the survey methods chosen on a group that would understand that the study was a pilot attempt to gain experience, participation was restricted to "in-house" volunteers. Announcements of the study were sent to all members of the Human Affairs Research Center's staff at Battelle. Twenty-one members of the staff, ranging from secretarial personnel to visiting professors, participated in the study. Table 3.30 describes the characteristics of this group. This sample is obviously not representative of the general population, and results from it must not be generalized.

The approach chosen involved administering a questionnaire to our twenty-one respondents in small groups. This questionnaire is attached as Appendix F. The questionnaire asked respondents to rate each of the seven risk elements with regard to each of the five methods of disposal. These ratings were made on a seven-point scale labeled "VERY DANGEROUS" at one end and "VERY SAFE"

TABLE 3.30. Characteristics of Participants of Pilot Study on Public Attitudes

Total number of participants = 21: 12 men, 9 women

Average age: 28 years

Average education: B.A. Degree + 1 year

Average tenure at Battelle: 1 year

Self rating of knowledge about nuclear energy: $\bar{X}$ (mean) = 4.47;
Standard Deviation = 1.50

(1 = "Know much less than most people"; 4 = "Know about as much as most people"; 7 = "Know much more than most people").

Source of knowledge about nuclear energy. Number of participants who checked each category:

16	Mass media (newspapers, magazines, T.V., etc.)
10	Independent reading (books, technical journals, etc.)
4	Formal training or courses
6	Battelle and/or AEC projects involving nuclear energy
7	Friends, relatives, etc. who were involved in nuclear energy-related jobs

at the other. Respondents were also asked to rank (from one to seven) the contribution of the seven elements of risk to the overall level of risk associated with each of the five disposal methods. This served as a direct measure of the importance of each risk element. Respondents also rated on the seven-point scale the overall level of risk involved with each disposal method. In addition, respondents ranked the contribution of the seven elements of risk to risks of nuclear waste disposal in general, and they ranked the acceptability of the five methods of disposal. These were overall judgments that served as internal cross-checks on the reliability of the judgments. Finally, respondents gave some biographical information, rated their own level of knowledge on nuclear energy and indicated how they obtained the knowledge they had.

A before-after research design was used in the study to obtain some measure of the effect of knowledge or information regarding the disposal concepts on the perceptions of risk. Two identical forms of the questionnaire were administered to each participant, first as a pretest and later as a posttest measure. After completing the pretest questionnaire based only upon the listing of disposal concepts, participants watched a 30-minute videotape lecture which described the five disposal methods in more detail. For each method, information was presented about the seven risk elements. Posttest measures were then taken by having the participants complete the questionnaire a second time.

3.5.2 Pilot Study Results

Table 3.31 presents pre- and posttest means and standard deviations for ratings of perceived danger level for the five disposal methods in terms of the seven risk elements. The averages of the seven means for each method are presented in the next-to-bottom row of the table. The overall ratings of risk for each waste disposal method are presented in the bottom row of the table. The means for each risk element were also averaged across the five methods and are shown in the far right column of Table 3.31.

As a rule of thumb for interpreting differences among means, the following guides will hold in most comparisons. A difference of 1.5 between means is statistically significant at the 95% confidence level, even when both samples exhibit large standard deviations, i.e., as large as 2.0.

Within Table 3.31, there are several shifts in mean ratings from pre- to posttest. However, the sample size was not sufficiently large to permit many of the pre-posttest mean shifts to reach statistical significance. One exception in Table 3.31 was the pre-post mean difference of 1.9 in which the Seabed Disposal method was seen as more dangerous with respect to Emplacement Operations. Had a larger sample been employed, considerably more of these

TABLE 3.31. Mean Scores for Ratings of Risk Level by Participants in Pilot Study

Risk Perception Factor	Mean Score ($\bar{X}$) and Standard Deviation (S.D.)	Geologic Disposal		Ice Sheet Disposal		Seabed Disposal		High-Earth Orbit		Retrievable Surface Storage		Average of $\bar{X}$'s of 5 Methods	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Distance	$\bar{X}$	3.7	4.8	5.4	4.9	4.7	5.1	5.4	6.0	3.0	3.4	4.4	4.8
	S.D.	1.9	1.9	2.1	2.1	2.3	2.2	2.2	2.0	1.9	2.1		
Population Density	$\bar{X}$	4.4	4.9	5.8	5.2	4.7	5.3	5.4	6.2	3.7	3.9	4.8	5.1
	S.D.	1.8	1.8	2.0	2.2	2.3	2.0	2.2	2.0	2.0	2.0		
Emplacement Operations	$\bar{X}$	3.7	3.5	3.2	1.6	3.5	1.6	1.9	1.4	4.0	4.2	3.3	2.5
	S.D.	1.7	1.7	1.9	0.7	2.1	0.9	1.4	0.7	2.1	1.9		
Stability	$\bar{X}$	2.7	3.7	3.2	2.7	2.6	3.3	3.9	3.0	3.2	1.9	3.1	2.9
	S.D	1.5	1.9	1.9	2.0	1.5	1.6	2.4	1.5	2.0	1.1		
Detectability	$\bar{X}$	4.7	4.2	2.7	1.3	1.9	1.8	2.3	1.5	5.6	6.0	3.4	3.0
	S.D.	2.0	2.0	1.7	0.5	1.5	1.0	1.8	0.8	2.0	1.4		
Retrievability	$\bar{X}$	4.3	3.1	2.2	1.3	1.6	1.3	1.3	1.9	5.6	6.0	3.0	2.7
	S.D.	1.6	1.4	1.3	0.4	0.7	0.5	0.6	1.0	2.0	1.7		
Protective Reaction	$\bar{X}$	3.3	2.3	2.2	1.1	1.3	1.1	1.6	1.4	3.9	5.3	2.5	2.2
	S.D.	1.6	1.2	1.6	0.3	1.1	0.4	1.0	0.9	2.2	2.1		
Average of 7 issues	$\bar{X}$	3.8	3.8	3.5	2.6	2.9	2.8	3.1	3.1	4.1	4.4	3.5	3.3
Overall rating of risk level for each method	$\bar{X}$	3.4	3.9	2.7	1.7	2.1	1.9	2.2	2.0	3.1	3.9	2.7	2.7
	S.D.	1.6	1.6	1.4	1.1	1.3	1.7	1.3	1.3	1.6	1.5		

1 = Very Dangerous 4 = Neutral/Undecided 7 = Very Safe

pre-post mean shifts would have reached statistical significance.

Mean values for posttest ratings of level of safety are graphed in Figure 3.14. The ice sheet, seabed and space orbit methods were similar in perceived safety of the seven risk elements, as can be seen in Figure 3.14. Examination of the ice sheet, seabed and orbit methods in Figure 3.14 indicates that these methods were perceived as quite dangerous with respect to Protective Reaction, Retrievability, Detectability, Emplacement Operations, moderately dangerous with respect to Stability, and relatively safe with respect to the risk elements of Distance and Population Density. The participants perceived the geologic method as relatively dangerous with regard to Protective Reaction and Retrievability, moderately dangerous with regard to Detectability, Emplacement Operations, and Stability, and relatively safe in terms of Distance and Population Density. The participants saw the retrievable surface storage method as dangerous with respect to Stability. In terms of Distance, Population Density, and Emplacement Operations, the retrievable surface storage method was rated as only moderately dangerous, and was seen as rather safe relative to Protective Reaction, Retrievability and Detectability.

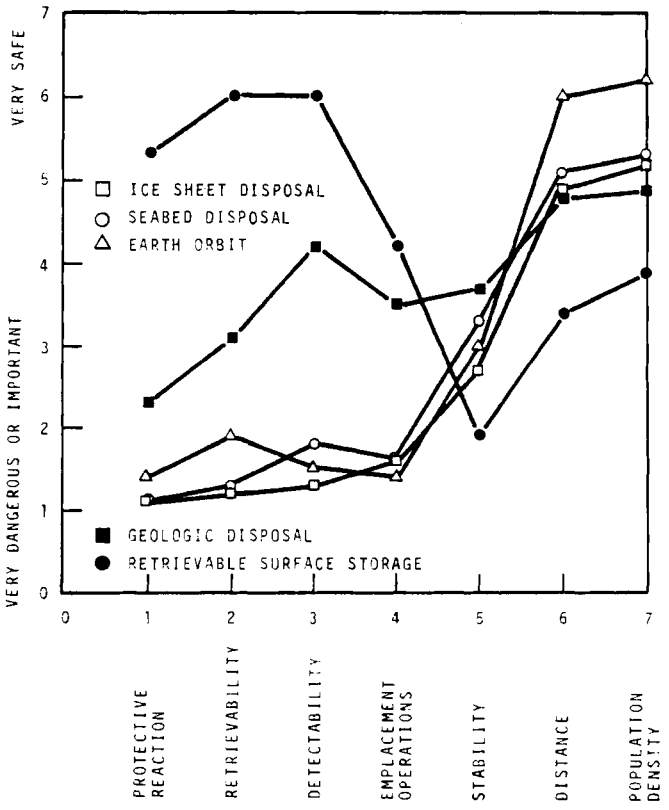


FIGURE 3.14. Mean Posttest Ratings of Perceived Risk Associated with Seven Elements of Risk

Although there are some exceptions, the posttest standard deviations are generally smaller than the pretest ones. This confirms the expectation that an increased level of knowledge should decrease the scatter in responses.

Pretest and posttest means and standard deviations for ranking the amount of risk each element contributed to total risk are presented in Table 3.32. Examination of pre-post shifts indicates relatively few significant shifts.

Comparison of Figure 3.14 with Figure 3.15 indicates a striking similarity between (1) the level of perceived danger associated with an element of risk, and (2) the perceived degree to which an issue contributes to overall risk (i.e., importance) of a disposal method. The close correspondence between perceived risk and importance is not too surprising in this situation. However, psychological research sometimes shows that highly salient variables are sometimes trivial in importance. For example, dirty washrooms are salient and cause many complaints but have a trivial effect on overall job satisfaction. In effect, the greater the perceived danger associated with a risk element, the more importance attached to that issue, and vice versa. This pattern of close correspondence between rated level of danger and ranked importance holds in virtually every case. Rho, the correlation index, ranged from 0.88 to 0.96, thereby indicating the close correspondence between the two sets of data.

Mean posttest ratings of perceived danger and rankings of perceived importance of risk elements for the seven issues were averaged across the five methods to obtain estimates of risk perceptions and importance of the elements. The conclusions to be gathered from these data are limited, for the results can be readily biased by the selection of the particular disposal concepts to be used as examples. The averages of the mean values are shown in the two right-hand columns in Table 3.33.

In an attempt to obtain indirect estimates of the participants' perceived importance of the seven elements of risk, the ratings of perceived risk were also analyzed using multiple regression techniques. For each disposal method, the ratings of each of the risk elements were treated as independent variables to predict the overall rating of perceived risk level for that method. The result is a linear equation which weights the independent variables (the seven risk elements) to maximize the prediction of the overall rating. The multiple regression coefficients, or beta weights, assigned to each risk element furnish an estimate of the relative importance of each risk element.

The weights which resulted from the multiple regression analyses did not lend themselves to clear-cut interpretation. There are at least two explanations for the difficulties encountered in the interpretation of these results. First, with small sample sizes, multiple regression analysis is susceptible to spurious

TABLE 3.32. Mean Scores for Importance Rankings of Risk Elements by Participants in Pilot Study

Risk Perception Factor	Mean Score ($\bar{X}$) and Standard Deviation (S.D.)	Geologic Disposal		Ice Sheet Disposal		Seabed Disposal		High Earth Orbit		Retrievable Surface Storage		Ranking of Issues		Average of $\bar{X}$'s	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Distance	$\bar{X}$	4.7	5.2	5.7	6.1	5.9	6.3	6.0	6.5	4.1	3.4	6.0	5.8	5.3	5.5
	S.D.	2.1	2.0	1.8	1.5	1.4	1.4	1.5	0.6	2.3	2.0	1.5	2.0		
Population Density	$\bar{X}$	4.4	5.1	5.9	6.0	6.1	5.9	5.6	6.3	4.1	3.7	5.2	5.6	5.2	5.4
	S.D	1.5	1.9	1.7	1.1	1.3	1.1	1.5	0.7	2.1	1.9	1.7	1.4		
Emplacement Operations	$\bar{X}$	4.1	3.6	3.7	3.9	4.6	3.6	3.0	2.7	3.8	3.2	4.0	4.0	3.8	3.4
	S.D.	2.2	1.8	1.8	1.4	1.6	1.3	2.0	1.6	1.7	1.5	1.7	1.5		
Stability	$\bar{X}$	2.8	3.6	2.0	3.7	3.3	4.4	4.1	4.2	2.7	1.9	3.5	2.9	3.0	3.7
	S.D.	1.6	2.0	1.6	1.9	1.5	1.4	1.7	1.2	1.8	1.1	2.0	1.8		
Detectability	$\bar{X}$	4.4	4.6	3.1	2.7	2.6	2.9	3.4	2.9	5.0	5.3	2.7	3.2	3.7	3.7
	S.D	2.2	1.8	1.5	1.3	1.4	1.2	1.7	1.2	1.7	1.4	1.7	1.6		
Retrievability	$\bar{X}$	4.7	3.2	3.3	3.2	2.9	3.8	3.1	3.1	4.8	5.9	4.0	3.7	3.8	3.8
	S.D.	2.1	1.7	1.6	1.5	1.4	1.4	1.4	1.3	1.9	1.1	1.8	1.7		
Protective Reaction	$\bar{X}$	3.3	2.6	3.2	2.4	2.5	2.0	2.7	2.3	3.4	4.6	2.7	2.6	3.0	2.8
	S.D.	1.6	1.5	1.7	1.5	1.4	1.5	1.4	1.4	1.7	1.8	1.4	1.5		

1 = Most Important Contribution to Perceived Risk

7 = Least Important Contribution to Perceived Risk

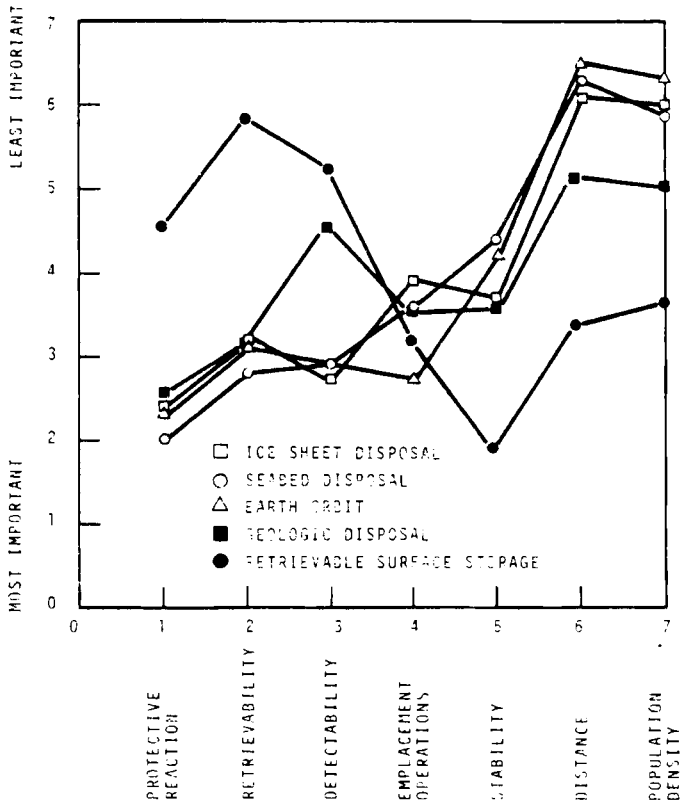


FIGURE 3.15. Mean Posttest Rankings of Perceived Relative Importance of Seven Risk Elements

relationships which occur through the operation of chance variation. Despite the relatively large standard deviations shown in Table 3.31, examination of individual cases indicates that several instances of large variation were actually caused by one or two extreme ratings. Thus the large standard deviation did not reflect an even distribution of scores about the mean but were caused instead by isolated cases. With the small sample sizes in this study, multiple regression tends to capitalize on chance fluctuation; the resulting beta weights erroneously reflect these chance fluctuations.

A second possible reason for the inconsistent pattern of beta weights may be due to the overlap among the seven elements of risk. In multiple regression analysis, if two predictions appear to overlap or to measure a similar characteristic, one of the two will receive a substantial weight and the other will receive a relatively small weight. For example, Population Density and Distance may have been perceived as similar dimensions; if so, the beta weights would be inconsistent. The tendency for risk elements to interact with one another can be minimized somewhat by (1) choosing risk elements which are independent of one another and (2) including instructions to the participant which clearly describe each risk element so that each is distinct from the others.

TABLE 3.33. Summary of Perception of Relative Danger and Importance Elements by Participants in Pilot Public Attitude Study

	Geologic Disposal		Ice Sheet Disposal		Seabed Disposal		High Earth Orbit Disposal		Retrievable Surface Storage		Overall Average for Each Element for all 5 Disposal Methods	
	Rating[a]	Ranking[b]	Rating[a]	Ranking[b]	Rating[a]	Ranking[b]	Rating[a]	Ranking[b]	Rating[a]	Ranking[b]	Rating[a]	Ranking[b]
Protective Reaction	2.3	2.6	1.1	2.4	1.1	2.0	1.4	2.3	5.3	4.6	2.2	2.8
Retrievability	3.1	3.2	1.2	3.2	1.3	2.8	1.9	3.1	6.0	5.9	2.7	3.6
Emplacement Operations	3.5	3.6	1.6	3.9	1.6	3.6	1.4	2.7	4.2	3.2	2.5	3.4
Stability	3.7	3.6	2.7	3.7	3.3	4.4	3.0	4.4	1.9	1.9	2.9	3.7
Detectability	4.2	4.6	1.3	2.7	1.8	2.9	1.5	2.9	6.0	5.3	3.0	3.7
Distance	4.8	5.2	4.9	6.1	5.1	6.3	6.0	6.5	3.4	3.4	4.8	5.3
Population Density	4.9	5.1	5.2	6.0	5.3	5.9	6.2	6.3	3.9	3.7	5.1	5.7
Correlation Between Rating and Ranking[c]	Rho = 0.96		Rho = 0.89		Rho = 0.93		Rho = 0.96		Rho = 0.88			

a. Rating of relative perceived danger

1 = very dangerous
7 = very safe

Ranking of perceived importance

1 = most important
7 = least important

c. Rho is an index of the correlation relationship between the two variables (1 = exact correlation).

3.5.3 Pilot Study Conclusions

Some conclusions can now be drawn about the methods used in this study to measure perceived risk and the relative importance of risk elements. First, the videotape method of presenting technical information about disposal systems appeared to be effective as a communications device and had the important advantage of presenting a standard message to the respondents (the videotape presentation used could be improved). Second, the direct ranking of importance of risk elements by the participants shown in Table 3.32 provided a useful method of determining which elements were most important in contributing to preceived overall risk. In future studies this direct method of measuring importance of elements should be supplemented and cross checked by indirect methods of measuring importance. The study design would permit multiple regression analyses yielding an indirect measure of importance if the number of respondents were increased considerably (say to between 200 and 300) and if the spectrum of participants' backgrounds and interests were much broader. Past research has shown that indirect measures of importance are sometimes more useful than direct measures in highly emotional or abstract content areas. Third, the current design involving judgments of risk, both before and after the videotape presentation, is a useful approach for exploring attitude change, an important topic in this arena where public preconceptions are often based on faulty data. On balance, the current approach with minor modifications appears useful for broader use.

Conclusions drawn from the "results" obtained in this pilot study must be tempered by several considerations. The sample was much too small to yield results of high reliability or to permit certain analyses that require large samples; the respondents were an "in-house" group sympathetic to the research approach; and the sample was far from representative of the general public. In these circumstances, the validity of the data is indeterminate by definition.

With these caveats in mind, what were the most striking findings? First, there appeared to be a direct relationship between the amount of danger perceived in a particular facet of risk and the importance attached to that facet. This finding might be expected on an intuitive basis; i.e., those features of a disposal method which are viewed as dangerous are also seen as the most important contributors to the overall risk of a method.

Second, within each disposal method, there are certain risk elements which the participants perceived as quite dangerous (and important) and other facets which they saw as relatively low in risk (and unimportant). Of particular interest is the participants' perception that Distance and Population Density tended to be regarded as relatively low in importance when compared with some of the more technical characteristics of waste disposal, such as

Detectability or Emplacement Operations. Also of interest is that, for four out of five methods (all but retrievable surface storage), the issue of Protective Reaction was seen as very important. If these views are replicated in future research, it would seem to be an important finding for policy makers to keep in mind.

3.5.4 Future Studies

The activities described in this section represent a pilot test of a methodology for measuring and describing public attitudes about the risks associated with nuclear waste disposal. The major value of the work reported here is as a point of departure for subsequent research on public acceptance and risk. In a second phase of work in this area, data should be gathered from a larger and more representative sample of the general public.

A larger sample size would lend itself to meaningful interpretation of the results and also permit the use of more extensive analytic tools. For example, the data from large samples could be analyzed using multiple regression techniques. Such an approach might be useful for obtaining indirect estimates of the importance of risk elements. Consideration also might be given to surveying particular groups such as the membership of special interest groups of key community organizations.

From the experience of conducting this study, several suggestions can be made which would strengthen future research efforts. First, the videotaped information package should be revised and carefully edited to assure that the information is solely descriptive and free of value-laden words or other biasing factors. Ambiguous or undefined technical-scientific material should also be minimized. Second, comments from participants and reviewers indicate that certain parts of the questionnaire should be changed or revised. For example, the participants reported difficulty in distinguishing between the concepts of Distance and Population Density. Also the elements of risk should be more explicitly defined and consideration should be given to modifying this list of seven elements, including a consideration of time duration. Modification of the questionnaire to give respondents a measure of the absolute risk of the nuclear waste (and other) alternatives should be considered. Finally, a disparity was noted among the risk elements being rated, and the adjectives used to define the rating scales (e.g., Very Dangerous and Very Safe) did not constitute meaningful categories for judging certain risk elements, such as Detectability and Retrievability. Attention should be directed toward improving the judgment categories used for rating and ranking.

In summary, the survey research methods used in this study appear to be useful tools for gathering information about public perceptions of risk. Recognized needs to improve this approach for future research would not require any fundamental

changes in design or format. Obviously, other approaches (for instance, hearings) should also continue to be used.

REFERENCES

1. D. F. Haasl, "Failure Mode and Effect Analysis," Boeing Company System Analysis Notes, Seattle, WA, 1964.

2. J. F. Magee, "Decision Trees for Decision Making," Harvard Business Review, vol. 42, no. 4, pp. 126-148, July-August, 1964.

3. D. F. Haasl, "Advanced Concepts in Fault Tree Analyses," University of Washington and Boeing System Safety Symposium, Seattle, WA, 1965.

4. F. Gera and D. G. Jacobs, Consideration in the Long Term Management of High Level Radioactive Wastes, U.S. AEC Report, ORNL-4762, Oak Ridge National Laboratory, Oak Ridge, TN, 1972.

5. The National Atlas of the United States, U.S. Department of the Interior Geological Survey, Washington, D.C., 1970.

6. Bureau of Mines Circular #57.

7. D. L. Katz and K. H. Coats, University of Michigan, Ann Arbor, MI, Personal Communication to T. I. McSweeney, Battelle-Northwest, Richland, WA.

8. D. L. Katz and K. H. Coats, Underground Storage of Fluids, University of Michigan, Ann Arbor, MI, 1968.

9. "Amoco Oil To Modify Its Cat Crackers," Oil and Gas Journal, vol. 71, no. 14, p. 32, April 2, 1973.

10. U.S. Bureau of the Census, Statistical Abstract of the United States, 92nd edition, Washington, D.C., 1971.

11. J. D. Martinez, R. L. Thomas and U. K. Jiudal, "Model Studies of Effects of Closure of Solution Caverns in Salt Domes," Third Symposium on Salt, Northern Ohio Geophysical Society, vol. 2, p. 308, 1970.

12. R. D. Terzaghi, "Brinefield Subsidence at Windsor, Ontario," Third Symposium on Salt, Northern Ohio Geophysical Society, vol. 2, p. 298, 1970.

13. Advisory Conference on Tunnelling, June 1970, PB 193 286-5, U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, Springfield, VA, 1970.

14. S. T. Algermissen, "Seismic Risk Studies in the United States," Proceedings of the 4th International Conference on Earthquake Engineering, Santiago, Chile, 1969.

15. B. Gutenberg and C. F. Richter, "Seismicity of the Earth," Princeton University Press, Princeton, NJ, 1954.

16. G. A. Bollinger, "Historical and Recent Seismic Activity in South Carolina," Bulletin of Seismological Society of America, vol. 62, no. 3, p. 851, June 1972.

17. R. L. Wiegel, Earthquake Engineering, Prentice-Hall, Englewood Cliffs, NJ, 1970.

18. M. J. S. Innes, "The Use of Gravity Methods to Study the Underground Structure and Impact Energy of Meteorite Craters," J. of Geophys. Res., vol. 66, 1961.

19. K. R. Wise and B. M. Cole, A Survey of Heat Sink Capacity of Major Stress Within the U.S., U.S. AEC Report, BNWL-951, 1969.

20. C. F. Richter, Elementary Seismology, W. H. Freeman & Co., San Francisco, CA, 1958.

21. J. Corbel, "Vitesse de l'Erosion," Festschrift für Geomorphologie, vol. 3, pp. 1-28, 1959.

22. "Forecast/Review," Oil and Gas Journal, January 29, 1973.

23. DOT Fourth Annual Report to the President - Fiscal Year 1970, U.S. Department of Transportation, Washington, D.C., 1971.

24. Annual Review of Aircraft Accident Data, National Transportation Safety Board, NTSB-ARC-71-1, Washington, D.C., 1971.

25. C. Starr, Benefit-Cost Studies in Sociotechnical Systems, Paper in Perspectives in Benefit-Risk Decision Making, The Natural Academy of Engineering, Washington, D.C., 1972.

26. International Commission on Radiological Protection, Recommendations of the International Commission on Radiological Protection (Adopted Sept. 17, 1965), ICRP Publ. 9, Pergamon Press Ltd., Oxford, 1966.

27. National Council on Radiation Protection and Measurements, Basic Radiation Protection Criteria, NCRP Report No. 39, NCRP Publ., Washington, D.C., 1971.

28. Federal Radiation Council, Background Material for the Development of Radiation Protection Standards, Staff Report No. 1, GPO, Washington, D.C., 1960.

29. Federal Radiation Council, Background Material for the Development of Radiation Protection Standards, Staff Report No. 2, GPO, Washington, D.C., 1961.

30. Code of Federal Regulations, 10CFR20, "Standards for Protection Against Radiation," GPO, Washington, D.C., 1971.

31. U.S. Atomic Energy Commission, AEC Manual, Chapter 0524, "Standards for Radiation Protection," GPO, Washington, D.C., June 1971.

32. General Assembly, United Nations, Report of the United Nations Scientific Committee on the Effects of Atomic Radiation, Official Records: 27th Session, Suppl. No. 25 (A/8725), United Nations, New York, NY, 1972.

33. Advisory Committee on the Biological Effects of Ionizing Radiations, The Effects on Populations of Exposure to Low-Levels of Ionizing Radiations, National Academy of Sciences, National Research Council, Washington, D.C., 1972.

34. Federal Radiation Council, Background Material for the Development of Radiation Protection Standards, Staff Report No. 5, GPO, Washington, D.C., 1964.

35. Federal Radiation Council, Background Material for the Development of Radiation Protection Standards, "Protective Action Guides for Strontium-89, Strontium-90, and Cesium-137," Staff Report No. 7, GPO, Washington, D.C., 1965.

36. J. F. Fletcher et al., HERMES--Digital Computer Code for Estimating Regional Radiological Effects from the Nuclear Power Industry, HEDL-TME-71-168, Hanford Engineering Development Laboratory, Richland, WA, p. 83, 1971.

37. J. K. Soldat, N. M. Robinson and D. A. Baker, Models and Computer Codes for Evaluating Environmental Radiation Doses, BNWL-1754, Battelle, Pacific Northwest Laboratories, Richland, WA, June 1973.

38. Task Group on Lung Dynamics, "Deposition and Retention Models for Internal Dosimetry of the Human Respiratory Tract (A Report Prepared for Committee II of the ICRP)," Health Physics, vol. 12, pp. 173-207, 1966.

39. International Commission on Radiological Protection, Permissible Dose for Internal Radiation, Report of Committee II, ICRP Publ. 2, Pergamon Press Ltd., Oxford, 1959.

40. International Commission on Radiological Protection, Recommendations of the International Commission on Radiological Protection, (As amended 1959 and revised 1962), ICRP Publ. 6, Pergamon Press, Oxford, 1964.

41. C. M. Lederer, J. M. Hollander and I. Perlman, Table of Isotopes, 6th ed., John Wiley & Sons, New York, NY, 1967.

42. J. K. Soldat, A Statistical Study of the Habits of Fishermen Utilizing the Columbia River Below Hanford, BNWL-SA-1451, Battelle, Pacific Northwest Laboratories, Richland, WA, 1968.

43. E. C. Watson and C. C. Gamertsfelder, Environmental Radioactive Contamination as a Factor in Nuclear Plant Siting Criteria, HW-SA-2809, Hanford Atomic Products Operation, Richland, WA, March 29, 1963.

44. Y. C. Ng et al., "Prediction of the Maximum Dosage to Man from the Fallout of Nuclear Devices," Part IV, Handbook for Estimating the Maximum Internal Dose from Radionuclides Released to the Biosphere, UCRL-50163, Univ. of Calif., Lawrence Radiation Laboratory, Livermore, CA, May 14, 1968.

45. S. E. Thompson, C. A. Burton, D. J. Quinn and Y. C. Ng, Concentration Factors of Chemical Elements in Edible Aquatic Organisms, UCRL-50564, Univ. of Calif., Lawrence Radiation Laboratory, Livermore, CA, Rev. 1, Oct. 10, 1972.

46. A. M. Freke, "A Model for the Approximate Calculation of Safe Rates of Discharge of Radioactive Wastes into Marine Environments," Health Physics, vol. 13, p. 43, 1965.

47. J. K. Soldat, N. M. Robinson and D. A. Baker, Models and Computer Codes for Evaluating Environmental Radiation Doses, BNWL-1754, Battelle, Pacific Northwest Laboratories, Richland, WA, February 1974.

48. J. P. Nichols et al., Projections of Fuel Reprocessing Requirements and High-Level Solidified Wastes from the U.S. Nuclear Power Industry, ORNL-TM-3965, Oak Ridge National Laboratory, Oak Ridge, TN, draft to be published.

49. D. J. Brown, "Migration Characteristics of Radionuclides Through Sediments Underlying the Hanford Reservation," Disposal of Radioactive Wastes in the Ground, Proceedings of a Symposium, Vienna 29, May-2 June 1967, International Atomic Energy Agency, pp. 215-228, 1967.

50. R. C. Routson, A Review of Studies on Soil-Waste Relationships in the Hanford Reservation from 1944-1967, BNWL-1464, Battelle, Pacific Northwest Laboratories, Richland, WA, p. 22, March 1973.

51. R. E. Baker, U.S. Atomic Energy Commission; Division of Regulatory Standards, Washington, D.C., to J. K. Soldat, Battelle, Pacific Northwest Laboratories, Richland, WA, private communication, April 24, 1972.

52. H. U. Sverdrup, M. W. Johnson and R. H. Fleming, The Oceans - Their Physics, Chemistry, and General Biology, Prentice-Hall, Englewood Cliffs, NJ, p. 684, 1942.

53. Food and Agricultural Organization of the United Nations, Yearbook of Fishery Statistics, United Nations, New York, NY, p. a-91, 1965.

54. Discount Rates To Be Used in Evaluating Time-Distributed Costs and Benefits, Office of Management and Budget Circular No. A-94, Revised, March 27, 1972.

55. Reactor Fuel Cycle Costs for Nuclear Power Evaluation, USAEC Report WASH-1099, Oak Ridge National Laboratory, Oak Ridge, TN, 1971.

56. J. L. McElroy, K. J. Schneider and others, Waste Solidification Program Summary Report, vol. 11, Evaluation of WSEP High Level Waste Solidification Processes, BNWL-1667, Battelle Pacific Northwest Laboratories, Richland, WA, July 1972.

57. Code of Federal Regulations, Appendix F, Federal Register, vol. 36, no. 56, March 23, 1971.

58. U.S. Naval Support Force, Introduction to Antarctica, p. 7, July 1969.

59. R. E. Hyland, NASA Lewis Research Center, Personal Communication to K. Drumheller, Battelle, Pacific Northwest Laboratories, Richland, WA, August 6, 1973.

60. C. A. Insko and J. Schopler, Experimental Social Psychology, Academic Press, New York, NY, 1972.

61. G. Lindzey and E. Aronson, (Eds), The Handbook of Social Psychology, 2nd Edition, vols. 2 and 5, Addison-Wesley, Reading, MA, 1968.

62. P. J. Runkel and J. E. McGrath, Research on Human Behavior, Holt, Rinehart and Winston, New York, NY, 1972.

63. L. Rappaport and D. A. Summers, Human Judgment and Social Interaction, Holt, Rinehart and Winston, New York, NY, 1973.

APPENDIX

SECTION 1: SUMMARY

APPENDIX 1.A

CONVERSION FACTORS

Conversion Factors

To Convert	Into	Multiply By
calories, gram	Btu	3.9685×10^{-3}
centigrade	Farenheit	(C° x 9/5) + 32
centimeters	inches	0.3937
cubic meters	cubic feet	35.31
cubic meters	liter	1000.0
cubic meters	gallons (U.S.)	264.2
grams	pounds	2.205×10^{-3}
grams/liter	pounds/cubic feet	0.062427
hectares	acres	2.47
hectares	square kilometers	0.01
kilograms	pounds	2.205
kilometers	miles	0.6214
kilometers	feet	3,281
kilowatts	Btu/min	56.92
kilowatts	horsepower	1.341
kilowatt-hrs	Btu	3413
liters	cubic feet	0.03531
liters	gallons (U.S.)	0.2642
liters/min	cu.ft/sec	5.886×10^{-4}
meters	feet	3.281
meters/min	feet/min	3.2.81
millimeters	inches	0.03937
mills/kilowatts-hrs*	dollars/kilogram U*	277.2
newtons	pounds	0.2248
square centimeters	sq. inches	0.1550
square kilometers	acres	247.1
square kilometers	square miles	0.3861
square meters	square feet	10.76
tons (metric)	kilograms	1000
tons (metric)	pounds	2205
watts	Btu/hr	3.413
watts hours	Btu	3.413
watts hours	ergs	3.60×10^{10}
watts hours	foot-pounds	2,656
watts hours	kilogram-calories	0.8598
watts/cm^2-°C	Btu/(hr-sq ft-°F)	1760.6
(watts/cm^2)(°C/cm)	(Btu/hr-sq ft)(°F/ft)	57.8

* at 33,000 megawatt days (thermal)/ton(metric) U and 35% conversion efficiency, thermal to electrical.

APPENDIX 1.B

GENERALIZED MAPS OF THE UNITED STATES

1.B-1 Seismic Risk Map of the United States

1.B-2 Principal Faults Located in the United States

1.B-3 Areas of the United States that Would be Inundated by 60- and 150-Meter Sea Level Rise

1.B-4 Productive Aquifers and Withdrawal from Wells

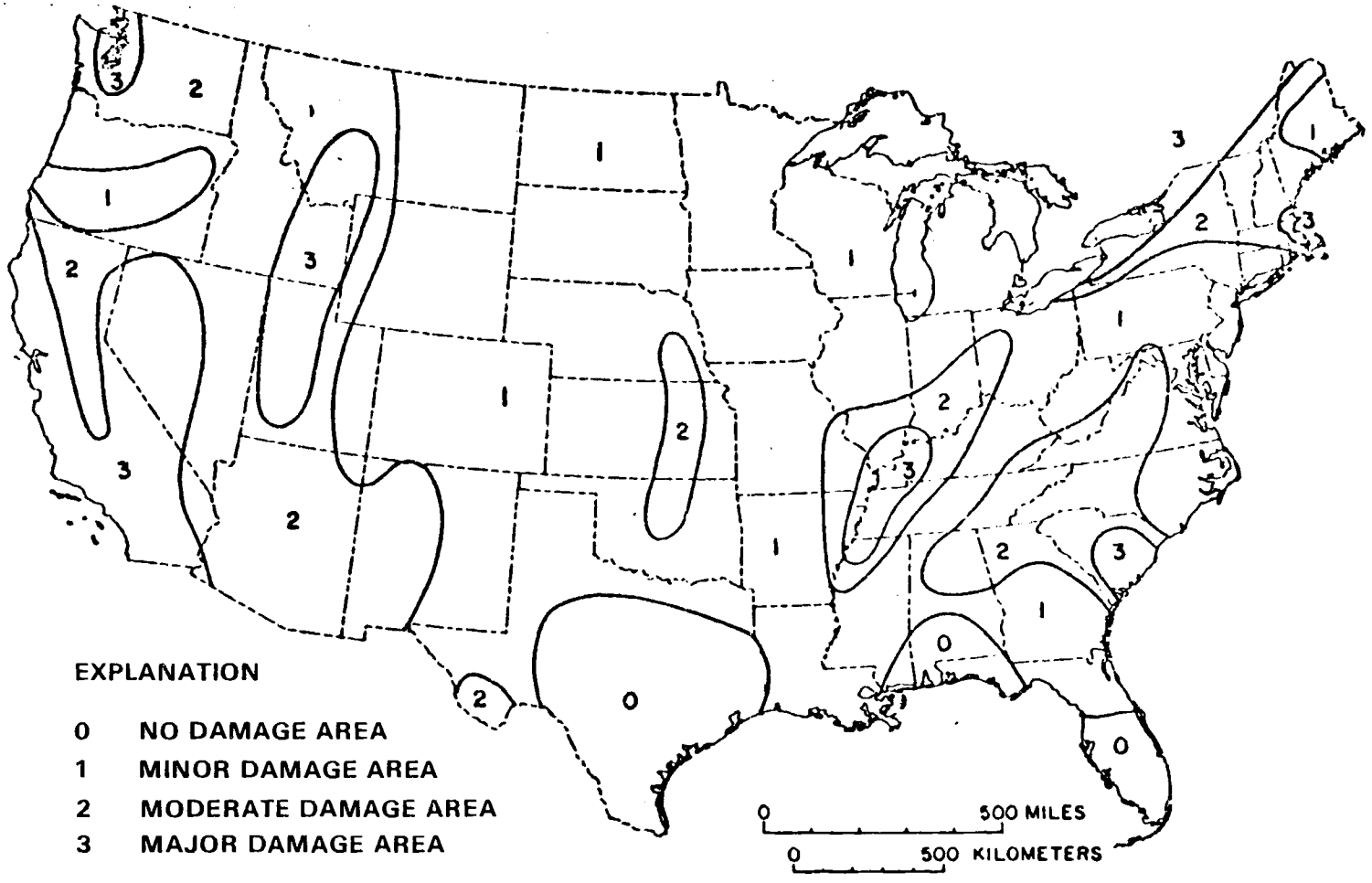


FIGURE 1.B-1. Seismic Risk Map of the United States (Modified from Algermissen, 1969)

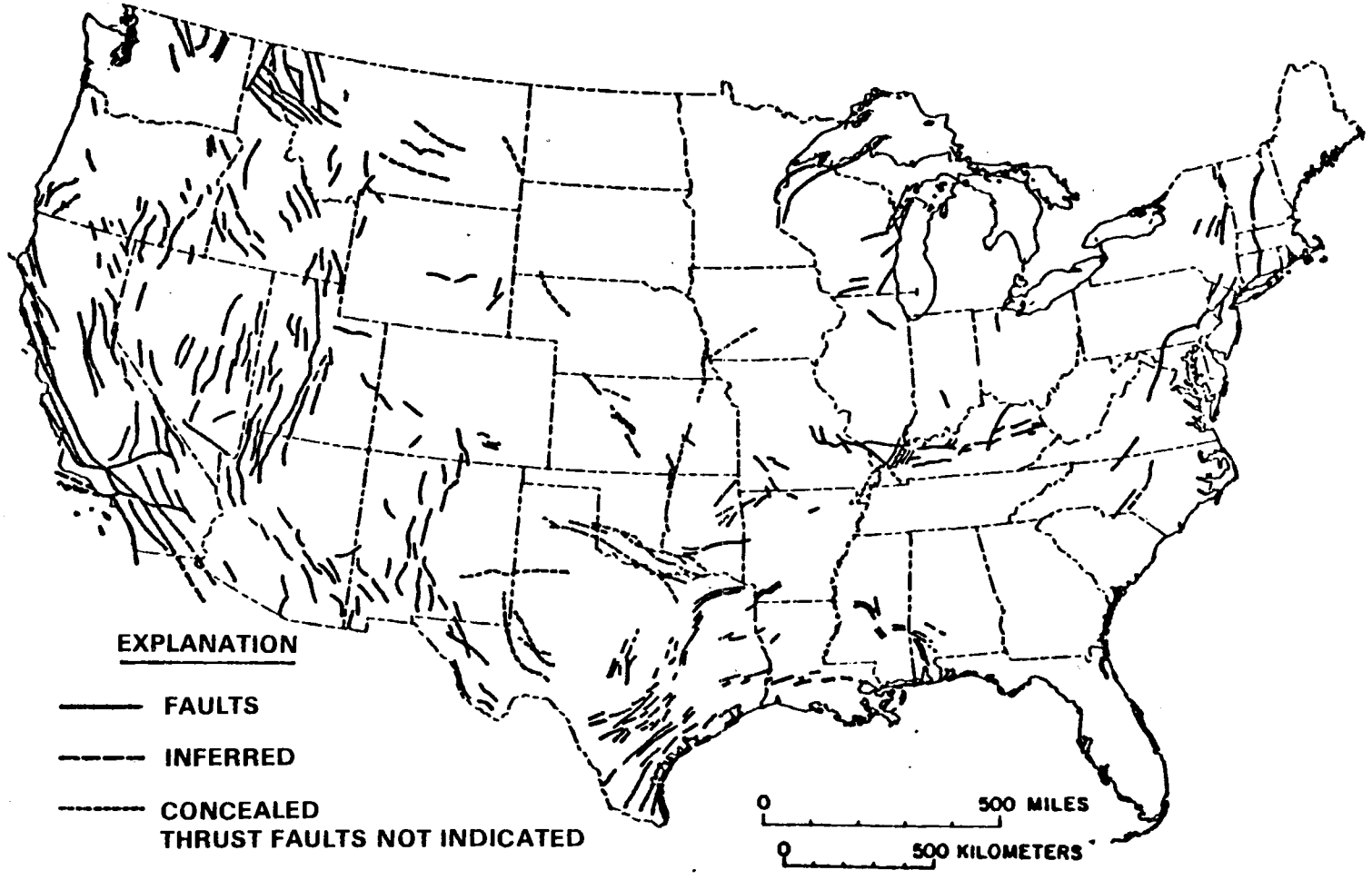


FIGURE 1.B-2. Principal Faults Located in the United States (Modified from P. B. King, 1967)

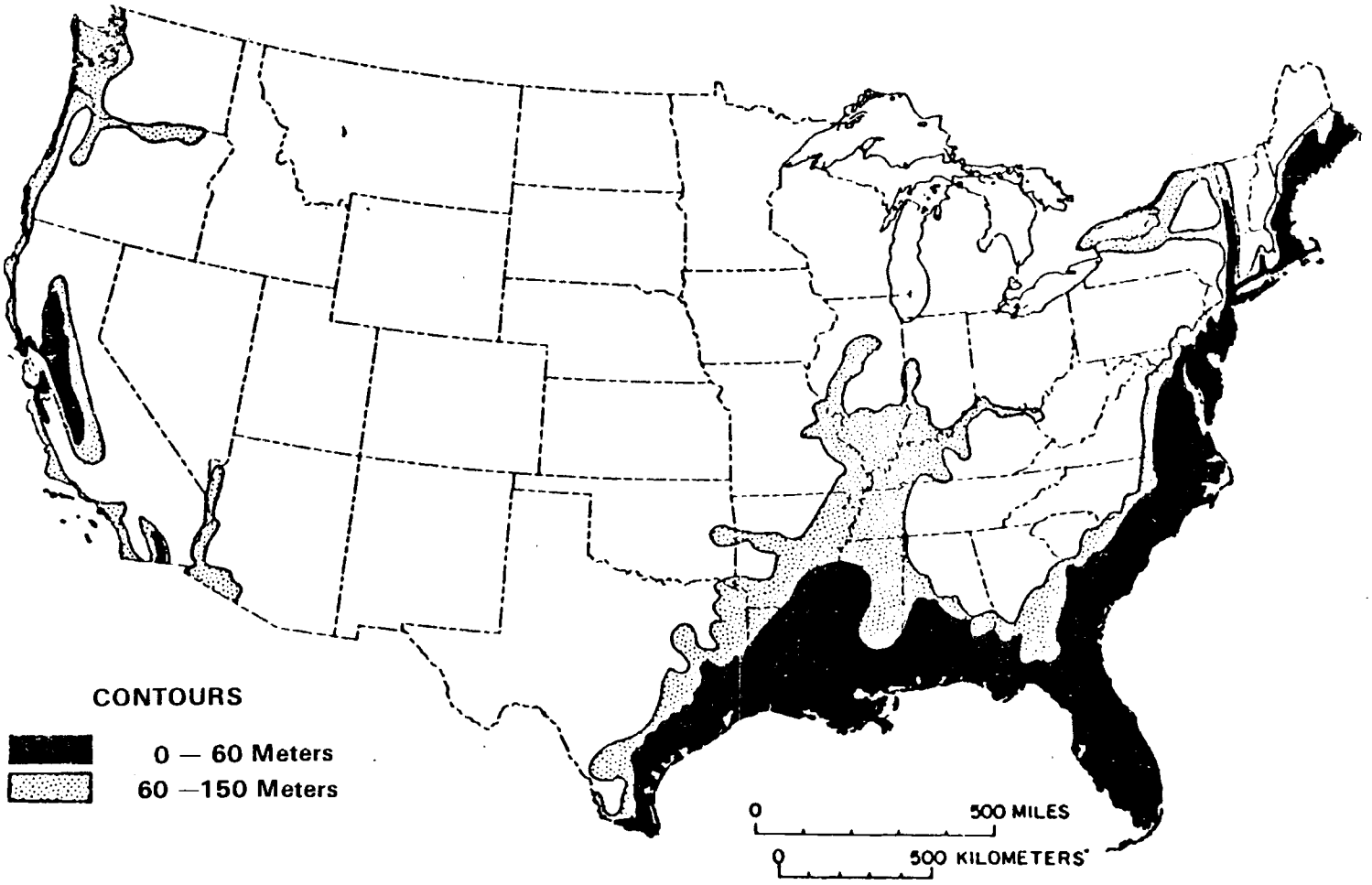


FIGURE 1.B-3. Areas of the United States that Would Be Inundated by 60 and 150-Meter Sea Level Rise (Modified from U.S. Geological Survey Maps)

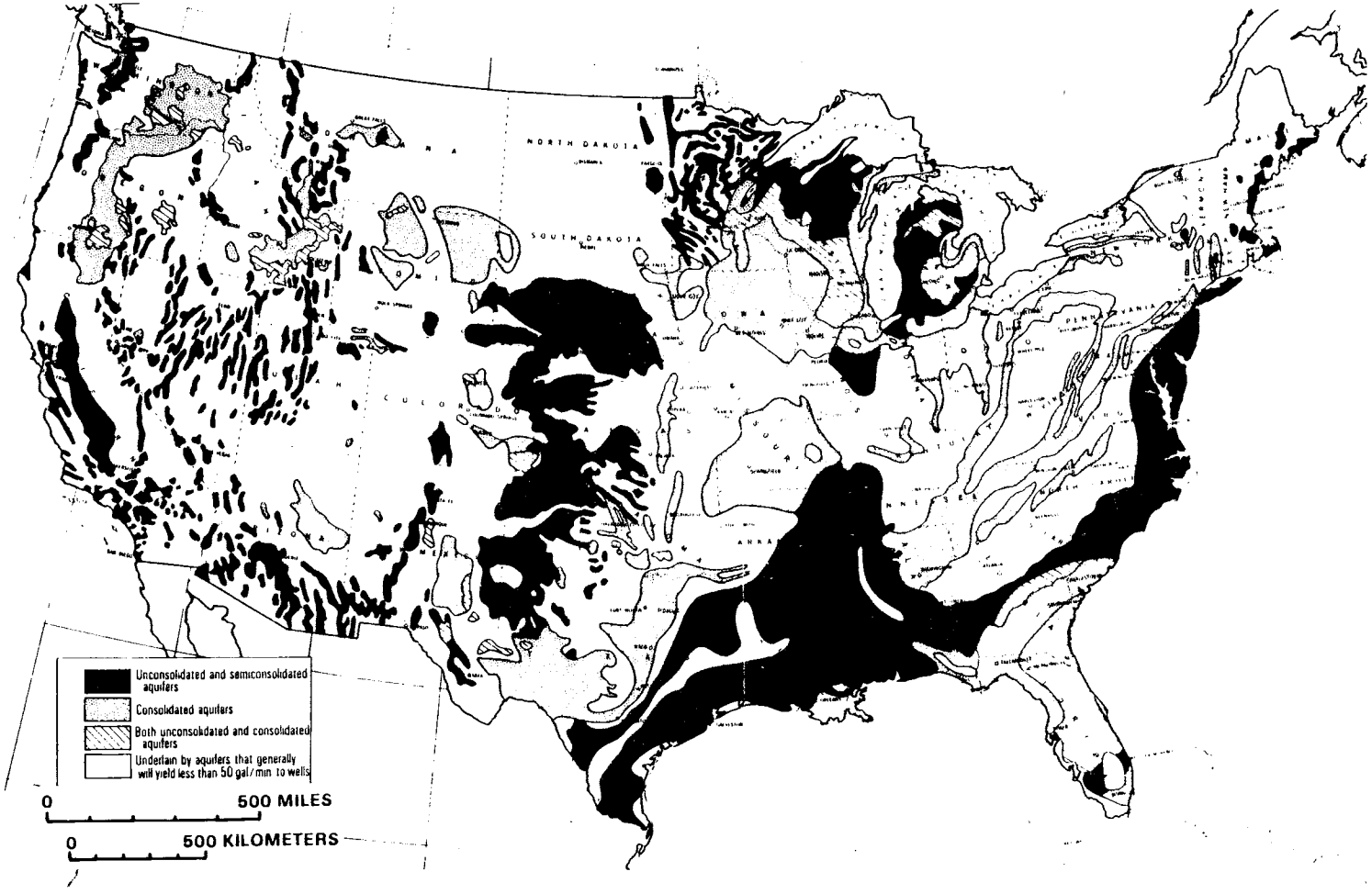


FIGURE 1.B-4. Productive Aquifers and Withdrawals from Wells (J. J. Geraghty et al., Water Atlas of the United States)

APPENDIX

SECTION 2: BACKGROUND AND DATA BASE

APPENDIX 2.A

NUCLEAR REACTORS BUILT, BEING BUILT, OR PLANNED

PLANT NAME	UTILITY NAME	REACTOR TYPE	CAPACITY, MWE	VENDOR	STATE	STARTUP YEAR
AGUIRRE	PUERTO RICO WATER RESOURCES AUTHORITY	PWR	583.00	WESTINGHOUSE ELECTRIC CORP.	PUERTO RICO	1976
ARKANSAS 1	ARKANSAS POWER & LIGHT COMPANY	PWR	820.00	BABCOCK & WILCOX COMPANY	ARKANSAS	1973
ARKANSAS 2	ARKANSAS POWER & LIGHT COMPANY	PWR	950.00	COMBUSTION ENGINEERING, INC.	ARKANSAS	1975
ATLANTIC 1	PUBLIC SERVICE E AND G	PWR	1150.00	WESTINGHOUSE ELECTRIC CORP.	NEW JERSEY	1980
ATLANTIC 2	PUBLIC SERVICE E AND G	PWR	1150.00	WESTINGHOUSE ELECTRIC CORP.	NEW JERSEY	1981
BAILLY	NORTHERN INDIANA PUBLIC SERVICE COMPANY	PWR	660.00	GENERAL ELECTRIC COMPANY	INDIANA	1976
BEAVER VALLEY 1	DUQUESNE LIGHT COMPANY	PWR	847.00	WESTINGHOUSE ELECTRIC CORP.	PENNSYLVANIA	1974
BEAVER VALLEY 2	DUQUESNE LIGHT COMPANY	PWR	847.00	WESTINGHOUSE ELECTRIC CORP.	PENNSYLVANIA	1978
BELL STATION	NEW YORK STATE ELEC AND GAS	BWR	838.00	GENERAL ELECTRIC COMPANY	NEW YORK	1978
BRAIDWOOD 1	COMMONWEALTH EDISON	PWR	1120.00	WESTINGHOUSE ELECTRIC CORP.	ILLINOIS	1980

2.4-1

PLANT NAME	UTILITY NAME	REACTOR TYPE	CAPACITY MWE	VENDOR	STATE	STARTUP YEAR
[illegible]	[illegible] COMMONWEALTH EDISON	[illegible]	1100.00	WESTINGHOUSE ELECTRIC CORP.	ILLINOIS	1981
[illegible]	[illegible] TENNESSEE VALLEY AUTHORITY	[illegible]	1065.00	GENERAL ELECTRIC COMPANY	ALABAMA	1973
[illegible]	[illegible] TENNESSEE VALLEY AUTHORITY	[illegible]	1065.00	GENERAL ELECTRIC COMPANY	ALABAMA	1974
[illegible]	[illegible] TENNESSEE VALLEY AUTHORITY	[illegible]	1065.00	GENERAL ELECTRIC COMPANY	ALABAMA	1974
[illegible]	[illegible] DUKE POWER COMPANY	[illegible]	821.00	GENERAL ELECTRIC COMPANY	NORTH CAROLINA	1975
[illegible]	[illegible] DUKE POWER COMPANY	[illegible]	821.00	GENERAL ELECTRIC COMPANY	NORTH CAROLINA	1974
[illegible]	[illegible] COMMONWEALTH EDISON	[illegible]	1100.00	WESTINGHOUSE ELECTRIC CORP.	ILLINOIS	1979
[illegible]	[illegible] COMMONWEALTH EDISON	[illegible]	1100.00	WESTINGHOUSE ELECTRIC CORP.	ILLINOIS	1980
[illegible]	[illegible] SOUTHERN CALIF. EDISON	[illegible]	770.00	GULF GENERAL ATOMICS	CALIFORNIA	1981
[illegible]	[illegible] SOUTHERN CALIF. EDISON	[illegible]	770.00	GULF GENERAL ATOMICS	CALIFORNIA	1983

PLANT NAME	UTILITY NAME	REACTOR TYPE	CAPACITY, MWE	VENDOR	STATE	STARTUP YEAR
CALVERT CLIFFS 1	BALTIMORE GAS AND ELECTRIC COMPANY	PWR	875.00	COMBUSTION ENGINEERING, INC.	MARYLAND	1974
CALVERT CLIFFS 2	BALTIMORE GAS AND ELECTRIC COMPANY	PWR	875.00	COMBUSTION ENGINEERING, INC.	MARYLAND	1975
CATAWBA 1	DUKE POWER	PWR	1140.00	WESTINGHOUSE ELECTRIC CORP.	SOUTH CAROLINA	1979
CATAWBA 2	DUKE POWER	PWR	1100.00	WESTINGHOUSE ELECTRIC CORP.	SOUTH CAROLINA	1980
COMANCHE PEAK 1	TEXAS UTILITIES	PWR	1150.00	WESTINGHOUSE ELECTRIC CORP.	TEXAS	1980
COMANCHE PEAK 2	TEXAS UTILITIES	PWR	1150.00	WESTINGHOUSE ELECTRIC CORP.	TEXAS	1982
CONNECTICUT YANKEE	CONNECTICUT YANKEE ATOMIC POWER COMPANY	PWR	575.00	WESTINGHOUSE ELECTRIC CORP.	CONNECTICUT	1968
COOK 1	INDIANA & MICHIGAN ELECTRIC COMPANY	PWR	1054.00	WESTINGHOUSE ELECTRIC CORP.	MICHIGAN	1974
COOK 2	INDIANA & MICHIGAN ELECTRIC COMPANY	PWR	1060.00	WESTINGHOUSE ELECTRIC CORP.	MICHIGAN	1975
COOPER	NEBRASKA PUBLIC POWER DISTRICT	BWR	778.00	GENERAL ELECTRIC COMPANY	NEBRASKA	1973

PLANT NAME	UTILITY NAME	REACTOR TYPE	CAPACITY, MWE	VENDOR	STATE	STARTUP YEAR
CRYSTAL RIVER 3	FLORIDA POWER CORPORATION	PWR	858.00	BABCOCK & WILCOX COMPANY	FLORIDA	1974
DAVIS BESSE	TOLEDO EDISON COMPANY	PWR	872.00	BABCOCK & WILCOX COMPANY	OHIO	1974
DELAWARE 1	DELAWARE POWER & LIGHT CO.	HTGR	770.00	GULF GENERAL ATOMICS	DELAWARE	1979
DELAWARE 2	DELAWARE POWER & LIGHT CO.	HTGR	770.00	GULF GENERAL ATOMICS	DELAWARE	1982
DIABLO CANYON 1	PACIFIC GAS & ELECTRIC COMPANY	PWR	1060.00	WESTINGHOUSE ELECTRIC CORP.	CALIFORNIA	1975
DIABLO CANYON 2	PACIFIC GAS & ELECTRIC COMPANY	PWR	1060.00	WESTINGHOUSE ELECTRIC CORP.	CALIFORNIA	1976
DOUGLAS POINT 1	PHILADELPHIA ELECTRIC POWER	PWR	1100.00	GENERAL ELECTRIC COMPANY	MARYLAND	1980
DOUGLAS POINT 2	PHILADELPHIA ELECTRIC POWER	PWR	1100.00	GENERAL ELECTRIC COMPANY	MARYLAND	1981
DRESDEN 2	COMMONWEALTH EDISON COMPANY	BWR	809.00	GENERAL ELECTRIC COMPANY	ILLINOIS	1970
DRESDEN 3	COMMONWEALTH EDISON COMPANY	BWR	809.00	GENERAL ELECTRIC COMPANY	ILLINOIS	1971

PLANT NAME	UTILITY NAME	REACTOR TYPE	CAPACITY, MWE	VENDOR	STATE	STARTUP YEAR
DUANE ARNOLD 1	IOWA ELECTRIC LIGHT AND POWER COMPANY	BWR	569.00	GENERAL ELECTRIC COMPANY	IOWA	1973
ENRICO FERMI 2	THE DETROIT EDISON COMPANY	BWR	1126.00	GENERAL ELECTRIC COMPANY	MICHIGAN	1976
ENRICO FERMI 3	DETROIT EDISON COMPANY	BWR	1150.00	GENERAL ELECTRIC CORP.	MICHIGAN	1979
FARLEY 1	ALABAMA POWER COMPANY	PWR	829.00	WESTINGHOUSE ELECTRIC CORP.	ALABAMA	1975
FARLEY 2	ALABAMA POWER COMPANY	PWR	829.00	WESTINGHOUSE ELECTRIC CORP.	ALABAMA	1977
FITZPATRICK 1	POWER AUTHORITY OF THE STATE OF N. Y.	BWR	821.00	GENERAL ELECTRIC COMPANY	NEW YORK	1973
FORKED RIVER 1	JERSEY CENTRAL POWER & LIGHT COMPANY	PWR	1140.00	COMBUSTION ENGINEERING, INC.	NEW JERSEY	1978
FORT CALHOUN 1	OMAHA PUBLIC POWER DISTRICT	PWR	457.00	COMBUSTION ENGINEERING, INC.	NEBRASKA	1973
FORT SAINT VRAIN	PUBLIC SERVICE COMPANY OF COLORADO	HTGR	330.00	GENERAL DYNAMICS	COLORADO	1973
GINNA 1	ROCHESTER GAS AND ELECTRIC COMPANY	PWR	420.00	WESTINGHOUSE ELECTRIC CORP.	NEW YORK	1970

PLANT NAME	UTILITY NAME	REACTOR TYPE	CAPACITY, MWE	VENDOR	STATE	STARTUP YEAR
GRAND GULF 1	MISSISSIPPI POWER AND LIGHT CO.	BWR	1250.00	GENERAL ELECTRIC CORP.	MISSISSIPPI	1979
GREENWOOD 1	DETROIT EDISON COMPANY	PWR	1150.00	BABCOCK AND WILCOX	MICHIGAN	1979
GREENWOOD 2	DETROIT EDISON COMPANY	PWR	1150.00	BABCOCK AND WILCOX	MICHIGAN	1981
HANCOCK LANDING 1	GEORGIA POWER	PWR	1100.00	WESTINGHOUSE ELECTRIC CORP.	GEORGIA	1978
HANCOCK LANDING 2	GEORGIA POWER	PWR	1100.00	WESTINGHOUSE ELECTRIC CORP.	GEORGIA	1979
HANFORD 1	WASH. PUBLIC POWER SUPPLY	BWR	1200.00	BABCOCK AND WILCOX	WASHINGTON	1980
HANFORD 2	WASHINGTON PUBLIC POWER SUPPLY SYSTEM	PWR	1100.00	GENERAL ELECTRIC COMPANY	WASHINGTON	1977
HATCH 1	GEORGIA POWER COMPANY	BWR	786.00	GENERAL ELECTRIC COMPANY	GEORGIA	1974
HATCH 2	GEORGIA POWER COMPANY	BWR	796.00	GENERAL ELECTRIC COMPANY	GEORGIA	1976
INDIAN POINT 2	CONSOLIDATED EDISON COMPANY OF N. Y.	PWR	873.00	WESTINGHOUSE ELECTRIC CORP.	NEW YORK	1973

PLANT NAME	UTILITY NAME	REACTOR TYPE	CAPACITY, MWE	VENDOR	STATE	STARTUP YEAR
INDIAN POINT 3	CONSOLIDATED EDISON COMPANY OF N. Y.	PWR	965.00	WESTINGHOUSE ELECTRIC CORP.	NEW YORK	1974
KEWAUNEE 1	WISCONSIN PUBLIC SERVICE CORP.	PWR	570.00	WESTINGHOUSE ELECTRIC CORP.	WISCONSIN	1973
LASALLE 1	COMMONWEALTH EDISON COMPANY	BWR	1078.00	GENERAL ELECTRIC COMPANY	ILLINOIS	1977
LASALLE 2	COMMONWEALTH EDISON COMPANY	BWR	1078.00	GENERAL ELECTRIC COMPANY	ILLINOIS	1978
LIMERICK 1	PHILADELPHIA ELECTRIC COMPANY	BWR	1065.00	GENERAL ELECTRIC COMPANY	PENNSYLVANIA	1978
LIMERICK 2	PHILADELPHIA ELECTRIC COMPANY	BWR	1065.00	GENERAL ELECTRIC COMPANY	PENNSYLVANIA	1979
MAINE YANKEE	MAINE YANKEE ATOMIC POWER COMPANY	PWR	790.00	COMBUSTION ENGINEERING, INC.	MAINE	1972
MCGUIRE 1	DUKE POWER COMPANY	PWR	1150.00	WESTINGHOUSE ELECTRIC CORP.	NORTH CAROLINA	1975
MCGUIRE 2	DUKE POWER COMPANY	PWR	1150.00	WESTINGHOUSE ELECTRIC CORP.	NORTH CAROLINA	1977
MENDOCINO 1	PACIFIC GAS & ELECTRIC COMPANY	BWR	1128.00	GENERAL ELECTRIC COMPANY	CALIFORNIA	1977

PLANT NAME	UTILITY NAME	REACTOR TYPE	CAPACITY, MWE	VENDOR	STATE	STARTUP YEAR
PEND OREILLE 2	PACIFIC GAS & ELECTRIC COMPANY	BWR	1128.00	GENERAL ELECTRIC COMPANY	CALIFORNIA	1979
MIDLAND 1	CONSUMERS POWER COMPANY	PWR	492.00	BABCOCK & WILCOX COMPANY	MICHIGAN	1977
MIDLAND 2	CONSUMERS POWER COMPANY	PWR	818.00	BABCOCK & WILCOX COMPANY	MICHIGAN	1978
MILLSTONE 1	MILLSTONE POINT COMPANY	BWR	652.00	GENERAL ELECTRIC COMPANY	CONNECTICUT	1970
MILLSTONE 2	MILLSTONE POINT COMPANY	PWR	828.00	COMBUSTION ENGINEERING, INC.	CONNECTICUT	1974
MONTICELLO	NORTHERN STATES POWER COMPANY	BWR	545.00	GENERAL ELECTRIC COMPANY	MINNESOTA	1971
NEWBOLD ISLAND 1	PUBLIC SERVICE ELECT. & GAS CO. OF N. J.	BWR	1088.00	GENERAL ELECTRIC COMPANY	NEW JERSEY	1975
NEWBOLD ISLAND 2	PUBLIC SERVICE ELECT. & GAS CO. OF N. J.	BWR	1088.00	GENERAL ELECTRIC COMPANY	NEW JERSEY	1977
NINE MILE POINT 1	NIAGARA MOHAWK POWER COMPANY	BWR	625.00	GENERAL ELECTRIC COMPANY	NEW YORK	1970
NINE MILE POINT 2	NIAGARA MOHAWK POWER CORP.	BWR	1100.00	GENERAL ELECTRIC CORP.	NEW YORK	1977

PLANT NAME	UTILITY NAME	REACTOR TYPE	CAPACITY, MWE	VENDOR	STATE	STARTUP YEAR
NORTH ANNA 1	VIRGINIA ELECTRIC & POWER COMPANY	PWR	845.00	WESTINGHOUSE ELECTRIC CORP.	VIRGINIA	1974
NORTH ANNA 2	VIRGINIA ELECTRIC & POWER COMPANY	PWR	845.00	WESTINGHOUSE ELECTRIC CORP.	VIRGINIA	1975
NORTH ANNA 3	VIRGINIA ELECTRIC COMPANY	PWR	940.00	BABCOCK AND WILCOX COMPANY	VIRGINIA	1977
NORTH ANNA 4	VIRGINIA ELECTRIC COMPANY	PWR	940.00	BABCOCK AND WILCOX COMPANY	VIRGINIA	1978
NORTHEAST UTILITIES	NORTHEAST UTILITIES	PWR	1100.00	WESTINGHOUSE ELECTRIC CORP.	CONNECTICUT	1979
OCONEE 1	DUKE POWER COMPANY	PWR	841.00	BABCOCK & WILCOX COMPANY	SOUTH CAROLINA	1973
OCONEE 2	DUKE POWER COMPANY	PWR	886.00	BABCOCK & WILCOX COMPANY	SOUTH CAROLINA	1973
OCONEE 3	DUKE POWER COMPANY	PWR	886.00	BABCOCK & WILCOX COMPANY	SOUTH CAROLINA	1974
OYSTER CREEK 1	JERSEY CENTRAL POWER AND LIGHT COMPANY	BWR	650.00	GENERAL ELECTRIC COMPANY	NEW JERSEY	1969
PALISADES	CONSUMERS POWER COMPANY	PWR	700.00	COMBUSTION ENGINEERING, INC.	MICHIGAN	1972

PLANT NAME	UTILITY NAME	REACTOR TYPE	CAPACITY, MWE	VENDOR	STATE	STARTUP YEAR
PEACH BOTTOM 2	PHILADELPHIA ELECTRIC COMPANY	BWR	1065.00	GENERAL ELECTRIC COMPANY	PENNSYLVANIA	1973
PEACH BOTTOM 3	PHILADELPHIA ELECTRIC COMPANY	BWR	1065.00	GENERAL ELECTRIC COMPANY	PENNSYLVANIA	1974
PERRY 1	CLEVELAND ELEC. ILL.	BWR	1100.00	GENERAL ELECTRIC COMPANY	OHIO	1979
PERRY 2	CLEVELAND ELEC. ILL.	BWR	1100.00	GENERAL ELECTRIC COMPANY	OHIO	1980
PHILADELPHIA 1	PHILADELPHIA ELECTRIC CO.	HTGR	1160.00	GULF GENERAL ATOMICS	PENNSYLVANIA	1980
PHILADELPHIA 2	PHILADELPHIA ELECTRIC CO.	HTGR	1160.00	GULF GENERAL ATOMICS	PENNSYLVANIA	1981
PILGRIM 1	BOSTON EDISON COMPANY	BWR	655.00	GENERAL ELECTRIC COMPANY	MASSACHUSETTS	1972
PILGRIM 2	BOSTON EDISON	PWR	1150.00	COMBUSTION ENGINEERING, INC.	MASSACHUSETTS	1978
POINT BEACH 1	WISCONSIN ELECTRIC POWER COMPANY	PWR	497.00	WESTINGHOUSE ELECTRIC CORP.	WISCONSIN	1970
POINT BEACH 2	WISCONSIN ELECTRIC POWER COMPANY	PWR	497.00	WESTINGHOUSE ELECTRIC CORP.	WISCONSIN	1971

PLANT NAME	UTILITY NAME	REACTOR TYPE	CAPACITY, MWE	VENDOR	STATE	STARTUP YEAR
PRAIRIE ISLAND 1	NORTHERN STATES POWER COMPANY	PWR	530.00	WESTINGHOUSE ELECTRIC CORP.	MINNESOTA	1973
PRAIRIE ISLAND 2	NORTHERN STATES POWER COMPANY	PWR	530.00	WESTINGHOUSE ELECTRIC CORP.	MINNESOTA	1974
QUAD CITIES 1	COMMONWEALTH EDISON COMPANY	BWR	809.00	GENERAL ELECTRIC COMPANY	ILLINOIS	1972
QUAD CITIES 2	COMMONWEALTH EDISON COMPANY	BWR	809.00	GENERAL ELECTRIC COMPANY	ILLINOIS	1972
QUANICASSEE 1	CONSUMERS POWER	PWR	1150.00	WESTINGHOUSE ELECTRIC CORP.	MICHIGAN	1981
QUANICASSEE 2	CONSUMERS POWER	PWR	1150.00	WESTINGHOUSE ELECTRIC CORP.	MICHIGAN	1982
RANCHO SECO	SACRAMENTO MUNICIPAL UTILITY DISTRICT	PWR	804.00	BABCOCK & WILCOX COMPANY	CALIFORNIA	1974
RIVERBEND 1	GULF STATES UTILITIES	BWR	940.00	GENERAL ELECTRIC COMPANY	LOUISIANA	1979
RIVERBEND 2	GULF STATES UTILITIES	BWR	940.00	GENERAL ELECTRIC COMPANY	LOUISIANA	1980
ROBINSON 2	CAROLINA POWER & LIGHT COMPANY	PWR	700.00	WESTINGHOUSE ELECTRIC CORP.	SOUTH CAROLINA	1971

PLANT NAME	UTILITY NAME	REACTOR TYPE	CAPACITY, MWE	VENDOR	STATE	STARTUP YEAR
ROME POINT 1	NARRAGANSETT ELECTRIC	PWR	950.00	WESTINGHOUSE ELECTRIC CORP.	RHODE ISLAND	1979
ROME POINT 2	NARRAGANSETT ELECTRIC	PWR	950.00	WESTINGHOUSE ELECTRIC CORP.	RHODE ISLAND	1981
SALEM 1	PUBLIC SERVICE ELECT. & GAS CO. OF N. J.	PWR	1050.00	WESTINGHOUSE ELECTRIC CORP.	NEW JERSEY	1974
SALEM 2	PUBLIC SERVICE ELECT. & GAS CO. OF N. J.	PWR	1050.00	WESTINGHOUSE ELECTRIC CORP.	NEW JERSEY	1975
SAN ONOFRE 1	SOUTHERN CALIFORNIA EDISON COMPANY	PWR	430.00	WESTINGHOUSE ELECTRIC CORP.	CALIFORNIA	1968
SAN ONOFRE 2	SOUTHERN CALIFORNIA EDISON COMPANY	PWR	1140.00	COMBUSTION ENGINEERING, INC.	CALIFORNIA	1975
SAN ONOFRE 3	SOUTHERN CALIFORNIA EDISON COMPANY	PWR	1140.00	COMBUSTION ENGINEERING, INC.	CALIFORNIA	1976
SEABROOK 1	PUBLIC SERVICE OF N.H.	PWR	1100.00	WESTINGHOUSE ELECTRIC CORP.	NEW HAMPSHIRE	1979
SEABROOK 2	PUBLIC SERVICE OF N.H.	PWR	1100.00	WESTINGHOUSE ELECTRIC CORP.	NEW HAMPSHIRE	1980
SELMA 1	ALABAMA POWER CO.	BWR	1200.00	GENERAL ELECTRIC COMPANY	ALABAMA	1981

PLANT NAME	UTILITY NAME	REACTOR TYPE	CAPACITY, MWE	VENDOR	STATE	STARTUP YEAR
SELMA 2	ALABAMA POWER CO.	PWR	1200.00	GENERAL ELECTRIC COMPANY	ALABAMA	1982
SEQUOYAH 1	TENNESSEE VALLEY AUTHORITY	PWR	1124.00	WESTINGHOUSE ELECTRIC CORP.	TENNESSEE	1975
SEQUOYAH 2	TENNESSEE VALLEY AUTHORITY	PWR	1124.00	WESTINGHOUSE ELECTRIC CORP.	TENNESSEE	1975
SHARON HARRIS 2	CAROLINA POWER & LIGHT COMPANY	PWR	915.00	WESTINGHOUSE ELECTRIC CORP.	NORTH CAROLINA	1978
SHARON HARRIS 3	CAROLINA POWER & LIGHT COMPANY	PWR	915.00	WESTINGHOUSE ELECTRIC CORP.	NORTH CAROLINA	1979
SHARON HARRIS 4	CAROLINA POWER & LIGHT COMPANY	PWR	915.00	WESTINGHOUSE ELECTRIC CORP.	NORTH CAROLINA	1980
SHEARON HARRIS 1	CAROLINA POWER & LIGHT COMPANY	PWR	915.00	WESTINGHOUSE ELECTRIC CORP.	NORTH CAROLINA	1977
SHOREHAM	LONG ISLAND LIGHTING COMPANY	BWR	819.00	GENERAL ELECTRIC COMPANY	NEW YORK	1975
ST. LUCIE 1	FLORIDA POWER AND LIGHT COMPANY	PWR	845.00	COMBUSTION ENGINEERING, INC.	FLORIDA	1975
ST. LUCIE 2	FLORIDA POWER AND LIGHT	PWR	890.00	COMBUSTION ENGINEERING, INC.	FLORIDA	1979

PLANT NAME	UTILITY NAME	REACTOR TYPE	CAPACITY, MWE	VENDOR	STATE	STARTUP YEAR
SURRY 1	VIRGINIA ELECTRIC & POWER COMPANY	PWR	700.00	WESTINGHOUSE ELECTRIC CORP.	VIRGINIA	1972
SURRY 2	VIRGINIA ELECTRIC & POWER COMPANY	PWR	700.00	WESTINGHOUSE ELECTRIC CORP.	VIRGINIA	1973
SUSQUEHANNA 1	PENNSYLVANIA POWER AND LIGHT COMPANY	BWR	1052.00	GENERAL ELECTRIC COMPANY	PENNSYLVANIA	1977
SUSQUEHANNA 2	PENNSYLVANIA POWER AND LIGHT COMPANY	BWR	1052.00	GENERAL ELECTRIC COMPANY	PENNSYLVANIA	1979
THREE MILE ISLAND 1	METROPOLITAN EDISON COMPANY	PWR	819.00	BABCOCK & WILCOX COMPANY	PENNSYLVANIA	1973
THREE MILE ISLAND 2	METROPOLITAN EDISON COMPANY	PWR	907.00	BABCOCK & WILCOX COMPANY	PENNSYLVANIA	1976
TROJAN	PORTLAND GENERAL ELECTRIC COMPANY	PWR	1130.00	WESTINGHOUSE ELECTRIC CORP.	OREGON	1974
TURKEY POINT 3	FLORIDA POWER AND LIGHT COMPANY	PWR	725.00	WESTINGHOUSE ELECTRIC CORP.	FLORIDA	1972
TURKEY POINT 4	FLORIDA POWER AND LIGHT COMPANY	PWR	725.00	WESTINGHOUSE ELECTRIC CORP.	FLORIDA	1973
WATTS BAR 1	TENNESSEE VALLEY AUTHORITY	PWR	1200.00	GENERAL ELECTRIC COMPANY	TENNESSEE	1980

PLANT NAME	UTILITY NAME	REACTOR TYPE	CAPACITY, MWE	VENDOR	STATE	STARTUP YEAR
TVA 2	TENNESSEE VALLEY AUTHORITY	BWR	1200.00	GENERAL ELECTRIC COMPANY	TENNESSEE	1981
TVA 3	TENNESSEE VALLEY AUTHORITY	BWR	1200.00	GENERAL ELECTRIC COMPANY	TENNESSEE	1981
TVA 4	TENNESSEE VALLEY AUTHORITY	BWR	1200.00	GENERAL ELECTRIC COMPANY	TENNESSEE	1982
TVA 77	TENNESSEE VALLEY AUTHORITY	PWR	1175.00	BABCOCK & WILCOX COMPANY	TENNESSEE	1977
TVA 78	TENNESSEE VALLEY AUTHORITY	PWR	1176.00	BABCOCK & WILCOX COMPANY	TENNESSEE	1978
VERGIL SUMMER	SOUTH CAROLINA ELECTRIC & GAS COMPANY	PWR	915.00	WESTINGHOUSE ELECTRIC CORP.	SOUTH CAROLINA	1977
VERMONT YANKEE	VERMONT YANKEE NUCLEAR POWER CORP.	BWR	514.00	GENERAL ELECTRIC COMPANY	VERMONT	1972
VIRGINIA 1	VIRGINIA ELECTRIC & POWER CO.	PWR	900.00	BABCOCK AND WILCOX	VIRGINIA	1980
VIRGINIA 2	VIRGINIA ELECTRIC & POWER CO.	PWR	900.00	BABCOCK AND WILCOX	VIRGINIA	1981
VOGTLE 1	COMMONWEALTH EDISON CO.	PWR	1100.00	WESTINGHOUSE ELECTRIC CORP.	ILLINOIS	1978

PLANT NAME	UTILITY NAME	REACTOR TYPE	CAPACITY, MWE	VENDOR	STATE	STARTUP YEAR
VOGTLE 2	GEORGIA POWER CO.	PWR	1100.00	WESTINGHOUSE ELECTRIC CORP.	ILLINOIS	1979
WATERFORD 3	LOUISIANA POWER & LIGHT COMPANY	PWR	1165.00	COMBUSTION ENGINEERING, INC.	LOUISIANA	1976
WATERFORD 4	LOUISIANA POWER & LIGHT COMPANY	PWR	1165.00	COMBUSTION ENGINEERING, INC.	LOUISIANA	1978
WATTS BAR 1	TENNESSEE VALLEY AUTHORITY	PWR	1130.00	WESTINGHOUSE ELECTRIC CORP.	TENNESSEE	1976
WATTS BAR 2	TENNESSEE VALLEY AUTHORITY	PWR	1130.00	WESTINGHOUSE ELECTRIC CORP.	TENNESSEE	1977
ZIMMER 1	CINCINNATI GAS & ELECTRIC COMPANY	BWR	810.00	GENERAL ELECTRIC COMPANY	OHIO	1977
ZION 1	COMMONWEALTH EDISON COMPANY	PWR	1050.00	WESTINGHOUSE ELECTRIC CORP.	ILLINOIS	1973
ZION 2	COMMONWEALTH EDISON COMPANY	PWR	1050.00	WESTINGHOUSE ELECTRIC CORP.	ILLINOIS	1973
TOTAL 158.	158.	152.	148542.	158.	158.	158.
AVERAGE			940.14			

APPENDIX 2.B

NUCLIDES AND RCG PERMISSIBLE CONCENTRATIONS USED IN PREPARATION OF TABLES 2.8, 2.9 AND SUMMARY TABLES OF APPENDICES 2.C THROUGH 2.G

(RCG is Radionuclide Concentration Guide as definded in 10CFR20, Appendix B)

Waste Fraction	Nuclide	MPC_w ($\mu Ci/cm^3$)	MPC_a ($\mu Ci/cm^3$)
Cladding	Mn-54	1.E-4	1.E-9
	Fe-55	8.E-4	3.E-8
	Cu-58	9.E-5	2.E-9
	Cu-60	3.E-5	3.E-10
	Ni-63	3.E-5	2.E-9
	Ni-59	2.E-4	2.E-8
	Zr-93	8.E-4	4.E-9
	Zr-95	6.E-5	1.E-9
	Nb-95	1.E-4	3.E-9
Fission Prod.	Se-79	4.E-3	4.E-9
	Kr-85	1.E+20	3.E-7
	Sr-89	3.E-6	3.E-10
	Sr-90,Y-90	3.E-7	3.E-11
	Zr-93	8.E-4	4.E-9
	Zr-95	6.E-5	1.E-9
	Nb-95	1.E-4	3.E-9
	Tc-99	2.E-4	2.E-9
	Ru-103,Rh-103M	8.E-5	3.E-9
	Ru-106,Rh-106	1.E-5	2.E-10
	Pd-107	1.E-3	2.E-7
	Sb-125,Te-125M	1.E-4	9.E-10
	Sn-126	4.E-4	2.E-9
	I-129	6.E-8	2.E-11
	Cs-134	9.E-6	4.E-10
	Cs-135	1.E-4	3.E-9
	Cs-137,Ba-137M	2.E-5	5.E-10
	Ce-144,Pr-144	1.E-5	2.E-10
	Pm-147	2.E-4	2.E-9
	Sm-151	4.E-4	2.E-9
	Eu-152	8.E-5	4.E-10
	Eu-154	2.E-5	1.E-10
	Eu-155	2.E-4	3.E-9
	Ho-166M	5.E-2	2.E-9
U + Th Fuel Waste	Th-228 Chain	7.E-6	2.E-13
	Th-232 Chain	2.89855E-8	1.42857E-13
	U-232	3.E-5	9.E-13
	U-233 Chain	3.E-8	1.99005E-14
	U-234 Chain	2.30061E-8	7.40741E-14
	U-235 Chain	6.09756E-7	2.64901E-14
	U-236	3.E-5	4.E-12
	U-238	4.E-4	3.E-12
Pu Fuel Waste	U-234 Chain*	2.30064E-8	7.40741E-14
	U-235 Chain*	6.09756E-7	2.64901E-14
	U-236*	3.E-5	4.E-12
	Pu-238	5.E-6	7.E-14
	Pu-239	5.E-6	6.E-14
	Pu-240	5.E-6	6.E-14
	Pu-241	2.E-4	3.E-12
	Am-241	4.E-6	2.E-13
	Pu-242	5.E-6	6.E-14
Trans Pu	U-233 Chain*	3.E-8	1.99005E-14
	U-234 Chain*	2.30061E-8	7.40741E-14
	U-235 Chain*	6.09756E-7	2.64901E-14
	U-236*	3.E-5	4.E-12
	Np-237	3.E-6	1.E-13
	Pu-238*	5.E-6	7.E-14
	Pu-239*	5.E-6	6.E-14
	Pu-240*	5.E-6	6.E-14
	Am-241	4.E-6	2.E-13
	Am-243	4.E-6	2.E-13
	Cm 242	2.E-5	4.E-12
	Cm-243	5.E-6	2.E-13
	Cm-244	7.E-6	3.E-13
	Am-242M	4.E-6	2.E-13
	Cm-245	4.E-6	2.E-13
	Cm-246	4.E-6	2.E-13
	Cm-247	4.E-6	2.E-13
	Cm-248	4.E-6	2.E-14

*Grows in after reprocessing
Decay chains are assumed to be in equilibrium with the parent

APPENDIX 2.C

LWR-U PLANT WASTE

(Power 30 MW/MT, Exposure 33,000 MWD/MT,
Spent Fuel Reprocessed 150 Days After Discharge
with 0.5% Fuel Loss to Waste)

LWR-U PLANT WASTE

Summary Tables

THERMAL POWER

WATTS PER METRIC TON OF FUEL

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	1.07E+02	1.39E+01	3.58E+00	2.23E-04	2.26E-05	1.37E-05	1.35E-05	1.29E-05	8.55E-06	1.36E-07	1.37E-25	.00E+00
STRONTIUM	9.05E+02	5.43E+02	4.33E+02	4.70E+01	2.45E-03	1.08E-08	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00
CESIUM	2.83E+03	2.17E+03	5.27E+02	5.63E+01	5.64E-03	1.39E-04	1.39E-04	1.36E-04	1.10E-04	1.38E-05	1.31E-14	.00E+00
SR+CS	3.74E+03	2.71E+03	9.60E+02	1.03E+02	8.09E-03	1.39E-04	1.39E-04	1.36E-04	1.10E-04	1.38E-05	1.31E-14	.00E+00
FP-SR-CS	1.54E+04	5.12E+03	5.91E+01	1.68E+00	4.80E-02	1.13E-02	1.03E-02	7.57E-03	5.57E-04	2.20E-05	4.12E-07	5.17E-23
KR85+I129	1.80E+01	1.68E+01	9.46E+00	2.98E-02	2.40E-05	2.40E-05	2.40E-05	2.39E-05	2.31E-05	1.60E-05	4.11E-07	5.17E-23
FISSION PROD.	1.91E+04	7.83E+03	1.02E+03	1.05E+02	5.61E-02	1.15E-02	1.04E-02	7.71E-03	6.67E-04	3.58E-05	4.12E-07	5.17E-23
U+TH WASTE	9.80E-04	9.80E-04	9.80E-04	9.79E-04	9.78E-04	9.77E-04	9.65E-04	8.53E-04	4.94E-04	4.54E-04	4.19E-04	3.56E-04
PU FUEL WASTE	1.28E+00	1.30E+00	1.45E+00	1.50E+00	1.03E+00	8.38E-01	3.05E-01	6.23E-03	2.82E-03	1.43E-03	1.11E-04	4.41E-06
TRANS PU	7.99E+02	2.43E+02	6.91E+01	8.63E+00	3.21E+00	1.87E+00	4.68E-01	5.48E-02	2.60E-02	1.44E-03	3.95E-05	1.52E-05
TOTAL WASTE	2.00E+04	8.09E+03	1.09E+03	1.15E+02	4.30E+00	2.72E+00	7.85E-01	6.96E-02	2.99E-02	3.36E-03	5.70E-04	3.75E-04

RADIOACTIVITY

CURIES PER METRIC TON OF FUEL
(PARENTS AND DAUGHTERS IN CHAINS ARE INCLUDED IN TOTALS)

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	1.98E+04	1.24E+03	2.37E+02	1.28E+00	1.86E-01	1.30E-01	1.27E-01	1.15E-01	7.17E-02	1.14E-03	1.15E-21	.00E+00
STRONTIUM	2.51E+05	1.51E+05	1.20E+05	1.31E+04	6.79E-01	3.00E-06	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00
CESIUM	4.27E+05	3.61E+05	1.77E+05	2.12E+04	2.36E+00	2.86E-01	2.85E-01	2.80E-01	2.27E-01	2.84E-02	2.70E-11	.00E+00
SR+CS	6.79E+05	5.12E+05	2.97E+05	3.43E+04	3.04E+00	2.86E-01	2.85E-01	2.80E-01	2.27E-01	2.84E-02	2.70E-11	.00E+00
FP-SR-CS	3.47E+06	1.17E+06	2.02E+04	6.39E+02	3.87E+01	1.76E+01	1.68E+01	1.27E+01	1.86E+00	8.42E-02	6.31E-04	7.86E-20
KR85+I129	1.10E+04	1.04E+04	5.82E+03	1.84E+01	3.65E-02	3.65E-02	3.65E-02	3.64E-02	3.51E-02	2.43E-02	6.25E-04	7.86E-20
FISSION PROD.	4.15E+06	1.68E+06	3.17E+05	3.49E+04	4.17E+01	1.79E+01	1.70E+01	1.30E+01	2.09E+00	1.13E-01	6.31E-04	7.86E-20
U+TH WASTE	6.02E-02	6.03E-02	6.05E-02	6.02E-02	6.00E-02	6.00E-02	5.92E-02	5.25E-02	3.11E-02	2.88E-02	2.74E-02	2.33E-02
PU FUEL WASTE	5.28E+02	5.06E+02	3.48E+02	4.51E+01	2.02E+01	1.10E+01	2.13E+00	1.72E-01	4.64E-02	3.38E-03	6.81E-04	2.68E-04
TRANS PU	2.20E+04	6.89E+03	2.14E+03	3.87E+02	1.65E+02	8.69E+01	1.52E+01	3.07E+00	1.70E+00	9.33E-02	2.33E-03	9.26E-04
TOTAL WASTE	4.19E+06	1.69E+06	3.20E+05	3.54E+04	2.27E+02	1.16E+02	3.46E+01	1.64E+01	3.93E+00	2.39E-01	3.10E-02	2.45E-02

INGESTION TOXICITY

THE INGESTION TOXICITY INDEX IS THE BASE 10 LOGARITHM OF THE CUBIC METERS OF WATER PER TON OF FUEL TO DILUTE TO RCG

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	8.42	7.48	6.89	4.59	3.39	2.74	2.73	2.68	2.47	.67	*****	*****
STRONTIUM	11.46	11.40	11.30	10.34	6.05	.70	*****	*****	*****	*****	*****	*****
CESIUM	10.46	10.35	9.70	8.72	4.74	3.46	3.46	3.45	3.36	2.45	-6.57	*****
SR+CS	11.50	11.44	11.31	10.35	6.07	3.46	3.46	3.45	3.36	2.45	-6.57	*****
FP-SR-CS	11.11	10.73	8.50	6.81	5.87	5.84	5.84	5.82	5.77	5.61	4.02	*****
KR85+I129	5.78	5.78	5.78	5.78	5.78	5.78	5.78	5.78	5.77	5.61	4.02	*****
FISSION PROD.	11.65	11.51	11.31	10.35	6.29	5.84	5.84	5.83	5.77	5.61	4.02	*****
U+TH FUEL WASTE	5.22	5.22	5.22	5.22	5.22	5.22	5.21	5.15	4.87	4.84	4.83	4.77
PU FUEL WASTE	6.79	6.79	6.82	6.78	6.48	6.27	5.80	5.28	4.31	2.74	2.19	1.81
TRANS PU	9.13	8.78	8.49	7.75	7.40	7.17	6.67	6.21	5.58	4.20	2.73	2.35
TOTAL WASTE	11.65	11.51	11.31	10.35	7.48	7.25	6.79	6.42	6.03	5.69	4.90	4.77

***** TOXICITY INDEX IS LESS THAN -10
RCG IS RADIONUCLIDE CONCENTRATION GUIDE BASED UPON 10 CFR 20

INHALATION TOXICITY

THE INHALATION TOXICITY INDEX IS THE BASE 10 LOGARITHM OF THE CUBIC METERS OF AIR TO DILUTE TO RCG PER METRIC TON OF FUEL

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	13.13	12.44	11.88	8.81	7.95	7.79	7.79	7.77	7.59	5.79	*****	*****
STRONTIUM	15.46	15.40	15.30	14.34	10.05	4.70	*****	*****	*****	*****	*****	*****
CESIUM	14.87	14.77	14.27	13.33	9.34	7.98	7.98	7.97	7.88	6.98	-2.05	*****
SR+CS	15.56	15.49	15.34	14.38	10.13	7.98	7.98	7.97	7.88	6.98	-2.05	*****
FP-SR-CS	15.81	15.44	13.71	12.07	10.32	10.02	10.00	9.91	9.43	9.09	7.50	-8.41
KR85+I129	10.59	10.56	10.33	9.28	9.26	9.26	9.26	9.26	9.24	9.09	7.50	-8.41
FISSION PROD.	16.01	15.77	15.35	14.38	10.54	10.03	10.01	9.91	9.44	9.09	7.50	-8.41
U+TH FUEL WASTE	10.74	10.74	10.74	10.74	10.74	10.74	10.73	10.68	10.43	10.40	10.39	10.30
PU FUEL WASTE	14.64	14.64	14.59	14.37	14.03	13.90	13.54	12.24	10.88	9.69	9.27	8.89
TRANS PU	16.15	16.04	15.90	15.23	14.76	14.55	14.13	13.27	12.90	11.63	9.81	9.43
TOTAL WASTE	16.39	16.24	16.02	15.33	14.84	14.64	14.23	13.31	12.90	11.66	10.51	10.37

***** TOXICITY INDEX IS LESS THAN -10
RCG IS RADIONUCLIDE CONCENTRATION GUIDE BASED UPON 10 CFR 20

LWR-PLANT WASTE FROM URANIUM FUELS

Actinides

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
HE 4	0.00	3.53-01	4.50-01	6.34-01	1.15+00	1.95+00	3.54+00	6.90+00	2.16+01	6.91+01	8.29+01	1.75+02
TL208	0.00	2.71-12	1.94-12	1.73-13	4.96-14	8.71-18	1.50-18	2.34-17	2.40-16	2.12-15	7.92-15	8.02-15
PB207	0.00	4.71-10	1.11-09	1.90-08	7.11-07	9.85-06	1.26-04	5.80-03	1.36-01	1.45+00	1.39+01	9.35+01
PB208	0.00	7.67-07	1.53-06	3.39-06	5.76-06	7.44-06	7.44-06	7.81-06	4.66-05	3.63-03	1.85-01	2.60+00
PB210	0.00	1.03-11	1.96-11	2.38-10	9.27-09	8.90-07	3.59-05	2.81-04	6.90-05	1.93-05	1.91-05	1.66-05
PB212	0.00	1.57-09	1.12-09	1.00-10	2.86-11	5.06-15	8.69-16	1.36-14	1.39-13	1.23-12	4.60-12	4.66-12
BI209	0.00	7.54-11	8.95-11	2.27-10	1.09-08	9.39-06	8.03-03	2.52+00	1.03+02	4.51+02	4.71+02	4.71+02
BI212	0.00	1.50-10	1.07-10	9.56-12	2.74-12	4.82-16	8.28-17	1.30-15	1.33-14	1.17-13	4.38-13	4.44-13
RN220	0.00	2.40-12	1.71-12	1.53-13	4.39-14	7.71-18	1.32-18	2.07-17	2.12-16	1.87-15	7.01-15	7.10-15
RA223	0.00	2.32-11	3.93-11	1.50-10	4.63-10	5.06-10	7.59-10	5.16-09	7.10-09	7.03-09	6.44-09	2.68-09
RA224	0.00	1.37-08	9.79-09	8.73-10	2.51-10	4.41-14	7.57-15	1.18-13	1.21-12	1.07-11	4.01-11	4.06-11
RA226	0.00	1.99-08	2.89-08	1.10-07	1.13-06	7.30-05	2.94-03	2.31-02	5.65-03	1.59-03	1.56-03	1.36-03
AC227	0.00	1.75-08	2.77-08	1.06-07	3.26-07	3.56-07	5.35-07	3.64-06	5.00-06	4.96-06	4.54-06	1.89-06
TH227	0.00	3.82-11	6.30-11	2.40-10	7.42-10	8.10-10	1.22-09	8.27-09	1.14-08	1.13-08	1.03-08	4.29-09
TH228	0.00	2.71-06	1.90-06	1.70-07	4.89-08	8.59-12	1.48-12	2.31-11	2.36-10	2.09-09	7.82-09	7.92-09
TH229	0.00	1.63-07	1.64-07	1.97-07	3.42-06	3.24-04	2.59-02	6.02-01	1.35+00	6.88-02	1.64-14	0.00
TH230	0.00	1.05-03	1.05-03	1.07-03	1.76-03	1.99-02	1.92-01	1.17+00	2.88-01	8.07-02	7.96-02	6.93-02
TH231	0.00	3.23-08	1.61-10	1.61-10	1.62-10	1.65-10	2.19-10	6.52-10	6.88-10	6.82-10	6.24-10	2.59-10
TH232	0.00	2.87-04	2.87-04	2.93-04	3.52-04	9.90-04	1.11-02	1.74-01	1.78+00	1.57+01	5.87+01	5.95+01
TH234	0.00	1.36-05	6.82-08	6.78-08	6.78-08	6.78-08	6.78-08	6.78-08	6.78-08	6.77-08	6.68-08	5.82-08
PA231	0.00	5.18-04	5.18-04	5.18-04	5.20-04	5.45-04	8.19-04	5.57-03	7.65-03	7.59-03	6.95-03	2.89-03
PA233	0.00	1.66-05	1.66-05	1.66-05	1.69-05	1.79-05	1.83-05	1.78-05	1.33-05	7.20-07	1.58-19	0.00
PA234M	0.00	4.57-10	2.30-12	2.29-12	2.29-12	2.29-12	2.29-12	2.29-12	2.29-12	2.28-12	2.25-12	1.96-12
U232	0.00	1.72-06	2.34-06	4.08-06	1.83-06	3.16-10	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	2.43-05	1.94-04	1.58-03	1.55-02	1.61-01	1.65+00	1.35+01	3.04+01	1.55+00	3.70-13	0.00
U234	2.64+02	6.10-01	6.38-01	1.07+00	4.13+00	7.37+00	7.20+00	5.65+00	6.86-01	2.54-01	2.50-01	2.18-01
U235	3.30+04	3.99+01	3.99+01	3.99+01	4.00+01	4.07+01	5.41+01	1.61+02	1.70+02	1.69+02	1.54+02	6.42+01
U236	0.00	2.27+01	2.27+01	2.27+01	2.31+01	2.66+01	4.88+01	6.32+01	6.16+01	4.75+01	3.49+00	1.62-11
U237	0.00	1.66-07	1.48-07	9.70-08	1.52-09	7.85-11	4.02-11	4.99-14	0.00	0.00	0.00	0.00
U238	9.67+05	4.71+03	4.71+03	4.71+03	4.71+03	4.71+03	4.71+03	4.71+03	4.72+03	4.71+03	4.64+03	4.04+03
NP237	0.00	4.82+02	4.82+02	4.83+02	4.89+02	5.21+02	5.30+02	5.15+02	3.85+02	2.09+01	4.60-12	0.00
NP239	0.00	7.55-05	7.55-05	7.54-05	7.48-05	6.89-05	3.05-05	8.78-09	1.13-12	7.79-13	1.86-14	1.12-30
PU236	0.00	2.99-06	2.34-06	2.63-07	8.23-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	0.00	8.41-01	5.32+00	6.11+00	3.11+00	4.86-03	7.49-21	0.00	0.00	0.00	0.00	0.00
PU239	0.00	2.63+01	2.63+01	2.64+01	2.72+01	3.34+01	6.55+01	9.17+00	4.29-06	2.96-06	7.06-08	4.27-24
PU240	0.00	1.08+01	1.19+01	2.05+01	4.04+01	3.74+01	1.49+01	1.46-03	0.00	0.00	0.00	0.00
PU241	0.00	5.04+00	4.81+00	3.16+00	4.94-02	2.56-03	1.31-03	1.62-06	1.41-35	0.00	0.00	0.00
PU242	0.00	1.76+00	1.76+00	1.76+00	1.79+00	1.86+00	1.96+00	1.71+00	3.30-01	2.36-08	0.00	0.00
AM241	0.00	4.41+01	4.43+01	4.53+01	4.20+01	1.00+01	3.83-02	4.75-05	0.00	0.00	0.00	0.00
AM242M	0.00	4.14-01	4.12-01	3.96-01	2.62-01	4.34-03	6.56-21	0.00	0.00	0.00	0.00	0.00

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
AM242	0.00	4.97-06	4.95-06	4.75-06	3.15-06	5.21-08	7.88-26	0.00	0.00	0.00	0.00	0.00
AM243	0.00	9.12+01	9.12+01	9.12+01	9.04+01	8.33+01	3.69+01	1.98-02	1.37-06	9.42-07	2.25-08	1.36-24
CM242	0.00	5.62+00	1.23+00	9.54-04	6.32-04	1.04-05	1.58-23	0.00	0.00	0.00	0.00	0.00
CM243	0.00	1.19-01	1.16-01	9.56-02	1.36-02	4.67-11	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	3.11+01	3.00+01	2.12+01	6.77-01	7.33-16	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	1.76+00	1.76+00	1.76+00	1.75+00	1.63+00	9.37-01	1.04-03	8.98-33	0.00	0.00	0.00
CM246	0.00	2.24-01	2.24-01	2.23-01	2.21-01	1.97-01	6.32-02	7.20-07	0.00	0.00	0.00	0.00
CM247	0.00	3.17-03	3.17-03	3.17-03	3.17-03	3.17-03	3.16-03	3.15-03	3.04-03	2.09-03	4.99-05	3.01-21
SUBTOT	1.00+06	5.48+03	5.48+03	5.48+03	5.48+03	5.48+03	5.48+03	5.50+03	5.49+03	5.49+03	5.43+03	4.91+03
TOTAL	1.00+06	5.48+03	5.48+03	5.48+03	5.48+03	5.48+03	5.48+03	5.50+03	5.50+03	5.50+03	5.50+03	5.50+03

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	1.19-06	2.01-06	7.68-06	2.37-05	2.59-05	3.89-05	2.64-04	3.64-04	3.60-04	3.30-04	1.37-04
TL208	0.00	7.91-04	5.65-04	5.04-05	1.45-05	2.54-09	4.37-10	6.83-09	6.99-08	6.17-07	2.31-06	2.34-06
TL209	0.00	7.68-10	7.71-10	9.29-10	1.61-08	1.53-06	1.22-04	2.83-03	6.34-03	3.24-04	7.74-17	0.00
PB209	0.00	3.49-08	3.50-08	4.22-08	7.31-07	6.94-05	5.54-03	1.29-01	2.88-01	1.47-02	3.52-15	0.00
PB210	0.00	8.37-10	1.59-09	1.93-08	7.52-07	7.22-05	2.91-03	2.28-02	5.59-03	1.57-03	1.55-03	1.35-03
PB211	0.00	1.19-06	2.02-06	7.70-06	2.38-05	2.60-05	3.90-05	2.65-04	3.65-04	3.61-04	3.31-04	1.38-04
PB212	0.00	2.20-03	1.57-03	1.40-04	4.02-05	7.06-09	1.21-09	1.90-08	1.94-07	1.71-06	6.42-06	6.50-06
PB214	0.00	1.96-08	2.85-08	1.09-07	1.11-06	7.22-05	2.91-03	2.28-02	5.59-03	1.57-03	1.55-03	1.35-03
BI210	0.00	6.25-10	1.59-09	1.93-08	7.52-07	7.22-05	2.91-03	2.28-02	5.59-03	1.57-03	1.55-03	1.35-03
BI211	0.00	1.19-06	2.02-06	7.70-06	2.38-05	2.60-05	3.90-05	2.65-04	3.65-04	3.61-04	3.31-04	1.38-04
BI212	0.00	2.20-03	1.57-03	1.40-04	4.02-05	7.06-09	1.21-09	1.90-08	1.94-07	1.71-06	6.42-06	6.50-06
BI213	0.00	3.49-08	3.50-08	4.22-08	7.31-07	6.94-05	5.54-03	1.29-01	2.88-01	1.47-02	3.52-15	0.00
BI214	0.00	1.96-08	2.85-08	1.09-07	1.11-06	7.22-05	2.91-03	2.28-02	5.59-03	1.57-03	1.55-03	1.35-03
PO210	0.00	5.63-10	1.17-09	1.93-08	7.52-07	7.22-05	2.91-03	2.28-02	5.59-03	1.57-03	1.55-03	1.35-03
PO211	0.00	3.58-09	6.06-09	2.31-08	7.14-08	7.79-08	1.17-07	7.96-07	1.09-06	1.08-06	9.93-07	4.13-07
PO212	0.00	1.41-03	1.00-03	8.96-05	2.57-05	4.52-09	7.76-10	1.21-08	1.24-07	1.10-06	4.11-06	4.16-06
PO213	0.00	3.41-08	3.43-08	4.13-08	7.15-07	6.79-05	5.42-03	1.26-01	2.82-01	1.44-02	3.44-15	0.00
PO214	0.00	1.96-08	2.85-08	1.09-07	1.11-06	7.22-05	2.91-03	2.28-02	5.59-03	1.57-03	1.55-03	1.35-03
PO215	0.00	1.19-06	2.02-06	7.70-06	2.38-05	2.60-05	3.90-05	2.65-04	3.65-04	3.61-04	3.31-04	1.38-04
PO216	0.00	2.20-03	1.57-03	1.40-04	4.02-05	7.06-09	1.21-09	1.90-08	1.94-07	1.71-06	6.42-06	6.50-06
PO218	0.00	1.96-08	2.85-08	1.09-07	1.11-06	7.22-05	2.91-03	2.28-02	5.59-03	1.57-03	1.55-03	1.35-03
AT217	0.00	3.49-08	3.50-08	4.22-08	7.31-07	6.94-05	5.54-03	1.29-01	2.88-01	1.47-02	3.52-15	0.00
RN219	0.00	1.19-06	2.02-06	7.70-06	2.38-05	2.60-05	3.90-05	2.65-04	3.65-04	3.61-04	3.31-04	1.38-04
RN220	0.00	2.20-03	1.57-03	1.40-04	4.02-05	7.06-09	1.21-09	1.90-08	1.94-07	1.71-06	6.42-06	6.50-06
RN222	0.00	1.96-08	2.85-08	1.09-07	1.11-06	7.22-05	2.91-03	2.28-02	5.59-03	1.57-03	1.55-03	1.35-03
FR221	0.00	3.49-08	3.50-08	4.22-08	7.31-07	6.94-05	5.54-03	1.29-01	2.88-01	1.47-02	3.52-15	0.00
FR223	0.00	1.79-08	2.82-08	1.68-07	3.33-07	3.64-07	5.46-07	3.71-06	5.10-06	5.06-06	4.63-06	1.93-06
RA223	0.00	1.19-06	2.02-06	7.70-06	2.38-05	2.60-05	3.90-05	2.65-04	3.65-04	3.61-04	3.31-04	1.38-04
RA224	0.00	2.20-03	1.57-03	1.40-04	4.02-05	7.06-09	1.21-09	1.90-08	1.94-07	1.71-06	6.42-06	6.50-06
RA225	0.00	3.48-08	3.50-08	4.22-08	7.31-07	6.94-05	5.54-03	1.29-01	2.88-01	1.47-02	3.52-15	0.00
RA226	0.00	1.97-08	2.85-08	1.09-07	1.11-06	7.22-05	2.91-03	2.28-02	5.59-03	1.57-03	1.55-03	1.35-03
AC225	0.00	3.49-08	3.50-08	4.22-08	7.31-07	6.94-05	5.54-03	1.29-01	2.88-01	1.47-02	3.52-15	0.00
AC227	0.00	1.28-06	2.02-06	7.70-06	2.38-05	2.60-05	3.90-05	2.65-04	3.65-04	3.61-04	3.31-04	1.38-04
TH227	0.00	1.21-06	1.99-06	7.59-06	2.35-05	2.56-05	3.85-05	2.62-04	3.60-04	3.56-04	3.26-04	1.36-04
TH228	0.00	2.22-03	1.56-03	1.40-04	4.02-05	7.06-09	1.21-09	1.90-08	1.94-07	1.71-06	6.42-06	6.50-06
TH229	0.00	3.49-08	3.50-08	4.22-08	7.31-07	6.94-05	5.54-03	1.29-01	2.88-01	1.47-02	3.52-15	0.00
TH230	0.00	2.04-05	2.05-05	2.09-05	3.42-05	3.86-04	3.74-03	2.28-02	5.59-03	1.57-03	1.55-03	1.35-03
TH231	0.00	1.71-02	8.55-05	8.55-05	8.57-05	8.73-05	1.16-04	3.46-04	3.65-04	3.61-04	3.31-04	1.38-04
TH232	0.00	3.14-11	3.14-11	3.21-11	3.85-11	1.08-10	1.21-09	1.90-08	1.94-07	1.71-06	6.42-06	6.50-06
TH234	0.00	3.14-01	1.58-03	1.57-03	1.57-03	1.57-03	1.57-03	1.57-03	1.57-03	1.57-03	1.55-03	1.35-03

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
PA231	0.00	2.47-05	2.47-05	2.47-05	2.48-05	2.60-05	3.90-05	2.65-04	3.65-04	3.61-04	3.31-04	1.38-04
PA233	0.00	3.40-01	3.40-01	3.41-01	3.45-01	3.67-01	3.74-01	3.63-01	2.72-01	1.47-02	3.24-15	0.00
PA234M	0.00	3.19-01	1.58-03	1.57-03	1.57-03	1.57-03	1.57-03	1.57-03	1.57-03	1.57-03	1.55-03	1.35-03
PA234	0.00	3.19-04	1.58-06	1.57-06	1.57-06	1.57-06	1.57-06	1.57-06	1.57-06	1.57-06	1.55-06	1.35-06
U232	0.00	3.69-05	5.01-05	8.73-05	3.91-05	6.77-09	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	2.31-07	1.64-06	1.49-05	1.47-04	1.52-03	1.56-02	1.26-01	2.89-01	1.47-02	3.51-15	0.00
U234	1.64+00	3.77-03	3.95-03	6.64-03	2.56-02	4.56-02	4.45-02	3.50-02	4.24-03	1.57-03	1.55-03	1.35-03
U235	7.07-02	8.55-05	8.55-05	8.55-05	8.57-05	8.73-05	1.16-04	3.46-04	3.65-04	3.61-04	3.31-04	1.38-04
U236	0.00	1.44-03	1.44-03	1.44-03	1.46-03	1.69-03	3.09-03	4.01-03	3.91-03	3.01-03	2.21-04	1.03-15
U237	0.00	1.35-02	1.21-02	7.92-03	1.24-04	6.41-06	3.28-06	4.07-09	0.00	0.00	0.00	0.00
U238	3.22-01	1.57-03	1.57-03	1.57-03	1.57-03	1.57-03	1.57-03	1.57-03	1.57-03	1.57-03	1.55-03	1.35-03
NP237	0.00	3.40-01	3.40-01	3.41-01	3.45-01	3.67-01	3.74-01	3.63-01	2.72-01	1.47-02	3.24-15	0.00
NP239	0.00	1.76+01	1.76+01	1.75+01	1.74+01	1.60+01	7.10+00	2.04-03	2.63-07	1.81-07	4.33-09	2.61-25
PU236	0.00	1.59-03	1.25-03	1.40-04	4.38-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	0.00	1.42+01	8.99+01	1.03+02	5.25+01	8.21-02	1.27-19	0.00	0.00	0.00	0.00	0.00
PU239	0.00	1.62+00	1.62+00	1.62+00	1.67+00	2.05+00	4.02+00	5.62-01	2.63-07	1.81-07	4.33-09	2.62-25
PU240	0.00	2.37+00	2.63+00	4.52+00	8.90+00	8.25+00	3.28+00	3.23-04	0.00	0.00	0.00	0.00
PU241	0.00	5.05+02	4.82+02	3.16+02	4.95+00	2.56-01	1.31-01	1.63-04	0.00	0.00	0.00	0.00
PU242	0.00	6.86-03	6.86-03	6.87-03	6.97-03	7.23-03	7.43-03	6.68-03	1.29-03	9.19-11	0.00	0.00
PU243	0.00	1.37-09	2.75-07	2.75-07	2.75-07	2.75-07	2.74-07	2.73-07	2.63-07	1.81-07	4.33-09	2.61-25
AM241	0.00	1.91+02	1.52+02	1.55+02	1.44+02	3.43+01	1.31-01	1.63-04	0.00	0.00	0.00	0.00
AM242M	0.00	4.03+00	4.01+00	3.85+00	2.55+00	4.22-02	6.38-20	0.00	0.00	0.00	0.00	0.00
AM242	0.00	4.03+00	4.01+00	3.85+00	2.55+00	4.22-02	6.38-20	0.00	0.00	0.00	0.00	0.00
AM243	0.00	1.76+01	1.76+01	1.75+01	1.74+01	1.60+01	7.10+00	2.04-03	2.63-07	1.81-07	4.33-09	2.61-25
CM242	0.00	1.93+04	4.06+03	3.16+00	2.09+00	3.46-02	5.24-20	0.00	0.00	0.00	0.00	0.00
CM243	0.00	5.46+00	5.34+00	4.40+00	6.26-01	2.15-09	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	2.52+03	2.43+03	1.72+03	5.48+01	5.94-14	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	2.76-01	2.76-01	2.76-01	2.74-01	2.56-01	1.31-01	1.63-04	0.00	0.00	0.00	0.00
CM246	0.00	5.93-02	5.93-02	5.93-02	5.86-02	5.23-02	1.68-02	1.91-07	0.00	0.00	0.00	0.00
CM247	0.00	2.75-07	2.75-07	2.75-07	2.75-07	2.75-07	2.74-07	2.73-07	2.63-07	1.81-07	4.33-09	2.61-25
SUBTOT	2.03+00	2.25+04	7.28+03	2.35+03	3.10+02	7.82+01	2.28+01	2.73+00	3.21+00	1.91-01	2.56-02	2.04-02
TOTAL	2.03+00	2.25+04	7.28+03	2.35+03	3.10+02	7.82+01	2.28+01	2.73+00	3.21+00	1.91-01	2.56-02	2.04-02

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	3.59-09	6.09-09	2.32-08	7.17-08	7.83-08	1.18-07	7.99-07	1.10-06	1.09-06	9.98-07	4.15-07
TL208	0.00	1.84-05	1.31-05	1.17-06	3.37-07	5.92-11	1.02-11	1.59-10	1.63-09	1.44-08	5.38-08	5.45-08
TL209	0.00	1.26-11	1.26-11	1.52-11	2.63-10	2.50-08	1.99-06	4.64-05	1.04-04	5.30-06	1.27-18	0.00
PB209	0.00	4.02-11	4.03-11	4.86-11	8.40-10	7.98-08	6.37-06	1.48-04	3.32-04	1.69-05	4.05-18	0.00
PB211	0.00	3.99-09	6.75-09	2.57-08	7.96-08	8.68-08	1.30-07	8.87-07	1.22-06	1.21-06	1.11-06	4.60-07
PB212	0.00	3.15-06	2.25-06	2.01-07	5.76-08	1.01-11	1.74-12	2.72-11	2.78-10	2.46-09	9.21-09	9.33-09
PB214	0.00	4.77-11	6.95-11	2.65-10	2.71-09	1.76-07	7.10-06	5.56-05	1.36-05	3.82-06	3.77-06	3.28-06
BI210	0.00	2.17-12	4.19-12	5.08-11	1.98-09	1.90-07	7.67-06	6.01-05	1.47-05	4.13-06	4.07-06	3.55-06
BI211	0.00	4.64-08	7.87-08	3.00-07	9.27-07	1.01-06	1.52-06	1.03-05	1.42-05	1.41-05	1.29-05	5.36-06
BI212	0.00	3.81-05	2.72-05	2.43-06	6.98-07	1.23-10	2.11-11	3.30-10	3.37-09	2.98-08	1.11-07	1.13-07
BI213	0.00	2.15-10	2.15-10	2.60-10	4.49-09	4.27-07	3.41-05	7.92-04	1.77-03	9.05-05	2.16-17	0.00
BI214	0.00	2.72-10	3.97-10	1.51-09	1.55-08	1.01-06	4.06-05	3.18-04	7.79-05	2.18-05	2.15-05	1.88-05
PO210	0.00	1.77-11	3.69-11	6.07-10	2.37-08	2.27-06	9.17-05	7.18-04	1.76-04	4.94-05	4.87-05	4.24-05
PO211	0.00	1.58-10	2.68-10	1.02-09	3.15-09	3.44-09	5.17-09	3.51-08	4.83-08	4.79-08	4.39-08	1.82-08
PO212	0.00	7.45-05	5.32-05	4.75-06	1.36-06	2.39-10	4.11-11	6.44-10	6.58-09	5.82-08	2.18-07	2.20-07
PO213	0.00	1.70-09	1.70-09	2.05-09	3.55-08	3.37-06	2.69-04	6.26-03	1.40-02	7.15-04	1.71-16	0.00
PO214	0.00	8.92-10	1.30-09	4.96-09	5.07-08	3.29-06	1.33-04	1.04-03	2.55-04	7.15-05	7.05-05	6.14-05
PO215	0.00	5.22-08	8.85-08	3.37-07	1.04-06	1.14-06	1.71-06	1.16-05	1.60-05	1.58-05	1.45-05	6.02-06
PO216	0.00	8.96-05	6.42-05	5.72-06	1.64-06	2.89-10	4.96-11	7.76-10	7.94-09	7.02-08	2.63-07	2.66-07
PO218	0.00	7.09-10	1.03-09	3.94-09	4.03-08	2.62-06	1.05-04	8.27-04	2.03-04	5.68-05	5.61-05	4.88-05
AT217	0.00	1.46-09	1.47-09	1.77-09	3.06-08	2.91-06	2.32-04	5.40-03	1.21-02	6.17-04	1.47-16	0.00
RN219	0.00	4.82-08	8.18-08	3.12-07	9.63-07	1.05-06	1.58-06	1.07-05	1.48-05	1.46-05	1.34-05	5.57-06
RN220	0.00	8.33-05	5.95-05	5.31-06	1.52-06	2.68-10	4.60-11	7.19-10	7.36-09	6.50-08	2.43-07	2.46-07
RN222	0.00	6.38-10	9.30-10	3.54-09	3.63-08	2.35-06	9.49-05	7.44-04	1.82-04	5.11-05	5.04-05	4.39-05
FR221	0.00	1.30-09	1.30-09	1.57-09	2.72-08	2.58-06	2.06-04	4.79-03	1.07-02	5.48-04	1.31-16	0.00
FR223	0.00	4.19-11	6.61-11	2.52-10	7.80-10	8.51-10	1.28-09	8.69-09	1.20-08	1.18-08	1.09-08	4.51-09
RA223	0.00	4.14-08	7.02-08	2.67-07	8.27-07	9.02-07	1.36-06	9.21-06	1.27-05	1.26-05	1.15-05	4.78-06
RA224	0.00	7.51-05	5.36-05	4.79-06	1.37-06	2.41-10	4.15-11	6.49-10	6.64-09	5.87-08	2.20-07	2.22-07
RA225	0.00	2.29-11	2.30-11	2.78-11	4.81-10	4.57-08	3.65-06	8.48-05	1.90-04	9.69-06	2.32-18	0.00
RA226	0.00	5.58-10	8.08-10	3.08-09	3.15-08	2.04-06	8.24-05	6.46-04	1.58-04	4.44-05	4.38-05	3.81-05
AC225	0.00	1.20-09	1.20-09	1.45-09	2.51-08	2.38-06	1.90-04	4.42-03	9.89-03	5.05-04	1.21-16	0.00
AC227	0.00	6.45-10	1.02-09	3.88-09	1.20-08	1.31-08	1.97-08	1.34-07	1.84-07	1.82-07	1.67-07	6.93-08
TH227	0.00	4.16-08	6.86-08	2.61-07	8.08-07	8.81-07	1.32-06	9.00-06	1.24-05	1.23-05	1.12-05	4.67-06
TH228	0.00	7.28-05	5.11-05	4.57-06	1.32-06	2.31-10	3.97-11	6.21-10	6.36-09	5.62-08	2.10-07	2.13-07
TH229	0.00	1.06-09	1.06-09	1.28-09	2.21-08	2.10-06	1.67-04	3.89-03	8.72-03	4.45-04	1.06-16	0.00
TH230	0.00	5.77-07	5.78-07	5.90-07	9.67-07	1.09-05	1.06-04	6.44-04	1.58-04	4.43-05	4.37-05	3.81-05
TH231	0.00	1.35-05	6.74-08	6.74-08	6.76-08	6.86-08	9.14-08	2.72-07	2.87-07	2.85-07	2.61-07	1.08-07
TH234	0.00	1.12-04	5.62-07	5.59-07	5.59-07	5.59-07	5.59-07	5.59-07	5.59-07	5.58-07	5.50-07	4.79-07
PA231	0.00	7.52-07	7.52-07	7.53-07	7.56-07	7.92-07	1.19-06	8.09-06	1.11-05	1.10-05	1.01-05	4.20-06
PA233	0.00	4.59-04	4.60-04	4.60-04	4.66-04	4.96-04	5.05-04	4.91-04	3.67-04	1.99-05	4.38-18	0.00

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
PA234M	0.00	1.62-03	8.13-06	8.08-06	8.08-06	8.08-06	8.08-06	8.08-06	8.08-06	8.07-06	7.96-06	6.93-06
PA234	0.00	2.86-06	1.44-08	1.43-08	1.43-08	1.43-08	1.43-08	1.43-08	1.43-08	1.43-08	1.41-08	1.22-08
U232	0.00	1.10-06	1.61-06	2.80-06	1.26-06	2.17-10	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	6.71-09	5.37-08	4.35-07	4.28-06	4.44-05	4.54-04	3.74-03	6.39-03	4.29-04	1.02-16	0.00
U234	4.71-02	1.09-04	1.14-04	1.91-04	7.36-04	1.31-03	1.28-03	1.01-03	1.22-04	4.52-05	4.45-05	3.88-05
U235	1.96-03	2.37-06	2.37-06	2.37-06	2.38-06	2.42-06	3.22-06	9.59-06	1.01-05	1.00-05	9.19-06	3.82-06
U236	0.00	3.91-05	3.91-05	3.91-05	3.96-05	4.56-05	9.39-05	1.09-04	1.06-04	8.16-05	6.00-06	2.79-17
U237	0.00	8.99-06	8.01-06	5.26-06	8.22-08	4.26-09	2.18-09	2.70-12	0.00	0.00	0.00	0.00
U238	3.15-03	3.97-05	3.97-05	3.97-05	3.97-05	3.97-05	3.97-05	3.97-05	3.98-05	3.97-05	3.92-05	3.41-05
NP237	0.00	9.99-03	9.99-13	1.00-02	1.01-02	1.08-02	1.10-02	1.07-02	7.98-03	4.33-04	9.52-17	0.00
NP239	0.00	2.37-02	2.37-02	2.37-02	2.35-02	2.17-02	9.59-03	2.76-06	3.56-10	2.45-10	5.85-12	3.53-28
PU236	0.00	5.53-05	4.34-05	4.86-06	1.52-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	0.00	4.70-01	2.96+00	3.42+00	1.74+00	2.72-03	4.19-21	0.00	0.00	0.00	0.00	0.00
PU239	0.00	5.02-02	5.02-02	5.04-02	5.18-02	6.36-02	1.25-01	1.75-02	8.19-09	5.63-09	1.35-10	8.13-27
PU240	0.00	7.39-02	8.18-02	1.41-01	2.77-01	2.57-01	1.02-01	1.01-05	0.00	0.00	0.00	0.00
PU241	0.00	2.19-02	2.00-02	1.31-02	2.05-04	1.06-05	5.45-06	6.76-09	0.00	0.00	0.00	0.00
PU242	0.00	2.02-04	2.02-04	2.03-04	2.06-04	2.14-04	2.25-04	1.97-04	3.80-05	2.71-12	0.00	0.00
PU243	0.00	1.94-12	3.89-10	3.89-10	3.89-10	3.89-10	3.89-10	3.87-10	3.73-10	2.57-10	6.13-12	3.70-28
AM241	0.00	5.04+00	5.06+00	5.18+00	4.80+00	1.15+00	4.36-03	5.44-04	0.00	0.00	0.00	0.00
AM242M	0.00	1.15-03	1.14-03	1.09-03	7.26-04	1.20-05	1.81-23	0.00	0.00	0.00	0.00	0.00
AM242	0.00	5.37-03	5.35-03	5.13-03	3.40-03	5.62-05	8.51-23	0.00	0.00	0.00	0.00	0.00
AM243	0.00	6.41-01	6.41-01	6.40-01	6.35-01	5.85-01	2.59-01	7.46-05	9.62-09	6.62-09	1.58-10	9.54-27
CM242	0.00	7.10+02	1.50+02	1.16-01	7.71-02	1.27-03	1.93-21	0.00	0.00	0.00	0.00	0.00
CM243	0.00	2.01-01	1.96-01	1.62-01	2.30-02	7.90-11	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	8.82+01	8.49+01	6.01+01	1.92+00	2.08-15	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	8.60-03	8.60-03	8.60-03	8.54-03	7.99-03	4.09-03	5.08-06	0.00	0.00	0.00	0.00
CM246	0.00	1.94-03	1.94-03	1.94-03	1.92-03	1.71-03	5.49-04	6.26-09	0.00	0.00	0.00	0.00
CM247	0.00	7.92-09	7.92-09	7.92-09	7.92-09	7.91-09	7.91-09	7.08-09	7.59-09	5.23-09	1.25-10	7.53-27
SUBTOT	5.72-02	8.05+02	2.44+02	6.99+01	9.57+00	2.10+00	5.20-01	6.48-02	7.62-02	4.45-03	5.28-04	4.16-04
TOTAL	5.72-02	8.05+02	2.44+02	6.99+01	9.57+00	2.10+00	5.20-01	6.48-02	7.62-02	4.45-03	5.28-04	4.16-04

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	-1.19-06	-2.01-06	-7.68-06	-2.37-05	-2.59-05	-3.89-05	-2.64-04	-3.64-04	-3.60-04	-3.30-04	-1.37-04
TL208	0.00	-7.91-04	-5.65-04	-5.04-05	-1.45-05	-2.54-09	-4.37-10	-6.83-09	-6.99-08	-6.17-07	-2.31-06	-2.34-06
TL209	0.00	-7.68-10	-7.71-10	-9.29-10	-1.61-08	-1.53-06	-1.22-04	-2.83-03	-6.34-03	-3.24-04	-7.74-17	0.00
PB209	0.00	-3.49-08	-3.50-08	-4.22-08	-7.31-07	-6.94-05	-5.54-03	-1.29-01	-2.88-01	-1.47-02	-3.52-15	0.00
PB210	0.00	2.09+02	3.98+02	4.82+03	1.88+05	1.81+07	7.28+08	5.71+09	1.40+09	3.92+08	3.87+08	3.37+08
PB211	0.00	-1.19-06	-2.02-06	-7.70-06	-2.38-05	-2.60-05	-3.90-05	-2.65-04	-3.65-04	-3.61-04	-3.31-04	-1.38-04
PB212	0.00	3.66+06	2.61+06	2.33+05	6.70+04	1.15+01	2.02+00	3.16+01	3.23+02	2.86+03	1.07+04	1.08+04
PB214	0.00	-1.96-08	-2.85-08	-1.09-07	-1.11-06	-7.22-05	-2.91-03	-2.28-02	-5.59-03	-1.57-03	-1.55-03	-1.35-03
BI210	0.00	4.13+00	7.96+00	9.64+01	3.76+03	3.61+05	1.46+07	1.14+08	2.80+07	7.85+06	7.74+06	6.74+06
BI211	0.00	-1.19-06	-2.02-06	-7.70-06	-2.38-05	-2.60-05	-3.90-05	-2.65-04	-3.65-04	-3.61-04	-3.31-04	-1.38-04
BI212	0.00	7.32+05	5.23+05	4.66+04	1.34+04	2.35+00	4.04-01	6.33+00	6.47+01	5.72+02	2.14+03	2.17+03
BI213	0.00	-3.49-08	-3.50-08	-4.22-08	-7.31-07	-6.94-05	-5.54-03	-1.29-01	-2.88-01	-1.47-02	-3.52-15	0.00
BI214	0.00	-1.96-08	-2.85-08	-1.09-07	-1.11-06	-7.22-05	-2.91-03	-2.28-02	-5.59-03	-1.57-03	-1.55-03	-1.35-03
PO210	0.00	8.04+01	1.67+02	2.76+03	1.07+05	1.03+07	4.16+08	3.26+09	7.99+08	2.24+08	2.21+08	1.93+08
PO211	0.00	-3.58-09	-6.06-09	-2.31-08	-7.14-08	-7.79-08	-1.17-07	-7.96-07	-1.09-06	-1.08-06	-9.93-07	-4.13-07
PO212	0.00	-1.41-03	-1.00-03	-8.96-05	-2.57-05	-4.52-09	-7.76-10	-1.21-08	-1.24-07	-1.10-06	-4.11-06	-4.16-06
PO213	0.00	-3.41-08	-3.43-08	-4.13-08	-7.15-07	-6.79-05	-5.42-03	-1.26-01	-2.82-01	-1.44-02	-3.44-15	0.00
PO214	0.00	-1.96-08	-2.85-08	-1.09-07	-1.11-06	-7.22-05	-2.91-03	-2.28-02	-5.59-03	-1.57-03	-1.55-03	-1.35-03
PO215	0.00	-1.19-06	-2.02-06	-7.70-06	-2.38-05	-2.60-05	-3.90-05	-2.65-04	-3.65-04	-3.61-04	-3.31-04	-1.38-04
PO216	0.00	-2.20-03	-1.57-03	-1.40-04	-4.02-05	-7.06-09	-1.21-09	-1.90-08	-1.94-07	-1.71-06	-6.42-06	-6.50-06
PO218	0.00	-1.96-08	-2.85-08	-1.09-07	-1.11-06	-7.22-05	-2.91-03	-2.28-02	-5.59-03	-1.57-03	-1.55-03	-1.35-03
AT217	0.00	-3.49-08	-3.50-08	-4.22-08	-7.31-07	-6.94-05	-5.54-03	-1.29-01	-2.88-01	-1.47-02	-3.52-15	0.00
RN219	0.00	-1.19-06	-2.02-06	-7.70-06	-2.38-05	-2.60-05	-3.90-05	-2.65-04	-3.65-04	-3.61-04	-3.31-04	-1.38-04
RN220	0.00	2.20+05	1.57+05	1.40+04	4.02+03	7.06-01	1.21-01	1.90+00	1.94+01	1.71+02	6.42+02	6.50+02
RN222	0.00	6.52+00	9.51+00	3.63+01	3.71+02	2.41+04	9.71+05	7.61+06	1.86+06	5.23+05	5.16+05	4.49+05
FR221	0.00	-3.49-08	-3.50-08	-4.22-08	-7.31-07	-6.94-05	-5.54-03	-1.29-01	-2.88-01	-1.47-02	-3.52-15	0.00
FR223	0.00	-1.79-08	-2.82-08	-1.08-07	-3.33-07	-3.64-07	-5.46-07	-3.71-06	-5.10-06	-5.06-06	-4.63-06	-1.93-06
RA223	0.00	1.49+05	2.53+05	9.63+05	2.98+06	3.25+06	4.88+06	3.32+07	4.56+07	4.52+07	4.14+07	1.72+07
RA224	0.00	1.10+08	7.84+07	7.00+06	2.01+06	3.53+02	6.06+01	9.49+02	9.70+03	8.57+04	3.21+05	3.25+05
RA225	0.00	6.96+02	7.00+02	8.45+02	1.46+04	1.39+06	1.11+08	2.58+09	5.77+09	2.95+08	7.04-05	0.00
RA226	0.00	9.85+03	1.43+04	5.44+04	5.57+05	3.61+07	1.46+09	1.14+10	2.80+09	7.85+08	7.74+08	6.74+08
RA228	0.00	3.80+00	6.52+00	2.18+01	3.85+01	1.08+02	1.21+03	1.90+04	1.94+05	1.71+06	6.42+06	6.50+06
AC225	0.00	-3.49-08	-3.50-08	-4.22-08	-7.31-07	-6.94-05	-5.54-03	-1.29-01	-2.88-01	-1.47-02	-3.52-15	0.00
AC227	0.00	1.60+07	2.52+07	9.62+07	2.98+08	3.25+08	4.88+08	3.32+09	4.56+09	4.52+09	4.14+09	1.72+09
AC228	0.00	6.34-03	1.09-02	3.64-02	6.41-02	1.80-01	2.02+00	3.16+01	3.23+02	2.86+03	1.07+04	1.08+04
TH227	0.00	2.01+05	3.32+05	1.27+06	3.91+06	4.27+06	6.41+06	4.36+07	5.99+07	5.94+07	5.44+07	2.26+07
TH228	0.00	1.11+10	7.80+09	6.98+08	2.01+08	3.53+04	6.06+03	9.49+04	9.70+05	8.57+06	3.21+07	3.25+07
TH229	0.00	4.37+05	4.38+05	5.28+05	9.13+06	8.68+08	6.93+10	1.61+12	3.60+12	1.84+11	4.40-02	0.00
TH230	0.00	2.55+08	2.56+08	2.61+08	4.28+08	4.83+09	4.67+10	2.85+11	6.99+10	1.96+10	1.93+10	1.68+10
TH231	0.00	4.28+05	2.14+03	2.14+03	2.14+03	2.18+03	2.90+03	8.64+03	9.12+03	9.04+03	8.28+03	3.44+03

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H232	0.00	3.19+01	3.19+01	3.21+01	3.35+01	1.08+02	1.21+03	1.90+04	1.94+05	1.71+06	6.42+06	6.50+06
H234	0.00	3.19+08	1.58+06	1.57+06	1.57+06	1.57+06	1.57+06	1.57+06	1.57+06	1.57+06	1.55+06	1.35+06
A231	0.00	6.16+08	6.16+08	6.17+08	6.20+08	6.49+08	9.75+08	6.63+09	9.12+09	9.04+09	8.28+09	3.44+09
A233	0.00	5.66+07	5.67+07	5.66+07	5.75+07	6.12+07	8.23+07	6.06+07	4.53+07	2.45+06	5.40-07	0.00
A234M	0.00	-3.19-01	-1.58-03	-1.57-03	-1.57-03	-1.57-03	-1.57-03	-1.57-03	-1.57-03	-1.57-03	-1.55-03	-1.35-03
A234	0.00	-3.19-04	-1.58-06	-1.57-06	-1.57-06	-1.57-06	-1.57-06	-1.57-06	-1.57-06	-1.57-06	-1.55-06	-1.35-06
U232	0.00	4.10+07	5.56+07	9.70+07	9.35+07	7.52+03	0.00	0.00	0.00	0.00	0.00	0.00
U233	1.00	5.76+04	4.61+05	3.79+06	3.67+07	3.81+06	3.90+09	3.21+10	7.20+10	3.68+09	8.77-04	0.00
U234	4.09+11	9.43+08	9.86+08	1.66+09	4.39+09	1.19+10	1.11+10	8.74+09	1.06+09	3.92+08	3.87+08	3.37+08
U235	1.77+10	2.19+07	2.19+07	2.19+07	2.19+07	2.18+07	2.90+07	8.64+07	9.12+07	9.04+07	6.28+07	3.44+07
U236	0.00	3.60+08	3.60+08	3.61+08	3.66+08	4.22+08	7.73+08	1.00+09	9.77+08	7.52+08	5.54+07	2.57-04
U237	0.00	-1.35-02	-1.21-02	-7.92-13	-1.24-04	-6.41-06	-3.28-06	-4.67-07	0.00	0.00	0.00	0.00
U238	1.07+11	5.24+08	5.24+08	5.24+08	5.24+08	5.24+08	5.24+08	5.24+08	5.24+08	5.23+08	5.16+08	4.49+08
P237	0.00	3.40+12	3.40+12	3.41+12	3.45+12	3.67+12	3.74+12	3.63+12	2.72+12	1.47+11	3.24-02	0.00
P239	0.00	8.78+08	8.78+08	8.77+08	8.70+08	8.02+08	3.55+08	1.02+05	1.32+01	9.06+00	2.16-01	1.31-17
U236	0.00	-1.59-03	-1.25-03	-1.40-04	-4.38-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U238	0.00	2.03+14	1.26+15	1.47+15	7.50+14	1.17+12	1.81-06	0.00	0.00	0.00	0.00	0.00
U239	0.00	2.69+13	2.69+13	2.70+13	2.70+13	3.41+13	6.69+13	9.37+12	4.39+06	3.02+06	7.22+04	4.36-12
U240	0.00	3.93+13	4.38+13	7.53+13	1.48+14	1.37+14	5.47+13	5.36+09	0.00	0.00	0.00	0.00
U241	0.00	1.68+14	1.61+14	1.05+14	1.65+12	8.55+10	4.38+10	5.43+07	0.00	0.00	0.00	0.00
U242	0.00	1.14+11	1.14+11	1.15+11	1.16+11	1.21+11	1.27+11	1.11+11	2.15+10	1.53+03	0.00	0.00
U243	0.00	2.29-02	4.58+00	4.58+00	4.58+00	4.58+00	4.57+00	4.56+00	4.39+00	3.02+00	7.22-02	4.35-18
M241	0.00	7.56+14	7.58+14	7.76+14	7.19+14	1.72+14	6.67+11	8.15+06	0.00	0.00	0.00	0.00
M242M	0.00	2.01+13	2.00+13	1.92+13	1.26+13	2.11+11	3.19-07	0.00	0.00	0.00	0.00	0.00
M242	0.00	4.13+09	4.01+09	3.65+09	2.65+09	4.22+07	6.38-11	0.00	0.00	0.00	0.00	0.00
M243	0.00	8.76+13	8.76+13	8.77+13	8.70+13	8.02+13	3.55+13	1.02+10	1.32+06	9.06+05	2.16+04	1.31-12
M242	0.00	4.62+15	1.02+15	7.90+11	5.23+11	8.64+09	1.31-08	0.00	0.00	0.00	0.00	0.00
M243	0.00	2.73+13	2.67+13	2.20+13	3.13+12	1.07+09	0.00	0.00	0.00	0.00	0.00	0.00
M244	0.00	6.40+15	8.09+15	5.73+15	1.83+14	1.98-01	0.00	0.00	0.00	0.00	0.00	0.00
M245	0.00	1.38+12	1.38+12	1.38+12	1.37+12	1.26+12	6.55+11	8.13+05	0.00	0.00	0.00	0.00
M246	0.00	2.97+11	2.97+11	2.96+11	2.93+11	2.61+11	6.33+10	9.56+05	0.00	0.00	0.00	0.00
M247	0.00	1.37+06	1.37+06	1.37+06	1.37+06	1.37+06	1.37+06	1.37+06	1.32+06	9.06+05	2.16+04	1.31-12
UBTOT	5.34+11	1.46+16	1.15+16	8.32+15	1.94+15	4.30+14	1.63+14	1.51+13	6.51+12	3.72+11	3.43+10	2.41+10
TOTAL	5.34+11	1.46+16	1.15+16	8.32+15	1.94+15	4.30+14	1.63+14	1.51+13	6.51+12	3.72+11	3.43+10	2.41+10

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	-1.19-06	-2.01-06	-7.68-06	-2.37-05	-2.59-05	-3.89-05	-2.64-04	-3.64-04	-3.60-04	-3.30-04	-1.37-04
TL208	0.00	-7.91-04	-5.65-04	-5.04-05	-1.45-05	-2.54-09	-4.37-10	-6.83-09	-6.99-08	-6.17-07	-2.31-06	-2.34-06
TL209	0.00	-7.68-10	-7.71-10	-9.29-10	-1.61-08	-1.53-06	-1.22-04	-2.83-03	-6.34-03	-3.24-04	-7.74-17	0.00
PB209	0.00	-3.49-08	-3.50-08	-4.22-08	-7.31-07	-6.94-05	-5.54-03	-1.29-01	-2.88-01	-1.47-02	-3.52-15	0.00
PB210	0.00	8.37-03	1.59-02	1.93-01	7.52+00	7.22+02	2.91+04	2.28+05	5.59+04	1.57+04	1.55+04	1.35+04
PB211	0.00	-1.19-06	-2.02-06	-7.70-06	-2.38-05	-2.60-05	-3.90-05	-2.65-04	-3.65-04	-3.61-04	-3.31-04	-1.38-04
PB212	0.00	1.10+02	7.84+01	7.00+00	2.01+00	3.53-04	6.06-05	9.49-04	9.70-03	8.57-02	3.21-01	3.25-01
PB214	0.00	-1.96-08	-2.85-08	-1.09-07	-1.11-06	-7.22-05	-2.91-03	-2.28-02	-5.59-03	-1.57-03	-1.55-03	-1.35-03
BI210	0.00	2.06-05	3.98-05	4.82-04	1.88-02	1.81+00	7.28+01	5.71+02	1.40+02	3.92+01	3.87+01	3.37+01
BI211	0.00	-1.19-06	-2.02-06	-7.70-06	-2.38-05	-2.60-05	-3.90-05	-2.65-04	-3.65-04	-3.61-04	-3.31-04	-1.38-04
BI212	0.00	5.49+00	3.92+00	3.50-01	1.00-01	1.76-05	3.03-06	4.74-05	4.85-04	4.29-03	1.60-02	1.63-02
BI213	0.00	-3.49-08	-3.50-08	-4.22-08	-7.31-07	-6.94-05	-5.54-03	-1.29-01	-2.88-01	-1.47-02	-3.52-15	0.00
BI214	0.00	-1.96-08	-2.85-08	-1.09-07	-1.11-06	-7.22-05	-2.91-03	-2.28-02	-5.59-03	-1.57-03	-1.55-03	-1.35-03
PO210	0.00	8.04-04	1.67-03	2.76-02	1.07+00	1.03+02	4.16+03	3.26+04	7.99+03	2.24+03	2.21+03	1.93+03
PO211	0.00	-3.58-09	-6.06-09	-2.31-08	-7.14-08	-7.79-08	-1.17-07	-7.96-07	-1.09-06	-1.08-06	-9.93-07	-4.13-07
PO212	0.00	-1.41-03	-1.00-03	-8.96-05	-2.57-05	-4.52-09	-7.76-10	-1.21-08	-1.24-07	-1.10-06	-4.11-06	-4.16-06
PO213	0.00	-3.41-08	-3.43-08	-4.13-08	-7.15-07	-6.79-05	-5.42-03	-1.26-01	-2.82-01	-1.44-02	-3.44-15	0.00
PO214	0.00	-1.96-08	-2.85-08	-1.09-07	-1.11-06	-7.22-05	-2.91-03	-2.28-02	-5.59-03	-1.57-03	-1.55-03	-1.35-03
PO215	0.00	-1.19-06	-2.02-06	-7.70-06	-2.38-05	-2.60-05	-3.90-05	-2.65-04	-3.65-04	-3.61-04	-3.31-04	-1.38-04
PO216	0.00	-2.20-03	-1.57-03	-1.40-04	-4.02-05	-7.06-09	-1.21-09	-1.90-08	-1.94-07	-1.71-06	-6.42-06	-6.50-06
PO218	0.00	-1.96-08	-2.85-08	-1.09-07	-1.11-06	-7.22-05	-2.91-03	-2.28-02	-5.59-03	-1.57-03	-1.55-03	-1.35-03
AT217	0.00	-3.49-08	-3.50-08	-4.22-08	-7.31-07	-6.94-05	-5.54-03	-1.29-01	-2.88-01	-1.47-02	-3.52-15	0.00
RN219	0.00	-1.19-06	-2.02-06	-7.70-06	-2.38-05	-2.60-05	-3.90-05	-2.65-04	-3.65-04	-3.61-04	-3.31-04	-1.38-04
RN220	0.00	-2.20-03	-1.57-03	-1.40-04	-4.02-05	-7.06-09	-1.21-09	-1.90-08	-1.94-07	-1.71-06	-6.42-06	-6.50-06
RN222	0.00	-1.96-08	-2.85-08	-1.09-07	-1.11-06	-7.22-05	-2.91-03	-2.28-02	-5.59-03	-1.57-03	-1.55-03	-1.35-03
FR221	0.00	-3.49-08	-3.50-08	-4.22-08	-7.31-07	-6.94-05	-5.54-03	-1.29-01	-2.88-01	-1.47-02	-3.52-15	0.00
FR223	0.00	-1.79-08	-2.82-08	-1.08-07	-3.33-07	-3.64-07	-5.46-07	-3.71-06	-5.10-06	-5.06-06	-4.63-06	-1.93-06
RA223	0.00	1.70+00	2.89+00	1.10+01	3.40+01	3.71+01	5.57+01	3.79+02	5.21+02	5.16+02	4.73+02	1.96+02
RA224	0.00	1.10+03	7.84+02	7.00+01	2.01+01	3.53-03	6.06-04	9.49-03	9.70-02	8.57-01	3.21+00	3.25+00
RA225	0.00	5.80-02	5.84-02	7.04-02	1.22+00	1.16+02	9.23+03	2.15+05	4.81+05	2.45+04	5.87-09	0.00
RA226	0.00	6.57-01	9.51-01	3.63+00	3.71+01	2.41+03	9.71+04	7.61+05	1.86+05	5.23+04	5.16+04	4.49+04
RA228	0.00	1.27-04	2.17-04	7.28-04	1.28-03	3.61-03	4.04-02	6.33-01	6.47+00	5.72+01	2.14+02	2.17+02
AC225	0.00	-3.49-08	-3.50-08	-4.22-08	-7.31-07	-6.94-05	-5.54-03	-1.29-01	-2.88-01	-1.47-02	-3.52-15	0.00
AC227	0.00	6.40-01	1.01+00	3.85+00	1.19+01	1.30+01	1.95+01	1.33+02	1.82+02	1.81+02	1.66+02	6.68+01
AC228	0.00	4.23-08	7.24-08	2.43-07	4.28-07	1.20-06	1.35-05	2.11-04	2.16-03	1.91-02	7.13-02	7.22-02
TH227	0.00	6.04-02	9.96-02	3.80-01	1.17+00	1.28+00	1.92+00	1.31+01	1.80+01	1.78+01	1.63+01	6.78+00
TH228	0.00	3.18+02	2.23+02	1.99+01	5.74+00	1.01-03	1.73-04	2.71-03	2.77-02	2.45-01	9.17-01	9.29-01
TH229	0.00	1.75-02	1.75-02	2.11-02	3.65-01	3.47+01	2.77+03	6.44+04	1.44+05	7.36+03	1.76-09	0.00
TH230	0.00	1.02+01	1.02+01	1.04+01	1.71+01	1.93+02	1.87+03	1.14+04	2.80+03	7.85+02	7.74+02	6.74+02
TH231	0.00	8.55+01	4.28-01	4.28-01	4.28-01	4.37-01	5.80-01	1.73+00	1.82+00	1.81+00	1.66+00	6.88-01

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TH232	0.00	1.57-05	1.57-05	1.60-05	1.92-05	5.41-05	6.06-04	9.49-03	9.70-02	8.57-01	3.21+00	3.25+00
TH234	0.00	1.57+04	7.90+01	7.85+01	7.85+01	7.85+01	7.85+01	7.86+01	7.86+01	7.85+01	7.74+01	6.74+01
PA231	0.00	2.74+01	2.74+01	2.74+01	2.75+01	2.88+01	4.33+01	2.95+02	4.05+02	4.02+02	3.68+02	1.53+02
PA233	0.00	3.40+03	3.40+03	3.41+03	3.45+03	3.67+03	3.74+03	3.63+03	2.72+03	1.47+02	3.24-11	0.00
PA234M	0.00	-3.14-01	-1.58-03	-1.57-03	-1.57-03	-1.57-03	-1.57-03	-1.57-03	-1.57-03	-1.57-03	-1.55-03	-1.35-03
PA234	0.00	-3.14-04	-1.58-06	-1.57-06	-1.57-06	-1.57-06	-1.57-06	-1.57-06	-1.57-06	-1.57-06	-1.55-06	-1.35-06
U232	0.00	1.23+00	1.67+00	2.91+00	1.30+00	2.26-04	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	7.68-03	6.14-02	4.98-01	4.90+00	5.06+01	5.20+02	4.26+03	9.61+03	4.91+02	1.17-10	0.00
U234	5.45+04	1.26+02	1.32+02	2.21+02	8.52+02	1.52+03	1.48+03	1.17+03	1.41+02	5.23+01	5.16+01	4.49+01
U235	2.36+03	2.85+00	2.85+00	2.85+00	2.86+00	2.91+00	3.87+00	1.15+01	1.22+01	1.20+01	1.10+01	4.58+00
U236	0.00	4.80+01	4.80+01	4.81+01	4.88+01	5.63+01	1.03+02	1.34+02	1.30+02	1.00+02	7.38+00	3.43-11
U237	0.00	-1.35-02	-1.21-02	-7.92-03	-1.24-04	-6.41-06	-3.28-06	-4.07-09	0.00	0.00	0.00	0.00
U238	9.65+03	3.93+01	3.93+01	3.93+01	3.93+01	3.93+01	3.93+01	3.93+01	3.93+01	3.92+01	3.87+01	3.37+01
NP237	0.00	1.13+05	1.13+05	1.14+05	1.15+05	1.22+05	1.25+05	1.21+05	9.05+04	4.91+03	1.08-09	0.00
NP239	0.00	1.76+05	1.76+05	1.75+05	1.74+05	1.60+05	7.10+04	2.04+01	2.63-03	1.81-03	4.33-05	2.61-21
PU236	0.00	-1.59-03	-1.25-03	-1.40-04	-4.38-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	0.00	2.64+06	1.80+07	2.06+07	1.05+07	1.64+04	2.53-14	0.00	0.00	0.00	0.00	0.00
PU239	0.00	3.23+05	3.23+05	3.24+05	3.33+05	4.09+05	8.03+05	1.12+05	5.27-02	3.63-02	8.66-04	5.23-20
PU240	0.00	4.75+05	5.25+05	9.03+05	1.78+06	1.65+06	6.56+05	6.45+01	0.00	0.00	0.00	0.00
PU241	0.00	2.53+06	2.41+06	1.58+06	2.47+04	1.28+03	6.56+02	8.15-01	0.00	0.00	0.00	0.00
PU242	0.00	1.37+03	1.37+03	1.37+03	1.39+03	1.45+03	1.53+03	1.34+03	2.58+02	1.84-05	0.00	0.00
PU243	0.00	4.58-06	9.15-04	9.15-04	9.15-04	9.15-04	9.15-04	9.11-04	8.78-04	6.04-04	1.44-05	8.70-22
AM241	0.00	3.78+07	3.79+07	3.88+07	3.60+07	8.58+06	3.28+04	4.07+01	0.00	0.00	0.00	0.00
AM242M	0.00	1.01+06	1.00+06	9.62+05	6.38+05	1.05+04	1.59-14	0.00	0.00	0.00	0.00	0.00
AM242	0.00	4.03+04	4.01+04	3.85+04	2.55+04	4.22+02	6.38-16	0.00	0.00	0.00	0.00	0.00
AM243	0.00	4.39+06	4.39+06	4.39+06	4.35+06	4.01+06	1.77+04	5.11+02	6.58-02	4.53-02	1.08-03	6.53-20
CM242	0.00	9.63+08	2.04+03	1.58+05	1.05+05	1.73+03	2.62-15	0.00	0.00	0.00	0.00	0.00
CM243	0.00	1.09+06	1.07+06	8.80+05	1.25+05	4.30-04	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	3.60+06	3.47+08	2.46+08	7.83+06	8.46-09	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	6.89+04	6.89+04	6.89+04	6.84+04	6.40+04	3.28+04	4.07+01	0.00	0.00	0.00	0.00
CM246	0.00	1.48+04	1.48+04	1.48+04	1.47+04	1.31+04	4.19+03	4.78-02	0.00	0.00	0.00	0.00
CM247	0.00	6.86-02	6.86-02	6.86-02	6.86-02	6.86-02	6.86-02	6.83-02	6.58-02	4.53-02	1.08-03	6.53-20
SUBTOT	6.50+04	1.37+09	6.17+08	3.15+08	6.21+07	1.50+07	3.65+06	1.56+06	9.83+05	1.10+05	7.15+04	6.18+04
TOTAL	6.50+04	1.37+09	6.17+08	3.15+08	6.21+07	1.50+07	3.65+06	1.56+06	9.83+05	1.10+05	7.15+04	6.18+04

LWR-PLANT WASTE FROM URANIUM FUELS

Fission Products

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33100.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	7.14-02	6.75-02	4.07-02	2.55-04	2.43-26	1.00	0.00	0.00	0.00	0.00	0.00
GE 72	0.00	5.84-03	5.84-03	5.84-03	5.84-03	5.84-03	5.84-03	5.84-03	5.84-03	5.84-03	5.84-03	5.84-03
GE 73	0.00	1.51-02	1.51-02	1.51-02	1.51-02	1.51-02	1.51-02	1.51-02	1.51-02	1.51-02	1.51-02	1.51-02
GE 74	0.00	5.57-02	5.57-02	5.57-02	5.57-02	5.57-02	5.57-02	5.57-02	5.57-02	5.57-02	5.57-02	5.57-02
AS 75	0.00	8.46-02	8.46-02	8.46-02	8.46-02	8.46-02	8.46-02	8.46-02	8.46-02	8.46-02	8.46-02	8.46-02
SE 76	0.00	2.94-01	2.94-01	2.94-01	2.94-01	2.94-01	2.94-01	2.94-01	2.94-01	2.94-01	2.94-01	2.94-01
SE 76	0.00	1.85-03	1.85-03	1.85-03	1.85-03	1.85-03	1.85-03	1.85-03	1.85-03	1.85-03	1.85-03	1.85-03
SE 77	0.00	9.47-01	9.47-01	9.47-01	9.47-01	9.47-01	9.47-01	9.47-01	9.47-01	9.47-01	9.47-01	9.47-01
SE 78	0.00	2.54+00	2.54+00	2.54+00	2.54+00	2.54+00	2.54+00	2.54+00	2.54+00	2.54+00	2.54+00	2.54+00
SE 79	0.00	5.72+00	5.72+00	5.72+00	5.71+00	5.66+00	5.14+00	1.97+00	1.34-04	0.00	0.00	0.00
BR 79	0.00	5.85-04	6.46-04	1.19-03	6.66-03	6.13-02	5.79-01	3.75+00	5.72+00	5.72+00	5.72+00	5.72+00
SE 80	0.00	9.99+00	9.99+00	9.99+00	9.99+00	9.99+00	9.99+00	9.99+00	9.99+00	9.99+00	9.99+00	9.99+00
KR 80	0.00	2.82-01	2.82-01	2.82-01	2.82-01	2.82-01	2.82-01	2.82-01	2.82-01	2.82-01	2.82-01	2.82-01
BR 81	0.00	1.53+01	1.53+01	1.53+01	1.53+01	1.53+01	1.53+01	1.53+01	1.53+01	1.53+01	1.53+01	1.53+01
KR 81	0.00	1.52-01	1.52-01	1.52-01	1.52-01	1.52-01	1.52-01	1.52-01	1.52-01	1.52-01	1.52-01	1.52-01
SE 82	0.00	3.29+01	3.29+01	3.29+01	3.29+01	3.29+01	3.29+01	3.29+01	3.29+01	3.29+01	3.29+01	3.29+01
KR 82	0.00	4.83-01	4.83-01	4.83-01	4.83-01	4.83-01	4.83-01	4.83-01	4.83-01	4.83-01	4.83-01	4.83-01
KR 83	0.00	4.07+01	4.07+01	4.07+01	4.07+01	4.07+01	4.07+01	4.07+01	4.07+01	4.07+01	4.07+01	4.07+01
KR 84	0.00	1.12+02	1.12+02	1.12+02	1.12+02	1.12+02	1.12+02	1.12+02	1.12+02	1.12+02	1.12+02	1.12+02
KR 85	0.00	2.64+01	2.67+01	1.50+01	4.65-02	3.66-27	0.00	0.00	0.00	0.00	0.00	0.00
RB 85	0.00	9.51+01	9.69+01	1.09+02	1.23+02	1.24+02	1.24+02	1.24+02	1.24+02	1.24+02	1.24+02	1.24+02
KR 86	0.00	1.93+02	1.93+02	1.93+02	1.93+02	1.93+02	1.93+02	1.93+02	1.93+02	1.93+02	1.93+02	1.93+02
RB 86	0.00	2.34-05	3.09-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 86	0.00	1.22-01	1.22-01	1.22-01	1.22-01	1.22-01	1.22-01	1.22-01	1.22-01	1.22-01	1.22-01	1.22-01
RB 87	0.00	2.39+02	2.39+02	2.39+02	2.39+02	2.39+02	2.39+02	2.39+02	2.39+02	2.39+02	2.39+02	2.36+02
SR 87	0.00	5.74-05	5.74-05	5.74-05	5.77-05	6.07-05	9.05-05	3.69-04	3.37-03	3.32-02	3.31-01	3.29+00
SR 88	0.00	3.50+02	3.50+02	3.50+02	3.50+02	3.50+02	3.50+02	3.50+02	3.50+02	3.50+02	3.50+02	3.50+02
SR 89	0.00	3.46+00	2.65-02	2.50-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y 89	0.00	4.63+02	4.67+02	4.67+02	4.67+02	4.67+02	4.67+02	4.67+02	4.67+02	4.67+02	4.67+02	4.67+02
SR 90	0.00	5.43+02	5.30+02	4.25+02	4.61+01	1.06-08	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	1.41-01	1.38-01	1.10-01	1.20-02	2.75-12	0.00	0.00	0.00	0.00	0.00	0.00
ZR 90	0.00	2.86+01	4.18+01	1.47+02	5.26+02	5.72+02	5.72+02	5.72+02	5.72+02	5.72+02	5.72+02	5.72+02
Y 91	0.00	6.61+00	8.92-02	1.33-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 91	0.00	6.04+02	6.11+02	6.11+02	6.11+02	6.11+02	6.11+02	6.11+02	6.11+02	6.11+02	6.11+02	6.11+02
ZR 92	0.00	6.64+02	6.64+02	6.64+02	6.64+02	6.64+02	6.64+02	6.64+02	6.64+02	6.64+02	6.64+02	6.64+02
ZR 93	0.00	7.36+02	7.36+02	7.36+02	7.36+02	7.36+02	7.33+02	7.03+02	4.64+02	7.25+00	6.35-18	0.00
NB 93M	0.00	6.39-04	9.36-04	3.05-03	6.64-03	6.67-03	6.64-03	6.37-03	4.20-03	6.57-05	5.75-23	0.00
NB 93	0.00	3.92-05	7.94-05	1.03-03	2.80-02	3.34-01	3.39+00	3.32+01	2.72+02	7.29+02	7.36+02	7.36+02
ZR 94	0.00	7.91+02	7.91+02	7.91+02	7.91+02	7.91+02	7.91+02	7.91+02	7.91+02	7.91+02	7.91+02	7.91+02
ZR 95	0.00	1.31+01	2.67-01	1.61-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
NB 95M	0.00	1.60-02	3.27-04	1.97-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	1.32+01	3.18-01	1.88-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MO 95	0.00	7.45+02	7.71+02	7.72+02	7.72+02	7.72+02	7.72+02	7.72+02	7.72+02	7.72+02	7.72+02	7.72+02
ZR 96	0.00	8.32+02	8.32+02	8.32+02	8.32+02	8.32+02	8.32+02	8.32+02	8.32+02	8.32+02	8.32+02	8.32+02
MO 96	0.00	3.97+01	3.97+01	3.97+01	3.97+01	3.97+01	3.97+01	3.97+01	3.97+01	3.97+01	3.97+01	3.97+01
MO 97	0.00	8.33+02	8.33+02	8.33+02	8.33+02	8.33+02	8.33+02	8.33+02	8.33+02	8.33+02	8.33+02	8.33+02
MO 98	0.00	8.50+02	8.50+02	8.50+02	8.50+02	8.50+02	8.50+02	8.50+02	8.50+02	8.50+02	8.50+02	8.50+02
TC 99	0.00	8.41+02	8.41+02	8.41+02	8.41+02	8.39+02	8.14+02	6.07+02	3.20+01	5.35-12	0.00	0.00
RU 99	0.00	5.32-03	8.07-03	3.28-02	2.80-01	2.75+00	2.71+01	2.35+02	8.09+02	8.41+02	8.41+02	8.41+02
MO100	0.00	9.72+02	9.72+02	9.72+02	9.72+02	9.72+02	9.72+02	9.72+02	9.72+02	9.72+02	9.72+02	9.72+02
RU100	0.00	5.60+01	5.60+01	5.60+01	5.60+01	5.60+01	5.60+01	5.60+01	5.60+01	5.60+01	5.60+01	5.60+01
RU101	0.00	7.77+02	7.77+02	7.77+02	7.77+02	7.77+02	7.77+02	7.77+02	7.77+02	7.77+02	7.77+02	7.77+02
RU102	0.00	7.68+02	7.68+02	7.68+02	7.68+02	7.68+02	7.68+02	7.68+02	7.68+02	7.68+02	7.68+02	7.68+02
RU103	0.00	2.76+00	4.62-03	4.80-28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	2.76-03	4.62-06	4.81-31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103	0.00	3.85+02	3.88+02	3.88+02	3.88+02	3.88+02	3.88+02	3.88+02	3.88+02	3.88+02	3.88+02	3.88+02
RU104	0.00	5.45+02	5.45+02	5.45+02	5.45+02	5.45+02	5.45+02	5.45+02	5.45+02	5.45+02	5.45+02	5.45+02
PD104	0.00	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02
PD105	0.00	2.95+02	2.95+02	2.95+02	2.95+02	2.95+02	2.95+02	2.95+02	2.95+02	2.95+02	2.95+02	2.95+02
RU106	0.00	1.22+02	6.13+01	1.24-01	1.36-28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	1.16-04	5.80-05	1.17-07	1.29-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD106	0.00	3.27+02	3.88+02	4.49+02	4.49+02	4.49+02	4.49+02	4.49+02	4.49+02	4.49+02	4.49+02	4.49+02
PD107	0.00	2.31+02	2.31+02	2.31+02	2.31+02	2.31+02	2.31+02	2.29+02	2.09+02	8.58+01	1.16-02	0.00
AG107	0.00	3.60-05	5.88-05	2.65-04	2.32-03	2.29-02	2.29-01	2.28+00	2.18+01	1.45+02	2.31+02	2.31+02
PD108	0.00	1.56+02	1.56+02	1.56+02	1.56+02	1.56+02	1.56+02	1.56+02	1.56+02	1.56+02	1.56+02	1.56+02
CD108	0.00	5.01-07	5.01-07	5.01-07	5.01-07	5.01-07	5.01-07	5.01-07	5.01-07	5.01-07	5.01-07	5.01-07
AG109	0.00	5.97+01	5.97+01	5.97+01	5.97+01	5.97+01	5.97+01	5.97+01	5.97+01	5.97+01	5.97+01	5.97+01
CD109	0.00	1.29-09	7.36-10	4.82-12	6.98-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD110	0.00	3.34+01	3.34+01	3.34+01	3.34+01	3.34+01	3.34+01	3.34+01	3.34+01	3.34+01	3.34+01	3.34+01
AG110M	0.00	5.57-02	2.05-02	2.52-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	8.08-09	2.97-09	3.65-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD110	0.00	4.10+01	4.10+01	4.10+01	4.10+01	4.10+01	4.10+01	4.10+01	4.10+01	4.10+01	4.10+01	4.10+01
CD111	0.00	1.72+01	1.72+01	1.72+01	1.72+01	1.72+01	1.72+01	1.72+01	1.72+01	1.72+01	1.72+01	1.72+01
CD112	0.00	9.33+00	9.33+00	9.33+00	9.33+00	9.33+00	9.33+00	9.33+00	9.33+00	9.33+00	9.33+00	9.33+00
CD113M	0.00	1.98-04	1.89-04	1.21-04	1.41-06	6.31-26	0.00	0.00	0.00	0.00	0.00	0.00
CD113	0.00	2.25-01	2.25-01	2.25-01	2.25-01	2.25-01	2.25-01	2.25-01	2.25-01	2.25-01	2.25-01	2.25-01
IN113	0.00	1.06-05	2.02-05	8.80-05	2.07-04	2.09-04	2.09-04	2.09-04	2.09-04	2.09-04	2.09-04	2.09-04
CD114	0.00	1.23+01	1.23+01	1.23+01	1.23+01	1.23+01	1.23+01	1.23+01	1.23+01	1.23+01	1.23+01	1.23+01
IN114M	0.00	7.19-10	4.55-12	7.44-32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN114	0.00	1.61-06	1.61-06	1.61-06	1.61-06	1.61-06	1.61-06	1.61-06	1.61-06	1.61-06	1.61-06	1.61-06

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
CD115M	0.00	1.70-03	4.71-06	4.63-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN115	0.00	1.23+00	1.23+00	1.23+00	1.23+00	1.23+00	1.23+00	1.23+00	1.23+00	1.23+00	1.23+00	1.23+00
SN115	0.00	1.94-01	1.94-01	1.94-01	1.94-01	1.94-01	1.94-01	1.94-01	1.94-01	1.94-01	1.94-01	1.94-01
CD116	0.00	3.76+00	3.76+00	3.76+00	3.76+00	3.76+00	3.76+00	3.76+00	3.76+00	3.76+00	3.76+00	3.76+00
SN116	0.00	2.73+00	2.73+00	2.73+00	2.73+00	2.73+00	2.73+00	2.73+00	2.73+00	2.73+00	2.73+00	2.73+00
SN117	0.00	3.90+00	3.90+00	3.90+00	3.90+00	3.90+00	3.90+00	3.90+00	3.90+00	3.90+00	3.90+00	3.90+00
SN118	0.00	3.98+00	3.98+00	3.98+00	3.98+00	3.98+00	3.98+00	3.98+00	3.98+00	3.98+00	3.98+00	3.98+00
SN119M	0.00	2.46-03	6.95-04	9.88-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119	0.00	4.12+00	4.12+00	4.12+00	4.12+00	4.12+00	4.12+00	4.12+00	4.12+00	4.12+00	4.12+00	4.12+00
SN120	0.00	4.30+00	4.30+00	4.30+00	4.30+00	4.30+00	4.30+00	4.30+00	4.30+00	4.30+00	4.30+00	4.30+00
SN121M	0.00	3.52-06	3.48-06	3.21-06	1.41-06	3.85-10	0.00	0.00	0.00	0.00	0.00	0.00
SB121	0.00	4.50+00	4.50+00	4.50+00	4.50+00	4.50+00	4.50+00	4.50+00	4.50+00	4.50+00	4.50+00	4.50+00
SN122	0.00	5.04+00	5.04+00	5.04+00	5.04+00	5.04+00	5.04+00	5.04+00	5.04+00	5.04+00	5.04+00	5.04+00
TE122	0.00	3.08-01	3.08-01	3.08-01	3.08-01	3.08-01	3.08-01	3.08-01	3.08-01	3.08-01	3.08-01	3.08-01
SN123M	0.00	5.56-02	7.33-03	8.93-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB123	0.00	5.41+00	5.46+00	5.46+00	5.46+00	5.46+00	5.46+00	5.46+00	5.46+00	5.46+00	5.46+00	5.46+00
TE123M	0.00	2.77-05	3.16-06	1.11-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123	0.00	4.32-04	4.56-04	4.59-04	4.59-04	4.59-04	4.59-04	4.59-04	4.59-04	4.59-04	4.59-04	4.59-04
SN124	0.00	7.51+00	7.51+00	7.51+00	7.51+00	7.51+00	7.51+00	7.51+00	7.51+00	7.51+00	7.51+00	7.51+00
SB124	0.00	4.66-03	7.15-05	2.32-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE124	0.00	1.69-01	1.74-01	1.74-01	1.74-01	1.74-01	1.74-01	1.74-01	1.74-01	1.74-01	1.74-01	1.74-01
SB125	0.00	7.54+00	5.83+00	5.79-01	5.36-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	1.79-01	1.42-01	1.41-02	1.31-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125	0.00	3.55+00	5.29+00	1.07+01	1.13+01	1.13+01	1.13+01	1.13+01	1.13+01	1.13+01	1.13+01	1.13+01
SN126	0.00	1.92+01	1.92+01	1.92+01	1.92+01	1.91+01	1.80+01	9.62+00	1.88-02	1.54-29	0.00	0.00
SB126M	0.00	6.95-09	6.95-09	6.95-09	6.95-09	6.90-09	6.49-09	3.48-09	6.80-12	0.00	0.00	0.00
SB126	0.00	6.69-06	6.52-06	6.52-06	6.52-06	6.47-06	6.08-06	3.26-06	6.38-09	0.00	0.00	0.00
TE126	0.00	4.48-02	4.49-02	4.41-02	5.81-02	1.78-01	1.33+00	9.66+00	1.93+01	1.93+01	1.93+01	1.93+01
TE127M	0.00	6.51-01	6.39-02	5.36-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	2.31-03	2.27-04	1.90-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I127	0.00	3.94+01	4.00+01	4.01+01	4.01+01	4.01+01	4.01+01	4.01+01	4.01+01	4.01+01	4.01+01	4.01+01
TE128	0.00	1.34+02	1.34+02	1.34+02	1.34+02	1.34+02	1.34+02	1.34+02	1.34+02	1.34+02	1.34+02	1.34+02
XE128	0.00	3.01+00	3.01+00	3.01+00	3.01+00	3.01+00	3.01+00	3.01+00	3.01+00	3.01+00	3.01+00	3.01+00
TE129M	0.00	2.21-01	1.29-04	1.03-33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	1.99-04	1.17-07	9.30-37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	2.29+02	2.30+02	2.30+02	2.30+02	2.30+02	2.30+02	2.29+02	2.21+02	1.53+02	3.90+00	4.54-16
XE129	0.00	9.06-02	9.06-02	9.07-02	9.15-02	1.00-01	1.84-01	1.03+00	9.27+00	7.70+01	2.26+02	2.30+02
TE130	0.00	4.25+02	4.25+02	4.25+02	4.25+02	4.25+02	4.25+02	4.25+02	4.25+02	4.25+02	4.25+02	4.25+02
XE130	0.00	1.06+01	1.06+01	1.06+01	1.06+01	1.06+01	1.06+01	1.06+01	1.06+01	1.06+01	1.06+01	1.06+01
XE131	0.00	4.41+02	4.41+02	4.41+02	4.41+02	4.41+02	4.41+02	4.41+02	4.41+02	4.41+02	4.41+02	4.41+02

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
XE132	0.00	1.15+03	1.15+03	1.15+03	1.15+03	1.15+03	1.15+03	1.15+03	1.15+03	1.15+03	1.15+03	1.15+03
CS133	0.00	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03
XE134	0.00	1.54+03	1.54+03	1.54+03	1.54+03	1.54+03	1.54+03	1.54+03	1.54+03	1.54+03	1.54+03	1.54+03
CS134	0.00	1.65+02	1.18+02	5.61+00	3.43-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BA134	0.00	9.36+01	1.41+02	2.53+02	2.58+02	2.58+02	2.58+02	2.58+02	2.58+02	2.58+02	2.58+02	2.58+02
CS135	0.00	3.24+02	3.24+02	3.24+02	3.24+02	3.24+02	3.23+02	3.17+02	2.57+02	3.22+01	3.01-08	0.00
BA135	0.00	3.54-02	3.55-02	3.61-02	4.29-02	1.10-01	7.83-01	7.43+00	6.68+01	2.92+02	3.24+02	3.24+02
XE136	0.00	2.31+03	2.31+03	2.31+03	2.31+03	2.31+03	2.31+03	2.31+03	2.31+03	2.31+03	2.31+03	2.31+03
BA136	0.00	2.50+01	2.50+01	2.50+01	2.50+01	2.50+01	2.50+01	2.50+01	2.50+01	2.50+01	2.50+01	2.50+01
CS137	0.00	1.23+03	1.20+03	9.74+02	1.22+02	1.14-07	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	1.85-04	1.81-04	1.47-04	1.84-05	1.72-14	0.00	0.00	0.00	0.00	0.00	0.00
BA137	0.00	5.49+01	8.29+01	3.08+02	1.16+03	1.28+03	1.28+03	1.28+03	1.28+03	1.28+03	1.28+03	1.28+03
BA138	0.00	1.22+03	1.22+03	1.22+03	1.22+03	1.22+03	1.22+03	1.22+03	1.22+03	1.22+03	1.22+03	1.22+03
LA139	0.00	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03
BA140	0.00	5.92-03	1.53-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	8.91-04	2.30-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE140	0.00	1.31+03	1.31+03	1.31+03	1.31+03	1.31+03	1.31+03	1.31+03	1.31+03	1.31+03	1.31+03	1.31+03
CE141	0.00	1.97+00	7.99-04	2.33-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR141	0.00	1.20+03	1.20+03	1.20+03	1.20+03	1.20+03	1.20+03	1.20+03	1.20+03	1.20+03	1.20+03	1.20+03
CE142	0.00	1.17+03	1.17+03	1.17+03	1.17+03	1.17+03	1.17+03	1.17+03	1.17+03	1.17+03	1.17+03	1.17+03
ND142	0.00	2.08+01	2.08+01	2.08+01	2.08+01	2.08+01	2.08+01	2.08+01	2.08+01	2.08+01	2.08+01	2.08+01
PR143	0.00	1.02-02	9.64-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND143	0.00	8.05+02	8.05+02	8.05+02	8.05+02	8.05+02	8.05+02	8.05+02	8.05+02	8.05+02	8.05+02	8.05+02
CE144	0.00	2.41+02	9.90+01	3.25-02	4.75-37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	1.02-02	4.19-03	1.38-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND144	0.00	1.10+03	1.24+03	1.34+03	1.34+03	1.34+03	1.34+03	1.34+03	1.34+03	1.34+03	1.34+03	1.34+03
ND145	0.00	6.97+02	6.97+02	6.97+02	6.97+02	6.97+02	6.97+02	6.97+02	6.97+02	6.97+02	6.97+02	6.97+02
ND146	0.00	7.02+02	7.02+02	7.02+02	7.02+02	7.02+02	7.02+02	7.02+02	7.02+02	7.02+02	7.02+02	7.02+02
PM147	0.00	1.06+02	8.10+01	7.49+00	3.44-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM147	0.00	6.38+01	8.83+01	1.62+02	1.69+02	1.69+02	1.69+02	1.69+02	1.69+02	1.69+02	1.69+02	1.69+02
ND148	0.00	3.73+02	3.73+02	3.73+02	3.73+02	3.73+02	3.73+02	3.73+02	3.73+02	3.73+02	3.73+02	3.73+02
PM148M	0.00	1.89-02	4.57-05	1.27-28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	1.95-04	4.72-07	1.31-30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM148	0.00	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02
SM149	0.00	6.23+00	6.23+00	6.23+00	6.23+00	6.23+00	6.23+00	6.23+00	6.23+00	6.23+00	6.23+00	6.23+00
ND150	0.00	1.77+02	1.77+02	1.77+02	1.77+02	1.77+02	1.77+02	1.77+02	1.77+02	1.77+02	1.77+02	1.77+02
SM150	0.00	3.19+02	3.19+02	3.19+02	3.19+02	3.19+02	3.19+02	3.19+02	3.19+02	3.19+02	3.19+02	3.19+02
SM151	0.00	4.21+01	4.17+01	3.89+01	1.90+01	1.46-02	1.07-33	0.00	0.00	0.00	0.00	0.00
EU151	0.00	1.92-01	5.26-01	3.41+00	2.33+01	4.23+01	4.23+01	4.23+01	4.23+01	4.23+01	4.23+01	4.23+01
SM152	0.00	9.11+01	9.12+01	9.12+01	9.12+01	9.12+01	9.12+01	9.12+01	9.12+01	9.12+01	9.12+01	9.12+01

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
EU152	0.00	5.80-02	5.48-02	3.26-02	1.80-34	4.82-27	0.00	0.00	0.00	0.00	0.00	0.00
GD152	0.00	1.44-01	1.45-01	1.51-01	1.60-01	1.60-01	1.60-01	1.60-01	1.60-01	1.60-01	1.60-01	1.60-01
EU153	0.00	1.28+02	1.28+02	1.28+02	1.28+02	1.28+02	1.28+02	1.28+02	1.28+02	1.28+02	1.28+02	1.28+02
GD153	0.00	6.32-03	2.22-03	1.81-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM154	0.00	3.69+01	3.69+01	3.69+01	3.69+01	3.69+01	3.69+01	3.69+01	3.69+01	3.69+01	3.69+01	3.69+01
EU154	0.00	4.66+01	4.45+01	3.02+01	6.12-01	7.21-18	0.00	0.00	0.00	0.00	0.00	0.00
GD154	0.00	2.53+00	4.50+00	1.89+01	4.85+01	4.91+01	4.91+01	4.91+01	4.91+01	4.91+01	4.91+01	4.91+01
EU155	0.00	4.96+00	3.36+00	1.06-01	1.17-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD155	0.00	9.15-01	2.49+00	5.76+00	5.87+00	5.87+00	5.87+00	5.87+00	5.87+00	5.87+00	5.87+00	5.87+00
EU156	0.00	3.93-03	1.84-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD156	0.00	8.36+01	8.36+01	8.36+01	8.36+01	8.36+01	8.36+01	8.36+01	8.36+01	8.36+01	8.36+01	8.36+01
GD157	0.00	4.15-02	4.15-02	4.15-02	4.15-02	4.15-02	4.15-02	4.15-02	4.15-02	4.15-02	4.15-02	4.15-02
GD158	0.00	1.34+01	1.34+01	1.34+01	1.34+01	1.34+01	1.34+01	1.34+01	1.34+01	1.34+01	1.34+01	1.34+01
TB159	0.00	1.78+00	1.78+00	1.78+00	1.78+00	1.78+00	1.78+00	1.78+00	1.78+00	1.78+00	1.78+00	1.78+00
GD160	0.00	9.51-01	9.51-01	9.51-01	9.51-01	9.51-01	9.51-01	9.51-01	9.51-01	9.51-01	9.51-01	9.51-01
TB160	0.00	2.63-02	2.01-09	1.52-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DY160	0.00	3.89-01	4.15-01	4.16-01	4.16-01	4.16-01	4.16-01	4.16-01	4.16-01	4.16-01	4.16-01	4.16-01
DY161	0.00	2.31-01	2.31-01	2.31-01	2.31-01	2.31-01	2.31-01	2.31-01	2.31-01	2.31-01	2.31-01	2.31-01
GD162	0.00	7.23-02	3.62-02	7.08-05	5.79-32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	1.03-06	5.16-07	1.01-09	8.26-37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DY162	0.00	1.82-01	2.18-01	2.54-01	2.54-01	2.54-01	2.54-01	2.54-01	2.54-01	2.54-01	2.54-01	2.54-01
DY163	0.00	1.67-01	1.67-01	1.67-01	1.67-01	1.67-01	1.67-01	1.67-01	1.67-01	1.67-01	1.67-01	1.67-01
DY164	0.00	5.39-02	5.39-02	5.39-02	5.39-02	5.39-02	5.39-02	5.39-02	5.39-02	5.39-02	5.39-02	5.39-02
HO165	0.00	8.29-02	8.29-02	8.29-02	8.29-02	8.29-02	8.29-02	8.29-02	8.29-02	8.29-02	8.29-02	8.29-02
HO166M	0.00	4.15-05	4.15-05	4.13-05	3.92-05	2.33-05	1.29-07	3.45-30	0.00	0.00	0.00	0.00
ER166	0.00	2.28-02	2.28-02	2.28-02	2.28-02	2.28-02	2.28-02	2.28-02	2.28-02	2.28-02	2.28-02	2.28-02
ER167	0.00	4.07-03	4.07-03	4.07-03	4.07-03	4.07-03	4.07-03	4.07-03	4.07-03	4.07-03	4.07-03	4.07-03
SUBTOT	0.00	3.49+04	3.49+04	3.49+04	3.49+04	3.49+04	3.49+04	3.49+04	3.49+04	3.49+04	3.49+04	3.49+04
TOTAL	0.00	3.49+04	3.49+04	3.49+04	3.49+04	3.49+04	3.49+04	3.49+04	3.49+04	3.49+04	3.49+04	3.49+04

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	6.92+02	6.54+02	3.94+02	2.47+00	2.35-22	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	3.98-01	3.98-01	3.98-01	3.98-01	3.94-01	3.58-01	1.37-01	9.34-06	0.00	0.00	0.00
KR 85	0.00	1.11+04	1.04+04	5.83+03	1.81+01	1.50-24	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	1.90+00	2.51-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	1.96-05	1.96-05	1.96-05	1.96-05	1.96-05	1.96-05	1.96-05	1.96-05	1.96-05	1.96-05	1.94-05
SR 89	0.00	9.72+04	7.48+02	7.05-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	7.68+04	7.50+04	6.01+04	6.53+03	1.50-06	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	7.69+04	7.50+04	6.01+04	6.53+03	1.50-06	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	1.61+05	2.18+03	3.26-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	1.89+00	1.89+00	1.89+00	1.89+00	1.89+00	1.88+00	1.80+00	1.19+00	1.86-02	1.63-20	0.00
NB 93M	0.00	1.81-01	2.65-01	8.62-01	1.88+00	1.89+00	1.88+00	1.80+00	1.19+00	1.86-02	1.63-20	0.00
ZR 95	0.00	2.77+05	5.65+03	3.40-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	5.88+03	1.20+02	7.21-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	5.20+05	1.25+04	7.37-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	1.43+01	1.43+01	1.43+01	1.43+01	1.43+01	1.39+01	1.03+01	5.46-01	9.12-14	0.00	0.00
RU103	0.00	8.83+04	1.48+02	1.54-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	8.83+04	1.48+02	1.54-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	4.10+05	2.06+05	4.15+02	4.58-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	4.10+05	2.06+05	4.15+02	4.58-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	1.10-01	1.10-01	1.10-01	1.10-01	1.10-01	1.10-01	1.09-01	9.99-02	4.10-02	5.54-06	0.00
AG109M	0.00	3.41-06	1.95-06	1.28-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	3.41-06	1.95-06	1.28-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	2.61+02	9.61+01	1.18-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	3.40+01	1.25+01	1.54-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	4.49-02	4.27-02	2.73-02	3.18-04	1.43-23	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	1.65-05	1.04-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	1.59-05	1.01-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	4.48+01	1.25-01	1.22-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	1.08+01	3.93+00	4.34-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	1.37-04	1.35-04	1.25-04	5.49-05	1.50-08	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	4.72+02	6.23+01	7.58-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	2.51-01	2.89-02	1.01-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	8.53+01	1.26+00	4.08-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SE125	0.00	7.99+03	6.18+03	6.14+02	5.70-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	3.22+03	2.56+03	2.54+02	2.36-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	5.46-01	5.46-01	5.46-01	5.46-01	5.42-01	5.10-01	2.73-01	5.34-04	0.00	0.00	0.00
SB126M	0.00	5.46-01	5.46-01	5.46-01	5.46-01	5.42-01	5.10-01	2.73-01	5.34-04	0.00	0.00	0.00
SB126	0.00	5.55-01	5.41-01	5.41-01	5.40-01	5.37-01	5.05-01	2.70-01	5.29-04	0.00	0.00	0.00
TE127M	0.00	6.15+03	6.03+02	5.06-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	6.08+03	5.96+02	5.00-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE129M	0.00	6.57+03	3.84+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	4.21+03	2.46+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	3.74-02	3.75-02	3.75-02	3.75-02	3.75-02	3.74-02	3.73-02	3.60-02	2.49-02	6.36-04	7.41-20
XE131M	0.00	1.31+01	6.43-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	2.15+05	1.53+05	7.30+03	4.47-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	2.86-01	2.86-01	2.86-01	2.86-01	2.86-01	2.85-01	2.80-01	2.27-01	2.84-02	2.66-11	0.00
CS136	0.00	2.05+01	7.16-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS137	0.00	1.07+05	1.04+05	9.48+04	1.06+04	9.92-06	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	9.99+04	9.76+04	7.93+04	9.91+03	9.27-06	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	4.31+02	1.11-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	4.96+02	1.28-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	5.64+04	2.29+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	6.79+02	6.43-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	7.71+05	3.16+05	1.04+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	7.71+05	3.16+05	1.04+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	5.04+01	6.29-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	9.80+04	7.52+04	6.96+03	3.19-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM146M	0.00	3.98+02	9.63-01	2.67-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	3.19+01	7.71-02	2.15-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	1.15+03	1.14+03	1.06+03	5.17+02	3.96-01	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	1.14+01	1.07+01	6.36+00	3.53-02	9.45-25	0.00	0.00	0.00	0.00	0.00	0.00
GD153	0.00	2.23+01	7.63+00	6.39-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	6.76+03	6.47+03	4.38+03	8.89+01	1.05-15	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	5.32+03	4.31+03	1.37+02	1.49-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	2.19+02	1.03-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	3.03+02	9.07+00	1.72-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	1.60+02	7.98+01	1.56-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	1.60+02	7.98+01	1.56-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HO166M	0.00	7.45-05	7.45-05	7.41-05	7.03-05	4.18-05	2.31-07	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	4.39+06	1.66+06	3.12+05	3.42+04	2.09+01	1.99+01	1.53+01	3.29+00	1.32-01	6.61-04	1.94-05
TOTAL	0.00	4.39+06	1.68+06	3.12+05	3.42+04	2.09+01	1.99+01	1.53+01	3.29+00	1.32-01	6.61-04	1.94-05

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	2.46-02	2.33-02	1.40-02	8.80-05	8.37-27	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	1.51-04	1.51-04	1.51-04	1.51-04	1.50-04	1.36-04	5.21-05	3.54-09	0.00	0.00	0.00
KR 85	0.00	1.80+01	1.69+01	9.47+00	2.94-02	2.44-27	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	8.96-03	1.19-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	1.28-08	1.28-08	1.28-08	1.28-08	1.28-08	1.28-08	1.28-08	1.28-08	1.28-08	1.28-08	1.26-08
SR 89	0.00	3.50+02	2.69+00	2.54-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	1.01+02	9.82+01	7.87+01	8.55+00	1.96-09	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	4.53+02	4.41+02	3.54+02	3.84+01	8.81-09	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	6.14+02	8.29+00	1.24-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	2.24-04	2.24-04	2.24-04	2.24-04	2.24-04	2.23-04	2.14-04	1.41-04	2.20-06	1.93-24	0.00
NB 93M	0.00	3.21-05	4.72-05	1.53-04	3.34-04	3.35-04	3.34-04	3.20-04	2.11-04	3.31-06	2.89-24	0.00
ZR 95	0.00	1.45+03	2.95+01	1.78-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	8.20+00	1.67-01	1.00-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	2.50+03	6.01+01	3.55-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	9.69-03	9.69-03	9.69-03	9.68-03	9.66-03	9.38-03	6.99-03	3.69-04	6.16-17	0.00	0.00
RU103	0.00	2.91+02	4.88-01	5.07-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	4.19+01	7.02-02	7.30-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	2.43+01	1.22+01	2.46-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	4.31+03	2.16+03	4.36+00	4.81-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	9.15-06	9.15-06	9.15-06	9.15-06	9.15-06	9.15-06	9.06-06	8.29-06	3.40-06	4.59-10	0.00
AG109M	0.00	3.55-09	2.03-09	1.33-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	3.39-09	1.94-09	1.27-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	4.42+00	1.62+00	2.00-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	2.47-01	9.07-02	1.11-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	5.93-05	5.64-05	3.61-05	4.20-07	1.69-26	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	1.78-08	1.13-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	7.49-08	4.74-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	1.64-01	4.56-04	4.48-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	1.14-02	4.15-03	4.58-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	1.73-07	1.72-07	1.58-07	6.97-08	1.90-11	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	1.67+00	2.21-01	2.68-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	7.38-04	8.48-05	2.97-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	1.17+00	1.73-02	5.60-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	3.24+01	2.51+01	2.49+00	2.31-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	5.53+00	4.40+00	4.37-01	4.06-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	5.89-04	5.89-04	5.89-04	5.89-04	5.85-04	5.50-04	2.95-04	5.76-07	0.00	0.00	0.00
SB126M	0.00	3.69-03	3.69-03	3.69-03	3.69-03	3.67-03	3.45-03	1.85-03	3.61-06	0.00	0.00	0.00
SB126	0.00	7.22-03	7.04-03	7.04-03	7.03-03	6.99-03	6.56-03	3.52-03	6.88-06	0.00	0.00	0.00
TE127M	0.00	3.39+00	3.32-01	2.79-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	9.80+00	9.61-01	8.06-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE129M	0.00	1.31+01	7.63-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	1.53+01	8.95-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	2.46-05	2.46-05	2.46-05	2.46-05	2.46-05	2.46-05	2.45-05	2.37-05	1.64-05	4.18-07	4.88-23
XE131M	0.00	2.55-02	1.25-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	2.27+03	1.62+03	7.74+01	4.74-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	1.39-04	1.39-04	1.39-04	1.39-04	1.39-04	1.39-04	1.36-04	1.10-04	1.38-05	1.29-14	0.00
CS136	0.00	2.81-01	9.83-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS137	0.00	1.75+02	1.71+02	1.39+02	1.73+01	1.62-08	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	3.92+02	3.83+02	3.11+02	3.90+01	3.64-08	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	1.44+00	3.72-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	8.75+00	2.26-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	1.11+02	4.50-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	1.47+00	1.39-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	6.31+02	2.59+02	8.56-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	5.97+03	2.45+03	8.04-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	1.64-01	2.09-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	5.05+01	3.86+01	3.59+00	1.65-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	4.93+00	1.19-02	3.31-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	2.59-01	6.25-04	1.74-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	2.00+00	1.98+00	1.84+00	9.00-01	6.93-04	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	2.04-01	1.92-01	1.14-01	6.33-04	1.69-26	0.00	0.00	0.00	0.00	0.00	0.00
GD153	0.00	3.21-02	1.13-02	9.21-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	5.55+01	5.31+01	3.60+01	7.29-01	6.58-16	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	5.32+00	3.63+00	1.16-01	1.25-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	2.16+00	1.02-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	2.56+00	7.70-02	1.46-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	5.43-01	2.72-01	5.31-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	2.15+00	1.08+00	2.11-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HO166M	0.00	8.01-07	8.01-07	7.97-07	7.56-07	4.50-07	2.49-09	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	1.99+04	7.85+03	1.02+03	1.05+02	2.25-02	2.08-02	1.34-02	8.74-04	3.91-05	4.32-07	1.26-08
TOTAL	0.00	1.99+04	7.85+03	1.02+03	1.05+02	2.25-02	2.08-02	1.34-02	8.74-04	3.91-05	4.32-07	1.26-08

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	3.46+09	3.27+09	1.97+09	1.24+07	1.18-15	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	9.96+07	9.96+07	9.96+07	9.95+07	9.86+07	8.95+07	3.43+07	2.33+03	0.00	0.00	0.00
KR 85	0.00	3.69+10	3.46+10	1.94+10	6.04+07	5.02-16	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	9.49+08	1.26+03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	9.82+03	9.82+03	9.82+03	9.82+03	9.82+03	9.82+03	9.82+03	9.82+03	9.82+03	9.81+03	9.69+03
SR 89	0.00	3.24+14	2.49+12	2.35-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	2.56+15	2.50+15	2.00+15	2.18+14	4.99+04	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	2.56+13	2.50+13	2.00+13	2.18+12	4.99+02	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	1.61+14	2.18+12	3.26-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	4.72+08	4.72+08	4.72+08	4.72+08	4.71+08	4.70+08	4.50+08	2.97+08	4.65+06	4.07-12	0.00
NB 93M	0.00	4.51+07	6.63+07	2.15+08	4.69+08	4.71+08	4.70+08	4.50+08	2.97+08	4.65+06	4.07-12	0.00
ZR 95	0.00	2.77+14	5.65+12	3.40-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	-5.86+03	-1.20+02	-7.21-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	1.73+14	4.16+12	2.46-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	7.17+09	7.17+09	7.17+09	7.17+09	7.14+09	6.94+09	5.17+09	2.73+08	4.56-05	0.00	0.00
RU103	0.00	2.94+13	4.93+10	5.13-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	4.42+10	7.40+07	7.70-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	2.05+15	1.03+15	2.07+12	2.29-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	-4.10+05	-2.06+05	-4.15+02	-4.56-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	5.52+05	5.52+05	5.52+05	5.52+05	5.52+05	5.51+05	5.46+05	5.00+05	2.05+05	2.77+01	0.00
AG109M	0.00	-3.41-06	-1.95-06	-1.28-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	1.70+03	9.74+02	6.38+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	8.71+11	3.20+11	3.94+07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	-3.40+01	-1.25+01	-1.54-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	-4.49-02	-4.27-02	-2.73-02	-3.18-04	-1.43-23	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	2.35+04	1.49+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	-1.59-05	-1.01-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	4.48+10	1.25+08	1.22-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN117M	0.00	-2.89-05	-4.06-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	-1.08+01	-3.93+00	-4.34-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	-1.37-04	-1.35-04	-1.25-04	-5.49-05	-1.50-08	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	-4.72+02	-6.23+01	-7.58-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	-2.51-01	-2.89-02	-1.61-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	1.22+11	1.79+09	5.82-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	8.88+12	6.87+12	6.82+11	6.33+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	8.04+11	6.40+11	6.36+10	5.90+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	2.73+08	2.73+06	2.73+08	2.73+08	2.71+08	2.55+08	1.37+08	2.67+05	0.00	0.00	0.00
SB126M	0.00	-5.46-01	-5.46-01	-5.46-01	-5.46-01	-5.42-01	-5.10-01	-2.73-01	-5.34-04	0.00	0.00	0.00
SB126	0.00	-5.55-01	-5.41-01	-5.41-01	-5.40-01	-5.37-01	-5.05-01	-2.70-01	-5.29-04	0.00	0.00	0.00
TE127M	0.00	6.15+12	6.03+11	5.06+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.M*D, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE127	0.00	2.03+11	1.99+10	1.67+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129M	0.00	6.57+12	3.84+09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	4.21+10	2.46+07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	1.87+09	1.87+09	1.87+09	1.87+09	1.87+09	1.87+09	1.87+09	1.80+09	1.25+09	3.18+07	3.71-09
XE129M	0.00	-2.64-05	-5.16-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I131	0.00	1.19+11	2.62-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XE131M	0.00	3.28+07	1.61-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	5.36+14	3.83+14	1.83+13	1.12+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	9.54+07	9.54+07	9.54+07	9.54+07	9.53+07	9.51+07	9.32+07	7.57+07	9.47+06	8.86-03	0.00
CS136	0.00	3.41+09	1.19+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS137	0.00	2.14+14	2.09+14	1.70+14	2.12+13	1.98+04	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	-9.99+04	-9.76+04	-7.93+04	-9.91+03	-9.27-06	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	4.31+11	1.11+03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	1.24+11	3.20+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	1.13+13	4.57+09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	1.13+11	1.07+03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	3.26+15	1.58+15	5.19+11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	-7.71+05	-3.16+05	-1.04+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	6.30+09	7.87-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	4.90+13	3.76+13	3.48+12	1.60+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	-3.98+02	-9.60-01	-2.67-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	-3.19+01	-7.71-02	-2.15-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	5.73+11	5.68+11	5.29+11	2.58+11	1.99+08	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	2.84+10	2.68+10	1.60+10	8.83+07	2.36-15	0.00	0.00	0.00	0.00	0.00	0.00
GD153	0.00	7.43+09	2.61+09	2.13+05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	6.76+13	6.47+13	4.38+13	8.89+11	1.05-05	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	2.11+12	1.44+12	4.58+10	4.96-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	-2.19+02	-1.03-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	3.03+11	9.07+09	1.72-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB161	0.00	-1.83-04	-2.14-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	-1.60+02	-7.98+01	-1.56-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	-1.60+02	-7.98+01	-1.56-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HO166M	0.00	3.73+04	3.72+04	3.70+04	3.52+04	2.09+04	1.16+02	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	1.04+16	5.85+15	2.26+15	2.42+14	1.06+10	1.02+10	8.20+09	2.74+09	1.27+09	3.18+07	9.69+03
TOTAL	0.00	1.04+16	5.85+15	2.26+15	2.42+14	1.06+10	1.02+10	8.20+09	2.74+09	1.27+09	3.18+07	9.69+03

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	2.31+05	2.18+05	1.31+05	8.25+02	7.84-20	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	9.96+01	9.96+01	9.96+01	9.95+01	9.86+01	8.95+01	3.43+01	2.33-03	0.00	0.00	0.00
KR 85	0.00	-1.11+04	-1.04+04	-5.83+03	-1.81+01	-1.50-24	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	9.49+04	1.26-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	1.96-01	1.96-01	1.96-01	1.96-01	1.96-01	1.96-01	1.96-01	1.96-01	1.96-01	1.96-01	1.94-01
SR 89	0.00	3.24+10	2.49+08	2.35-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	2.56+11	2.50+11	2.00+11	2.16+10	4.99+00	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	3.85+09	3.75+09	3.00+09	3.26+08	7.49-02	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	5.38+09	7.26+07	1.09-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	2.36+03	2.36+03	2.36+03	2.36+03	2.36+03	2.35+03	2.25+03	1.49+03	2.32+01	2.03-17	0.00
NB 93M	0.00	4.51+02	6.63+02	2.15+03	4.69+03	4.71+03	4.70+03	4.50+03	2.97+03	4.65+01	4.07-17	0.00
ZR 95	0.00	4.62+09	9.41+07	5.66-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	-5.88+03	-1.20+02	-7.21-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	5.20+09	1.25+08	7.37-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	7.17+04	7.17+04	7.17+04	7.17+04	7.14+04	6.94+04	5.17+04	2.73+03	4.56-10	0.00	0.00
RU103	0.00	1.10+09	1.85+06	1.92-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	8.83+06	1.48+04	1.54-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	4.10+10	2.06+10	4.15+07	4.58-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	-4.10+05	-2.06+05	-4.15+02	-4.58-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	1.10+02	1.10+02	1.10+02	1.10+02	1.10+02	1.10+02	1.09+02	9.99+01	4.10+01	5.54-03	0.00
AG109M	0.00	-3.41-06	-1.95-06	-1.28-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	1.70-02	9.74-03	6.38-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	8.71+06	3.20+06	3.94+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	-3.40+01	-1.25+01	-1.54-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	-4.49-02	-4.27-02	-2.73-02	-3.18-04	-1.43-23	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	8.24-01	5.22-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	-1.59-05	-1.01-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	1.49+06	4.15+03	4.08-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN117M	0.00	-2.89-05	-4.06-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	-1.08+01	-3.93+00	-4.34-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	-1.37-04	-1.35-04	-1.25-04	-5.49-05	-1.50-08	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	-4.72+02	-6.23+01	-7.58-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	-2.51-01	-2.89-02	-1.01-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	4.27+06	6.28+04	2.04-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN125	0.00	1.06+04	2.15-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	7.99+07	6.18+07	6.14+06	5.70-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	3.22+07	2.56+07	2.54+06	2.36-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	1.37+03	1.37+03	1.37+03	1.36+03	1.36+03	1.27+03	6.83+02	1.34+00	0.00	0.00	0.00
SB126M	0.00	-5.46-01	-5.46-01	-5.46-01	-5.46-01	-5.42-01	-5.10-01	-2.73-01	-5.34-04	0.00	0.00	0.00
SB126	0.00	-5.55-01	-5.41-01	-5.41-01	-5.40-01	-5.37-01	-5.05-01	-2.70-01	-5.29-04	0.00	0.00	0.00

REFERENCE PWR 3.3 PERCENT ENRICHED U PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 2.92+13N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT OF U CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE127M	0.00	1.23+08	1.21+07	1.01-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	3.04+07	2.98+06	2.50-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129M	0.00	3.29+08	1.92+05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	5.27+06	3.08+03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	6.24+05	6.24+05	6.24+05	6.24+05	6.24+05	6.24+05	6.22+05	5.99+05	4.15+05	1.06+04	1.24-12
XE129M	0.00	-2.64-05	-5.16-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I131	0.00	3.96+07	8.75-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XE131M	0.00	-1.31+01	-6.43-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XE133	0.00	-5.33-03	-7.38-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	2.36+10	1.70+10	8.11+08	4.97-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	2.86+03	2.86+03	2.86+03	2.86+03	2.86+03	2.85+03	2.80+03	2.27+03	2.84+02	2.66-07	0.00
CS136	0.00	3.41+05	1.19-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS137	0.00	5.34+09	5.22+09	4.24+09	5.30+08	4.96-01	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	-9.99+04	-9.76+04	-7.93+04	-9.91+03	-9.27-06	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	2.16+07	5.57-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	2.48+07	6.41-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	6.27+08	2.54+05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	1.36+07	1.29-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	7.71+10	3.16+10	1.04+07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	-7.71+05	-3.16+05	-1.04+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	8.39+05	1.05-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	4.90+08	3.76+08	3.48+07	1.60-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	-3.96+02	-9.60-01	-2.67-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	-3.19+01	-7.71-02	-2.15-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	2.86+06	2.84+06	2.64+06	1.29+06	9.94+02	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	1.42+05	1.34+05	7.98+04	4.41+02	1.10-20	0.00	0.00	0.00	0.00	0.00	0.00
GD153	0.00	1.11+05	3.92+04	3.20+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	3.38+08	3.24+08	2.19+08	4.44+06	5.23-11	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	3.16+07	2.15+07	6.87+05	7.44-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	-2.19+02	-1.03-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	7.58+06	2.27+05	4.30-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB161	0.00	-1.83-04	-2.14-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	-1.60+02	-7.98+01	-1.56-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	-1.60+02	-7.98+01	-1.56-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HO166M	0.00	1.49-03	1.49-03	1.48-03	1.41-03	8.36-04	4.63-06	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	4.56+11	3.29+11	2.09+11	2.26+10	7.08+05	7.05+05	6.84+05	6.09+05	4.16+05	1.06+04	1.94-01
TOTAL	0.00	4.58+11	3.29+11	2.09+11	2.26+10	7.08+05	7.05+05	6.84+05	6.09+05	4.16+05	1.06+04	1.94-01

APPENDIX 2.D

LWR-PLANT WASTE, PU FUEL FRACTION

(Power 30 MW/MT, Burnup 33,000 MWD/MT,
Spent Fuel Processed 150 Days After
Discharge with 0.5% Fuel Loss to Waste)

LWR PLANT WASTE, PU FUEL FRACTION

Summary Tables

THERMAL POWER

WATTS PER METRIC TON OF FUEL

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	8.25E+01	1.01E+01	2.57E+00	1.11E-04	1.38E-05	9.78E-06	9.65E-06	9.26E-06	6.12E-06	9.70E-08	9.78E-26	.00E+00
STRONTIUM	5.77E+02	3.23E+02	2.57E+02	2.79E+01	1.45E-03	6.41E-09	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00
CESIUM	2.75E+03	2.12E+03	5.39E+02	5.81E+01	5.92E-03	2.40E-04	2.40E-04	2.35E-04	1.91E-04	2.39E-05	2.27E-14	.00E+00
SR+CS	3.33E+03	2.44E+03	7.95E+02	8.61E+01	7.37E-03	2.40E-04	2.40E-04	2.35E-04	1.91E-04	2.39E-05	2.27E-14	.00E+00
FP-SR-CS	1.72E+04	6.22E+03	7.90E+01	2.29E+00	5.92E-02	1.20E-02	1.07E-02	7.82E-03	5.44E-04	3.28E-05	6.11E-07	7.66E-23
KR85+I129	1.12E+01	1.05E+01	5.90E+00	1.86E-02	3.57E-05	3.57E-05	3.56E-05	3.55E-05	3.42E-05	2.37E-05	6.10E-07	7.66E-23
FISSION PROD.	2.05E+04	8.67E+03	8.74E+02	8.83E+01	6.66E-02	1.22E-02	1.10E-02	8.05E-03	7.35E-04	5.67E-05	6.11E-07	7.66E-23
U+TH WASTE	3.63E-04	3.63E-04	3.63E-04	3.63E-04	3.63E-04	3.63E-04	3.64E-04	3.76E-04	4.13E-04	4.14E-04	4.03E-04	3.48E-04
PU FUEL WASTE	5.19E+00	5.29E+00	5.96E+00	6.07E+00	3.80E+00	2.94E+00	9.92E-01	1.98E-02	9.68E-03	4.82E-03	3.64E-04	9.23E-06
TRANS PU	1.03E+04	3.50E+03	1.22E+03	9.85E+01	2.88E+01	1.82E+01	5.43E+00	3.69E-01	1.12E-01	6.77E-03	4.38E-04	1.59E-04
TOTAL WASTE	3.09E+04	1.22E+04	2.10E+03	1.93E+02	3.27E+01	2.11E+01	6.43E+00	3.97E-01	1.22E-01	1.21E-02	1.21E-03	5.16E-04

RADIOACTIVITY

CURIES PER METRIC TON OF FUEL
(PARENTS AND DAUGHTERS IN CHAINS ARE INCLUDED IN TOTALS)

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	1.53E+04	9.05E+02	1.68E+02	6.14E-01	1.14E-01	8.89E-02	8.74E-02	8.06E-02	5.13E-02	8.14E-04	8.21E-22	.00E+00
STRONTIUM	1.60E+05	8.96E+04	7.13E+04	7.75E+03	4.03E-01	1.78E-06	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00
CESIUM	4.25E+05	3.61E+05	1.82E+05	2.19E+04	2.63E+00	4.95E-01	4.94E-01	4.83E-01	3.93E-01	4.92E-02	4.67E-11	.00E+00
SR+CS	5.85E+05	4.51E+05	2.53E+05	2.97E+04	3.04E+00	4.95E-01	4.94E-01	4.83E-01	3.93E-01	4.92E-02	4.67E-11	.00E+00
FP-SR-CS	3.78E+06	1.36E+06	2.19E+04	8.25E+02	4.50E+01	1.80E+01	1.69E+01	1.27E+01	1.72E+00	1.36E-01	9.39E-04	1.16E-19
KR85+I129	6.89E+03	6.46E+03	3.63E+03	1.15E+01	5.42E-02	5.42E-02	5.42E-02	5.40E-02	5.20E-02	3.61E-02	9.27E-04	1.16E-19
FISSION PROD.	4.37E+06	1.81E+06	2.75E+05	3.05E+04	4.80E+01	1.85E+01	1.74E+01	1.32E+01	2.12E+00	1.85E-01	9.39E-04	1.16E-19
U+TH WASTE	2.40E-02	2.40E-02	2.40E-02	2.40E-02	2.39E-02	2.39E-02	2.40E-02	2.47E-02	2.69E-02	2.70E-02	2.64E-02	2.28E-02
PU FUEL WASTE	2.46E+03	2.35E+03	1.62E+03	2.07E+02	8.75E+01	4.45E+01	5.83E+00	5.85E-01	1.64E-01	1.02E-02	1.47E-03	5.60E-04
TRANS PU	2.84E+05	9.88E+04	3.61E+04	3.91E+03	1.38E+03	7.78E+02	1.69E+02	1.80E+01	6.82E+00	3.97E-01	2.53E-02	9.68E-03
TOTAL WASTE	4.67E+06	1.92E+06	3.13E+05	3.46E+04	1.52E+03	8.41E+02	1.92E+02	3.19E+01	9.18E+00	6.20E-01	5.41E-02	3.31E-02

INGESTION TOXICITY

THE INGESTION TOXICITY INDEX IS THE BASE 10 LOGARITHM OF THE
CUBIC METERS OF WATER PER TON OF FUEL TO DILUTE TO RCG

TIME,YEARS SINCE SEPARATION	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	8.30	7.34	6.74	4.25	3.09	2.57	2.56	2.53	2.33	.53	*****	*****
STRONTIUM	11.24	11.17	11.07	10.11	5.83	.47	*****	*****	*****	*****	*****	*****
CESIUM	10.45	10.33	9.71	8.74	4.77	3.69	3.69	3.68	3.59	2.69	-6.33	*****
SR+CS	11.31	11.23	11.09	10.13	5.86	3.69	3.69	3.68	3.59	2.69	-6.33	*****
FP-SR-CS	11.17	10.80	8.66	6.97	6.02	5.99	5.99	5.98	5.94	5.78	4.19	*****
KR85+I129	5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.95	5.94	5.78	4.19	*****
FISSION PROD.	11.54	11.37	11.09	10.13	6.25	6.00	5.99	5.98	5.94	5.78	4.19	*****
U-TH FUEL WASTE	4.76	4.76	4.76	4.76	4.76	4.76	4.76	4.78	4.83	4.83	4.82	4.76
PU FUEL WASTE	7.46	7.47	7.49	7.44	7.11	6.87	6.35	5.97	4.97	3.20	2.52	2.13
TRANS PU	10.28	9.98	9.72	8.77	8.35	8.17	7.73	7.21	6.36	4.84	3.75	3.37
TOTAL WASTE	11.57	11.38	11.11	10.15	8.38	8.19	7.76	7.26	6.52	5.87	4.95	4.78

***** TOXICITY INDEX IS LESS THAN -10
RCG IS RADIONUCLIDE CONCENTRATION GUIDE BASED UPON 10 CFR 20

INHALATION TOXICITY

THE INHALATION TOXICITY INDEX IS THE BASE 10 LOGARITHM OF THE
CUBIC METERS OF AIR TO DILUTE TO RCG PER METRIC TON OF FUEL

TIME,YEARS SINCE SEPARATION	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	13.02	12.30	11.74	8.49	7.76	7.64	7.64	7.62	7.44	5.64	*****	*****
STRONTIUM	15.24	15.17	15.07	14.11	9.83	4.47	*****	*****	*****	*****	*****	*****
CESIUM	14.86	14.76	14.28	13.34	9.36	8.22	8.22	8.21	8.12	7.21	-1.81	*****
SR+CS	15.39	15.32	15.14	14.18	9.96	8.22	8.22	8.21	8.12	7.21	-1.81	*****
FP-SR-CS	15.87	15.51	13.87	12.23	10.40	10.06	10.04	9.95	9.53	9.26	7.67	-8.23
KR85+I129	10.41	10.38	10.17	9.44	9.43	9.43	9.43	9.43	9.42	9.26	7.67	-8.23
FISSION PROD.	15.99	15.72	15.16	14.18	10.53	10.07	10.05	9.96	9.54	9.26	7.67	-8.23
U-TH FUEL WASTE	10.30	10.30	10.30	10.29	10.29	10.29	10.30	10.31	10.35	10.36	10.35	10.28
PU FUEL WASTE	15.31	15.31	15.26	15.01	14.59	14.42	13.96	12.64	11.52	10.14	9.60	9.21
TRANS PU	17.35	17.27	17.12	16.29	15.78	15.61	15.23	14.09	13.45	12.19	10.83	10.45
TOTAL WASTE	17.37	17.28	17.13	16.31	15.80	15.64	15.25	14.10	13.45	12.20	10.97	10.69

***** TOXICITY INDEX IS LESS THAN -10
RCG IS RADIONUCLIDE CONCENTRATION GUIDE BASED UPON 10 CFR 20

LWR-PLANT WASTE, Pu FUEL FRACTION

Actinides

PLUTONIUM FUEL FRACTION IN A PWR 3.58 ENR, PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
HE 4	0.00	9.63+00	1.09+01	1.41+01	2.21+01	2.91+01	4.65+01	7.30+01	9.62+01	1.48+02	1.77+02	3.23+02
PB207	0.00	1.05-10	2.60-10	4.75-09	1.81-07	2.55-06	5.35-05	2.58-02	7.78-01	8.40+00	8.10+01	5.43+02
PB208	0.00	2.92-07	5.82-07	1.31-06	2.39-06	3.17-06	3.18-06	6.53-06	3.77-04	3.47-02	1.77+00	2.49+01
PB210	0.00	2.36-12	4.72-12	6.54-11	1.32-08	8.26-06	3.71-04	2.91-03	5.45-04	1.92-05	1.89-05	1.65-05
PB212	0.00	6.02-10	4.31-10	4.26-11	1.33-11	2.31-15	5.13-15	1.27-13	1.33-12	1.18-11	4.42-11	4.47-11
BI209	0.00	1.43-11	1.76-11	5.00-11	3.15-09	4.47-06	6.84-03	2.50+00	1.05+02	4.60+02	4.81+02	4.81+02
BI212	0.00	5.74-11	4.10-11	4.06-12	1.26-12	2.20-16	4.89-16	1.21-14	1.27-13	1.12-12	4.21-12	4.26-12
RA223	0.00	5.47-12	9.58-12	3.78-11	1.18-10	1.34-10	5.30-10	2.77-08	4.13-08	4.09-08	3.75-08	1.56-08
RA224	0.00	5.25-09	3.75-09	3.71-10	1.16-10	2.01-14	4.47-14	1.11-12	1.16-11	1.03-10	3.85-10	3.89-10
RA226	0.00	4.93-09	7.42-09	3.19-08	2.09-06	6.78-04	3.04-02	2.39-01	4.47-02	1.58-03	1.55-03	1.35-03
AC227	0.00	4.16-09	6.74-09	2.66-08	8.31-08	9.43-08	3.73-07	1.95-05	2.91-05	2.88-05	2.64-05	1.10-05
TH227	0.00	9.02-12	1.53-11	6.05-11	1.89-10	2.14-10	8.48-10	4.43-08	6.61-08	6.55-08	6.00-08	2.49-08
TH228	0.00	1.04-06	7.28-07	7.21-08	2.25-08	4.03-12	8.71-12	2.16-10	2.26-09	2.00-08	7.50-08	7.60-08
TH229	0.00	3.80-08	3.81-08	4.75-08	1.04-06	1.71-04	2.29-02	6.06-01	1.38+00	7.03-02	1.55-14	0.00
TH230	0.00	2.92-04	2.93-04	3.68-04	6.48-03	1.95-01	1.99+00	1.21+01	2.27+00	8.02-02	7.90-02	6.88-02
TH231	0.00	1.22-08	6.12-11	6.13-11	6.19-11	7.21-11	4.45-10	3.73-09	4.00-09	3.96-09	3.63-09	1.51-09
TH232	0.00	4.57-05	4.58-05	4.69-05	6.27-05	9.75-04	6.55-02	1.62+00	1.70+01	1.51+02	5.63+02	5.71+02
TH234	0.00	1.34-05	6.74-08	6.70-08	6.70-08	6.71-08	6.71-08	6.71-08	6.73-08	6.73-08	6.63-08	5.78-08
PA231	0.00	1.32-04	1.32-04	1.32-04	1.33-04	1.44-04	5.71-04	2.98-02	4.45-02	4.41-02	4.04-02	1.68-02
PA233	0.00	4.51-06	4.54-06	4.70-06	6.29-06	1.43-05	1.76-05	1.81-05	1.36-05	7.35-07	1.62-19	0.00
PA234M	0.00	4.52-10	2.27-12	2.26-12	2.26-12	2.26-12	2.26-12	2.26-12	2.27-12	2.27-12	2.24-12	1.95-12
U232	0.00	6.77-07	9.85-07	1.87-06	8.42-07	1.46-10	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	9.86-06	5.62-05	4.40-04	5.02-03	9.79-02	1.50+00	1.36+01	3.11+01	1.59+00	3.78-13	0.00
U234	5.34+01	2.15-01	5.11-01	5.43+00	4.00+01	7.67+01	7.49+01	5.82+01	4.89+00	2.52-01	2.48-01	2.16-01
U235	6.77+03	1.51+01	1.51+01	1.52+01	1.53+01	1.78+01	1.10+02	9.21+02	9.89+02	9.80+02	8.98+02	3.73+02
U236	0.00	4.01+00	4.01+00	4.14+00	8.70+00	6.16+01	3.91+02	6.07+02	5.91+02	4.56+02	3.35+01	1.56-10
U237	0.00	7.21-07	6.85-07	4.51-07	9.60-09	2.79-09	1.43-09	1.77-12	0.00	0.00	0.00	0.00
U238	9.53+05	4.66+03	4.66+03	4.66+03	4.66+03	4.66+03	4.66+03	4.66+03	4.68+03	4.68+03	4.61+03	4.02+03
NP237	0.00	1.31+02	1.32+02	1.36+02	1.83+02	4.14+02	5.12+02	5.27+02	3.93+02	2.13+01	4.70-12	0.00
NP239	0.00	7.88-04	7.88-04	7.87-04	7.81-04	7.20-04	3.18-04	9.17-08	5.54-11	3.82-11	9.11-13	5.50-29
PU236	0.00	1.49-06	1.17-06	1.31-07	4.11-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	7.73+02	4.42+00	5.91+01	6.90+01	3.51+01	5.59-02	8.79-20	0.00	0.00	0.00	0.00	0.00
PU239	2.40+04	5.46+01	5.48+01	5.58+01	6.45+01	1.35+02	5.18+02	6.94+01	2.10-04	1.45-04	3.46-06	2.09-22
PU240	9.76+03	3.67+01	5.84+01	2.20+02	5.98+02	5.56+02	2.21+02	2.18-02	0.00	0.00	0.00	0.00
PU241	4.27+03	2.34+01	2.23+01	1.47+01	3.12-01	9.08-02	4.65-02	5.77-05	0.00	0.00	0.00	0.00
PU242	1.59+03	1.38+01	1.38+01	1.38+01	1.42+01	1.55+01	1.95+01	1.83+01	3.54+00	2.52-07	0.00	0.00
PU243	0.00	2.59-14	5.19-12	5.19-12	5.19-12	5.19-12	5.19-12	5.17-12	4.98-12	3.43-12	8.18-14	4.93-30
AM241	3.25+02	3.35+02	3.35+02	3.38+02	3.06+02	7.46+01	1.36+00	1.69-03	0.00	0.00	0.00	0.00
AM242M	0.00	4.87+00	4.85+00	4.65+00	3.09+00	5.10-02	0.00	0.00	0.00	0.00	0.00	0.00
AM242	0.00	5.85-05	5.82-05	5.59-05	3.71-05	6.12-07	9.26-25	0.00	0.00	0.00	0.00	0.00

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
AM243	0.00	9.52+02	9.52+02	9.52+02	9.44+02	8.70+02	3.85+02	1.11-01	6.70-05	4.61-05	1.10-06	6.65-23
CM242	0.00	7.08+01	1.50+01	1.12-02	7.43-03	1.23-04	1.86-22	0.00	0.00	0.00	0.00	0.00
CM243	0.00	1.85+00	1.81+00	1.49+00	2.12-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	5.38+02	5.66+02	4.01+02	1.28+01	1.38-14	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	6.25+01	6.25+01	6.24+01	6.20+01	5.80+01	2.97+01	3.69-02	0.00	0.00	0.00	0.00
CM246	0.00	7.37+00	7.37+00	7.36+00	7.28+00	6.49+00	2.08+00	0.00	0.00	0.00	0.00	0.00
CM247	0.00	1.55-01	1.55-01	1.55-01	1.55-01	1.55-01	1.55-01	1.54-01	1.49-01	1.02-01	2.44-03	0.00
SUBTOT	1.00+06	6.98+03	6.98+03	6.98+03	6.98+03	6.98+03	6.98+03	6.97+03	6.91+03	6.90+03	6.85+03	6.33+03
TOTAL	1.00+06	6.98+03	6.98+03	6.98+03	6.98+03	6.98+03	6.98+03	6.98+03	6.98+03	6.98+03	6.98+03	6.98+03

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR, PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	2.80-07	4.91-07	1.94-06	6.05-06	6.86-06	2.71-05	1.42-03	2.11-03	2.10-03	1.92-03	7.97-04
TL208	0.00	3.03-04	2.16-04	2.14-05	6.66-06	1.16-09	2.58-09	6.40-08	6.69-07	5.92-06	2.22-05	2.25-05
TL209	0.00	1.77-10	1.79-10	2.24-10	4.88-09	8.04-07	1.08-04	2.85-03	6.48-03	3.31-04	7.29-17	0.00
PB209	0.00	8.02-09	8.15-09	1.02-08	2.22-07	3.65-05	4.90-03	1.30-01	2.95-01	1.50-02	3.31-15	0.00
PB210	0.00	1.91-10	3.83-10	5.31-09	1.07-06	6.70-04	3.01-02	2.36-01	4.42-02	1.56-03	1.54-03	1.34-03
PB211	0.00	2.81-07	4.92-07	1.94-06	6.07-06	6.88-06	2.72-05	1.42-03	2.12-03	2.10-03	1.92-03	8.00-04
PB212	0.00	8.40-04	6.01-04	5.94-05	1.85-05	3.22-09	7.16-09	1.76-07	1.86-06	1.65-05	6.16-05	6.24-05
PB214	0.00	4.84-09	7.34-09	3.15-08	2.06-06	6.70-04	3.01-02	2.36-01	4.42-02	1.56-03	1.54-03	1.34-03
BI210	0.00	1.86-10	3.83-10	5.31-09	1.07-06	6.70-04	3.01-02	2.36-01	4.42-02	1.56-03	1.54-03	1.34-03
BI211	0.00	2.81-07	4.92-07	1.94-06	6.07-06	6.68-06	2.72-05	1.42-03	2.12-03	2.10-03	1.92-03	8.00-04
BI212	0.00	8.40-04	6.01-04	5.94-05	1.85-05	3.22-09	7.16-09	1.78-07	1.86-06	1.65-05	6.16-05	6.24-05
BI213	0.00	8.02-09	8.15-09	1.02-08	2.22-07	3.65-05	4.90-03	1.30-01	2.95-01	1.50-02	3.31-15	0.00
BI214	0.00	4.84-09	7.34-09	3.15-08	2.06-06	6.70-04	3.01-02	2.36-01	4.42-02	1.56-03	1.54-03	1.34-03
PO210	0.00	1.27-10	2.77-10	5.31-09	1.07-06	6.70-04	3.01-02	2.36-01	4.42-02	1.56-03	1.54-03	1.34-03
PO211	0.00	8.43-10	1.48-09	5.82-09	1.82-08	2.06-08	8.16-08	4.26-06	6.36-06	6.30-06	5.77-06	2.40-06
PO212	0.00	5.38-04	3.84-04	3.80-05	1.18-05	2.06-09	4.58-09	1.14-07	1.19-06	1.05-05	3.94-05	3.99-05
PO213	0.00	7.85-09	7.97-09	9.94-09	2.17-07	3.57-05	4.80-03	1.27-01	2.88-01	1.47-02	3.24-15	0.00
PO214	0.00	4.84-09	7.34-09	3.15-08	2.06-06	6.70-04	3.01-02	2.36-01	4.42-02	1.56-03	1.54-03	1.34-03
PO215	0.00	2.81-07	4.92-07	1.94-06	6.07-06	6.88-06	2.72-05	1.42-03	2.12-03	2.10-03	1.92-03	8.00-04
PO216	0.00	8.40-04	6.01-04	5.94-05	1.85-05	3.22-09	7.16-09	1.78-07	1.86-06	1.65-05	6.16-05	6.24-05
PO218	0.00	4.84-09	7.34-09	3.15-08	2.06-06	6.70-04	3.01-02	2.36-01	4.42-02	1.56-03	1.54-03	1.34-03
AT217	0.00	8.02-09	8.15-09	1.02-08	2.22-07	3.65-05	4.90-03	1.30-01	2.95-01	1.50-02	3.31-15	0.00
RN219	0.00	2.81-07	4.92-07	1.94-06	6.07-06	6.88-06	2.72-05	1.42-03	2.12-03	2.10-03	1.92-03	8.00-04
RN220	0.00	8.40-04	6.01-04	5.94-05	1.85-05	3.22-09	7.16-09	1.78-07	1.86-06	1.65-05	6.16-05	6.24-05
RN222	0.00	4.84-09	7.34-09	3.15-08	2.06-06	6.70-04	3.01-02	2.36-01	4.42-02	1.56-03	1.54-03	1.34-03
FR221	0.00	8.02-09	8.15-09	1.02-08	2.22-07	3.65-05	4.90-03	1.30-01	2.95-01	1.50-02	3.31-15	0.00
FR223	0.00	4.24-09	6.88-09	2.72-08	8.49-08	9.63-08	3.81-07	1.99-05	2.97-05	2.94-05	2.69-05	1.12-05
RA223	0.00	2.81-07	4.92-07	1.94-06	6.07-06	6.88-06	2.72-05	1.42-03	2.12-03	2.10-03	1.92-03	8.00-04
RA224	0.00	8.40-04	6.01-04	5.94-05	1.85-05	3.22-09	7.16-09	1.78-07	1.86-06	1.65-05	6.16-05	6.24-05
RA225	0.00	8.04-09	8.15-09	1.02-08	2.22-07	3.65-05	4.90-03	1.30-01	2.95-01	1.50-02	3.31-15	0.00
RA226	0.00	4.87-09	7.34-09	3.15-08	2.06-06	6.70-04	3.01-02	2.36-01	4.42-02	1.56-03	1.54-03	1.34-03
AC225	0.00	8.02-09	8.15-09	1.02-08	2.22-07	3.65-05	4.90-03	1.30-01	2.95-01	1.50-02	3.31-15	0.00
AC227	0.00	3.03-07	4.91-07	1.94-06	6.07-06	6.88-06	2.72-05	1.42-03	2.12-03	2.10-03	1.92-03	8.00-04
TH227	0.00	2.85-07	4.85-07	1.91-06	5.98-06	6.78-06	2.68-05	1.40-03	2.09-03	2.07-03	1.90-03	7.88-04
TH228	0.00	8.51-04	5.98-04	5.93-05	1.85-05	3.31-09	7.16-09	1.78-07	1.86-06	1.65-05	6.16-05	6.24-05
TH229	0.00	8.12-09	8.15-09	1.02-08	2.22-07	3.65-05	4.90-03	1.30-01	2.95-01	1.50-02	3.32-15	0.00
TH230	0.00	5.68-06	5.70-06	7.15-06	1.26-04	3.79-03	3.87-02	2.36-01	4.42-02	1.56-03	1.54-03	1.34-03
TH231	0.00	6.49-03	3.25-05	3.25-05	3.28-05	3.82-05	2.36-04	1.98-03	2.12-03	2.10-03	1.92-03	8.00-04
TH234	0.00	3.11-01	1.56-03	1.55-03	1.55-03	1.55-03	1.55-03	1.55-03	1.56-03	1.56-03	1.54-03	1.34-03
PA231	0.00	6.27-06	6.27-06	6.27-06	6.32-06	6.87-06	2.72-05	1.42-03	2.12-03	2.10-03	1.92-03	8.00-04

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
PA233	0.00	9.23-02	9.28-02	9.62-02	1.29-01	2.92-01	3.61-01	3.71-01	2.77-01	1.50-02	3.31-15	0.00
PA234M	0.00	3.11-01	1.56-03	1.55-03	1.55-03	1.55-03	1.55-03	1.55-03	1.56-03	1.56-03	1.54-03	1.34-03
PA234	0.00	3.11-04	1.56-06	1.55-06	1.55-06	1.55-06	1.55-06	1.55-06	1.56-06	1.56-06	1.54-06	1.34-06
U232	0.00	1.45-05	2.11-05	4.00-05	1.80-05	3.12-09	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	9.34-08	5.32-07	4.17-06	4.76-05	9.26-04	1.42-02	1.29-01	2.94-01	1.50-02	3.58-15	0.00
U234	3.30-01	1.33-03	3.16-03	3.36-02	2.47-01	4.74-01	4.63-01	3.60-01	3.03-02	1.56-03	1.54-03	1.34-03
U235	1.45-02	3.25-05	3.25-05	3.25-05	3.28-05	3.82-05	2.36-04	1.98-03	2.12-03	2.10-03	1.92-03	8.00-04
U236	0.00	2.54-04	2.54-04	2.63-04	5.52-04	3.90-03	2.48-02	3.85-02	3.75-02	2.89-02	2.13-03	9.86-15
U237	0.00	5.88-02	5.59-02	3.68-02	7.84-04	2.28-04	1.17-04	1.45-07	0.00	0.00	0.00	0.00
U238	3.17-01	1.55-03	1.55-03	1.55-03	1.55-03	1.55-03	1.55-03	1.55-03	1.56-03	1.56-03	1.54-03	1.34-03
NP237	0.00	9.25-02	9.28-02	9.62-02	1.29-01	2.92-01	3.61-01	3.71-01	2.77-01	1.50-02	3.31-15	0.00
NP239	0.00	1.83+02	1.83+02	1.83+02	1.82+02	1.67+02	7.41+01	2.13-02	1.29-05	8.88-06	2.12-07	1.28-23
PU236	0.00	7.93-04	6.22-04	6.97-05	2.18-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	1.30+04	7.46+01	9.97+02	1.17+03	5.93+02	9.43-01	1.48-18	0.00	0.00	0.00	0.00	0.00
PU239	1.47+03	3.35+00	3.36+00	3.42+00	3.96+00	8.27+00	3.18+01	4.26+00	1.29-05	8.88-06	2.12-07	1.28-23
PU240	2.15+03	8.09+00	1.29+01	4.86+01	1.32+02	1.23+02	4.88+01	4.80-03	0.00	0.00	0.00	0.00
PU241	4.28+05	2.34+03	2.24+03	1.47+03	3.13+01	9.10+00	4.66+00	5.78-03	0.00	0.00	0.00	0.00
PU242	6.19+00	5.37-02	5.37-02	5.39-02	5.53-02	6.04-02	7.62-02	7.15-02	1.38-02	9.83-10	0.00	0.00
PU243	0.00	6.72-08	1.34-05	1.34-05	1.34-05	1.34-05	1.34-05	1.34-05	1.29-05	8.88-06	2.12-07	1.28-23
AM241	1.12+03	1.15+03	1.15+03	1.16+03	1.05+03	2.56+02	4.66+00	5.78-03	0.00	0.00	0.00	0.00
AM242M	0.00	4.73+01	4.71+01	4.52+01	3.00+01	4.96-01	0.00	0.00	0.00	0.00	0.00	0.00
AM242	0.00	4.73+01	4.71+01	4.52+01	3.00+01	4.96-01	7.50-19	0.00	0.00	0.00	0.00	0.00
AM243	0.00	1.83+02	1.83+02	1.83+02	1.82+02	1.67+02	7.41+01	2.13-02	1.29-05	8.88-06	2.12-07	1.28-23
CM242	0.00	2.35+05	4.97+04	3.71+01	2.46+01	4.06-01	6.17-19	0.00	0.00	0.00	0.00	0.00
CM243	0.00	8.50+01	9.32+01	6.84+01	9.74+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	4.76+04	4.58+04	3.25+04	1.03+03	1.12-12	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	9.79+00	9.79+00	9.78+00	9.72+00	9.09+00	4.65+00	5.78-03	0.00	0.00	0.00	0.00
CM246	0.00	1.96+00	1.95+00	1.95+00	1.93+00	1.72+00	5.52-01	0.00	0.00	0.00	0.00	0.00
CM247	0.00	1.34-05	1.34-05	1.34-05	1.34-05	1.34-05	1.34-05	1.34-05	1.29-05	8.88-06	2.12-07	0.00
SUBTOT	4.46+05	2.86+05	1.00+05	3.69+04	3.31+03	7.45+02	2.45+02	9.09+00	3.76+00	2.40-01	4.52-02	2.80-02
TOTAL	4.46+05	2.86+05	1.00+05	3.69+04	3.31+03	7.45+02	2.45+02	9.09+00	3.76+00	2.40-01	4.54-02	2.82-02

PLUTONIUM FUEL FRACTION IN A PWR 3.58 ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	8.47-10	1.48-09	5.85-09	1.83-08	2.07-08	8.20-08	4.28-06	6.39-06	6.33-06	5.80-06	2.41-06
TL208	0.00	7.04-06	5.03-06	4.98-07	1.55-07	2.70-11	6.00-11	1.49-09	1.56-08	1.38-07	5.16-07	5.23-07
TL209	0.00	2.89-12	2.93-12	3.66-12	7.98-11	1.31-08	1.76-06	4.66-05	1.06-04	5.41-06	1.19-18	0.00
PB209	0.00	9.23-12	9.37-12	1.17-11	2.55-10	4.20-08	5.64-06	1.49-04	3.39-04	1.73-05	3.81-18	0.00
PB211	0.00	9.39-10	1.65-09	6.49-09	2.03-08	2.30-08	9.10-08	4.75-06	7.09-06	7.03-06	6.44-06	2.67-06
PB212	0.00	1.21-06	8.62-07	8.52-08	2.66-08	4.62-12	1.03-11	2.55-10	2.67-09	2.36-08	8.84-08	8.95-08
PB214	0.00	1.18-11	1.79-11	7.68-11	5.03-09	1.63-06	7.33-05	5.76-04	1.08-04	3.80-06	3.74-06	3.26-06
BI210	0.00	4.96-13	1.01-12	1.40-11	2.82-09	1.76-06	7.92-05	6.22-04	1.16-04	4.10-06	4.04-06	3.52-06
BI211	0.00	1.09-08	1.92-08	7.56-08	2.36-07	2.68-07	1.06-06	5.53-05	8.25-05	8.18-05	7.50-05	3.11-05
BI212	0.00	1.46-05	1.04-05	1.03-06	3.21-07	5.60-11	1.24-10	3.09-09	3.23-08	2.86-07	1.07-06	1.08-06
BI213	0.00	4.93-11	5.01-11	6.25-11	1.36-09	2.25-07	3.01-05	7.97-04	1.81-03	9.25-05	2.04-17	0.00
BI214	0.00	6.74-11	1.02-10	4.39-10	2.87-08	9.33-06	4.19-04	3.29-03	6.15-04	2.17-05	2.14-05	1.86-05
PO210	0.00	4.00-12	8.71-12	1.67-10	3.37-08	2.11-05	9.47-04	7.44-03	1.39-03	4.90-05	4.84-05	4.21-05
PO211	0.00	3.72-11	6.52-11	2.57-10	8.04-10	9.11-10	3.60-09	1.88-07	2.81-07	2.78-07	2.55-07	1.06-07
PO212	0.00	2.85-05	2.04-05	2.01-06	6.28-07	1.09-10	2.43-10	6.03-09	6.30-08	5.58-07	2.09-06	2.12-06
PO213	0.00	3.90-10	3.96-10	4.93-10	1.08-08	1.77-06	2.38-04	6.29-03	1.43-02	7.31-04	1.61-16	0.00
PO214	0.00	2.20-10	3.34-10	1.44-09	9.40-08	3.05-05	1.37-03	1.08-02	2.01-03	7.10-05	7.00-05	6.10-05
PO215	0.00	1.23-08	2.16-08	8.50-08	2.66-07	3.01-07	1.19-06	6.22-05	9.28-05	9.20-05	8.43-05	3.50-05
PO216	0.00	3.44-05	2.46-05	2.43-06	7.57-07	1.32-10	2.93-10	7.27-09	7.60-08	6.73-07	2.52-06	2.55-06
PO218	0.00	1.75-10	2.66-10	1.14-09	7.47-08	2.43-05	1.09-03	8.56-03	1.60-03	5.64-05	5.57-05	4.85-05
AT217	0.00	3.36-10	3.42-10	4.26-10	9.29-09	1.53-06	2.06-04	5.43-03	1.23-02	6.31-04	1.39-16	0.00
RN219	0.00	1.14-08	1.99-08	7.86-08	2.45-07	2.78-07	1.10-06	5.75-05	8.58-05	8.50-05	7.79-05	3.24-05
RN220	0.00	3.19-05	2.28-05	2.25-06	7.02-07	1.22-10	2.71-10	6.74-09	7.05-08	6.24-07	2.34-06	2.37-06
RN222	0.00	1.58-10	2.39-10	1.03-09	6.72-08	2.18-05	9.81-04	7.70-03	1.44-03	5.08-05	5.01-05	4.36-05
FR221	0.00	2.98-10	3.03-10	3.78-10	8.25-09	1.36-06	1.82-04	4.82-03	1.10-02	5.60-04	1.23-16	0.00
FR223	0.00	9.94-12	1.61-11	6.36-11	1.99-10	2.25-10	8.92-10	4.66-08	6.95-08	6.89-08	6.31-08	2.62-08
RA223	0.00	9.76-09	1.71-08	6.74-08	2.11-07	2.39-07	9.45-07	4.94-05	7.36-05	7.30-05	6.69-05	2.78-05
RA224	0.00	2.87-05	2.05-05	2.03-06	6.33-07	1.10-10	2.45-10	6.08-09	6.36-08	5.63-07	2.11-06	2.13-06
RA225	0.00	5.29-12	5.36-12	6.69-12	1.46-10	2.40-08	3.23-06	8.53-05	1.94-04	9.90-06	2.18-18	0.00
RA226	0.00	1.36-10	2.08-10	8.92-10	5.84-08	1.90-05	8.52-04	6.69-03	1.25-03	4.41-05	4.35-05	3.79-05
AC225	0.00	2.75-10	2.80-10	3.49-10	7.61-09	1.25-06	1.68-04	4.45-03	1.01-02	5.16-04	1.14-16	0.00
AC227	0.00	1.53-10	2.46-10	9.78-10	3.06-09	3.46-09	1.37-08	7.16-07	1.07-06	1.06-06	9.70-07	4.03-07
TH227	0.00	9.82-09	1.67-08	6.59-08	2.06-07	2.33-07	9.23-07	4.82-05	7.19-05	7.13-05	6.53-05	2.71-05
TH228	0.00	2.79-05	1.96-05	1.94-06	6.06-07	1.08-10	2.34-10	5.62-09	6.09-08	5.39-07	2.02-06	2.04-06
TH229	0.00	2.45-10	2.46-10	3.07-10	6.70-09	1.10-06	1.48-04	3.92-03	8.90-03	4.55-04	1.00-16	0.00
TH230	0.00	1.61-07	1.61-07	2.02-07	3.56-06	1.07-04	1.09-03	6.67-03	1.25-03	4.40-05	4.34-05	3.78-05
TH231	0.00	5.12-06	2.56-08	2.56-08	2.59-08	3.01-08	1.86-07	1.56-06	1.67-06	1.66-06	1.52-06	6.30-07
TH234	0.00	1.10-04	5.55-07	5.52-07	5.52-07	5.52-07	5.52-07	5.53-07	5.54-07	5.54-07	5.46-07	4.76-07
PA231	0.00	1.91-07	1.91-07	1.91-07	1.93-07	2.10-07	8.30-07	4.34-05	6.47-05	6.41-05	5.87-05	2.44-05
PA233	0.00	1.25-04	1.25-04	1.30-04	1.74-04	3.95-04	4.88-04	5.02-04	3.75-04	2.03-05	4.48-18	0.00

PLUTONIUM FUEL FRACTION IN A PWR 3.58 ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
PA234M	0.00	1.60-03	8.04-06	7.99-06	7.99-06	7.99-06	7.99-06	8.00-06	8.02-06	8.02-06	7.91-06	6.88-06
PA234	0.00	2.82-06	1.42-08	1.41-08	1.41-08	1.41-08	1.41-08	1.41-08	1.42-08	1.42-08	1.40-08	1.22-08
U232	0.00	4.65-07	6.77-07	1.28-06	5.78-07	1.00-10	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	2.72-09	1.55-08	1.21-07	1.38-06	2.70-05	4.15-04	3.76-03	8.57-03	4.38-04	1.04-16	0.00
U234	9.50-03	3.83-05	9.09-05	9.67-04	7.12-03	1.37-02	1.33-02	1.04-02	6.71-04	4.48-05	4.42-05	3.85-05
U235	4.03-04	9.00-07	9.01-07	9.01-07	9.10-07	1.06-06	6.54-06	5.48-05	5.88-05	5.83-05	5.34-05	2.22-05
U236	0.00	6.89-06	6.90-06	7.12-06	1.49-05	1.06-04	6.72-04	1.04-03	1.02-03	7.83-04	5.76-05	2.67-16
U237	0.00	3.91-05	3.71-05	2.44-05	5.20-07	1.51-07	7.74-08	9.60-11	0.00	0.00	0.00	0.00
U238	8.03-03	3.93-05	3.93-05	3.93-05	3.93-05	3.93-05	3.93-05	3.93-05	3.94-05	3.94-05	3.89-05	3.39-05
NP237	0.00	2.72-03	2.73-03	2.83-03	3.78-03	6.58-03	1.06-02	1.09-02	8.15-03	4.42-04	9.73-17	0.00
NP239	0.00	2.48-01	2.48-01	2.47-01	2.45-01	2.26-01	1.00-01	2.88-05	1.74-08	1.20-08	2.86-10	1.73-26
PU236	0.00	2.76-05	2.16-05	2.43-06	7.60-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	4.32+02	2.47+00	3.30+01	3.86+01	1.96+01	3.12-02	4.91-20	0.00	0.00	0.00	0.00	0.00
PU239	4.57+01	1.04-01	1.04-01	1.06-01	1.23-01	2.57-01	9.88-01	1.32-01	4.01-07	2.76-07	6.59-09	3.98-25
PU240	6.70+01	2.52-01	4.01-01	1.51+00	4.10+00	3.82+00	1.52+00	1.49-04	0.00	0.00	0.00	0.00
PU241	1.78+01	9.72-02	9.27-02	6.10-02	1.30-03	3.74-04	1.93-04	2.40-07	0.00	0.00	0.00	0.00
PU242	1.83-01	1.59-03	1.59-03	1.59-03	1.63-03	1.78-03	2.25-03	2.11-03	4.07-04	2.90-11	0.00	0.00
PU243	0.00	9.52-11	1.90-08	1.90-08	1.90-08	1.90-08	1.90-08	1.90-08	1.83-08	1.26-08	3.00-10	1.81-26
AM241	3.72+01	3.83+01	3.83+01	3.87+01	3.50+01	8.53+00	1.56-01	1.93-04	0.00	0.00	0.00	0.00
AM242M	0.00	1.35-02	1.34-02	1.29-02	8.54-03	1.41-04	0.00	0.00	0.00	0.00	0.00	0.00
AM242	0.00	6.31-02	6.29-02	6.03-02	4.00-02	6.61-04	1.00-21	0.00	0.00	0.00	0.00	0.00
AM243	0.00	6.69+00	6.69+00	6.68+00	6.63+00	6.11+00	2.70+00	7.79-04	4.71-07	3.24-07	7.74-09	4.67-25
CM242	0.00	8.65+03	1.83+03	1.37+00	9.07-01	1.50-02	2.27-20	0.00	0.00	0.00	0.00	0.00
CM243	0.00	3.12+00	3.06+00	2.51+00	3.58-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	1.67+03	1.60+03	1.14+03	3.62+01	3.92-14	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	3.05-01	3.05-01	3.05-01	3.03-01	2.84-01	1.45-01	1.80-04	0.00	0.00	0.00	0.00
CM246	0.00	6.41-02	6.40-02	6.40-02	6.32-02	5.64-02	1.81-02	0.00	0.00	0.00	0.00	0.00
CM247	0.00	3.88-07	3.88-07	3.86-07	3.88-07	3.88-07	3.87-07	3.86-07	3.72-07	2.56-07	6.11-09	0.00
SUBTOT	6.00+02	1.04+04	3.52+03	1.23+03	1.04+02	1.94+01	5.67+00	2.41-01	8.88-02	5.69-03	9.99-04	5.95-04
TOTAL	6.00+02	1.04+04	3.52+03	1.23+03	1.04+02	1.94+01	5.67+00	2.41-01	8.88-02	5.69-03	1.00-03	5.97-04

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	-2.80-07	-4.91-07	-1.94-06	-6.05-06	-6.86-06	-2.71-05	-1.42-03	-2.11-03	-2.10-03	-1.92-03	-7.97-04
TL208	0.00	-3.03-04	-2.16-04	-2.14-05	-6.66-06	-1.16-09	-2.58-09	-6.40-08	-6.69-07	-5.92-06	-2.22-05	-2.25-05
TL209	0.00	-1.77-10	-1.79-10	-2.24-10	-4.88-09	-8.04-07	-1.08-04	-2.85-03	-6.48-03	-3.31-04	-7.29-17	0.00
PB209	0.00	-8.02-09	-8.15-09	-1.02-08	-2.22-07	-3.65-05	-4.90-03	-1.30-01	-2.95-01	-1.50-02	-3.31-15	0.00
PB210	0.00	4.79+01	9.57+01	1.33+03	2.68+05	1.68+08	7.52+09	5.91+10	1.10+10	3.89+08	3.84+08	3.35+08
PB211	0.00	-2.81-07	-4.92-07	-1.94-06	-6.07-06	-6.88-06	-2.72-05	-1.42-03	-2.12-03	-2.10-03	-1.92-03	-8.00-04
PB212	0.00	1.40+06	1.00+06	9.90+04	3.08+04	5.37+00	1.19+01	2.96+02	3.10+03	2.74+04	1.03+05	1.04+05
PB214	0.00	-4.84-09	-7.34-09	-3.15-08	-2.06-06	-6.70-04	-3.01-02	-2.36-01	-4.42-02	-1.56-03	-1.54-03	-1.34-03
BI210	0.00	9.42-01	1.92+00	2.65+01	5.36+03	3.35+06	1.50+08	1.18+09	2.21+08	7.79+06	7.68+06	6.69+06
BI211	0.00	-2.81-07	-4.92-07	-1.94-06	-6.07-06	-6.88-06	-2.72-05	-1.42-03	-2.12-03	-2.10-03	-1.92-03	-8.00-04
BI212	0.00	2.80+05	2.00+05	1.98+04	6.17+03	1.07+00	2.39+00	5.92+01	6.19+02	5.49+03	2.05+04	2.08+04
BI213	0.00	-8.02-09	-8.15-09	-1.02-08	-2.22-07	-3.65-05	-4.90-03	-1.30-01	-2.95-01	-1.50-02	-3.31-15	0.00
BI214	0.00	-4.84-09	-7.34-09	-3.15-08	-2.06-06	-6.70-04	-3.01-02	-2.36-01	-4.42-02	-1.56-03	-1.54-03	-1.34-03
PO210	0.00	1.82+01	3.95+01	7.58+02	1.53+05	9.57+07	4.30+09	3.38+10	6.31+09	2.23+08	2.20+08	1.91+08
PO211	0.00	-8.43-10	-1.48-09	-5.82-09	-1.82-08	-2.06-08	-8.16-08	-4.26-06	-6.36-06	-6.30-06	-5.77-06	-2.40-06
PO212	0.00	-5.38-04	-3.84-04	-3.80-05	-1.18-05	-2.06-09	-4.58-09	-1.14-07	-1.19-06	-1.05-05	-3.94-05	-3.99-05
PO213	0.00	-7.85-09	-7.97-09	-9.94-09	-2.17-07	-3.57-05	-4.80-03	-1.27-01	-2.88-01	-1.47-02	-3.24-15	0.00
PO214	0.00	-4.84-09	-7.34-09	-3.15-08	-2.06-06	-6.70-04	-3.01-02	-2.36-01	-4.42-02	-1.56-03	-1.54-03	-1.34-03
PO215	0.00	-2.81-07	-4.92-07	-1.94-06	-6.07-06	-6.88-06	-2.72-05	-1.42-03	-2.12-03	-2.10-03	-1.92-03	-8.00-04
PO216	0.00	-8.40-04	-6.01-04	-5.94-05	-1.85-05	-3.22-09	-7.16-09	-1.78-07	-1.86-06	-1.65-05	-6.16-05	-6.24-05
PO218	0.00	-4.84-09	-7.34-09	-3.15-08	-2.06-06	-6.70-04	-3.01-02	-2.36-01	-4.42-02	-1.56-03	-1.54-03	-1.34-03
AT217	0.00	-8.02-09	-8.15-09	-1.02-08	-2.22-07	-3.65-05	-4.90-03	-1.30-01	-2.95-01	-1.50-02	-3.31-15	0.00
RN219	0.00	-2.81-07	-4.92-07	-1.94-06	-6.07-06	-6.88-06	-2.72-05	-1.42-03	-2.12-03	-2.10-03	-1.92-03	-8.00-04
RN220	0.00	8.40+04	6.01+04	5.94+03	1.85+03	3.22-01	7.16-01	1.78+01	1.86+02	1.65+03	6.16+03	6.24+03
RN222	0.00	1.61+00	2.45+00	1.05+01	6.88+02	2.23+05	1.00+07	7.88+07	1.47+07	5.19+05	5.12+05	4.46+05
FR221	0.00	-8.02-09	-8.15-09	-1.02-08	-2.22-07	-3.65-05	-4.90-03	-1.30-01	-2.95-01	-1.50-02	-3.31-15	0.00
FR223	0.00	-4.24-09	-6.88-09	-2.72-08	-8.49-08	-9.63-08	-3.81-07	-1.99-05	-2.97-05	-2.94-05	-2.69-05	-1.12-05
RA223	0.00	3.51+04	6.15+04	2.43+05	7.58+05	8.60+05	3.40+06	1.78+08	2.65+08	2.63+08	2.41+08	1.00+08
RA224	0.00	4.20+07	3.00+07	2.97+06	9.25+05	1.61+02	3.58+02	8.88+03	9.29+04	8.23+05	3.08+06	3.12+06
RA225	0.00	1.61+02	1.63+02	2.03+02	4.43+03	7.31+05	9.81+07	2.59+09	5.89+09	3.01+08	6.62-05	0.00
RA226	0.00	2.44+03	3.67+03	1.58+04	1.03+06	3.35+08	1.50+10	1.18+11	2.21+10	7.79+08	7.68+08	6.69+08
RA228	0.00	5.69-01	1.00+00	3.47+00	6.86+00	1.07+02	7.16+03	1.78+05	1.86+06	1.65+07	6.16+07	6.24+07
AC225	0.00	-8.02-09	-8.15-09	-1.02-08	-2.22-07	-3.65-05	-4.90-03	-1.30-01	-2.95-01	-1.50-02	-3.31-15	0.00
AC227	0.00	3.79+06	6.14+06	2.43+07	7.58+07	8.60+07	3.40+08	1.78+10	2.65+10	2.63+10	2.41+10	1.00+10
AC228	0.00	9.48-04	1.67-03	5.78-03	1.14-02	1.78-01	1.19+01	2.96+02	3.10+03	2.74+04	1.03+05	1.04+05
TH227	0.00	4.76+04	8.09+04	3.19+05	9.97+05	1.13+06	4.47+06	2.34+06	3.48+08	3.45+08	3.16+08	1.31+08
TH228	0.00	4.26+09	2.99+09	2.96+08	9.25+07	1.65+04	3.58+04	8.86+05	9.29+06	8.23+07	3.08+08	3.12+08
TH229	0.00	1.01+05	1.02+05	1.27+05	2.77+06	4.57+08	6.13+10	1.62+12	3.68+12	1.88+11	4.15-02	0.00
TH230	0.00	7.10+07	7.12+07	8.93+07	1.57+09	4.74+10	4.84+11	2.95+12	5.52+11	1.95+10	1.92+10	1.67+10
TH231	0.00	1.62+05	8.11+02	8.12+02	8.20+02	9.56+02	5.89+03	4.94+04	5.30+04	5.25+04	4.81+04	2.00+04

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TH232	0.00	5.00+00	5.01+00	5.12+00	6.86+00	1.07+02	7.16+03	1.78+05	1.86+06	1.65+07	6.16+07	6.24+07
TH234	0.00	3.11+08	1.56+06	1.55+06	1.55+06	1.55+06	1.55+06	1.55+06	1.56+06	1.56+06	1.54+06	1.34+06
PA231	0.00	1.57+08	1.57+08	1.57+08	1.58+08	1.72+08	6.80+08	3.55+10	5.30+10	5.25+10	4.81+10	2.00+10
PA233	0.00	1.54+07	1.55+07	1.60+07	2.15+07	4.87+07	6.02+07	6.19+07	4.62+07	2.51+06	5.52-07	0.00
PA234M	0.00	-3.11-01	-1.56-03	-1.55-03	-1.55-03	-1.55-03	-1.55-03	-1.55-03	-1.56-03	-1.56-03	-1.54-03	-1.34-03
PA234	0.00	-3.11-04	-1.56-06	-1.55-06	-1.55-06	-1.55-06	-1.55-06	-1.55-06	-1.56-06	-1.56-06	-1.54-06	-1.34-06
U232	0.00	1.61+07	2.34+07	4.44+07	2.00+07	3.46+03	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	2.34+04	1.33+05	1.04+06	1.19+07	2.32+08	3.56+09	3.23+10	7.36+10	3.76+09	8.96-04	0.00
U234	8.25+10	3.33+08	7.90+08	8.40+09	6.19+10	1.19+11	1.16+11	9.01+10	7.57+09	3.89+08	3.84+08	3.35+08
U235	3.63+09	8.11+06	8.11+06	8.12+06	8.20+06	9.56+06	5.89+07	4.94+08	5.30+08	5.25+08	4.81+08	2.00+08
U236	0.00	6.35+07	6.36+07	6.57+07	1.38+08	9.76+08	6.20+09	9.62+09	9.38+09	7.22+09	5.31+08	2.47-03
U237	0.00	-5.88-02	-5.59-02	-3.68-02	-7.84-04	-2.28-04	-1.17-04	-1.45-07	0.00	0.00	0.00	0.00
U238	1.06+11	5.18+08	5.18+08	5.18+08	5.18+08	5.18+08	5.18+08	5.18+08	5.20+08	5.19+08	5.12+08	4.46+08
NP237	0.00	9.25+11	9.28+11	9.62+11	1.29+12	2.92+12	3.61+12	3.71+12	2.77+12	1.50+11	3.31-02	0.00
NP239	0.00	9.16+09	9.16+09	9.15+09	9.08+09	8.37+09	3.70+09	1.07+06	6.45+02	4.44+02	1.06+01	6.39-16
PU236	0.00	-7.93-04	-6.22-04	-6.97-05	-2.18-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	1.66+17	1.07+15	1.42+16	1.66+16	6.48+15	1.35+13	2.12-05	0.00	0.00	0.00	0.00	0.00
PU239	2.45+16	5.58+13	5.60+13	5.71+13	6.60+13	1.38+14	5.30+14	7.10+13	2.15+08	1.48+09	3.53+06	2.13-10
PU240	3.59+16	1.35+14	2.15+14	8.10+14	2.20+15	2.04+15	8.13+14	8.00+10	0.00	0.00	0.00	0.00
PU241	1.43+17	7.61+14	7.45+14	4.90+14	1.04+13	3.03+12	1.55+12	1.93+09	0.00	0.00	0.00	0.00
PU242	1.03+14	8.95+11	8.96+11	8.99+11	9.22+11	1.01+12	1.27+12	1.19+12	2.30+11	1.64+04	0.00	0.00
PU243	0.00	1.12+00	2.24+02	2.24+02	2.24+02	2.24+02	2.24+02	2.23+02	2.15+02	1.43+02	3.53+00	2.13-16
AM241	5.58+15	5.74+15	5.75+15	5.79+15	5.24+15	1.28+15	2.33+13	2.89+10	0.00	0.00	0.00	0.00
AM242M	0.00	2.37+14	2.36+14	2.26+14	1.50+14	2.48+12	0.00	0.00	0.00	0.00	0.00	0.00
AM242	0.00	4.73+10	4.71+10	4.52+10	3.00+10	4.96+08	7.50-10	0.00	0.00	0.00	0.00	0.00
AM243	0.00	9.16+14	9.16+14	9.15+14	9.08+14	8.37+14	3.70+14	1.07+11	6.45+07	4.44+07	1.06+06	6.39-11
CM242	0.00	5.87+16	1.24+16	9.26+12	6.15+12	1.02+11	1.54-07	0.00	0.00	0.00	0.00	0.00
CM243	0.00	4.25+14	4.16+14	3.42+14	4.87+13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	1.59+17	1.53+17	1.08+17	3.45+15	3.74+00	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	4.89+13	4.89+13	4.89+13	4.86+13	4.54+13	2.33+13	2.89+10	0.00	0.00	0.00	0.00
CM246	0.00	9.78+12	9.77+12	9.76+12	9.65+12	8.61+12	2.76+12	0.00	0.00	0.00	0.00	0.00
CM247	0.00	6.72+07	6.72+07	6.72+07	6.72+07	6.72+07	6.72+07	6.69+07	6.45+07	4.44+07	1.06+06	0.00
SUBTOT	3.95+17	2.27+17	1.88+17	1.34+17	2.06+16	4.37+15	1.77+15	8.11+13	7.46+12	4.52+11	9.57+10	4.96+10
TOTAL	3.95+17	2.27+17	1.86+17	1.34+17	2.06+16	4.37+15	1.77+15	8.11+13	7.46+12	4.52+11	9.57+10	4.96+10

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	-2.80-07	-4.91-07	-1.94-06	-6.05-06	-6.86-06	-2.71-05	-1.42-03	-2.11-03	-2.10-03	-1.92-03	-7.97-04
TL208	0.00	-3.03-04	-2.16-04	-2.14-05	-6.66-06	-1.16-09	-2.58-09	-6.40-08	-6.69-07	-5.92-06	-2.22-05	-2.25-05
TL209	0.00	-1.77-10	-1.79-10	-2.24-10	-4.88-09	-8.04-07	-1.08-04	-2.85-03	-6.48-03	-3.31-04	-7.29-17	0.00
PB209	0.00	-8.02-09	-8.15-09	-1.02-08	-2.22-07	-3.65-05	-4.90-03	-1.30-01	-2.95-01	-1.50-02	-3.31-15	0.00
PB210	0.00	1.91-03	3.83-03	5.31-02	1.07+01	6.70+03	3.01+05	2.36+06	4.42+05	1.56+04	1.54+04	1.34+04
PB211	0.00	-2.81-07	-4.92-07	-1.94-06	-6.07-06	-6.88-06	-2.72-05	-1.42-03	-2.12-03	-2.10-03	-1.92-03	-8.00-04
PB212	0.00	4.20+01	3.00+01	2.97+00	9.25-01	1.61-04	3.58-04	8.68-03	9.29-02	8.23-01	3.08+00	3.12+00
PB214	0.00	-4.84-09	-7.34-09	-3.15-08	-2.06-06	-6.70-04	-3.01-02	-2.36-01	-4.42-02	-1.56-03	-1.54-03	-1.34-03
BI210	0.00	4.71-06	9.58-06	1.33-04	2.68-02	1.68+01	7.52+02	5.91+03	1.10+03	3.89+01	3.84+01	3.35+01
BI211	0.00	-2.81-07	-4.92-07	-1.94-06	-6.07-06	-6.88-06	-2.72-05	-1.42-03	-2.12-03	-2.10-03	-1.92-03	-8.00-04
BI212	0.00	2.10+00	1.50+00	1.48-01	4.63-02	8.06-06	1.79-05	4.44-04	4.65-03	4.11-02	1.54-01	1.56-01
BI213	0.00	-8.02-09	-8.15-09	-1.02-08	-2.22-07	-3.65-05	-4.90-03	-1.30-01	-2.95-01	-1.50-02	-3.31-15	0.00
BI214	0.00	-4.84-09	-7.34-09	-3.15-08	-2.06-06	-6.70-04	-3.01-02	-2.36-01	-4.42-02	-1.56-03	-1.54-03	-1.34-03
PO210	0.00	1.82-04	3.95-04	7.58-03	1.53+00	9.57+02	4.30+04	3.38+05	6.31+04	2.23+03	2.20+03	1.91+03
PO211	0.00	-8.43-10	-1.46-09	-5.82-09	-1.82-08	-2.06-08	-8.16-08	-4.26-06	-6.36-06	-6.30-06	-5.77-06	-2.40-06
PO212	0.00	-5.38-04	-3.84-04	-3.80-05	-1.18-05	-2.06-09	-4.58-09	-1.14-07	-1.19-06	-1.05-05	-3.94-05	-3.99-05
PO213	0.00	-7.85-09	-7.97-09	-9.94-09	-2.17-07	-3.57-05	-4.80-03	-1.27-01	-2.88-01	-1.47-02	-3.24-15	0.00
PO214	0.00	-4.84-09	-7.34-09	-3.15-08	-2.06-06	-6.70-04	-3.01-02	-2.36-01	-4.42-02	-1.56-03	-1.54-03	-1.34-03
PO215	0.00	-2.81-07	-4.92-07	-1.94-06	-6.07-06	-6.88-06	-2.72-05	-1.42-03	-2.12-03	-2.10-03	-1.92-03	-8.00-04
PO216	0.00	-8.40-04	-6.01-04	-5.94-05	-1.85-05	-3.22-09	-7.16-09	-1.78-07	-1.86-06	-1.65-05	-6.16-05	-6.24-05
PO218	0.00	-4.84-09	-7.34-09	-3.15-08	-2.06-06	-6.70-04	-3.01-02	-2.36-01	-4.42-02	-1.56-03	-1.54-03	-1.34-03
AT217	0.00	-8.02-09	-8.15-09	-1.02-08	-2.22-07	-3.65-05	-4.90-03	-1.30-01	-2.95-01	-1.50-02	-3.31-15	0.00
RN219	0.00	-2.81-07	-4.92-07	-1.94-06	-6.07-06	-6.88-06	-2.72-05	-1.42-03	-2.12-03	-2.10-03	-1.92-03	-8.00-04
RN220	0.00	-8.40-04	-6.01-04	-5.94-05	-1.85-05	-3.22-09	-7.16-09	-1.78-07	-1.86-06	-1.65-05	-6.16-05	-6.24-05
RN222	0.00	-4.84-09	-7.34-09	-3.15-08	-2.06-06	-6.70-04	-3.01-02	-2.36-01	-4.42-02	-1.56-03	-1.54-03	-1.34-03
FR221	0.00	-8.02-09	-8.15-09	-1.02-08	-2.22-07	-3.65-05	-4.90-03	-1.30-01	-2.95-01	-1.50-02	-3.31-15	0.00
FR223	0.00	-4.24-09	-6.88-09	-2.72-08	-8.49-08	-9.63-08	-3.81-07	-1.99-05	-2.97-05	-2.94-05	-2.69-05	-1.12-05
RA223	0.00	4.01-01	7.03-01	2.77+00	8.66+00	9.82+00	3.89+01	2.03+03	3.03+03	3.00+03	2.75+03	1.14+03
RA224	0.00	4.20+02	3.00+02	2.97+01	9.25+00	1.61-03	3.58-03	8.88-02	9.29-01	8.23+00	3.08+01	3.12+01
RA225	0.00	1.34-02	1.36-02	1.69-02	3.70-01	6.09+01	8.17+03	2.16+05	4.91+05	2.51+04	5.52-09	0.00
RA226	0.00	1.62-01	2.45-01	1.05+00	6.88+01	2.23+04	1.00+06	7.88+06	1.47+06	5.19+04	5.12+04	4.46+04
RA228	0.00	1.90-05	3.35-05	1.16-04	2.29-04	3.55-03	2.39-01	5.92+00	6.19+01	5.49+02	2.05+03	2.08+03
AC225	0.00	-8.02-09	-8.15-09	-1.02-08	-2.22-07	-3.65-05	-4.90-03	-1.30-01	-2.95-01	-1.50-02	-3.31-15	0.00
AC227	0.00	1.52-01	2.46-01	9.70-01	3.03+00	3.44+00	1.36+01	7.11+02	1.06+03	1.05+03	9.62+02	4.00+02
AC228	0.00	6.32-09	1.12-08	3.86-08	7.62-08	1.18-06	7.95-05	1.97-03	2.06-02	1.83-01	6.85-01	6.93-01
TH227	0.00	1.43-02	2.43-02	9.57-02	2.99-01	3.39-01	1.34+00	7.01+01	1.05+02	1.04+02	9.49+01	3.94+01
TH228	0.00	1.22+02	8.54+01	8.46+00	2.64+00	4.73-04	1.02-03	2.54-02	2.65-01	2.35+00	8.80+00	8.91+00
TH229	0.00	4.06-03	4.08-03	5.08-03	1.11-01	1.83+01	2.45+03	6.48+04	1.47+05	7.52+03	1.66-09	0.00
TH230	0.00	2.84+00	2.85+00	3.57+00	6.30+01	1.89+03	1.93+04	1.18+05	2.21+04	7.79+02	7.68+02	6.69+02
TH231	0.00	3.25+01	1.62-01	1.62-01	1.64-01	1.91-01	1.18+00	9.88+00	1.06+01	1.05+01	9.62+00	4.00+00

PLUTONIUM FUEL FRACTION IN A PAR 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TH232	0.00	2.50-06	2.50-06	2.56-06	3.43-06	5.33-05	3.58-03	8.86-02	9.29-01	8.23+00	3.08+01	3.12+01
TH234	0.00	1.55+04	7.01+01	7.77+01	7.77+01	7.77+01	7.77+01	7.77+01	7.79+01	7.79+01	7.68+01	6.69+01
PA231	0.00	6.96+00	6.96+00	6.97+00	7.03+00	7.64+00	3.02+01	1.58+03	2.36+03	2.33+03	2.14+03	8.89+02
PA233	0.00	9.23+02	9.28+02	9.62+02	1.29+03	2.92+03	3.61+03	3.71+03	2.77+03	1.50+02	3.31-11	0.00
PA234M	0.00	-3.11-01	-1.56-03	-1.55-03	-1.55-03	-1.55-03	-1.55-03	-1.55-03	-1.56-03	-1.56-03	-1.54-03	-1.34-03
PA234	0.00	-3.11-04	-1.56-06	-1.55-06	-1.55-06	-1.55-06	-1.55-06	-1.55-06	-1.56-06	-1.56-06	-1.54-06	-1.34-06
U232	0.00	4.83-01	7.03-01	1.33+00	6.01-01	1.04-04	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	3.11-03	1.77-02	1.39-01	1.59+00	3.09+01	4.75+02	4.31+03	9.81+03	5.02+02	1.19-10	0.00
U234	1.10+04	4.43+01	1.05+02	1.12+03	8.25+03	1.56+04	1.54+04	1.20+04	1.01+03	5.19+01	5.12+01	4.46+01
U235	4.84+02	1.05+00	1.08+00	1.08+00	1.09+00	1.27+00	7.86+00	6.58+01	7.07+01	7.00+01	6.42+01	2.67+01
U236	0.00	5.47+00	5.48+00	5.76+00	1.84+01	1.30+02	8.27+02	1.28+03	1.25+03	9.63+02	7.08+01	3.29-10
U237	0.00	-5.68-02	-5.59-02	-3.69-02	-7.84-04	-2.28-04	-1.17-04	-1.45-07	0.00	0.00	0.00	0.00
U238	7.93+03	3.88+01	3.88+01	3.88+01	3.88+01	3.88+01	3.88+01	3.89+01	3.90+01	3.89+01	3.89+01	3.35+01
NP237	0.00	3.08+04	3.09+04	3.21+04	4.29+04	9.73+04	1.20+05	1.24+05	9.25+04	5.02+03	1.10-09	0.00
NP239	0.00	1.63+06	1.63+06	1.63+06	1.62+06	1.67+06	7.41+05	2.13+02	1.29-01	8.88-02	2.12-03	1.28-19
PU236	0.00	-7.93-04	-6.22-04	-6.97-05	-2.18-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	2.61+07	1.49+07	1.49+07	2.33+08	1.19+08	1.89+05	2.97-13	0.00	0.00	0.00	0.00	0.00
PU239	2.94+06	6.70+05	6.72+05	6.85+05	7.91+05	1.65+06	6.36+06	8.52+05	2.58+00	1.78+00	4.24-02	2.56-18
PU240	4.30+08	1.62+06	2.57+06	9.72+06	2.63+07	2.45+07	9.75+06	9.60+02	0.00	0.00	0.00	0.00
PU241	2.14+09	1.17+07	1.12+07	7.35+06	1.57+05	4.55+04	2.33+04	2.89+01	0.00	0.00	0.00	0.00
PU242	1.24+06	1.07+04	1.07+04	1.08+04	1.11+04	1.21+04	1.52+04	1.43+04	2.76+03	1.97-04	0.00	0.00
PU243	0.00	2.24-04	4.48-02	4.48-02	4.48-02	4.48-02	4.48-02	4.46-02	4.30-02	2.96-02	7.07-04	4.26-20
AM241	2.79+08	2.87+08	2.87+08	2.90+08	2.62+08	6.39+07	1.17+06	1.45+03	0.00	0.00	0.00	0.00
AM242M	0.00	1.18+07	1.18+07	1.13+07	7.50+06	1.24+05	0.00	0.00	0.00	0.00	0.00	0.00
AM242	0.00	4.73+05	4.71+05	4.52+05	3.00+05	4.96+03	7.50-15	0.00	0.00	0.00	0.00	0.00
AM243	0.00	4.58+07	4.58+07	4.58+07	4.54+07	4.18+07	1.85+07	5.33+03	3.22+00	2.22+00	5.30-02	3.20-18
CM242	0.00	1.17+10	2.49+09	1.66+06	1.23+06	2.03+04	3.08-14	0.00	0.00	0.00	0.00	0.00
CM243	0.00	1.70+07	1.66+07	1.37+07	1.95+06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	6.80+09	6.55+09	4.64+09	1.48+08	1.60-07	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	2.45+06	2.45+06	2.45+06	2.43+06	2.27+06	1.16+06	1.44+03	0.00	0.00	0.00	0.00
CM246	0.00	4.89+05	4.89+05	4.88+05	4.83+05	4.31+05	1.38+05	0.00	0.00	0.00	0.00	0.00
CM247	0.00	3.36+00	3.36+00	3.36+00	3.36+00	3.36+00	3.36+00	3.35+00	3.22+00	2.22+00	5.30-02	0.00
SUBTOT	5.76+09	1.89+10	9.61+09	5.26+09	6.17+08	1.37+08	3.94+07	1.20+07	2.76+06	1.17+05	7.80+04	6.54+04
TOTAL	5.76+09	1.89+10	9.61+09	5.26+09	6.17+08	1.37+08	3.94+07	1.20+07	2.76+06	1.17+05	7.80+04	6.54+04

LWR-PLANT WASTE, Pu FUEL FRACTION

Fission Products

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	9.40-02	8.89-02	5.35-02	3.36-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GE 72	0.00	1.12-02	1.12-02	1.12-02	1.12-02	1.12-02	1.12-02	1.12-02	1.12-02	1.12-02	1.12-02	1.12-02
GE 73	0.00	1.98-02	1.98-02	1.98-02	1.98-02	1.98-02	1.98-02	1.98-02	1.98-02	1.98-02	1.98-02	1.98-02
GE 74	0.00	7.91-02	7.91-02	7.91-02	7.91-02	7.91-02	7.91-02	7.91-02	7.91-02	7.91-02	7.91-02	7.91-02
AS 75	0.00	8.42-02	8.42-02	8.42-02	8.42-02	8.42-02	8.42-02	8.42-02	8.42-02	8.42-02	8.42-02	8.42-02
GE 76	0.00	3.19-01	3.19-01	3.19-01	3.19-01	3.19-01	3.19-01	3.19-01	3.19-01	3.19-01	3.19-01	3.19-01
SE 76	0.00	1.63-03	1.63-03	1.63-03	1.63-03	1.63-03	1.63-03	1.63-03	1.63-03	1.63-03	1.63-03	1.63-03
SE 77	0.00	1.05+00	1.05+00	1.05+00	1.05+00	1.05+00	1.05+00	1.05+00	1.05+00	1.05+00	1.05+00	1.05+00
SE 78	0.00	2.79+00	2.79+00	2.79+00	2.79+00	2.79+00	2.79+00	2.79+00	2.79+00	2.79+00	2.79+00	2.79+00
SE 79	0.00	4.80+00	4.80+00	4.79+00	4.79+00	4.74+00	4.31+00	1.65+00	1.12-04	0.00	0.00	0.00
BR 79	0.00	5.11-04	5.62-04	1.02-03	5.62-03	5.14-02	4.85-01	3.14+00	4.80+00	4.80+00	4.80+00	4.80+00
SE 80	0.00	8.15+00	8.15+00	8.15+00	8.15+00	8.15+00	8.15+00	8.15+00	8.15+00	8.15+00	8.15+00	8.15+00
KR 80	0.00	3.26-01	3.26-01	3.26-01	3.26-01	3.26-01	3.26-01	3.26-01	3.26-01	3.26-01	3.26-01	3.26-01
BR 81	0.00	1.40+01	1.40+01	1.40+01	1.40+01	1.40+01	1.40+01	1.40+01	1.40+01	1.40+01	1.40+01	1.40+01
KR 81	0.00	1.62-01	1.62-01	1.62-01	1.62-01	1.62-01	1.62-01	1.62-01	1.62-01	1.62-01	1.62-01	1.62-01
SE 82	0.00	2.57+01	2.57+01	2.57+01	2.57+01	2.57+01	2.57+01	2.57+01	2.57+01	2.57+01	2.57+01	2.57+01
KR 82	0.00	4.09-01	4.09-01	4.09-01	4.09-01	4.09-01	4.09-01	4.09-01	4.09-01	4.09-01	4.09-01	4.09-01
KR 83	0.00	3.25+01	3.25+01	3.25+01	3.25+01	3.25+01	3.25+01	3.25+01	3.25+01	3.25+01	3.25+01	3.25+01
KR 84	0.00	7.18+01	7.18+01	7.18+01	7.18+01	7.18+01	7.18+01	7.18+01	7.18+01	7.18+01	7.18+01	7.18+01
KR 85	0.00	1.77+01	1.66+01	9.34+00	2.90-02	2.41-27	0.00	0.00	0.00	0.00	0.00	0.00
RB 85	0.00	5.67+01	5.98+01	6.71+01	7.64+01	7.65+01	7.65+01	7.65+01	7.65+01	7.65+01	7.65+01	7.65+01
KR 86	0.00	1.14+02	1.14+02	1.14+02	1.14+02	1.14+02	1.14+02	1.14+02	1.14+02	1.14+02	1.14+02	1.14+02
RB 86	0.00	9.10-06	1.20-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 86	0.00	4.45-02	4.46-02	4.46-02	4.46-02	4.46-02	4.46-02	4.46-02	4.46-02	4.46-02	4.46-02	4.46-02
RB 87	0.00	1.40+02	1.40+02	1.40+02	1.40+02	1.40+02	1.40+02	1.40+02	1.40+02	1.40+02	1.39+02	1.38+02
SR 87	0.00	9.52-06	9.52-06	9.54-06	9.71-06	1.15-05	2.89-05	2.03-04	1.94-03	1.94-02	1.93-01	1.92+00
SR 88	0.00	2.12+02	2.12+02	2.12+02	2.12+02	2.12+02	2.12+02	2.12+02	2.12+02	2.12+02	2.12+02	2.12+02
SR 89	0.00	2.44+00	1.87-02	1.77-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y 89	0.00	2.66+02	2.68+02	2.69+02	2.68+02	2.68+02	2.68+02	2.68+02	2.68+02	2.68+02	2.68+02	2.68+02
SR 90	0.00	3.23+02	3.15+02	2.52+02	2.74+01	6.28-09	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	8.39-02	8.18-02	6.55-02	7.12-03	1.63-12	0.00	0.00	0.00	0.00	0.00	0.00
ZR 90	0.00	1.54+01	2.32+01	8.59+01	3.11+02	3.38+02	3.38+02	3.38+02	3.38+02	3.38+02	3.38+02	3.38+02
Y 91	0.00	4.95+00	6.68-02	9.99-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 91	0.00	3.93+02	3.98+02	3.98+02	3.96+02	3.98+02	3.98+02	3.98+02	3.98+02	3.98+02	3.98+02	3.98+02
ZR 92	0.00	4.68+02	4.68+02	4.68+02	4.68+02	4.68+02	4.68+02	4.68+02	4.68+02	4.68+02	4.68+02	4.68+02
ZR 93	0.00	5.69+02	5.69+02	5.69+02	5.69+02	5.69+02	5.67+02	5.44+02	3.59+02	5.61+00	4.91-18	0.00
NB 93M	0.00	4.79-04	7.11-04	2.35-03	5.13-03	5.16-03	5.14-03	4.93-03	3.25-03	5.09-05	4.45-23	0.00
NB 93	0.00	2.87-05	5.91-05	7.89-04	2.17-02	2.58-01	2.62+00	2.57+01	2.11+02	5.64+02	5.69+02	5.69+02
ZR 94	0.00	6.54+02	6.54+02	6.54+02	6.54+02	6.54+02	6.54+02	6.54+02	6.54+02	6.54+02	6.54+02	6.54+02
ZR 95	0.00	1.22+01	2.48-01	1.50-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
NB 95M	0.00	1.49-02	3.04-04	1.83-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	1.23+01	2.96-01	1.74-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MO 95	0.00	6.68+02	6.92+02	6.93+02	6.93+02	6.93+02	6.93+02	6.93+02	6.93+02	6.93+02	6.93+02	6.93+02
ZR 96	0.00	7.48+02	7.48+02	7.48+02	7.48+02	7.48+02	7.48+02	7.48+02	7.48+02	7.48+02	7.48+02	7.48+02
MO 96	0.00	3.04+01	3.04+01	3.04+01	3.04+01	3.04+01	3.04+01	3.04+01	3.04+01	3.04+01	3.04+01	3.04+01
MO 97	0.00	7.99+02	7.99+02	7.99+02	7.99+02	7.99+02	7.99+02	7.99+02	7.99+02	7.99+02	7.99+02	7.99+02
MO 98	0.00	8.52+02	8.52+02	8.52+02	8.52+02	8.52+02	8.52+02	8.52+02	8.52+02	8.52+02	8.52+02	8.52+02
TC 99	0.00	8.50+02	8.50+02	8.50+02	8.49+02	8.47+02	8.22+02	6.13+02	3.23+01	5.41-12	0.00	0.00
RU 99	0.00	5.38-03	8.16-03	3.32-02	2.83-01	2.78+00	2.73+01	2.37+02	8.17+02	8.50+02	8.50+02	8.50+02
MO100	0.00	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03
RU100	0.00	4.61+01	4.61+01	4.61+01	4.61+01	4.61+01	4.61+01	4.61+01	4.61+01	4.61+01	4.61+01	4.61+01
RU101	0.00	8.39+02	8.39+02	8.39+02	8.39+02	8.39+02	8.39+02	8.39+02	8.39+02	8.39+02	8.39+02	8.39+02
RU102	0.00	9.06+02	9.06+02	9.06+02	9.06+02	9.06+02	9.06+02	9.06+02	9.06+02	9.06+02	9.06+02	9.06+02
RU103	0.00	3.13+00	5.25-03	5.46-28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	3.13-03	5.26-06	5.46-31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103	0.00	5.18+02	5.21+02	5.21+02	5.21+02	5.21+02	5.21+02	5.21+02	5.21+02	5.21+02	5.21+02	5.21+02
RU104	0.00	8.53+02	8.53+02	8.53+02	8.53+02	8.53+02	8.53+02	8.53+02	8.53+02	8.53+02	8.53+02	8.53+02
PD104	0.00	3.10+02	3.10+02	3.10+02	3.10+02	3.10+02	3.10+02	3.10+02	3.10+02	3.10+02	3.10+02	3.10+02
PD105	0.00	5.51+02	5.51+02	5.51+02	5.51+02	5.51+02	5.51+02	5.51+02	5.51+02	5.51+02	5.51+02	5.51+02
RU106	0.00	2.04+02	1.02+02	2.06-01	2.27-28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	1.93-04	9.68-05	1.95-07	2.15-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD106	0.00	6.39+02	7.41+02	8.43+02	8.43+02	8.43+02	8.43+02	8.43+02	8.43+02	8.43+02	8.43+02	8.43+02
PD107	0.00	4.80+02	4.80+02	4.80+02	4.80+02	4.80+02	4.79+02	4.75+02	4.34+02	1.78+02	2.41-02	0.00
AG107	0.00	9.09-05	1.38-04	5.66-04	4.84-03	4.76-02	4.75-01	4.73+00	4.52+01	3.01+02	4.80+02	4.80+02
PD108	0.00	3.34+02	3.34+02	3.34+02	3.34+02	3.34+02	3.34+02	3.34+02	3.34+02	3.34+02	3.34+02	3.34+02
CD108	0.00	7.42-07	7.42-07	7.42-07	7.42-07	7.42-07	7.42-07	7.42-07	7.42-07	7.42-07	7.42-07	7.42-07
AG109	0.00	1.20+02	1.20+02	1.20+02	1.20+02	1.20+02	1.20+02	1.20+02	1.20+02	1.20+02	1.20+02	1.20+02
CD109	0.00	9.81-10	5.61-10	3.67-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD110	0.00	7.10+01	7.10+01	7.10+01	7.10+01	7.10+01	7.10+01	7.10+01	7.10+01	7.10+01	7.10+01	7.10+01
AG110M	0.00	6.37-02	2.34-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	9.25-09	3.40-09	4.18-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD110	0.00	1.03+02	1.03+02	1.03+02	1.03+02	1.03+02	1.03+02	1.03+02	1.03+02	1.03+02	1.03+02	1.03+02
CD111	0.00	3.44+01	3.44+01	3.44+01	3.44+01	3.44+01	3.44+01	3.44+01	3.44+01	3.44+01	3.44+01	3.44+01
CD112	0.00	1.86+01	1.86+01	1.86+01	1.86+01	1.86+01	1.86+01	1.86+01	1.86+01	1.86+01	1.86+01	1.86+01
CD113M	0.00	2.24-04	2.14-04	1.37-04	1.59-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113	0.00	5.46-01	5.46-01	5.46-01	5.46-01	5.46-01	5.46-01	5.46-01	5.46-01	5.46-01	5.46-01	5.46-01
IN113	0.00	1.26-05	2.37-05	1.00-04	2.35-04	2.37-04	2.37-04	2.37-04	2.37-04	2.37-04	2.37-04	2.37-04
CD114	0.00	1.84+01	1.84+01	1.84+01	1.84+01	1.84+01	1.84+01	1.84+01	1.84+01	1.84+01	1.84+01	1.84+01
IN114M	0.00	4.44-10	2.81-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN114	0.00	2.19-06	2.19-06	2.19-06	2.19-06	2.19-06	2.19-06	2.19-06	2.19-06	2.19-06	2.19-06	2.19-06

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
CD115M	0.00	2.13-03	5.91-06	5.81-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN115	0.00	1.81+00	1.81+00	1.81+00	1.81+00	1.81+00	1.81+00	1.81+00	1.81+00	1.81+00	1.81+00	1.81+00
SN115	0.00	3.16-01	3.16-01	3.16-01	3.16-01	3.16-01	3.16-01	3.16-01	3.16-01	3.16-01	3.16-01	3.16-01
CD116	0.00	6.05+00	6.05+00	6.05+00	6.05+00	6.05+00	6.05+00	6.05+00	6.05+00	6.05+00	6.05+00	6.05+00
SN116	0.00	4.63+00	4.63+00	4.63+00	4.63+00	4.63+00	4.63+00	4.63+00	4.63+00	4.63+00	4.63+00	4.63+00
SN117	0.00	6.24+00	6.24+00	6.24+00	6.24+00	6.24+00	6.24+00	6.24+00	6.24+00	6.24+00	6.24+00	6.24+00
SN118	0.00	6.37+00	6.37+00	6.37+00	6.37+00	6.37+00	6.37+00	6.37+00	6.37+00	6.37+00	6.37+00	6.37+00
SN119M	0.00	3.38-03	1.23-03	1.35-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119	0.00	6.50+00	6.51+00	6.51+00	6.51+00	6.51+00	6.51+00	6.51+00	6.51+00	6.51+00	6.51+00	6.51+00
SN120	0.00	6.63+00	6.63+00	6.63+00	6.63+00	6.63+00	6.63+00	6.63+00	6.63+00	6.63+00	6.63+00	6.63+00
SN121M	0.00	2.81-06	2.79-06	2.57-06	1.13-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB121	0.00	6.83+00	6.83+00	6.83+00	6.83+00	6.83+00	6.83+00	6.83+00	6.83+00	6.83+00	6.83+00	6.83+00
SN122	0.00	7.58+00	7.58+00	7.58+00	7.58+00	7.58+00	7.58+00	7.58+00	7.58+00	7.58+00	7.58+00	7.58+00
TE122	0.00	4.85-01	4.85-01	4.85-01	4.85-01	4.85-01	4.85-01	4.85-01	4.85-01	4.85-01	4.85-01	4.85-01
SN123M	0.00	7.18-02	9.48-03	1.15-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB123	0.00	8.41+00	8.47+00	8.48+00	8.48+00	8.48+00	8.48+00	8.48+00	8.48+00	8.48+00	8.48+00	8.48+00
TE123M	0.00	2.12-05	2.43-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123	0.00	3.61-04	3.79-04	3.92-04	3.82-04	3.82-04	3.82-04	3.82-04	3.82-04	3.82-04	3.82-04	3.82-04
SN124	0.00	1.18+01	1.18+01	1.18+01	1.18+01	1.18+01	1.18+01	1.18+01	1.18+01	1.18+01	1.18+01	1.18+01
SB124	0.00	7.52-03	1.11-04	3.59-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE124	0.00	2.88-01	2.95-01	2.95-01	2.95-01	2.95-01	2.95-01	2.95-01	2.95-01	2.95-01	2.95-01	2.95-01
SB125	0.00	1.25+01	9.64+00	9.57-01	8.89-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	2.97-01	2.35-01	2.33-02	2.17-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125	0.00	6.99+00	9.82+00	1.87+01	1.97+01	1.97+01	1.97+01	1.97+01	1.97+01	1.97+01	1.97+01	1.97+01
SN126	0.00	3.33+01	3.33+01	3.32+01	3.32+01	3.30+01	3.10+01	1.66+01	3.25-02	0.00	0.00	0.00
SB126M	0.00	1.20-08	1.20-08	1.20-08	1.20-08	1.19-08	1.12-08	6.01-09	1.17-11	0.00	0.00	0.00
SB126	0.00	1.14-05	1.13-05	1.13-05	1.13-05	1.12-05	1.05-05	5.63-06	1.10-08	0.00	0.00	0.00
TE126	0.00	7.29-02	7.31-02	7.52-02	9.59-02	3.03-01	2.30+00	1.67+01	3.33+01	3.33+01	3.33+01	3.33+01
TE127M	0.00	8.20-01	8.04-02	6.74-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	2.91-03	2.86-04	2.39-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I127	0.00	6.06+01	6.14+01	6.14+01	6.14+01	6.14+01	6.14+01	6.14+01	6.14+01	6.14+01	6.14+01	6.14+01
TE128	0.00	2.06+02	2.06+02	2.06+02	2.06+02	2.06+02	2.06+02	2.06+02	2.06+02	2.06+02	2.06+02	2.06+02
XE128	0.00	4.91+00	4.91+00	4.91+00	4.91+00	4.91+00	4.91+00	4.91+00	4.91+00	4.91+00	4.91+00	4.91+00
TE129M	0.00	2.62-01	1.53-04	1.22-33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	2.36-04	1.38-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	3.38+02	3.38+02	3.38+02	3.38+02	3.38+02	3.38+02	3.37+02	3.25+02	2.25+02	5.74+00	6.69-16
XE129	0.00	1.07-01	1.07-01	1.08-01	1.09-01	1.21-01	2.45-01	1.48+00	1.36+01	1.13+02	3.33+02	3.39+02
TE130	0.00	4.79+02	4.79+02	4.79+02	4.79+02	4.79+02	4.79+02	4.79+02	4.79+02	4.79+02	4.79+02	4.79+02
XE130	0.00	1.22+01	1.22+01	1.22+01	1.22+01	1.22+01	1.22+01	1.22+01	1.22+01	1.22+01	1.22+01	1.22+01
XE131	0.00	4.76+02	4.76+02	4.76+02	4.76+02	4.76+02	4.76+02	4.76+02	4.76+02	4.76+02	4.76+02	4.76+02

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
XE132	0.00	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03
CS133	0.00	1.02+03	1.02+03	1.02+03	1.02+03	1.02+03	1.02+03	1.02+03	1.02+03	1.02+03	1.02+03	1.02+03
XE134	0.00	1.47+03	1.47+03	1.47+03	1.47+03	1.47+03	1.47+03	1.47+03	1.47+03	1.47+03	1.47+03	1.47+03
CS134	0.00	1.58+02	1.13+02	5.38+00	3.29-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BA134	0.00	8.72+01	1.32+02	2.40+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02
CS135	0.00	5.61+02	5.61+02	5.61+02	5.61+02	5.61+02	5.60+02	5.48+02	4.45+02	5.57+01	5.21-08	0.00
BA135	0.00	1.52-02	1.54-02	1.65-02	2.82-02	1.45-01	1.31+00	1.28+01	1.16+02	5.05+02	5.61+02	5.61+02
XE136	0.00	2.13+03	2.13+03	2.13+03	2.13+03	2.13+03	2.13+03	2.13+03	2.13+03	2.13+03	2.13+03	2.13+03
BA136	0.00	4.44+01	4.44+01	4.44+01	4.44+01	4.44+01	4.44+01	4.44+01	4.44+01	4.44+01	4.44+01	4.44+01
CS137	0.00	1.27+03	1.24+03	1.01+03	1.26+02	1.18-07	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	1.91-04	1.87-04	1.52-04	1.90-05	1.78-14	0.00	0.00	0.00	0.00	0.00	0.00
BA137	0.00	5.73+01	8.62+01	3.19+02	1.20+03	1.32+03	1.32+03	1.32+03	1.32+03	1.32+03	1.32+03	1.32+03
BA138	0.00	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03
LA139	0.00	1.20+03	1.20+03	1.20+03	1.20+03	1.20+03	1.20+03	1.20+03	1.20+03	1.20+03	1.20+03	1.20+03
BA140	0.00	5.67-03	1.46-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	8.54-04	2.20-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE140	0.00	1.21+03	1.21+03	1.21+03	1.21+03	1.21+03	1.21+03	1.21+03	1.21+03	1.21+03	1.21+03	1.21+03
CE141	0.00	1.84+00	7.44-04	2.17-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR141	0.00	1.07+03	1.07+03	1.07+03	1.07+03	1.07+03	1.07+03	1.07+03	1.07+03	1.07+03	1.07+03	1.07+03
CE142	0.00	1.07+03	1.07+03	1.07+03	1.07+03	1.07+03	1.07+03	1.07+03	1.07+03	1.07+03	1.07+03	1.07+03
ND142	0.00	1.23+01	1.23+01	1.23+01	1.23+01	1.23+01	1.23+01	1.23+01	1.23+01	1.23+01	1.23+01	1.23+01
PR143	0.00	9.47-03	8.97-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND143	0.00	8.32+02	8.33+02	8.33+02	8.33+02	8.33+02	8.33+02	8.33+02	8.33+02	8.33+02	8.33+02	8.33+02
CE144	0.00	2.07+02	8.51+01	2.79-02	4.08-37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	8.77-03	3.60-03	1.18-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND144	0.00	8.02+02	9.25+02	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03	1.01+03
ND145	0.00	6.29+02	6.29+02	6.29+02	6.29+02	6.29+02	6.29+02	6.29+02	6.29+02	6.29+02	6.29+02	6.29+02
ND146	0.00	6.26+02	6.26+02	6.26+02	6.26+02	6.26+02	6.26+02	6.26+02	6.26+02	6.26+02	6.26+02	6.26+02
PM147	0.00	1.05+02	8.08+01	7.47+00	3.43-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM147	0.00	6.52+01	8.96+01	1.63+02	1.70+02	1.70+02	1.70+02	1.70+02	1.70+02	1.70+02	1.70+02	1.70+02
ND148	0.00	3.74+02	3.74+02	3.74+02	3.74+02	3.74+02	3.74+02	3.74+02	3.74+02	3.74+02	3.74+02	3.74+02
PM148M	0.00	1.25-02	3.02-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	1.29-04	3.12-07	8.68-31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM148	0.00	2.27+02	2.27+02	2.27+02	2.27+02	2.27+02	2.27+02	2.27+02	2.27+02	2.27+02	2.27+02	2.27+02
SM149	0.00	1.04+01	1.04+01	1.04+01	1.04+01	1.04+01	1.04+01	1.04+01	1.04+01	1.04+01	1.04+01	1.04+01
ND150	0.00	2.13+02	2.13+02	2.13+02	2.13+02	2.13+02	2.13+02	2.13+02	2.13+02	2.13+02	2.13+02	2.13+02
SM150	0.00	3.26+02	3.26+02	3.26+02	3.26+02	3.26+02	3.26+02	3.26+02	3.26+02	3.26+02	3.26+02	3.26+02
SM151	0.00	5.41+01	5.37+01	5.00+01	2.44+01	1.88-02	1.38-33	0.00	0.00	0.00	0.00	0.00
EU151	0.00	3.26-01	7.56-01	4.47+00	3.00+01	5.44+01	5.44+01	5.44+01	5.44+01	5.44+01	5.44+01	5.44+01
SM152	0.00	1.07+02	1.07+02	1.07+02	1.07+02	1.07+02	1.07+02	1.07+02	1.07+02	1.07+02	1.07+02	1.07+02

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR, PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
EU152	0.00	1.53-01	1.45-01	8.60-02	4.76-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD152	0.00	2.08-01	2.10-01	2.27-01	2.51-01	2.51-01	2.51-01	2.51-01	2.51-01	2.51-01	2.51-01	2.51-01
EU153	0.00	1.70+02	1.70+02	1.70+02	1.70+02	1.70+02	1.70+02	1.70+02	1.70+02	1.70+02	1.70+02	1.70+02
GD153	0.00	4.23-03	1.49-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM154	0.00	6.02+01	6.02+01	6.02+01	6.02+01	6.02+01	6.02+01	6.02+01	6.02+01	6.02+01	6.02+01	6.02+01
EU154	0.00	6.98+01	6.69+01	4.53+01	9.18-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD154	0.00	3.81+00	6.76+00	2.83+01	7.27+01	7.36+01	7.36+01	7.36+01	7.36+01	7.36+01	7.36+01	7.36+01
EU155	0.00	7.72+00	5.26+00	1.68-01	1.82-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD155	0.00	1.53+00	3.98+00	9.08+00	9.24+00	9.24+00	9.24+00	9.24+00	9.24+00	9.24+00	9.24+00	9.24+00
EU156	0.00	3.65-03	1.71-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD156	0.00	1.04+02	1.04+02	1.04+02	1.04+02	1.04+02	1.04+02	1.04+02	1.04+02	1.04+02	1.04+02	1.04+02
GD157	0.00	9.26-02	9.26-02	9.26-02	9.26-02	9.26-02	9.26-02	9.26-02	9.26-02	9.26-02	9.26-02	9.26-02
GD158	0.00	2.58+01	2.58+01	2.58+01	2.58+01	2.58+01	2.58+01	2.58+01	2.58+01	2.58+01	2.58+01	2.58+01
TB159	0.00	3.55+00	3.55+00	3.55+00	3.55+00	3.55+00	3.55+00	3.55+00	3.55+00	3.55+00	3.55+00	3.55+00
GD160	0.00	2.04+00	2.04+00	2.04+00	2.04+00	2.04+00	2.04+00	2.04+00	2.04+00	2.04+00	2.04+00	2.04+00
TB160	0.00	5.28-02	1.58-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DY160	0.00	8.92-01	9.44-01	9.45-01	9.45-01	9.45-01	9.45-01	9.45-01	9.45-01	9.45-01	9.45-01	9.45-01
DY161	0.00	5.22-01	5.22-01	5.22-01	5.22-01	5.22-01	5.22-01	5.22-01	5.22-01	5.22-01	5.22-01	5.22-01
GD162	0.00	1.30-01	6.49-02	1.27-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	1.85-06	9.26-07	1.81-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DY162	0.00	3.76-01	4.41-01	5.06-01	5.06-01	5.06-01	5.06-01	5.06-01	5.06-01	5.06-01	5.06-01	5.06-01
DY163	0.00	3.83-01	3.83-01	3.83-01	3.83-01	3.83-01	3.83-01	3.83-01	3.83-01	3.83-01	3.83-01	3.83-01
DY164	0.00	1.85-01	1.85-01	1.85-01	1.85-01	1.85-01	1.85-01	1.85-01	1.85-01	1.85-01	1.85-01	1.85-01
HO165	0.00	1.66-01	1.66-01	1.66-01	1.66-01	1.66-01	1.66-01	1.66-01	1.66-01	1.66-01	1.66-01	1.66-01
HO166M	0.00	4.53-05	4.53-05	4.50-05	4.28-05	2.54-05	1.41-07	0.00	0.00	0.00	0.00	0.00
ER166	0.00	4.74-02	4.74-02	4.74-02	4.74-02	4.74-02	4.74-02	4.74-02	4.74-02	4.74-02	4.74-02	4.74-02
ER167	0.00	1.12-02	1.12-02	1.12-02	1.12-02	1.12-02	1.12-02	1.12-02	1.12-02	1.12-02	1.12-02	1.12-02
SUBTOT	0.00	3.51+04	3.51+04	3.51+04	3.51+04	3.51+04	3.51+04	3.51+04	3.51+04	3.51+04	3.51+04	3.51+04
TOTAL	0.00	3.51+04	3.51+04	3.51+04	3.51+04	3.51+04	3.51+04	3.51+04	3.51+04	3.51+04	3.51+04	3.51+04

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	9.12+02	8.62+02	5.19+02	3.26+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	3.34-01	3.34-01	3.34-01	3.34-01	3.30-01	3.00-01	1.15-01	7.83-06	0.00	0.00	0.00
KR 85	0.00	6.91+03	6.48+03	3.64+03	1.13+01	9.38-25	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	7.39-01	9.78-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	1.15-05	1.15-05	1.15-05	1.15-05	1.15-05	1.15-05	1.15-05	1.15-05	1.15-05	1.15-05	1.13-05
SR 89	0.00	6.88+04	5.29+02	4.99-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	4.56+04	4.45+04	3.56+04	3.87+03	8.86-07	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	4.56+04	4.45+04	3.57+04	3.87+03	8.89-07	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	1.21+05	1.63+03	2.44-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	1.46+00	1.46+00	1.46+00	1.46+00	1.46+00	1.45+00	1.39+00	9.20-01	1.44-02	1.26-20	0.00
NB 93M	0.00	1.35-01	2.01-01	6.64-01	1.45+00	1.46+00	1.45+00	1.39+00	9.20-01	1.44-02	1.26-20	0.00
ZR 95	0.00	2.58+05	5.25+03	3.16-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	5.48+03	1.12+02	6.71-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	4.83+05	1.16+04	6.65-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	1.45+01	1.45+01	1.45+01	1.45+01	1.44+01	1.40+01	1.04+01	5.51-01	9.21-14	0.00	0.00
RU103	0.00	1.00+05	1.68+02	1.75-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	1.00+05	1.68+02	1.75-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	6.84+05	3.43+05	6.92+02	7.64-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	6.84+05	3.43+05	6.92+02	7.64-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	2.29-01	2.29-01	2.29-01	2.29-01	2.29-01	2.29-01	2.27-01	2.07-01	8.51-02	1.15-05	0.00
AG109M	0.00	2.59-06	1.48-06	9.72-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	2.59-06	1.48-06	9.72-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	2.99+02	1.10+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	3.89+01	1.43+01	1.76-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	5.07-02	4.83-02	3.09-02	3.59-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	1.02-05	6.44-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	9.82-06	6.22-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	5.62+01	1.56-01	1.53-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	1.48+01	5.38+00	5.94-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	1.09-04	1.08-04	9.99-05	4.40-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	6.10+02	8.05+01	9.80-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	1.92-01	2.21-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	1.32+02	1.94+00	6.30-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	1.32+04	1.02+04	1.01+03	9.42-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	5.35+03	4.23+03	4.20+02	3.90-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	9.44-01	9.44-01	9.44-01	9.43-01	9.37-01	8.81-01	4.72-01	9.23-04	0.00	0.00	0.00
SB126M	0.00	9.44-01	9.44-01	9.44-01	9.43-01	9.37-01	8.81-01	4.72-01	9.23-04	0.00	0.00	0.00
SB126	0.00	9.49-01	9.34-01	9.34-01	9.34-01	9.28-01	8.72-01	4.67-01	9.14-04	0.00	0.00	0.00
TE127M	0.00	7.74+03	7.59+02	6.36-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	7.65+03	7.50+02	6.29-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE129M	0.00	7.79+03	4.55+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	4.99+03	2.92+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	5.52-02	5.52-02	5.52-02	5.52-02	5.52-02	5.52-02	5.50-02	5.30-02	3.67-02	9.37-04	1.09-19
XE131M	0.00	3.33+00	1.63-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	2.06+05	1.47+05	7.00+03	4.29-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	4.96-01	4.96-01	4.96-01	4.96-01	4.95-01	4.94-01	4.84-01	3.93-01	4.92-02	4.60-11	0.00
CS137	0.00	1.10+05	1.08+05	8.75+04	1.09+04	1.02-05	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	1.03+05	1.01+05	8.18+04	1.02+04	9.57-06	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	4.13+02	1.07-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	4.76+02	1.23-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	5.26+04	2.13+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	6.32+02	5.98-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	6.62+05	2.72+05	8.92+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	6.62+05	2.72+05	8.92+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	4.75+01	5.94-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	9.77+04	7.50+04	6.94+03	3.18-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	2.63+02	6.35-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	2.11+01	5.10-02	1.42-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	1.47+03	1.46+03	1.36+03	6.64+02	5.12-01	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	3.00+01	2.64+01	1.69+01	9.32-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD153	0.00	1.49+01	5.25+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	1.01+04	9.70+03	6.57+03	1.33+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	9.84+03	6.71+03	2.14+02	2.32-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	2.04+02	9.57-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	5.98+02	1.79+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	2.87+02	1.43+02	2.80-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	2.87+02	1.43+02	2.80-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HO166M	0.00	6.13-05	6.13-05	6.09-05	7.68-05	4.57-05	2.53-07	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	4.57+06	1.81+06	2.70+05	2.98+04	2.18+01	2.06+01	1.55+01	3.05+00	2.00-01	9.59-04	1.13-05
TOTAL	0.00	4.57+06	1.81+06	2.70+05	2.98+04	2.18+01	2.06+01	1.55+01	3.05+00	2.00-01	9.59-04	1.13-05

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	3.24-02	3.06-02	1.85-02	1.16-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	1.27-04	1.27-04	1.27-04	1.27-04	1.25-04	1.14-04	4.36-05	2.97-09	0.00	0.00	0.00
KR 85	0.00	1.12+01	1.05+01	5.91+00	1.83-02	1.52-27	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	3.49-03	4.62-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	7.48-09	7.48-09	7.48-09	7.48-09	7.48-09	7.48-09	7.48-09	7.48-09	7.48-09	7.47-09	7.38-09
SR 89	0.00	2.47+02	1.90+00	1.79-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	5.98+01	5.83+01	4.67+01	5.07+00	1.16-09	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	2.69+02	2.62+02	2.10+02	2.28+01	5.23-09	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	4.59+02	6.21+00	9.28-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	1.73-04	1.73-04	1.73-04	1.73-04	1.73-04	1.72-04	1.65-04	1.09-04	1.71-06	1.49-24	0.00
NB 93M	0.00	2.41-05	3.58-05	1.18-04	2.58-04	2.60-04	2.58-04	2.48-04	1.64-04	2.56-06	2.24-24	0.00
ZR 95	0.00	1.35+03	2.75+01	1.66-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	7.63+00	1.55-01	9.35-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	2.33+03	5.59+01	3.30-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	9.78-03	9.78-03	9.78-03	9.78-03	9.75-03	9.47-03	7.06-03	3.72-04	6.22-17	0.00	0.00
RU103	0.00	3.31+02	5.54-01	5.76-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	4.76+01	7.98-02	8.30-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	4.06+01	2.04+01	4.10-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	7.20+03	3.61+03	7.28+00	8.03-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	1.90-05	1.90-05	1.90-05	1.90-05	1.90-05	1.90-05	1.88-05	1.72-05	7.06-06	9.54-10	0.00
AG109M	0.00	2.71-09	1.55-09	1.01-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	2.58-09	1.48-09	9.68-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	5.05+00	1.86+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	2.82-01	1.04-01	1.28-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	6.71-05	6.38-05	4.09-05	4.75-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	1.10-08	6.95-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	4.63-08	2.93-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	2.06-01	5.71-04	5.61-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	1.56-02	5.68-03	6.27-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	1.39-07	1.38-07	1.27-07	5.58-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	2.16+00	2.85-01	3.47-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	5.65-04	6.49-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	1.81+00	2.67-02	8.66-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	5.35+01	4.14+01	4.11+00	3.82-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	9.20+00	7.27+00	7.22-01	6.71-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	1.02-03	1.02-03	1.02-03	1.02-03	1.01-03	9.50-04	5.09-04	9.96-07	0.00	0.00	0.00
SB126M	0.00	6.38-03	6.38-03	6.38-03	6.38-03	6.34-03	5.96-03	3.19-03	6.24-06	0.00	0.00	0.00
SB126	0.00	1.23-02	1.22-02	1.22-02	1.21-02	1.21-02	1.13-02	6.08-03	1.19-05	0.00	0.00	0.00
TE127M	0.00	4.26+00	4.18-01	3.51-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	1.23+01	1.21+00	1.01-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

PLUTONIUM FUEL FRACTION IN A P/R 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE129M	0.00	1.55+01	9.04-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	1.81+01	1.06-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	3.63-05	3.63-05	3.63-05	3.63-05	3.63-05	3.63-05	3.62-05	3.49-05	2.42-05	6.16-07	7.18-23
XE131M	0.00	6.47-03	3.16-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	2.18+03	1.55+03	7.41+01	4.54-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	2.41-04	2.41-04	2.41-04	2.41-04	2.41-04	2.40-04	2.35-04	1.91-04	2.39-05	2.24-14	0.00
CS137	0.00	1.60+02	1.76+02	1.43+02	1.79+01	1.67-08	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	4.05+02	3.96+02	3.21+02	4.02+01	3.76-08	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	1.38+00	3.56-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	8.38+00	2.17-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	1.03+02	4.19-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	1.37+00	1.30-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	5.42+02	2.22+02	7.30-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	5.13+03	2.10+03	6.91-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	1.54-01	1.93-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	5.04+01	3.87+01	3.58+00	1.64-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	3.26+00	7.87-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	1.71-01	4.13-04	1.15-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	2.57+00	2.55+00	2.37+00	1.16+00	8.92-04	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	5.36-01	5.08-01	3.02-01	1.67-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD153	0.00	2.15-02	7.56-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	8.31+01	7.96+01	5.39+01	1.09+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	8.28+00	5.65+00	1.80-01	1.95-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	2.03+00	9.52-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	5.08+00	1.52-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	9.76-01	4.88-01	9.54-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	3.87+00	1.93+00	3.78-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HO166M	0.00	8.75-07	8.74-07	8.70-07	8.26-07	4.91-07	2.72-09	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	2.12+04	8.69+03	8.75+02	8.83+01	3.09-02	2.86-02	1.76-02	9.07-04	5.94-05	6.25-07	7.38-09
TOTAL	0.00	2.12+04	8.69+03	8.75+02	8.83+01	3.09-02	2.86-02	1.76-02	9.07-04	5.94-05	6.25-07	7.38-09

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	4.56+09	4.31+09	2.59+09	1.63+07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	8.35+07	8.35+07	8.35+07	8.34+07	8.26+07	7.51+07	2.68+07	1.96+03	0.00	0.00	0.00
KR 85	0.00	2.30+10	2.16+10	1.21+10	3.76+07	3.13-16	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	3.69+08	4.89+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	5.74+03	5.74+03	5.74+03	5.74+03	5.74+03	5.74+03	5.74+03	5.74+03	5.74+03	5.73+03	5.66+03
SR 89	0.00	2.29+14	1.76+12	1.66-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	1.52+15	1.48+15	1.19+15	1.29+14	2.96+04	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	1.52+13	1.48+13	1.19+13	1.29+12	2.96+02	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	1.21+14	1.63+12	2.44-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	3.65+08	3.65+08	3.65+06	3.65+08	3.65+08	3.63+08	3.49+08	2.30+08	3.60+06	3.15-12	0.00
NB 93M	0.00	3.38+07	5.03+07	1.66+06	3.63+08	3.65+08	3.63+08	3.49+08	2.30+08	3.60+06	3.15-12	0.00
ZR 95	0.00	2.58+14	5.25+12	3.16-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	-5.48+03	-1.12+02	-6.71-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	1.61+14	3.87+12	2.28-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	7.24+09	7.24+09	7.24+09	7.24+09	7.22+09	7.01+09	5.22+09	2.75+08	4.61-05	0.00	0.00
RU103	0.00	3.34+13	5.61+10	5.83-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	5.02+10	8.42+07	8.75-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	3.42+15	1.72+15	3.46+12	3.82-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	-6.84+05	-3.43+05	-6.92+02	-7.64-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	1.15+06	1.15+06	1.15+06	1.15+06	1.15+06	1.14+06	1.13+06	1.04+06	4.26+05	5.75+01	0.00
AG109M	0.00	-2.59-06	-1.48-06	-9.72-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	1.30+03	7.42+02	4.86+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	9.97+11	3.67+11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	-3.89+01	-1.43+01	-1.76-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	-5.07-02	-4.83-02	-3.09-02	-3.59-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	1.45+04	9.20+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	-9.82-06	-6.22-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	5.62+10	1.56+08	1.53-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	-1.48+01	-5.38+00	-5.94-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	-1.09-04	-1.08-04	-9.99-05	-4.40-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	-6.10+02	-8.05+01	-9.80-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	-1.92-01	-2.21-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	1.69+11	2.78+09	9.01-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	1.47+13	1.14+13	1.13+12	1.05+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	1.34+12	1.06+12	1.05+11	9.76+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	4.72+08	4.72+08	4.72+06	4.72+08	4.69+08	4.40+08	2.36+08	4.61+05	0.00	0.00	0.00
SB126M	0.00	-9.44-01	-9.44-01	-9.44-01	-9.43-01	-9.37-01	-8.81-01	-4.72-01	-9.23-04	0.00	0.00	0.00
SB126	0.00	-9.49-01	-9.34-01	-9.34-01	-9.34-01	-9.28-01	-8.72-01	-4.67-01	-9.14-04	0.00	0.00	0.00
TE127M	0.00	7.74+12	7.59+11	6.36+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	2.55+11	2.50+10	2.10+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE129M	0.00	7.79+12	4.55+09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	4.99+10	2.92+07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	2.76+09	2.76+09	2.76+09	2.76+09	2.76+09	2.76+09	2.75+09	2.65+09	1.84+09	4.60+07	5.46-09
XE131M	0.00	8.32+06	4.07-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	5.14+14	3.67+14	1.75+13	1.07+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	1.65+08	1.65+08	1.65+08	1.65+08	1.65+08	1.65+08	1.61+08	1.31+08	1.64+07	1.53-02	0.00
CS137	0.00	2.20+14	2.15+14	1.75+14	2.19+13	2.05+04	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	-1.03+05	-1.01+05	-8.18+04	-1.02+04	-9.57-06	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	4.13+11	1.07+03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	1.19+11	3.07+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	1.05+13	4.26+09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	1.05+11	9.97+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	3.31+15	1.36+15	4.46+11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	-6.62+05	-2.72+05	-8.92+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	5.94+09	7.43-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	4.89+13	3.75+13	3.47+12	1.59+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	-2.63+02	-6.35-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	-2.11+01	-5.10-02	-1.42-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	7.37+11	7.31+11	6.80+11	3.32+11	2.56+08	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	7.51+10	7.09+10	4.21+10	2.33+08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD153	0.00	4.98+09	1.75+09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	1.01+14	9.70+13	6.57+13	1.33+12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	3.28+12	2.24+12	7.13+10	7.73-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	-2.04+02	-9.57-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	5.98+11	1.79+10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB161	0.00	-2.45-04	-2.87-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	-2.87+02	-1.43+02	-2.80-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	-2.87+02	-1.43+02	-2.80-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HO166M	0.00	4.07+04	4.06+04	4.04+04	3.84+04	2.28+04	1.26+02	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	1.00+16	5.32+15	1.47+15	1.54+14	1.17+10	1.12+10	9.09+09	3.52+09	1.86+09	4.68+07	5.66+03
TOTAL	0.00	1.00+16	5.32+15	1.47+15	1.54+14	1.17+10	1.12+10	9.09+09	3.52+09	1.86+09	4.68+07	5.66+03

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR. PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	3.04+05	2.87+05	1.73+05	1.09+03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	8.35+01	8.35+01	8.35+01	8.34+01	8.26+01	7.51+01	2.88+01	1.96-03	0.00	0.00	0.00
KR 85	0.00	-6.91+03	-6.48+03	-3.64+03	-1.13+01	-9.38-25	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	3.69+04	4.89-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	1.15-01	1.15-01	1.15-01	1.15-01	1.15-01	1.15-01	1.15-01	1.15-01	1.15-01	1.15-01	1.13-01
SR 89	0.00	2.29+10	1.76+08	1.66-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	1.52+11	1.48+11	1.19+11	1.29+10	2.96+00	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	2.28+09	2.23+09	1.78+09	1.94+08	4.44-02	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	4.02+09	5.44+07	8.13-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	1.83+03	1.83+03	1.83+03	1.82+03	1.82+03	1.82+03	1.74+03	1.15+03	1.80+01	1.57-17	0.00
NB 93M	0.00	3.38+02	5.03+02	1.66+03	3.63+03	3.65+03	3.63+03	3.49+03	2.30+03	3.60+01	3.15-17	0.00
ZR 95	0.00	4.30+09	8.76+07	5.27-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	-5.48+03	-1.12+02	-6.71-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	4.83+09	1.16+08	6.85-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	7.24+04	7.24+04	7.24+04	7.24+04	7.22+04	7.01+04	5.22+04	2.75+03	4.61-10	0.00	0.00
RU103	0.00	1.25+09	2.10+06	2.19-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	1.00+07	1.68+04	1.75-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	6.84+10	3.43+10	6.92+07	7.64-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	-6.84+05	-3.43+05	-6.92+02	-7.64-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	2.29+02	2.29+02	2.29+02	2.29+02	2.29+02	2.29+02	2.27+02	2.07+02	8.51+01	1.15-02	0.00
AG109M	0.00	-2.59-06	-1.48-06	-9.72-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	1.30-02	7.42-03	4.86-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	9.97+06	3.67+06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	-3.89+01	-1.43+01	-1.76-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	-5.07-02	-4.83-02	-3.09-02	-3.59-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	5.09-01	3.22-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	-9.82-06	-6.22-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	1.87+06	5.21+03	5.12-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	-1.48+01	-5.38+00	-5.94-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	-1.09-04	-1.08-04	-9.99-05	-4.40-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN123N	0.00	-6.10+02	-8.05+01	-9.80-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	-1.92-01	-2.21-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	6.60+06	9.72+04	3.15-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	1.32+08	1.02+08	1.01+07	9.42-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	5.35+07	4.23+07	4.20+06	3.90-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	2.36+03	2.36+03	2.36+03	2.36+03	2.34+03	2.20+03	1.18+03	2.31+00	0.00	0.00	0.00
SB126M	0.00	-9.44-01	-9.44-01	-9.44-01	-9.43-01	-9.37-01	-8.81-01	-4.72-01	-9.23-04	0.00	0.00	0.00
SB126	0.00	-9.49-01	-9.34-01	-9.34-01	-9.34-01	-9.28-01	-8.72-01	-4.67-01	-9.14-04	0.00	0.00	0.00
TE127M	0.00	1.55+08	1.52+07	1.27-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	3.82+07	3.75+06	3.14-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

PLUTONIUM FUEL FRACTION IN A PWR 3.5% ENR, PROPERTIES AFTER SEPARATION

POWER = 30.00 MW, BURNUP = 33000.MWD, FLUX= 1.67+13N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT MCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE129M	0.00	3.69+08	2.28+05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	6.24+06	3.65+03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	9.19+05	9.20+05	9.20+05	9.20+05	9.20+05	9.20+05	9.16+05	8.83+05	6.12+05	1.56+04	1.82-12
I131	0.00	7.63+06	1.69-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XE131M	0.00	-3.33+00	-1.63-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XE133	0.00	-5.24-03	-7.25-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	2.29+10	1.63+10	7.78+06	4.76-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	4.96+03	4.96+03	4.96+03	4.96+03	4.95+03	4.94+03	4.84+03	3.93+03	4.92+02	4.60-07	0.00
CS137	0.00	5.51+09	5.39+09	4.37+09	5.47+08	5.12-01	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	-1.03+05	-1.01+05	-8.18+04	-1.02+04	-9.57-06	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	2.07+07	5.34-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	2.38+07	6.14-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	5.84+08	2.36+05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	1.26+07	1.20-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	6.62+10	2.72+10	8.92+06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	-6.62+05	-2.72+05	-8.92+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	7.92+05	9.90-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	4.89+08	3.75+08	3.47+07	1.59-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	-2.63+02	-6.35-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	-2.11+01	-5.10-02	-1.42-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	3.68+06	3.65+06	3.40+06	1.66+06	1.28+03	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	3.75+05	3.54+05	2.11+05	1.17+03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD153	0.00	7.47+04	2.62+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	5.07+06	4.85+08	3.29+08	6.66+06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	4.92+07	3.35+07	1.07+06	1.16-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	-2.04+02	-9.57-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	1.49+07	4.47+05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB161	0.00	-2.45-04	-2.87-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	-2.67+02	-1.43+02	-2.80-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	-2.87+02	-1.43+02	-2.80-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HO166M	0.00	1.63-03	1.63-03	1.62-03	1.54-03	9.13-04	5.05-06	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	3.57+11	2.35+11	1.26+11	1.37+10	1.01+06	1.00+06	9.80+05	8.93+05	6.13+05	1.56+04	1.13-01
TOTAL	0.00	3.57+11	2.35+11	1.26+11	1.37+10	1.01+06	1.00+06	9.80+05	8.93+05	6.13+05	1.56+04	1.13-01

APPENDIX 2.E

HTGR PLANT WASTE

(Power 65 MW/MT, Burnup 94, 271 MWD/MT, Spent Fuel Processed 365 Days After Discharge, 0.5% Loss to Waste During Reprocessing Plus U-235 Recycled Makeup that is Discarded Without Reprocessing)

HTGR PLANT WASTE

Summary Tables

THERMAL POWER

WATTS PER METRIC TON OF FUEL

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	2.29E+01	1.99E+01	5.94E+00	5.23E-04	2.36E-05	5.46E-07	5.64E-11	5.41E-11	3.58E-11	5.67E-13	5.72E-31	.00E+00
STRONTIUM	2.13E+03	2.00E+03	1.60E+03	1.74E+02	9.05E-03	3.99E-08	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00
CESIUM	7.56E+03	5.81E+03	1.46E+03	1.57E+02	1.57E-02	3.29E-04	3.28E-04	3.21E-04	2.61E-04	3.27E-05	3.10E-14	.00E+00
SR+CS	9.69E+03	7.81E+03	3.06E+03	3.31E+02	2.47E-02	3.29E-04	3.28E-04	3.21E-04	2.61E-04	3.27E-05	3.10E-14	.00E+00
FP-SR-CS	1.14E+04	4.53E+03	1.30E+02	1.98E+00	4.48E-02	2.57E-02	2.45E-02	1.80E-02	1.49E-03	6.14E-05	1.31E-06	1.65E-22
KR85+I129	9.63E+01	9.03E+01	5.07E+01	1.60E-01	7.67E-05	7.67E-05	7.67E-05	7.64E-05	7.36E-05	5.11E-05	1.31E-06	1.65E-22
FISSION PROD.	2.11E+04	1.23E+04	3.19E+03	3.33E+02	6.95E-02	2.60E-02	2.49E-02	1.84E-02	1.75E-03	9.41E-05	1.31E-06	1.65E-22
U-TH WASTE	5.55E-01	5.57E-01	5.57E-01	5.18E-01	4.90E-01	4.88E-01	4.72E-01	3.41E-01	2.20E-02	5.98E-03	8.18E-04	3.03E-04
PU FUEL WASTE	2.37E+02	2.36E+02	2.22E+02	1.16E+02	1.18E+01	5.69E+00	2.23E+00	5.20E-01	1.51E-01	1.34E-02	6.06E-04	1.67E-05
TRANS PU	9.05E+01	6.26E+01	4.06E+01	5.18E+00	3.85E+00	3.79E+00	3.57E+00	3.28E+00	2.44E+00	1.31E-01	1.74E-05	6.50E-06
TOTAL WASTE	2.15E+04	1.27E+04	3.46E+03	4.55E+02	1.62E+01	1.00E+01	6.29E+00	4.16E+00	2.62E+00	1.51E-01	1.44E-03	3.26E-04

RADIOACTIVITY

CURIES PER METRIC TON OF FUEL
(PARENTS AND DAUGHTERS IN CHAINS ARE INCLUDED IN TOTALS)

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	1.99E+03	1.68E+03	4.23E+02	3.06E+00	1.90E-01	4.50E-02	3.84E-02	1.76E-02	7.48E-06	4.76E-09	4.80E-27	.00E+00
STRONTIUM	5.92E+05	5.55E+05	4.45E+05	4.83E+04	2.51E+00	1.11E-05	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00
CESIUM	1.16E+06	9.86E+05	4.93E+05	5.93E+04	6.47E+00	6.77E-01	6.75E-01	6.62E-01	5.37E-01	6.73E-02	6.39E-11	.00E+00
SR+CS	1.75E+06	1.54E+06	9.37E+05	1.08E+05	8.98E+00	6.77E-01	6.75E-01	6.62E-01	5.37E-01	6.73E-02	6.39E-11	.00E+00
FP-SR-CS	2.76E+06	1.17E+06	5.25E+04	5.69E+02	5.43E+01	4.33E+01	4.19E+01	3.18E+01	5.55E+00	1.60E-01	2.00E-03	2.51E-19
KR85+I129	5.92E+04	5.55E+04	3.12E+04	9.83E+01	1.17E-01	1.17E-01	1.17E-01	1.16E-01	1.12E-01	7.76E-02	1.99E-03	2.51E-19
FISSION PROD.	4.51E+06	2.71E+06	9.90E+05	1.08E+05	6.32E+01	4.40E+01	4.25E+01	3.25E+01	6.09E+00	2.27D-01	2.00E-03	2.51E-19
U-TH WASTE	3.69E+01	3.88E+01	4.15E+01	3.07E+01	2.28E+01	2.26E+01	2.19E+01	1.60E+01	1.04E+00	2.30E-01	3.89E-02	1.73E-02
PU FUEL WASTE	1.15E+04	1.13E+04	9.43E+03	3.57E+03	3.37E+02	1.19E+02	4.43E+01	2.93E+01	6.62E+00	2.48E-01	2.65E-03	1.02E-03
TRANS PU	2.68E+03	1.92E+03	1.30E+03	2.87E+02	2.47E+02	2.44E+02	2.37E+02	2.24E+02	1.67E+02	9.00E+00	1.02E-03	3.95E-04
TOTAL WASTE	4.53E+06	2.72E+06	1.00E+06	1.12E+05	6.70E+02	4.30E+02	3.45E+02	3.02E+02	1.81E+02	9.70E+00	4.45E-02	1.87E-02

INGESTION TOXICITY

THE INGESTION TOXICITY INDEX IS THE BASE 10 LOGARITHM OF THE
CUBIC METERS OF WATER PER TON OF FUEL TO DILUTE TO RCG

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	7.68	7.62	7.11	5.00	3.71	2.32	2.28	1.94	-1.43	-4.71	*****	*****
STRONTIUM	11.98	11.97	11.87	10.91	6.62	1.27	*****	*****	*****	*****	*****	*****
CESIUM	10.89	10.77	10.15	9.17	5.18	3.83	3.83	3.82	3.73	2.83	-6.19	*****
SR+CS	12.01	11.99	11.88	10.91	6.64	3.83	3.83	3.82	3.73	2.83	-6.19	*****
FP-SR-CS	11.07	10.69	8.68	7.04	6.34	6.33	6.33	6.32	6.28	6.11	4.52	*****
KR85+I129	6.29	6.29	6.29	6.29	6.29	6.29	6.29	6.29	6.27	6.11	4.52	*****
FISSION PROD.	12.06	12.01	11.88	10.91	6.81	6.33	6.33	6.32	6.28	6.11	4.52	*****
U+TH FUEL WASTE	7.47	7.47	7.47	7.47	7.46	7.46	7.45	7.34	6.23	4.70	4.64	4.58
PU FUEL WASTE	9.16	9.15	9.13	8.87	8.20	8.09	8.04	7.92	6.87	4.61	2.78	2.39
TRANS PU	8.48	8.42	8.28	7.67	7.62	7.62	7.60	7.57	7.45	6.18	2.36	1.98
TOTAL WASTE	12.06	12.02	11.88	10.92	8.37	8.29	8.25	8.16	7.59	6.46	4.89	4.58

***** TOXICITY INDEX IS LESS THAN -10
RCG IS RADIONUCLIDE CONCENTRATION GUIDE BASED UPON 10 CFR 20

INHALATION TOXICITY

THE INHALATION TOXICITY INDEX IS THE BASE 10 LOGARITHM OF THE
CUBIC METERS OF AIR TO DILUTE TO RCG PER METRIC TON OF FUEL

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	12.68	12.62	12.10	9.18	7.88	6.32	6.28	5.94	2.72	.41	*****	*****
STRONTIUM	15.98	15.97	15.87	14.91	10.62	5.27	*****	*****	*****	*****	*****	*****
CESIUM	15.30	15.20	14.72	13.77	9.78	8.35	8.35	8.34	8.25	7.35	-1.67	*****
SR+CS	16.06	16.04	15.90	14.94	10.68	8.35	8.35	8.34	8.25	7.35	-1.67	*****
FP-SR-CS	15.78	15.41	13.94	12.25	10.51	10.43	10.42	10.34	9.93	9.59	8.00	-7.90
KR85+I129	11.31	11.28	11.04	9.79	9.77	9.77	9.77	9.76	9.75	9.59	8.00	-7.90
FISSION PROD.	16.25	16.13	15.90	14.94	10.91	10.44	10.43	10.34	9.94	9.60	8.00	-7.90
U+TH FUEL WASTE	13.51	13.52	13.53	13.47	13.42	13.41	13.40	13.26	11.95	10.95	10.60	10.31
PU FUEL WASTE	17.01	17.01	16.98	16.67	15.44	14.73	14.28	13.57	12.92	11.50	9.85	9.47
TRANS PU	15.81	15.79	15.68	15.15	15.10	15.10	15.08	15.05	14.92	13.65	9.44	9.06
TOTAL WASTE	17.10	17.08	17.03	16.69	15.61	15.26	15.16	15.07	14.93	13.66	10.70	10.39

***** TOXICITY INDEX IS LESS THAN -10
RCG IS RADIONUCLIDE CONCENTRATION GUIDE BASED UPON 10 CFR 20

HTGR PLANT WASTE

Actinides

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 842.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
HE 4	0.00	4.80-01	6.40-01	1.99+00	1.11+01	2.14+01	2.59+01	5.36+01	2.46+02	4.82+02	5.68+02	6.85+02
TL207	0.00	4.06-10	5.44-10	1.49-09	4.14-09	4.22-09	3.48-09	5.16-10	6.75-12	6.69-12	6.13-12	2.55-12
TL208	0.00	2.43-07	1.40-09	1.73-09	7.33-10	6.94-13	5.67-13	5.69-13	5.87-13	7.40-13	1.21-12	1.20-12
PB206	0.00	3.70-10	7.63-10	1.42-08	7.96-07	1.42-03	8.10-01	9.07+01	9.98+02	1.10+03	1.12+03	1.34+03
PB207	0.00	5.68-05	9.28-05	8.62-04	2.46-02	3.16-01	2.95+00	1.36+01	1.59+01	2.05+01	6.45+01	3.45+02
PB208	0.00	2.36-01	2.40-01	2.45-01	2.79-01	3.04-01	3.06-01	3.23-01	4.93-01	2.45+00	3.39+01	3.93+02
PB209	0.00	2.34-08	1.42-10	3.60-10	2.42-09	2.22-06	1.51-07	2.90-07	2.81-07	1.42-08	3.39-21	0.00
PB210	0.00	1.26-06	1.97-06	7.34-06	5.26-07	1.36-04	6.02-03	4.71-02	8.53-03	8.02-06	7.91-06	6.69-06
PB211	0.00	3.13-09	4.70-09	1.15-08	3.19-08	3.25-08	2.68-08	3.96-09	5.20-11	5.15-11	4.72-11	1.96-11
PB212	0.00	1.41-04	8.16-07	1.01-06	4.26-07	4.03-10	3.30-10	3.31-10	3.41-10	4.30-10	7.04-10	6.95-10
BI209	0.00	1.55-04	1.59-04	1.63-04	3.92-04	2.10-02	1.60+00	4.42+01	5.53+02	2.08+03	2.17+03	2.17+03
BI210	0.00	6.33-12	1.29-11	4.79-11	3.45-10	9.02-08	3.93-06	3.06-05	5.57-06	5.24-09	5.17-09	4.50-09
BI211	0.00	1.47-10	2.50-10	6.63-10	1.90-09	1.93-09	1.60-09	2.37-10	3.10-12	3.07-12	2.81-12	1.17-12
BI212	0.00	1.34-05	7.77-06	9.53-06	4.06-08	3.64-11	3.14-11	3.15-11	3.25-11	4.10-11	6.71-11	6.62-11
BI213	0.00	5.66-09	3.45-11	8.47-11	5.85-10	5.36-09	3.65-08	7.02-08	6.81-08	3.43-09	8.20-22	0.00
PO210	0.00	1.67-10	2.86-10	1.32-09	9.56-09	2.48-06	1.08-04	8.46-04	1.54-04	1.44-07	1.42-07	1.24-07
PO216	0.00	5.85-10	3.27-12	4.03-12	1.71-12	1.61-15	1.32-15	1.32-15	1.37-15	1.72-15	2.82-15	2.78-15
RN219	0.00	6.90-12	8.04-12	2.20-11	8.11-11	6.23-11	5.14-11	7.62-12	9.97-14	9.68-14	9.05-14	3.76-14
RN220	0.00	2.15-07	1.24-09	1.53-09	8.48-10	6.14-13	5.02-13	5.03-13	5.19-13	6.55-13	1.07-12	1.06-12
RN222	0.00	1.19-10	1.19-10	1.22-10	4.25-10	7.27-08	3.17-06	2.48-05	4.49-06	4.22-09	4.17-09	3.63-09
FR221	0.00	6.00-10	3.65-12	8.95-12	8.20-11	5.65-10	3.87-09	7.44-09	7.21-09	3.64-10	8.69-23	0.00
FR223	0.00	2.52-11	3.78-11	1.03-10	2.88-10	2.95-10	2.42-10	3.58-11	4.69-13	4.65-13	4.26-13	1.77-13
RA223	0.00	1.51-06	2.02-06	5.51-06	1.53-05	1.56-05	1.29-05	1.91-06	2.50-08	2.48-08	2.27-08	9.43-09
RA224	0.00	1.23-03	7.10-06	8.76-06	3.71-06	3.51-09	2.87-09	2.88-09	2.97-09	3.74-09	6.13-09	6.05-09
RA225	0.00	2.73-06	1.65-08	4.16-08	2.63-07	2.57-06	1.75-05	3.36-05	3.26-05	1.64-06	3.93-19	0.00
RA226	0.00	1.55-05	1.86-05	1.91-05	6.62-05	1.13-02	9.94-01	3.87+00	7.00-01	6.58-04	6.49-04	5.65-04
RA228	0.00	1.64-04	1.48-04	5.94-05	1.97-06	1.96-06	1.96-06	1.97-06	2.03-06	2.56-06	4.20-06	4.14-06
AC225	0.00	1.63-06	1.12-08	2.74-08	1.89-07	1.74-06	1.18-05	2.27-05	2.20-05	1.11-06	2.65-19	0.00
AC227	0.00	1.10-03	1.42-03	3.88-03	1.08-02	1.10-02	9.08-03	1.35-03	1.76-05	1.75-05	1.60-05	6.64-06
AC228	0.00	1.71-08	1.54-08	6.20-09	2.05-10	2.05-10	2.05-10	2.06-10	2.12-10	2.67-10	4.38-10	4.32-10
TH227	0.00	1.22-08	3.23-06	8.83-06	2.40-05	2.50-05	2.06-05	3.06-06	4.00-08	3.97-08	3.64-08	1.51-08
TH228	0.00	1.19-03	1.38-03	1.71-03	7.23-04	6.85-07	5.60-07	5.62-07	5.79-07	7.30-07	1.20-06	1.18-06
TH229	0.00	2.54-03	3.03-03	7.44-03	5.14-02	4.71-01	3.21+00	6.17+00	5.98+00	3.01-01	7.20-14	0.00
TH230	0.00	3.50-03	3.95-03	8.99-03	1.39-01	3.21+00	3.23+01	1.96+02	3.56+01	3.35-02	3.30-02	2.87-02
TH231	0.00	1.29-10	1.27-09	1.27-09	1.27-09	1.30-09	1.52-09	2.35-09	2.42-09	2.40-09	2.20-09	9.14-10
TH232	9.07+05	4.20+03	4.20+03	4.20+03	4.20+03	4.20+03	4.21+03	4.22+03	4.35+03	5.48+03	8.98+03	8.86+03
TH234	0.00	4.43-05	2.66-06	2.66-06	2.66-08	2.66-05	2.67-05	2.69-08	2.79-08	2.81-08	2.77-08	2.41-08
PA231	0.00	1.72+01	1.72+01	1.72+01	1.72+01	1.68+01	1.39+01	2.06+00	2.70-02	2.67-02	2.45-02	1.02-02
PA233	0.00	2.19-01	9.79-05	7.66-05	7.70-05	7.95-05	8.01-05	7.78-05	5.81-05	3.15-06	6.94-19	0.00
U232	1.42+01	6.78-02	6.77-02	6.39-02	2.70-02	4.67-06	0.00	0.00	0.00	0.00	0.00	0.00

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
U233	2.33+04	1.17+02	1.17+02	1.17+02	1.17+02	1.17+02	1.19+02	1.35+02	1.35+02	6.61+00	1.62-12	0.00
U234	1.03+04	1.58+02	1.66+02	2.39+02	7.46+02	1.24+03	1.21+03	9.41+02	7.55+01	1.05-01	1.04-01	9.03-02
U235	4.65+04	3.14+02	3.14+02	3.14+02	3.15+02	3.21+02	3.77+02	5.82+02	5.99+02	5.94+02	5.44+02	2.26+02
U236	8.12+03	5.02+03	5.02+03	5.02+03	5.03+03	5.04+03	5.13+03	5.17+03	5.04+03	3.88+03	2.85+02	1.32-09
U237	0.00	1.58-08	3.01-06	1.97-06	2.92-08	3.99-11	2.04-11	2.54-14	0.00	0.00	0.00	0.00
U238	4.74+03	1.85+03	1.85+03	1.85+03	1.85+03	1.85+03	1.85+03	1.87+03	1.94+03	1.95+03	1.93+03	1.68+03
NP237	0.00	2.22+03	2.22+03	2.22+03	2.23+03	2.31+03	2.32+03	2.26+03	1.69+03	9.15+01	2.01-11	0.00
NP239	0.00	3.22-05	3.22-05	3.21-05	3.19-05	2.94-05	1.30-05	3.75-09	2.69-12	1.85-12	4.42-14	2.67-30
PU236	0.00	2.79-03	2.18-03	2.45-04	7.67-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	0.00	1.11+03	1.10+03	1.02+03	5.03+02	4.60-01	6.45-22	0.00	0.00	0.00	0.00	0.00
PU239	0.00	2.45+02	2.45+02	2.45+02	2.45+02	2.42+02	2.04+02	1.76+01	1.02-05	7.02-06	1.68-07	1.01-23
PU240	0.00	1.45+02	1.45+02	1.50+02	1.61+02	1.47+02	5.86+01	5.77-03	0.00	0.00	0.00	0.00
PU241	0.00	1.03+02	9.78+01	6.42+01	9.50-01	1.30-03	6.66-04	8.26-07	7.15-36	0.00	0.00	0.00
PU242	0.00	1.06+02	1.06+02	1.06+02	1.06+02	1.06+02	1.05+02	8.88+01	1.71+01	1.22-06	0.00	0.00
AM241	0.00	8.01+00	1.27+01	4.59+01	9.63+01	2.31+01	1.95-02	2.42-05	0.00	0.00	0.00	0.00
AM242M	0.00	3.56-02	3.55-02	3.40-02	2.26-02	3.73-04	5.64-22	0.00	0.00	0.00	0.00	0.00
AM242	0.00	4.28-07	4.26-07	4.09-07	2.71-07	4.48-09	6.78-27	0.00	0.00	0.00	0.00	0.00
AM243	0.00	3.89+01	3.89+01	3.88+01	3.85+01	3.55+01	1.57+01	4.53-03	3.25-06	2.24-06	5.34-08	3.22-24
CM242	0.00	2.72-01	5.77-02	8.20-05	5.44-05	8.98-07	1.36-24	0.00	0.00	0.00	0.00	0.00
CM243	0.00	2.91-02	2.84-02	2.34-02	3.33-03	1.14-11	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	1.90+01	1.83+01	1.29+01	4.12-01	4.47-16	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	8.95-01	6.95-01	8.94-01	8.88-01	8.31-01	4.25-01	5.28-04	4.57-33	0.00	0.00	0.00
CM246	0.00	3.56-01	3.56-01	3.55-01	3.51-01	3.13-01	1.00-01	1.15-06	0.00	0.00	0.00	0.00
CM247	0.00	7.51-03	7.51-03	7.51-03	7.51-03	7.51-03	7.51-03	7.48-03	7.21-03	4.96-03	1.18-04	7.15-21
SUBTOT	1.00+06	1.57+04	1.57+04	1.57+04	1.57+04	1.57+04	1.57+04	1.57+04	1.57+04	1.57+04	1.57+04	1.57+04
TOTAL	1.00+06	1.57+04	1.57+04	1.57+04	1.57+04	1.57+04	1.57+04	1.57+04	1.57+04	1.57+04	1.57+04	1.57+04

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	7.71-02	1.03-01	2.62-01	7.85-01	8.00-01	6.69-01	9.79-02	1.28-03	1.27-03	1.16-03	4.83-04
TL208	0.00	7.09+01	4.10-01	5.05-01	2.14-01	2.02-04	1.66-04	1.66-04	1.71-04	2.16-04	3.54-04	3.49-04
TL209	0.00	2.34-03	1.42-05	3.50-05	2.42-04	2.22-03	1.51-02	2.90-02	2.81-02	1.42-03	3.39-16	0.00
PB209	0.00	1.06-01	6.47-04	1.59-03	1.10-02	1.01-01	6.86-01	1.32+00	1.28+00	6.45-02	1.54-14	0.00
PB210	0.00	1.03-06	1.60-06	5.95-06	4.28-05	1.12-02	4.88-01	3.82+00	6.92-01	6.51-04	6.42-04	5.59-04
PB211	0.00	7.73-02	1.04-01	2.63-01	7.88-01	8.02-01	6.62-01	9.82-02	1.28-03	1.27-03	1.17-03	4.84-04
PB212	0.00	1.97+02	1.14+00	1.40+00	5.94-01	5.62-04	4.60-04	4.61-04	4.76-04	6.00-04	9.82-04	9.69-04
PB214	0.00	1.83-05	1.84-05	1.88-05	6.55-05	1.12-02	4.88-01	3.82+00	6.92-01	6.51-04	6.42-04	5.59-04
BI210	0.00	1.03-06	1.60-06	5.95-06	4.28-05	1.12-02	4.88-01	3.82+00	6.92-01	6.51-04	6.42-04	5.59-04
BI211	0.00	7.73-02	1.04-01	2.63-01	7.88-01	8.02-01	6.62-01	9.82-02	1.28-03	1.27-03	1.17-03	4.84-04
BI212	0.00	1.97+02	1.14+00	1.40+00	5.94-01	5.62-04	4.60-04	4.61-04	4.76-04	6.00-04	9.82-04	9.69-04
BI213	0.00	1.06-01	6.47-04	1.59-03	1.10-02	1.01-01	6.86-01	1.32+00	1.28+00	6.45-02	1.54-14	0.00
BI214	0.00	1.83-05	1.84-05	1.88-05	6.55-05	1.12-02	4.88-01	3.82+00	6.92-01	6.51-04	6.42-04	5.59-04
PO210	0.00	7.03-07	1.26-06	5.95-06	4.28-05	1.12-02	4.88-01	3.82+00	6.92-01	6.51-04	6.42-04	5.59-04
PO211	0.00	2.32-04	3.11-04	3.49-04	2.36-03	2.41-03	1.97-03	2.95-03	3.85-06	3.02-06	3.50-06	1.45-06
PO212	0.00	1.26+02	7.20-01	3.98-01	3.80-01	3.60-04	2.99-04	2.99-04	3.84-04	3.84-04	6.29-04	6.20-04
PO213	0.00	1.09-01	6.63-04	1.66-03	1.97-02	9.85-02	6.71-01	1.29+00	1.25+00	6.31-02	1.51-14	0.00
PO214	0.00	1.83-05	1.84-05	1.88-05	6.55-05	1.12-02	4.88-01	3.82+00	6.92-01	6.51-04	6.42-04	5.59-04
PO215	0.00	7.73-02	1.04-01	2.63-01	7.88-01	8.02-01	6.62-01	9.82-02	1.28-03	1.27-03	1.17-03	4.84-04
PO216	0.00	1.97+02	1.14+00	1.40+00	5.94-01	5.62-04	4.60-04	4.61-04	4.76-04	6.00-04	9.82-04	9.69-04
PO218	0.00	1.83-05	1.84-05	1.88-05	6.55-05	1.12-02	4.88-01	3.82+00	6.92-01	6.51-04	6.42-04	5.59-04
AT217	0.00	1.06-01	6.47-04	1.59-03	1.10-02	1.01-01	6.86-01	1.32+00	1.28+00	6.45-02	1.54-14	0.00
RN219	0.00	7.73-02	1.04-01	2.63-01	7.88-01	8.02-01	6.62-01	9.82-02	1.28-03	1.27-03	1.17-03	4.84-04
RN220	0.00	1.97+02	1.14+00	1.40+00	5.94-01	5.62-04	4.60-04	4.61-04	4.76-04	6.00-04	9.82-04	9.69-04
RN222	0.00	1.83-05	1.84-05	1.88-05	6.55-05	1.12-02	4.88-01	3.82+00	6.92-01	6.51-04	6.42-04	5.59-04
FR221	0.00	1.06-01	6.47-04	1.59-03	1.10-02	1.01-01	6.86-01	1.32+00	1.28+00	6.45-02	1.54-14	0.00
FR223	0.00	1.12-03	1.45-03	3.96-03	1.10-02	1.12-02	9.27-05	1.37-03	1.80-05	1.78-05	1.63-05	6.78-06
RA223	0.00	7.73-02	1.04-01	2.63-01	7.88-01	8.02-01	6.62-01	9.82-02	1.28-03	1.27-03	1.17-03	4.84-04
RA224	0.00	1.97+02	1.14+00	1.40+00	5.94-01	5.62-04	4.60-04	4.61-04	4.76-04	6.00-04	9.82-04	9.69-04
RA225	0.00	1.06-01	6.47-04	1.59-03	1.10-02	1.01-01	6.86-01	1.32+00	1.28+00	6.45-02	1.54-14	0.00
RA226	0.00	1.83-05	1.84-05	1.88-05	6.55-05	1.12-02	4.88-01	3.82+00	6.92-01	6.51-04	6.42-04	5.59-04
RA228	0.00	3.03-02	3.46-02	1.39-02	4.61-04	4.60-04	4.60-04	4.61-04	4.76-04	6.00-04	9.82-04	9.69-04
AC225	0.00	1.05-01	6.47-04	1.59-03	1.10-02	1.01-01	6.86-01	1.32+00	1.28+00	6.45-02	1.54-14	0.00
AC227	0.00	8.01-02	1.03-01	2.63-01	7.88-01	8.02-01	6.62-01	9.82-02	1.28-03	1.27-03	1.17-03	4.84-04
AC228	0.00	3.03-02	3.46-02	1.37-02	4.61-04	4.60-04	4.60-04	4.61-04	4.76-04	6.00-04	9.82-04	9.69-04
TH227	0.00	3.86-04	1.02-01	2.79-01	7.77-01	7.91-01	6.53-01	9.68-02	1.27-03	1.26-03	1.15-03	4.78-04
TH228	0.00	9.80-01	1.13+00	1.40+00	5.94-01	5.62-04	4.60-04	4.61-04	4.76-04	6.00-04	9.82-04	9.69-04
TH229	0.00	5.42-04	6.47-04	1.59-03	1.10-02	1.01-01	6.86-01	1.32+00	1.28+00	6.45-02	1.54-14	0.00
TH230	0.00	6.81-05	7.67-05	1.75-04	2.69-03	6.24-02	6.27-01	3.82+00	6.92-01	6.51-04	6.42-04	5.59-04
TH231	0.00	6.83-05	6.73-04	6.73-04	6.74-04	6.87-04	8.08-04	1.25-03	1.28-03	1.27-03	1.17-03	4.84-04

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TH232	9.92-02	4.60-04	4.60-04	4.60-04	4.60-04	4.60-04	4.60-04	4.61-04	4.76-04	6.00-04	9.82-04	9.69-04
TH234	0.00	1.03-03	6.17-04	6.17-04	6.17-04	6.17-04	6.17-04	6.23-04	6.46-04	6.51-04	6.42-04	5.59-04
PA231	0.00	8.19-01	8.19-01	8.19-01	8.17-01	8.02-01	6.62-01	9.61-02	1.28-03	1.27-03	1.17-03	4.84-04
PA233	0.00	4.48+03	2.00+00	1.57+00	1.58+00	1.63+00	1.64+00	1.59+00	1.19+00	6.45-02	1.42-14	0.00
PA234M	0.00	2.05-01	6.17-04	6.17-04	6.17-04	6.17-04	6.17-04	6.23-04	6.46-04	6.51-04	6.42-04	5.59-04
PA234	0.00	2.05-04	6.17-07	6.17-07	6.17-07	6.17-07	6.17-07	6.23-07	6.46-07	6.51-07	6.42-07	5.59-07
U232	3.03+02	1.45+00	1.45+00	1.37+00	5.78-01	9.99-05	0.00	0.00	0.00	0.00	0.00	0.00
U233	2.21+02	1.10+00	1.11+00	1.11+00	1.11+00	1.11+00	1.13+00	1.28+00	1.28+00	6.45-02	1.54-14	0.00
U234	6.37+01	9.76-01	1.03+00	1.48+00	4.62+00	7.69+00	7.50+00	5.83+00	4.67-01	6.51-04	6.42-04	5.59-04
U235	9.97-02	6.73-04	6.73-04	6.73-04	6.74-04	6.87-04	8.08-04	1.25-03	1.28-03	1.27-03	1.17-03	4.84-04
U236	5.15-01	3.19-01	3.19-01	3.19-01	3.19-01	3.20-01	3.25-01	3.28-01	3.19-01	2.46-01	1.81-02	8.40-14
U237	0.00	1.29-03	2.46-01	1.61-01	2.39-03	3.26-06	1.67-06	2.07-09	0.00	0.00	0.00	0.00
U238	1.38-03	6.17-04	6.17-04	6.17-04	6.17-04	6.17-04	6.17-04	6.23-04	6.46-04	6.51-04	6.42-04	5.59-04
NP237	0.00	1.57+00	1.57+00	1.57+00	1.58+00	1.63+00	1.64+00	1.59+00	1.19+00	6.45-02	1.42-14	0.00
NP239	0.00	7.48+00	7.48+00	7.47+00	7.41+00	6.83+00	3.02+00	8.71-04	6.25-07	4.30-07	1.03-08	6.20-25
PU236	0.00	1.48+00	1.16+00	1.30-01	4.08-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	0.00	1.87+04	1.85+04	1.73+04	8.58+03	7.76+00	1.09-20	0.00	0.00	0.00	0.00	0.00
PU239	0.00	1.50+01	1.50+01	1.50+01	1.50+01	1.48+01	1.25+01	1.08+00	6.25-07	4.30-07	1.03-08	6.21-25
PU240	0.00	3.19+01	3.20+01	3.32+01	3.56+01	3.25+01	1.29+01	1.27-03	0.00	0.00	0.00	0.00
PU241	0.00	1.03+04	9.81+03	6.44+03	9.53+01	1.30-01	6.67-02	8.28-05	0.00	0.00	0.00	0.00
PU242	0.00	4.14-01	4.14-01	4.14-01	4.14-01	4.14-01	4.08-01	3.46-01	6.68-02	4.76-09	0.00	0.00
PU243	0.00	6.52-07	6.52-07	6.52-07	6.52-07	6.51-07	6.51-07	6.49-07	6.25-07	4.30-07	1.03-08	6.20-25
AM241	0.00	2.74+01	4.35+01	1.57+02	3.30+02	7.91+01	6.68-02	8.28-05	0.00	0.00	0.00	0.00
AM242M	0.00	3.46-01	3.45-01	3.31-01	2.20-01	3.63-03	5.49-21	0.00	0.00	0.00	0.00	0.00
AM242	0.00	3.46-01	3.45-01	3.31-01	2.20-01	3.63-03	5.49-21	0.00	0.00	0.00	0.00	0.00
AM243	0.00	7.48+00	7.48+00	7.47+00	7.41+00	6.83+00	3.02+00	8.71-04	6.25-07	4.30-07	1.03-08	6.20-25
CM242	0.00	9.01+02	1.91+02	2.72-01	1.80-01	2.97-03	4.51-21	0.00	0.00	0.00	0.00	0.00
CM243	0.00	1.34+00	1.31+00	1.08+00	1.53-01	5.26-10	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	1.54+03	1.48+03	1.05+03	3.34+01	3.62-14	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	1.40-01	1.40-01	1.40-01	1.39-01	1.30-01	6.66-02	8.27-05	0.00	0.00	0.00	0.00
CM246	0.00	9.44-02	9.44-02	9.43-02	9.32-02	8.32-02	2.67-02	3.04-07	0.00	0.00	0.00	0.00
CM247	0.00	6.52-07	6.52-07	6.52-07	6.52-07	6.51-07	6.51-07	6.49-07	6.25-07	4.30-07	1.03-08	6.20-25
SUBTOT	5.88+02	3.72+04	3.01+04	2.50+04	9.13+03	1.69+02	6.08+01	6.17+01	2.17+01	9.85-01	4.97-02	2.28-02
TOTAL	5.88+02	3.72+04	3.01+04	2.50+04	9.13+03	1.69+02	6.08+01	6.17+01	2.17+01	9.85-01	4.97-02	2.28-02

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 99271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	2.33-04	3.12-04	8.53-04	2.37-03	2.42-03	2.80-03	2.96-04	3.47-06	3.84-08	3.51-06	1.46-06
TL208	0.00	1.45+00	9.54-03	1.14-02	4.96-03	4.71-06	3.85-06	3.87-06	3.97-06	5.03-08	8.23-06	8.12-06
TL209	0.00	3.01-05	2.33-07	5.73-07	3.95-06	3.63-06	2.47-04	4.75-04	4.60-04	2.32-06	5.55-18	0.00
PB209	0.00	1.22-04	7.45-07	1.83-06	1.20-05	1.16-04	7.69-04	1.52-03	1.47-03	7.42-06	1.77-17	0.00
PB210	0.00	9.25-11	6.62-11	2.47-10	1.70-09	9.65-07	2.03-05	1.59-04	2.07-05	2.70-07	2.66-08	2.32-08
PB211	0.00	2.59-04	3.48-04	9.56-04	3.03-03	2.06-02	4.21-03	3.20-03	4.29-04	4.26-06	3.95-06	1.62-06
PB212	0.00	5.02-01	1.63-03	2.01-03	6.95-04	8.07-07	6.60-07	6.62-07	6.82-07	8.60-07	1.41-08	1.39-06
PB214	0.00	9.47-06	5.47-08	4.57-06	1.57-07	2.73-05	1.19-03	9.32-04	1.07-03	1.05-06	1.56-06	1.36-06
BI210	0.00	2.72-05	4.20-04	1.57-06	1.13-07	2.95-05	1.20-03	1.31-02	1.82-03	1.71-06	1.07-06	1.47-06
BI211	0.00	5.11-05	4.03-03	1.11-02	3.07-02	3.12-02	2.50-02	3.02-03	5.00-05	4.96-07	4.54-05	1.89-05
BI212	0.00	3.52+00	1.96-02	2.44-02	1.13-02	9.77-06	7.99-04	8.01-06	1.26-06	1.19-06	1.71-05	1.68-05
BI213	0.00	7.54-04	3.98-06	9.70-06	6.78-05	8.19-04	9.22-03	8.11-02	7.66-03	3.96-04	7.47-17	0.00
BI214	0.00	2.59-07	2.06-07	2.61-07	9.11-07	1.56-04	8.80-03	5.32-02	9.63-03	9.08-06	8.94-06	7.78-06
PO210	0.00	2.94-06	5.04-08	1.07-07	1.30-06	3.53-04	1.54-02	1.20-01	2.18-02	2.09-05	2.02-05	1.76-05
PO211	0.00	1.12-05	1.37-05	3.79-05	1.04-04	1.06-04	8.77-05	1.30-05	1.70-07	1.69-07	1.54-07	6.42-08
PO212	0.00	1.00+01	5.06-04	9.74-02	2.01-02	1.91-05	1.56-04	1.56-05	1.61-05	2.03-06	2.03-05	3.29-05
PO213	0.00	5.17-03	3.39-03	7.73-05	5.34-04	4.69-03	3.33-02	6.91-06	6.21-02	3.13-03	7.54-18	0.00
PO214	0.00	7.20-07	6.37-07	8.52-07	2.90-06	5.10-04	2.24-02	1.74-01	3.15-02	2.96-04	2.92-05	2.55-05
PO215	0.00	3.29-02	4.94-03	1.24-02	3.43-02	3.61-02	2.90-02	4.30-03	5.62-05	5.57-05	5.11-05	2.12-05
PO216	0.00	1.00+01	4.65-03	5.74-02	2.43-02	2.30-05	1.88-05	1.89-05	1.95-05	2.45-05	4.02-05	3.96-05
PO218	0.00	7.01-07	6.66-07	6.66-07	2.37-06	4.06-04	1.77-02	1.39-01	2.51-02	2.36-05	2.32-05	2.02-05
AT217	0.00	9.90-03	2.71-03	6.57-03	4.61-04	4.22-03	2.69-02	5.53-03	5.36-02	2.70-03	6.45-16	0.00
RN219	0.00	5.13-03	9.17-02	1.15-02	3.17-02	3.25-02	2.66-02	3.97-03	5.20-05	5.15-05	4.72-05	1.96-05
RN220	0.00	7.40+00	9.31-02	5.32-02	2.29-02	2.13-05	1.74-03	1.75-05	1.80-05	2.17-05	3.72-05	3.67-05
RN222	0.00	5.71-07	1.90-07	6.12-07	2.13-06	3.65-04	1.57-02	1.25-01	2.25-02	2.12-05	2.09-05	1.82-05
FR221	0.00	3.76-03	2.91-03	5.92-03	4.09-04	3.75-02	2.55-02	4.91-03	4.76-02	2.40-03	5.73-16	0.00
FR223	0.00	2.63-06	3.39-06	9.27-06	2.58-05	2.63-05	2.17-03	3.22-06	4.21-06	4.17-08	3.92-08	1.59-08
RA223	0.00	2.69-03	3.60-03	9.83-03	2.74-02	2.79-02	2.36-02	3.41-03	4.46-05	4.42-05	4.05-05	1.68-05
RA224	0.00	6.73+00	3.89-02	4.20-02	2.03-02	1.92-05	1.67-03	1.58-05	1.63-05	2.05-05	3.36-05	3.32-05
RA225	0.00	7.06-05	4.26-07	1.05-06	7.23-06	6.63-05	4.51-04	8.56-04	8.41-04	4.24-05	1.01-17	0.00
RA226	0.00	5.19-07	5.20-07	5.31-07	1.85-06	3.17-04	1.33-02	1.06-01	1.96-02	1.64-05	1.82-05	1.58-05
RA228	0.00	2.75-06	2.66-06	1.07-06	3.56-06	3.54-06	4.54-05	3.55-04	3.66-06	4.62-08	7.57-08	7.47-08
AC225	0.00	3.65-03	4.22-05	5.46-05	3.77-04	3.46-03	2.35-02	4.63-02	4.39-02	2.21-03	5.29-16	0.00
AC227	0.00	4.04-05	5.21-05	1.43-04	3.97-04	4.04-04	3.34-04	4.95-05	6.47-07	6.41-07	5.87-07	2.44-07
AC228	0.00	2.03-04	1.43-04	7.34-05	2.45-06	2.44-06	2.44-04	2.45-04	2.52-06	3.18-06	5.21-06	5.14-06
TH227	0.00	1.33-05	3.52-03	9.60-03	2.67-02	2.72-02	2.25-02	3.33-03	4.36-05	4.32-05	3.96-05	1.64-05
TH228	0.00	3.21-02	3.71-02	4.89-02	1.95-02	1.84-05	1.51-05	1.51-05	1.56-05	1.96-05	3.22-05	3.17-05
TH229	0.00	1.64-05	1.96-05	4.81-05	3.32-04	3.05-03	2.07-02	3.99-02	5.87-02	1.75-03	4.66-16	0.00
TH230	0.00	1.92-06	2.17-06	4.94-06	7.61-05	1.76-03	1.77-02	1.06-01	1.96-02	1.64-05	1.81-05	1.58-05
TH231	0.00	5.39-08	5.30-07	5.31-07	5.32-07	5.42-07	6.37-07	9.64-07	1.01-06	1.00-06	9.19-07	3.82-07

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TH232	2.40-03	1.11-05	1.11-05	1.11-05	1.11-05	1.11-05	1.11-05	1.12-05	1.15-05	1.45-05	2.38-05	2.34-05
TH234	0.00	3.65-07	2.19-07	2.19-07	2.19-07	2.19-07	2.20-07	2.21-07	2.30-07	2.31-07	2.28-07	1.99-07
PA231	0.00	2.50-02	2.50-02	2.50-02	2.49-02	2.45-02	2.02-02	2.99-03	3.92-05	3.88-05	3.56-05	1.48-05
PA233	0.00	6.05+00	2.71-03	2.12-03	2.13-03	2.20-03	2.21-03	2.15-03	1.61-03	8.72-05	1.92-17	0.00
PA234M	0.00	1.06-03	3.17-06	3.17-06	3.17-06	3.17-06	3.18-06	3.20-06	3.32-06	3.35-06	3.30-06	2.88-06
PA234	0.00	1.67-06	5.60-09	5.60-09	5.60-09	5.60-09	5.61-09	5.66-09	5.87-09	5.91-09	5.83-09	5.08-09
U232	9.72+00	4.66-02	4.66-02	4.39-02	1.85-02	3.21-06	0.00	0.00	0.00	0.00	0.00	0.00
U233	6.43+00	3.21-02	3.22-02	3.22-02	3.22-02	3.23-02	3.29-02	3.74-02	3.72-02	1.88-03	4.47-16	0.00
U234	1.83+00	2.81-02	2.96-02	4.26-02	1.33-01	2.21-01	2.16-01	1.68-01	1.34-02	1.87-05	1.85-05	1.61-05
U235	2.77-03	1.67-05	1.87-05	1.87-05	1.87-05	1.91-05	2.24-05	3.46-05	3.56-05	3.53-05	3.23-05	1.34-05
U236	1.40-02	8.64-03	8.64-03	8.64-03	8.64-03	8.66-03	8.81-03	8.89-03	8.66-03	6.67-03	4.91-04	2.28-15
U237	0.00	8.54-07	1.63-04	1.07-04	1.58-06	2.16-09	1.11-09	1.38-12	0.00	0.00	0.00	0.00
U238	3.99-05	1.56-05	1.56-05	1.56-05	1.56-05	1.56-05	1.56-05	1.57-05	1.63-05	1.65-05	1.62-05	1.41-05
NP237	0.00	4.60-02	4.60-02	4.60-02	4.63-02	4.78-02	4.81-02	4.68-02	3.49-02	1.89-03	4.17-16	0.00
NP239	0.00	1.01-02	1.01-02	1.01-02	1.00-02	9.23-03	4.09-03	1.18-06	8.45-10	5.81-10	1.39-11	8.38-28
PU236	0.00	5.16-02	4.09-02	4.53-03	1.42-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	0.00	6.19+02	6.14+02	5.73+02	2.84+02	2.57-01	3.61-22	0.00	0.00	0.00	0.00	0.00
PU239	0.00	4.68-01	4.68-01	4.66-01	4.67-01	4.61-01	3.89-01	3.35-02	1.94-08	1.34-08	3.19-10	1.93-26
PU240	0.00	9.94-01	9.98-01	1.03+00	1.11+00	1.01+00	4.03-01	3.96-05	0.00	0.00	0.00	0.00
PU241	0.00	4.27-01	4.07-01	2.67-01	3.95-03	5.41-06	2.77-06	3.44-09	0.00	0.00	0.00	0.00
PU242	0.00	1.22-02	1.22-02	1.22-02	1.22-02	1.22-02	1.20-02	1.02-02	1.97-03	1.41-10	0.00	0.00
PU243	0.00	9.23-10	9.23-10	9.23-10	9.23-10	9.23-10	9.23-10	9.19-10	8.85-10	6.10-10	1.46-11	8.78-28
AM241	0.00	9.16-01	1.45+00	5.25+00	1.10+01	2.64+00	2.23-03	2.76-06	0.00	0.00	0.00	0.00
AM242M	0.00	9.86-05	9.81-05	9.42-05	6.25-05	1.03-06	1.56-24	0.00	0.00	0.00	0.00	0.00
AM242	0.00	4.62-04	4.60-04	4.41-04	2.93-04	4.84-06	7.32-24	0.00	0.00	0.00	0.00	0.00
AM243	0.00	2.73-01	2.73-01	2.73-01	2.71-01	2.49-01	1.10-01	3.18-05	2.28-08	1.57-08	3.75-10	2.26-26
CM242	0.00	3.32+01	7.04+00	1.00-02	6.64-03	1.10-04	1.66-22	0.00	0.00	0.00	0.00	0.00
CM243	0.00	4.91-02	4.81-02	3.96-02	5.63-03	1.93-11	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	5.38+01	5.17+01	3.67+01	1.17+00	1.27-15	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	4.37-03	4.37-03	4.37-03	4.34-03	4.06-03	2.08-03	2.58-06	0.00	0.00	0.00	0.00
CM246	0.00	3.09-03	3.09-03	3.09-03	3.05-03	2.72-03	8.73-04	9.96-09	0.00	0.00	0.00	0.00
CM247	0.00	1.88-08	1.88-08	1.88-08	1.88-08	1.88-08	1.88-08	1.87-08	1.80-08	1.24-08	2.96-10	1.79-26
SUBTOT	1.80+01	7.50+02	6.77+02	6.17+02	2.99+02	5.17+00	1.63+00	1.44+00	5.08-01	2.41-02	1.20-03	5.11-04
TOTAL	1.80+01	7.50+02	6.77+02	6.17+02	2.99+02	5.17+00	1.63+00	1.44+00	5.08-01	2.41-02	1.20-03	5.11-04

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	-7.71-02	-1.03-01	-2.82-01	-7.85-01	-8.00-01	-8.60-01	-9.79-02	-1.28-03	-1.27-03	-1.16-03	-4.83-04
TL208	0.00	-7.09+01	-4.10-01	-5.05-01	-2.14-01	-2.02-04	-1.66-04	-1.66-04	-1.71-04	-2.16-04	-3.54-04	-3.49-04
TL209	0.00	-2.34-03	-1.42-05	-3.50-05	-2.42-04	-2.22-03	-1.51-02	-2.90-02	-2.81-02	-1.42-03	-3.39-16	0.00
PB209	0.00	-1.06-01	-6.47-04	-1.59-03	-1.10-02	-1.01-01	-6.86-01	-1.32+00	-1.28+00	-6.45-02	-1.54-14	0.00
PB210	0.00	2.59+05	3.99+05	1.49+06	1.07+07	2.80+09	1.22+11	9.56+11	1.73+11	1.63+08	1.60+08	1.40+08
PB211	0.00	-7.73-02	-1.04-01	-2.83-01	-7.88-01	-8.02-01	-6.62-01	-9.82-02	-1.28-03	-1.27-03	-1.17-03	-4.84-04
PB212	0.00	3.28+11	1.90+09	2.34+09	9.90+08	9.37+05	7.66+05	7.69+05	7.93+05	9.99+05	1.64+06	1.62+06
PB214	0.00	-1.93-05	-1.84-05	-1.68-05	-6.55-05	-1.12-02	-4.88-01	-3.82+00	-6.92-01	-6.51-04	-6.42-04	-5.59-04
BI210	0.00	5.17+03	7.98+03	2.98+04	2.14+05	5.60+07	2.44+09	1.91+10	3.46+09	3.25+06	3.21+06	2.79+06
BI211	0.00	-7.73-02	-1.04-01	-2.83-01	-7.88-01	-8.02-01	-6.62-01	-9.82-02	-1.28-03	-1.27-03	-1.17-03	-4.84-04
BI212	0.00	6.56+10	3.79+08	4.68+08	1.98+08	1.87+05	1.53+05	1.54+05	1.59+05	2.00+05	3.27+05	3.23+05
BI213	0.00	-1.06-01	-6.47-04	-1.59-03	-1.10-02	-1.01-01	-6.86-01	-1.32+00	-1.28+00	-6.45-02	-1.54-14	0.00
BI214	0.00	-1.93-05	-1.84-05	-1.68-05	-6.55-05	-1.12-02	-4.86-01	-3.82+00	-6.92-01	-6.51-04	-6.42-04	-5.59-04
PO210	0.00	1.09+05	1.83+05	8.59+05	6.12+06	1.60+09	6.97+10	5.46+11	9.86+10	9.29+07	9.17+07	7.98+07
PO211	0.00	-2.32-04	-3.11-04	-8.49-04	-2.36-03	-2.41-03	-1.97-03	-2.95-04	-3.85-06	-3.82-06	-3.50-06	-1.45-06
PO212	0.00	-1.26+02	-7.23-01	-6.93-01	-3.80-01	-3.60-04	-2.94-04	-2.95-04	-3.04-04	-3.84-04	-6.29-04	-6.20-04
PO213	0.00	-1.04-01	-6.33-04	-1.56-03	-1.07-02	-9.85-02	-6.71-01	-1.29+00	-1.25+00	-6.31-02	-1.51-14	0.00
PO214	0.00	-1.93-05	-1.84-05	-1.68-05	-6.55-05	-1.12-02	-4.88-01	-3.82+00	-6.92-01	-6.51-04	-6.42-04	-5.59-04
PO215	0.00	-7.73-02	-1.04-01	-2.83-01	-7.88-01	-8.02-01	-6.62-01	-9.82-02	-1.28-03	-1.27-03	-1.17-03	-4.84-04
PO216	0.00	-1.97+02	-1.14+00	-1.49+00	-5.94-01	-5.62-04	-4.60-04	-4.61-04	-4.76-04	-6.00-04	-9.82-04	-9.69-04
PO218	0.00	-1.93-05	-1.84-05	-1.68-05	-6.55-05	-1.12-02	-4.88-01	-3.82+00	-6.92-01	-6.51-04	-6.42-04	-5.59-04
AT217	0.00	-1.06-01	-6.47-04	-1.59-03	-1.10-02	-1.01-01	-6.86-01	-1.32+00	-1.28+00	-6.45-02	-1.54-14	0.00
RN219	0.00	-7.73-02	-1.04-01	-2.83-01	-7.88-01	-8.02-01	-6.62-01	-9.82-02	-1.28-03	-1.27-03	-1.17-03	-4.84-04
RN220	0.00	1.97+10	1.14+04	1.49+06	5.94+07	5.62+04	4.60+04	4.61+04	4.76+04	6.00+04	9.82+04	9.69+04
RN222	0.00	6.11+03	6.12+03	6.26+03	2.18+04	3.73+06	1.63+09	1.27+09	2.31+08	2.17+05	2.14+05	1.86+05
FR221	0.00	-1.06-01	-6.47-04	-1.59-03	-1.10-02	-1.01-01	-6.86-01	-1.32+00	-1.28+00	-6.45-02	-1.54-14	0.00
FR223	0.00	-1.12-03	-1.45-03	-3.96-03	-1.10-02	-1.12-02	-9.27-03	-1.37-03	-1.80-05	-1.78-05	-1.63-05	-6.78-06
RA223	0.00	9.67+09	1.30+10	3.54+10	9.85+10	1.00+11	8.28+10	1.23+10	1.61+08	1.59+08	1.46+08	6.05+07
RA224	0.00	9.84+12	5.69+10	7.01+10	2.97+10	2.81+07	2.30+07	2.31+07	2.38+07	3.00+07	4.91+07	4.85+07
RA225	0.00	2.15+09	1.29+07	3.18+07	2.20+08	2.02+09	1.37+10	2.64+10	2.56+10	1.29+09	3.06-04	0.00
RA226	0.00	9.17+06	9.18+06	9.38+06	3.27+07	5.60+09	2.44+11	1.91+12	3.46+11	3.25+08	3.21+08	2.79+08
RA228	0.00	3.83+10	3.46+10	1.39+10	4.61+08	4.60+08	4.60+04	4.61+08	4.76+08	6.00+08	9.82+08	9.69+08
AC225	0.00	-1.06-01	-6.47-04	-1.59-03	-1.10-02	-1.01-01	-6.86-01	-1.32+00	-1.28+00	-6.45-02	-1.54-14	0.00
AC227	0.00	1.00+12	1.29+12	3.54+12	9.85+12	1.00+13	8.28+12	1.23+12	1.61+10	1.59+10	1.46+10	6.05+09
AC228	0.00	6.38+07	5.76+07	2.32+07	7.68+05	7.66+05	7.66+05	7.69+05	7.93+05	9.99+05	1.64+06	1.62+06
TH227	0.00	6.44+07	1.70+10	4.65+10	1.29+11	1.32+11	1.09+11	1.61+10	2.11+08	2.09+08	1.92+08	7.96+07
TH228	0.00	4.90+12	5.67+12	7.01+12	2.97+12	2.81+09	2.30+09	2.31+09	2.38+09	3.00+09	4.91+09	4.85+09
TH229	0.00	6.78+09	8.09+09	1.99+10	1.37+11	1.26+12	8.58+12	1.65+13	1.60+13	8.06+11	1.93-01	0.00
TH230	0.00	8.50+08	9.59+08	2.18+09	3.37+10	7.81+11	7.84+12	4.77+13	6.65+12	8.13+09	8.02+09	6.99+09
TH231	0.00	1.71+03	1.68+04	1.69+04	1.69+04	1.72+04	2.02+04	3.12+04	3.21+04	3.18+04	2.91+04	1.21+04

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TH232	9.92+10	4.60+08	4.60+08	4.60+08	4.60+08	4.60+08	4.60+08	4.61+08	4.76+08	6.00+08	9.82+08	9.69+08
TH234	0.00	1.03+06	6.17+05	6.17+05	6.17+05	6.17+05	6.17+05	6.23+05	6.46+05	6.51+05	6.42+05	5.59+05
PA231	0.00	2.05+13	2.05+13	2.05+13	2.04+13	2.00+13	1.65+13	2.45+12	3.21+10	3.10+10	2.91+10	1.21+10
PA233	0.00	7.46+11	3.34+06	2.61+09	2.63+09	2.71+08	2.73+08	2.65+08	1.98+08	1.08+07	2.37-06	0.00
PA234M	0.00	-2.05-01	-6.17-04	-6.17-04	-6.17-04	-6.17-04	-6.17-04	-6.23-04	-6.46-04	-6.51-04	-6.42-04	-5.59-04
PA234	0.00	-2.05-04	-6.17-07	-6.17-07	-6.17-07	-6.17-07	-6.17-07	-6.23-07	-6.46-07	-6.51-07	-6.42-07	-5.59-07
U232	3.37+14	1.61+12	1.61+12	1.52+12	6.42+11	1.11+08	0.00	0.00	0.00	0.00	0.00	0.00
U233	5.52+13	2.76+11	2.77+11	2.77+11	2.77+11	2.77+11	2.82+11	3.21+11	3.19+11	1.61+10	3.84-03	0.00
U234	1.59+13	2.49+11	2.57+11	3.70+11	1.13+12	1.92+12	1.87+12	1.46+12	1.17+11	1.63+08	1.60+08	1.40+08
U235	2.49+10	1.68+08	1.68+08	1.68+08	1.69+08	1.72+08	2.02+08	3.12+08	3.21+08	3.18+08	2.91+08	1.21+08
U236	1.29+11	7.97+10	7.97+10	7.97+10	7.97+10	7.99+10	8.13+10	8.20+10	7.99+10	6.15+10	4.52+09	2.10-02
U237	0.00	-1.29-03	-2.46-01	-1.61-01	-2.39-03	-3.26-06	-1.67-06	-2.07-09	0.00	0.00	0.00	0.00
U238	5.26+08	2.06+08	2.06+08	2.06+08	2.06+08	2.06+08	2.06+08	2.08+08	2.15+08	2.17+08	2.14+08	1.86+08
NP237	0.00	1.57+13	1.57+13	1.57+13	1.58+13	1.63+13	1.64+13	1.59+13	1.19+13	6.45+11	1.42-01	0.00
NP239	0.00	3.74+08	3.74+08	3.74+08	3.71+08	3.42+08	1.51+08	4.36+04	3.13+01	2.15+01	5.14-01	3.10-17
PU236	0.00	-1.48+00	-1.16+00	-1.30-01	-4.08-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	0.00	2.67+17	2.65+17	2.47+17	1.23+17	1.11+14	1.56-07	0.00	0.00	0.00	0.00	0.00
PU239	0.00	2.51+14	2.51+14	2.51+14	2.50+14	2.47+14	2.09+14	1.80+13	1.04+07	7.17+06	1.71+05	1.03-11
PU240	0.00	5.32+14	5.32+14	5.53+14	5.93+14	5.42+14	2.15+14	2.12+10	0.00	0.00	0.00	0.00
PU241	0.00	3.43+15	3.27+15	2.15+15	3.18+13	4.34+10	2.22+10	2.76+07	0.00	0.00	0.00	0.00
PU242	0.00	6.90+12	6.90+12	6.90+12	6.90+12	6.89+12	6.79+12	5.77+12	1.11+12	7.93+04	0.00	0.00
PU243	0.00	1.09+01	1.09+01	1.09+01	1.09+01	1.09+01	1.09+01	1.08+01	1.04+01	7.17+00	1.71-01	1.03-17
AM241	0.00	1.37+14	2.17+14	7.86+14	1.65+15	3.95+14	3.34+11	4.14+08	0.00	0.00	0.00	0.00
AM242M	0.00	1.73+12	1.72+12	1.65+12	1.10+12	1.81+10	2.79-08	0.00	0.00	0.00	0.00	0.00
AM242	0.00	3.46+08	3.45+08	3.31+08	2.20+08	3.63+06	5.49-12	0.00	0.00	0.00	0.00	0.00
AM243	0.00	3.74+13	3.74+13	3.74+13	3.71+13	3.42+13	1.51+13	4.36+09	3.13+06	2.15+06	5.14+04	3.10-12
CM242	0.00	2.25+14	4.77+13	6.79+10	4.50+10	7.44+08	1.13-09	0.00	0.00	0.00	0.00	0.00
CM243	0.00	6.68+12	6.54+12	5.38+12	7.66+11	2.63+03	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	5.12+15	4.93+15	3.49+15	1.11+14	1.21-01	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	7.01+11	7.01+11	7.00+11	6.96+11	6.51+11	3.33+11	4.14+08	0.00	0.00	0.00	0.00
CM246	0.00	4.72+11	4.72+11	4.71+11	4.66+11	4.16+11	1.33+11	1.52+06	0.00	0.00	0.00	0.00
CM247	0.00	3.26+06	3.26+06	3.26+06	3.26+06	3.26+06	3.26+06	3.24+06	3.13+06	2.15+06	5.14+04	3.10-12
SUBTOT	4.08+14	2.77+17	2.74+17	2.54+17	1.25+17	1.39+15	5.07+14	1.13+14	3.89+13	1.59+12	6.48+10	3.31+10
TOTAL	4.08+14	2.77+17	2.74+17	2.54+17	1.25+17	1.39+15	5.07+14	1.13+14	3.89+13	1.59+12	6.48+10	3.31+10

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	-7.71-02	-1.03-01	-2.82-01	-7.85-01	-8.00-01	-6.60-01	-9.79-02	-1.28-03	-1.27-03	-1.16-03	-4.83-04
TL208	0.00	-7.69+01	-4.10-01	-5.05-01	-2.14-01	-2.02-04	-1.66-04	-1.66-04	-1.71-04	-2.16-04	-3.54-04	-3.49-04
TL209	0.00	-2.34-03	-1.42-05	-3.50-05	-2.42-04	-2.22-03	-1.51-02	-2.90-02	-2.81-02	-1.42-03	-3.39-16	0.00
PB209	0.00	-1.06-01	-6.47-04	-1.59-03	-1.10-02	-1.01-01	-6.86-01	-1.32+00	-1.28+00	-6.45-02	-1.54-14	0.00
PB210	0.00	1.03+01	1.60+01	5.95+01	4.28+02	1.12+05	4.88+06	3.82+07	6.92+06	6.51+03	6.42+03	5.59+03
PB211	0.00	-7.73-02	-1.04-01	-2.83-01	-7.88-01	-8.02-01	-6.62-01	-9.82-02	-1.28-03	-1.27-03	-1.17-03	-4.84-04
PB212	0.00	9.64+06	5.69+04	7.01+04	2.97+04	2.81+01	2.30+01	2.31+01	2.38+01	3.00+01	4.91+01	4.85+01
PB214	0.00	-1.83-05	-1.84-05	-1.88-05	-6.55-05	-1.12-02	-4.88-01	-3.82+00	-6.92-01	-6.51-04	-6.42-04	-5.59-04
BI210	0.00	2.59-02	3.99-02	1.49-01	1.07+00	2.80+02	1.22+04	9.56+04	1.73+04	1.63+01	1.60+01	1.40+01
BI211	0.00	-7.73-02	-1.04-01	-2.83-01	-7.88-01	-8.02-01	-6.62-01	-9.82-02	-1.28-03	-1.27-03	-1.17-03	-4.84-04
BI212	0.00	4.92+05	2.84+03	3.51+03	1.49+03	1.41+00	1.15+00	1.15+00	1.19+00	1.50+00	2.46+00	2.42+00
BI213	0.00	-1.06-01	-6.47-04	-1.59-03	-1.10-02	-1.01-01	-6.86-01	-1.32+00	-1.28+00	-6.45-02	-1.54-14	0.00
BI214	0.00	-1.83-05	-1.84-05	-1.88-05	-6.55-05	-1.12-02	-4.88-01	-3.82+00	-6.92-01	-6.51-04	-6.42-04	-5.59-04
PO210	0.00	1.09+00	1.83+00	8.50+00	6.12+01	1.60+04	6.97+05	5.46+06	9.88+05	9.29+02	9.17+02	7.98+02
PO211	0.00	-2.32-04	-3.11-04	-8.49-04	-2.36-03	-2.41-03	-1.99-03	-2.95-04	-3.85-06	-3.82-06	-3.50-06	-1.45-06
PO212	0.00	-1.26+02	-7.28-01	-8.98-01	-3.80-01	-3.60-04	-2.94-04	-2.95-04	-3.04-04	-3.84-04	-6.29-04	-6.20-04
PO213	0.00	-1.04-01	-6.33-04	-1.56-03	-1.07-02	-9.85-02	-6.71-01	-1.29+00	-1.25+00	-6.31-02	-1.51-14	0.00
PO214	0.00	-1.83-05	-1.84-05	-1.88-05	-6.55-05	-1.12-02	-4.88-01	-3.82+00	-6.92-01	-6.51-04	-6.42-04	-5.59-04
PO215	0.00	-7.73-02	-1.04-01	-2.83-01	-7.88-01	-8.02-01	-6.62-01	-9.82-02	-1.28-03	-1.27-03	-1.17-03	-4.84-04
PO216	0.00	-1.97+02	-1.14+00	-1.40+00	-5.94-01	-5.62-04	-4.60-04	-4.61-04	-4.76-04	-6.00-04	-9.82-04	-9.69-04
PO218	0.00	-1.83-05	-1.84-05	-1.88-05	-6.55-05	-1.12-02	-4.88-01	-3.82+00	-6.92-01	-6.51-04	-6.42-04	-5.59-04
AT217	0.00	-1.06-01	-6.47-04	-1.59-03	-1.10-02	-1.01-01	-6.86-01	-1.32+00	-1.28+00	-6.45-02	-1.54-14	0.00
RN219	0.00	-7.73-02	-1.04-01	-2.83-01	-7.88-01	-8.02-01	-6.62-01	-9.82-02	-1.28-03	-1.27-03	-1.17-03	-4.84-04
RN220	0.00	-1.97+02	-1.14+00	-1.40+00	-5.94-01	-5.62-04	-4.60-04	-4.61-04	-4.76-04	-6.00-04	-9.82-04	-9.69-04
RN222	0.00	-1.83-05	-1.84-05	-1.88-05	-6.55-05	-1.12-02	-4.88-01	-3.82+00	-6.92-01	-6.51-04	-6.42-04	-5.59-04
FR221	0.00	-1.06-01	-6.47-04	-1.59-03	-1.10-02	-1.01-01	-6.86-01	-1.32+00	-1.28+00	-6.45-02	-1.54-14	0.00
FR223	0.00	-1.12-03	-1.45-03	-3.96-03	-1.10-02	-1.12-02	-9.27-03	-1.37-03	-1.80-05	-1.78-05	-1.63-05	-6.78-06
RA223	0.00	1.10+05	1.48+05	4.04+05	1.13+06	1.15+06	9.46+05	1.40+05	1.83+03	1.82+03	1.67+03	6.92+02
RA224	0.00	9.64+07	5.69+05	7.01+05	2.97+05	2.81+02	2.30+02	2.31+02	2.38+02	3.00+02	4.91+02	4.85+02
RA225	0.00	1.79+05	1.08+03	2.65+03	1.83+04	1.68+05	1.14+06	2.20+06	2.13+06	1.08+05	2.57-08	0.00
RA226	0.00	6.11+02	6.12+02	6.26+02	2.18+03	3.73+05	1.63+07	1.27+08	2.31+07	2.17+04	2.14+04	1.86+04
RA228	0.00	1.28+06	1.15+06	4.63+05	1.54+04	1.53+04	1.53+04	1.54+04	1.59+04	2.00+04	3.27+04	3.23+04
AC225	0.00	-1.06-01	-6.47-04	-1.59-03	-1.10-02	-1.01-01	-6.86-01	-1.32+00	-1.28+00	-6.45-02	-1.54-14	0.00
AC227	0.00	4.31+04	5.17+04	1.41+05	3.94+05	4.01+05	3.31+05	4.91+04	6.42+02	6.36+02	5.83+02	2.42+02
AC228	0.00	4.25+02	3.84+02	1.55+02	5.12+00	5.11+00	5.11+00	5.13+00	5.28+00	6.66+00	1.09+01	1.08+01
TH227	0.00	1.93+01	5.11+03	1.40+04	3.88+04	3.95+04	3.26+04	4.84+03	6.33+01	6.28+01	5.75+01	2.39+01
TH228	0.00	1.40+05	1.62+05	2.00+05	8.49+04	8.03+01	6.57+01	6.59+01	6.79+01	8.57+01	1.40+02	1.38+02
TH229	0.00	2.71+02	3.24+02	7.96+02	5.49+03	5.04+04	3.43+05	6.60+05	6.39+05	3.23+04	7.71-09	0.00
TH230	0.00	3.40+01	3.83+01	8.73+01	1.35+03	3.12+04	3.14+05	1.91+06	3.46+05	3.25+02	3.21+02	2.79+02
TH231	0.00	3.42-01	3.36+00	3.36+00	3.37+00	3.44+00	4.04+00	6.24+00	6.42+00	6.36+00	5.83+00	2.42+00

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TH232	4.96+04	2.30+02	2.30+02	2.30+02	2.30+02	2.30+02	2.30+02	2.31+02	2.36+02	3.00+02	4.91+02	4.85+02
TH234	0.00	5.13+01	3.08+01	3.08+01	3.08+01	3.08+01	3.09+01	3.11+01	3.23+01	3.25+01	3.21+01	2.79+01
PA231	0.00	9.10+05	9.10+05	9.10+05	9.06+05	8.91+05	7.35+05	1.09+05	1.43+03	1.41+03	1.30+03	5.38+02
PA233	0.00	4.48+07	2.00+04	1.57+04	1.58+04	1.63+04	1.64+04	1.59+04	1.19+04	6.45+02	1.42-10	0.00
PA234M	0.00	-2.05-01	-6.17-04	-6.17-04	-6.17-04	-6.17-04	-6.17-04	-6.23-04	-6.46-04	-6.51-04	-6.42-04	-5.59-04
PA234	0.00	-2.05-04	-6.17-07	-6.17-07	-6.17-07	-6.17-07	-6.17-07	-6.23-07	-6.46-07	-6.51-07	-6.42-07	-5.59-07
U232	1.01+07	4.84+04	4.84+04	4.56+04	1.93+04	3.33+00	0.00	0.00	0.00	0.00	0.00	0.00
U233	7.36+06	3.68+04	3.69+04	3.69+04	3.69+04	3.69+04	3.76+04	4.26+04	4.26+04	2.15+03	5.12-10	0.00
U234	2.12+06	3.25+04	3.43+04	4.93+04	1.54+05	2.56+05	2.50+05	1.94+05	1.56+04	2.17+01	2.14+01	1.86+01
U235	3.32+03	2.24+01	2.24+01	2.24+01	2.25+01	2.29+01	2.69+01	4.16+01	4.28+01	4.24+01	3.89+01	1.61+01
U236	1.72+04	1.06+04	1.06+04	1.06+04	1.06+04	1.07+04	1.08+04	1.09+04	1.06+04	8.20+03	6.03+02	2.80-09
U237	0.00	-1.29-03	-2.46-01	-1.61-01	-2.39-03	-3.26-06	-1.67-04	-2.07-09	0.00	0.00	0.00	0.00
U238	3.95+01	1.54+01	1.54+01	1.54+01	1.54+01	1.54+01	1.54+01	1.56+01	1.61+01	1.63+01	1.60+01	1.40+01
NP237	0.00	5.22+05	5.22+05	5.22+05	5.25+05	5.42+05	5.46+05	5.31+05	3.96+05	2.15+04	4.73-09	0.00
NP239	0.00	7.48+04	7.48+04	7.47+04	7.41+04	6.83+04	3.02+04	3.71+00	3.25-03	4.30-03	1.03-04	6.20-21
PU236	0.00	-1.48+00	-1.16+00	-1.30-01	-4.06-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	0.00	3.74+09	3.71+09	3.46+09	1.72+09	1.55+06	2.18-15	0.00	0.00	0.00	0.00	0.00
PU239	0.00	3.01+06	3.01+06	3.01+06	3.01+06	2.97+06	2.50+04	2.15+05	1.25-01	8.60-02	2.05-03	1.24-19
PU240	0.00	6.36+06	6.41+06	6.63+06	7.11+06	6.50+06	2.56+06	2.54+02	0.00	0.00	0.00	0.00
PU241	0.00	5.14+07	4.90+07	3.22+07	4.76+05	6.52+02	3.34+02	4.14-01	0.00	0.00	0.00	0.00
PU242	0.00	8.28+04	8.28+04	8.28+04	8.28+04	8.27+04	8.15+04	6.92+04	1.34+04	9.52-04	0.00	0.00
PU243	0.00	2.17-03	2.17-03	2.17-03	2.17-03	2.17-03	2.17-03	2.16-03	2.03-03	1.43-03	3.42-05	2.07-21
AM241	0.00	6.86+06	1.09+07	3.93+07	8.25+07	1.98+07	1.67+04	2.07+01	0.00	0.00	0.00	0.00
AM242M	0.00	8.66+04	8.62+04	8.27+04	5.49+04	9.07+02	1.37-15	0.00	0.00	0.00	0.00	0.00
AM242	0.00	3.46+03	3.45+03	3.31+03	2.20+03	3.63+01	5.49-17	0.00	0.00	0.00	0.00	0.00
AM243	0.00	1.87+06	1.87+06	1.87+06	1.85+06	1.71+06	7.56+05	2.18+02	1.56-01	1.08-01	2.57-03	1.55-19
CM242	0.00	4.51+07	9.55+06	1.36+04	9.00+03	1.49+02	2.26-16	0.00	0.00	0.00	0.00	0.00
CM243	0.00	2.67+05	2.62+05	2.15+05	3.07+04	1.05-04	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	2.20+08	2.11+08	1.50+08	4.77+06	5.17-09	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	3.50+04	3.50+04	3.50+04	3.48+04	3.25+04	1.67+04	2.07+01	0.00	0.00	0.00	0.00
CM246	0.00	2.36+04	2.36+04	2.36+04	2.33+04	2.08+04	6.66+03	7.60-02	0.00	0.00	0.00	0.00
CM247	0.00	1.63-01	1.63-01	1.63-01	1.63-01	1.63-01	1.63-01	1.62-01	1.56-01	1.08-01	2.57-03	1.55-19
SUBTOT	1.97+07	4.23+09	4.00+09	3.69+09	1.82+09	3.68+07	3.26+07	1.77+08	3.46+07	2.26+05	6.73+04	6.04+04
TOTAL	1.97+07	4.23+09	4.00+09	3.69+09	1.82+09	3.68+07	3.26+07	1.77+08	3.46+07	2.26+05	6.73+04	6.04+04

HTGR PLANT WASTE

Fission Products

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	1.28-01	1.21-01	7.28-02	4.57-04	4.35-26	0.00	0.00	0.00	0.00	0.00	0.00
GE 72	0.00	3.57-02	3.57-02	3.57-02	3.57-02	3.57-02	3.57-02	3.57-02	3.57-02	3.57-02	3.57-02	3.57-02
GE 73	0.00	1.15-01	1.15-01	1.15-01	1.15-01	1.15-01	1.15-01	1.15-01	1.15-01	1.15-01	1.15-01	1.15-01
GE 74	0.00	2.29-01	2.29-01	2.29-01	2.29-01	2.29-01	2.29-01	2.29-01	2.29-01	2.29-01	2.29-01	2.29-01
AS 75	0.00	6.21-01	6.21-01	6.21-01	6.21-01	6.21-01	6.21-01	6.21-01	6.21-01	6.21-01	6.21-01	6.21-01
GE 76	0.00	1.25+00	1.25+00	1.25+00	1.25+00	1.25+00	1.25+00	1.25+00	1.25+00	1.25+00	1.25+00	1.25+00
SE 76	0.00	2.02-02	2.02-02	2.02-02	2.02-02	2.02-02	2.02-02	2.02-02	2.02-02	2.02-02	2.02-02	2.02-02
SE 77	0.00	4.41+00	4.41+00	4.41+00	4.41+00	4.41+00	4.41+00	4.41+00	4.41+00	4.41+00	4.41+00	4.41+00
SE 78	0.00	1.45+01	1.45+01	1.45+01	1.45+01	1.45+01	1.45+01	1.45+01	1.45+01	1.45+01	1.45+01	1.45+01
SE 79	0.00	2.64+01	2.64+01	2.64+01	2.64+01	2.61+01	2.37+01	9.09+00	6.19-04	0.00	0.00	0.00
BR 79	0.00	3.41-02	3.44-02	3.70-02	6.23-02	3.14-01	2.70+00	1.73+01	2.64+01	2.64+01	2.64+01	2.64+01
SE 80	0.00	5.25+01	5.25+01	5.25+01	5.25+01	5.25+01	5.25+01	5.25+01	5.25+01	5.25+01	5.25+01	5.25+01
KR 80	0.00	4.22-02	4.22-02	4.22-02	4.22-02	4.22-02	4.22-02	4.22-02	4.22-02	4.22-02	4.22-02	4.22-02
BR 81	0.00	9.70+01	9.70+01	9.70+01	9.70+01	9.70+01	9.70+01	9.70+01	9.70+01	9.70+01	9.70+01	9.70+01
KR 81	0.00	3.20-02	3.20-02	3.20-02	3.20-02	3.20-02	3.20-02	3.20-02	3.20-02	3.20-02	3.20-02	3.20-02
SE 82	0.00	1.80+02	1.80+02	1.80+02	1.80+02	1.80+02	1.80+02	1.80+02	1.80+02	1.80+02	1.80+02	1.80+02
KR 82	0.00	4.27+00	4.27+00	4.27+00	4.27+00	4.27+00	4.27+00	4.27+00	4.27+00	4.27+00	4.27+00	4.27+00
KR 83	0.00	1.73+02	1.73+02	1.73+02	1.73+02	1.73+02	1.73+02	1.73+02	1.73+02	1.73+02	1.73+02	1.73+02
KR 84	0.00	6.77+02	6.77+02	6.77+02	6.77+02	6.77+02	6.77+02	6.77+02	6.77+02	6.77+02	6.77+02	6.77+02
KR 85	0.00	1.52+02	1.43+02	8.00+01	2.48-01	2.06-26	0.00	0.00	0.00	0.00	0.00	0.00
RB 85	0.00	5.48+02	5.57+02	6.30+02	7.00+02	7.00+02	7.00+02	7.00+02	7.00+02	7.00+02	7.00+02	7.00+02
KR 86	0.00	9.81+02	9.81+02	9.81+02	9.81+02	9.81+02	9.81+02	9.81+02	9.81+02	9.81+02	9.81+02	9.81+02
SR 86	0.00	1.57+00	1.57+00	1.57+00	1.57+00	1.57+00	1.57+00	1.57+00	1.57+00	1.57+00	1.57+00	1.57+00
RB 87	0.00	1.32+03	1.32+03	1.32+03	1.32+03	1.32+03	1.32+03	1.32+03	1.32+03	1.32+03	1.32+03	1.31+03
SR 87	0.00	2.00-03	2.00-03	2.00-03	2.00-03	2.01-03	2.18-03	3.83-03	2.03-02	1.85-01	1.84+00	1.82+01
SR 88	0.00	1.68+03	1.68+03	1.68+03	1.68+03	1.68+03	1.68+03	1.68+03	1.68+03	1.68+03	1.68+03	1.68+03
SR 89	0.00	7.98-01	6.14-03	5.79-22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y 89	0.00	1.99+03	1.99+03	1.99+03	1.99+03	1.99+03	1.99+03	1.99+03	1.99+03	1.99+03	1.99+03	1.99+03
SR 90	0.00	2.01+03	1.96+03	1.57+03	1.71+02	3.92-06	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	5.23-01	5.10-01	4.09-01	4.44-02	1.02-11	0.00	0.00	0.00	0.00	0.00	0.00
ZR 90	0.00	1.61+02	2.10+02	6.01+02	2.00+03	2.17+03	2.17+03	2.17+03	2.17+03	2.17+03	2.17+03	2.17+03
Y 91	0.00	1.66+00	2.24-02	3.35-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 91	0.00	2.32+03	2.32+03	2.32+03	2.32+03	2.32+03	2.32+03	2.32+03	2.32+03	2.32+03	2.32+03	2.32+03
ZR 92	0.00	2.46+03	2.46+03	2.46+03	2.46+03	2.46+03	2.46+03	2.46+03	2.46+03	2.46+03	2.46+03	2.46+03
ZR 93	0.00	2.56+03	2.56+03	2.56+03	2.56+03	2.56+03	2.55+03	2.44+03	1.61+03	2.52+01	2.21-17	0.00
NB 93M	0.00	3.27-03	4.26-03	1.12-02	2.31-02	2.32-02	2.31-02	2.22-02	1.46-02	2.29-04	2.00-22	0.00
NB 93	0.00	2.94-04	4.86-04	4.16-03	9.88-02	1.16+00	1.18+01	1.16+02	9.47+02	2.53+03	2.56+03	2.56+03
ZR 94	0.00	2.63+03	2.63+03	2.63+03	2.63+03	2.63+03	2.63+03	2.63+03	2.63+03	2.63+03	2.63+03	2.63+03
ZR 95	0.00	3.12+00	6.34-02	3.82-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	3.81-03	7.77-05	4.68-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
NB 95	0.00	3.57+00	7.56-02	4.46-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MO 95	0.00	2.23+03	2.24+03	2.24+03	2.24+03	2.24+03	2.24+03	2.24+03	2.24+03	2.24+03	2.24+03	2.24+03
ZR 96	0.00	2.37+03	2.37+03	2.37+03	2.37+03	2.37+03	2.37+03	2.37+03	2.37+03	2.37+03	2.37+03	2.37+03
MO 96	0.00	2.15+02	2.15+02	2.15+02	2.15+02	2.15+02	2.15+02	2.15+02	2.15+02	2.15+02	2.15+02	2.15+02
MO 97	0.00	2.27+03	2.27+03	2.27+03	2.27+03	2.27+03	2.27+03	2.27+03	2.27+03	2.27+03	2.27+03	2.27+03
MO 98	0.00	2.25+03	2.25+03	2.25+03	2.25+03	2.25+03	2.25+03	2.25+03	2.25+03	2.25+03	2.25+03	2.25+03
TC 99	0.00	1.98+03	1.98+03	1.98+03	1.98+03	1.97+03	1.91+03	1.43+03	7.52+01	1.26-11	0.00	0.00
RU 99	0.00	2.00-02	2.64-02	8.46-02	6.66-01	6.47+00	6.36+01	5.51+02	1.90+03	1.98+03	1.98+03	1.98+03
MO100	0.00	2.19+03	2.19+03	2.19+03	2.19+03	2.19+03	2.19+03	2.19+03	2.19+03	2.19+03	2.19+03	2.19+03
RU100	0.00	2.56+02	2.56+02	2.56+02	2.56+02	2.56+02	2.56+02	2.56+02	2.56+02	2.56+02	2.56+02	2.56+02
RU101	0.00	1.53+03	1.53+03	1.53+03	1.53+03	1.53+03	1.53+03	1.53+03	1.53+03	1.53+03	1.53+03	1.53+03
RU102	0.00	1.40+03	1.40+03	1.40+03	1.40+03	1.40+03	1.40+03	1.40+03	1.40+03	1.40+03	1.40+03	1.40+03
RU103	0.00	6.32-02	1.06-04	1.10-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	6.32-05	1.06-07	1.10-32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103	0.00	4.16+02	4.16+02	4.16+02	4.16+02	4.16+02	4.16+02	4.16+02	4.16+02	4.16+02	4.16+02	4.16+02
RU104	0.00	5.98+02	5.98+02	5.98+02	5.98+02	5.98+02	5.98+02	5.98+02	5.98+02	5.98+02	5.98+02	5.98+02
PD104	0.00	6.08+02	6.08+02	6.08+02	6.08+02	6.08+02	6.08+02	6.08+02	6.08+02	6.08+02	6.08+02	6.08+02
PD105	0.00	2.22+02	2.22+02	2.22+02	2.22+02	2.22+02	2.22+02	2.22+02	2.22+02	2.22+02	2.22+02	2.22+02
RU106	0.00	2.83+01	1.42+01	2.86-02	3.16-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	2.68-05	1.34-05	2.71-08	2.99-35	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD106	0.00	2.44+02	2.58+02	2.73+02	2.73+02	2.73+02	2.73+02	2.73+02	2.73+02	2.73+02	2.73+02	2.73+02
PD107	0.00	9.41+01	9.41+01	9.41+01	9.41+01	9.41+01	9.40+01	9.32+01	8.52+01	3.50+01	4.72-03	0.00
AG107	0.00	2.58-05	3.52-05	1.19-04	9.58-04	9.34-03	9.32-02	9.27-01	8.87+00	5.91+01	9.41+01	9.41+01
PD108	0.00	4.52+01	4.52+01	4.52+01	4.52+01	4.52+01	4.52+01	4.52+01	4.52+01	4.52+01	4.52+01	4.52+01
CD108	0.00	1.07-06	1.07-06	1.07-06	1.07-06	1.07-06	1.07-06	1.07-06	1.07-06	1.07-06	1.07-06	1.07-06
AG109	0.00	1.38+01	1.38+01	1.38+01	1.38+01	1.38+01	1.38+01	1.38+01	1.38+01	1.38+01	1.38+01	1.38+01
CD109	0.00	5.95-09	3.40-09	2.23-11	3.22-33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD110	0.00	1.48+01	1.48+01	1.48+01	1.48+01	1.48+01	1.48+01	1.48+01	1.48+01	1.48+01	1.48+01	1.48+01
AG110M	0.00	1.88-02	6.90-03	8.49-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	2.72-09	1.00-09	1.23-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD110	0.00	1.78+01	1.78+01	1.78+01	1.78+01	1.78+01	1.78+01	1.78+01	1.78+01	1.78+01	1.78+01	1.78+01
CD111	0.00	1.17+01	1.17+01	1.17+01	1.17+01	1.17+01	1.17+01	1.17+01	1.17+01	1.17+01	1.17+01	1.17+01
CD112	0.00	7.46+00	7.46+00	7.46+00	7.46+00	7.46+00	7.46+00	7.46+00	7.46+00	7.46+00	7.46+00	7.46+00
CD113M	0.00	5.06-04	4.82-04	3.08-04	3.58-06	1.61-25	0.00	0.00	0.00	0.00	0.00	0.00
CD113	0.00	8.42-02	8.42-02	8.42-02	8.42-02	8.42-02	8.42-02	8.42-02	8.42-02	8.42-02	8.42-02	8.42-02
IN113	0.00	4.69-05	7.13-05	2.44-04	5.49-04	5.52-04	5.52-04	5.52-04	5.52-04	5.52-04	5.52-04	5.52-04
CD114	0.00	1.94+01	1.94+01	1.94+01	1.94+01	1.94+01	1.94+01	1.94+01	1.94+01	1.94+01	1.94+01	1.94+01
IN114M	0.00	2.95-10	1.87-12	3.06-32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN114	0.00	8.46-06	8.46-06	8.46-06	8.46-06	8.46-06	8.46-06	8.46-06	8.46-06	8.46-06	8.46-06	8.46-06
CD115M	0.00	7.10-05	1.97-07	1.94-30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
IN115	0.00	1.46+00	1.46+00	1.46+00	1.46+00	1.46+00	1.46+00	1.46+00	1.46+00	1.46+00	1.46+00	1.46+00
SN115	0.00	3.99-01	3.99-01	3.99-01	3.99-01	3.99-01	3.99-01	3.99-01	3.99-01	3.99-01	3.99-01	3.99-01
CD116	0.00	7.36+00	7.36+00	7.36+00	7.36+00	7.36+00	7.36+00	7.36+00	7.36+00	7.36+00	7.36+00	7.36+00
SN116	0.00	6.67+00	6.67+00	6.67+00	6.67+00	6.67+00	6.67+00	6.67+00	6.67+00	6.67+00	6.67+00	6.67+00
SN117	0.00	7.25+00	7.25+00	7.25+00	7.25+00	7.25+00	7.25+00	7.25+00	7.25+00	7.25+00	7.25+00	7.25+00
SN118	0.00	7.49+00	7.49+00	7.49+00	7.49+00	7.49+00	7.49+00	7.49+00	7.49+00	7.49+00	7.49+00	7.49+00
SN119M	0.00	1.80-03	6.55-04	7.23-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119	0.00	7.55+00	7.56+00	7.56+00	7.56+00	7.56+00	7.56+00	7.56+00	7.56+00	7.56+00	7.56+00	7.56+00
SN120	0.00	8.28+00	8.28+00	8.28+00	8.28+00	8.28+00	8.28+00	8.28+00	8.28+00	8.28+00	8.28+00	8.28+00
SN121M	0.00	2.12-05	2.10-05	1.93-05	8.50-06	2.32-09	0.00	0.00	0.00	0.00	0.00	0.00
SB121	0.00	7.82+00	7.82+00	7.82+00	7.82+00	7.82+00	7.82+00	7.82+00	7.82+00	7.82+00	7.82+00	7.82+00
SN122	0.00	1.25+01	1.25+01	1.25+01	1.25+01	1.25+01	1.25+01	1.25+01	1.25+01	1.25+01	1.25+01	1.25+01
TE122	0.00	9.10-01	9.10-01	9.10-01	9.10-01	9.10-01	9.10-01	9.10-01	9.10-01	9.10-01	9.10-01	9.10-01
SN123M	0.00	3.39-02	4.47-03	5.45-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB123	0.00	1.65+01	1.65+01	1.65+01	1.65+01	1.65+01	1.65+01	1.65+01	1.65+01	1.65+01	1.65+01	1.65+01
TE123M	0.00	5.85-05	6.72-06	2.35-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123	0.00	3.19-03	3.24-03	3.25-03	3.25-03	3.25-03	3.25-03	3.25-03	3.25-03	3.25-03	3.25-03	3.25-03
SN124	0.00	2.57+01	2.57+01	2.57+01	2.57+01	2.57+01	2.57+01	2.57+01	2.57+01	2.57+01	2.57+01	2.57+01
SB124	0.00	1.34-03	1.97-05	6.39-22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE124	0.00	7.62-01	7.63-01	7.63-01	7.63-01	7.63-01	7.63-01	7.63-01	7.63-01	7.63-01	7.63-01	7.63-01
SB125	0.00	1.62+01	1.25+01	1.24+00	1.15-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	3.93-01	3.05-01	3.03-02	2.81-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125	0.00	1.50+01	1.87+01	3.02+01	3.15+01	3.15+01	3.15+01	3.15+01	3.15+01	3.15+01	3.15+01	3.15+01
SN126	0.00	3.51+01	3.51+01	3.51+01	3.50+01	3.48+01	3.27+01	1.75+01	3.43-02	2.81-29	0.00	0.00
SB126M	0.00	1.27-08	1.27-08	1.27-08	1.27-08	1.26-08	1.18-08	6.34-09	1.24-11	0.00	0.00	0.00
SB126	0.00	1.19-05	1.19-05	1.19-05	1.19-05	1.18-05	1.11-05	5.94-06	1.16-08	0.00	0.00	0.00
TE126	0.00	3.55+01	3.55+01	3.55+01	3.55+01	3.57+01	3.78+01	5.30+01	7.05+01	7.06+01	7.06+01	7.06+01
TE127M	0.00	6.00-01	5.89-02	4.94-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	2.13-03	2.09-04	1.75-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I127	0.00	1.87+02	1.88+02	1.88+02	1.88+02	1.88+02	1.88+02	1.88+02	1.88+02	1.88+02	1.88+02	1.88+02
TE128	0.00	4.62+02	4.62+02	4.62+02	4.62+02	4.62+02	4.62+02	4.62+02	4.62+02	4.62+02	4.62+02	4.62+02
XE128	0.00	2.25+01	2.25+01	2.25+01	2.25+01	2.25+01	2.25+01	2.25+01	2.25+01	2.25+01	2.25+01	2.25+01
TE129M	0.00	6.52-03	3.81-06	3.04-35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	5.89-06	3.44-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	7.27+02	7.27+02	7.27+02	7.27+02	7.27+02	7.27+02	7.25+02	6.98+02	4.84+02	1.23+01	1.44-15
XE129	0.00	4.01-01	4.01-01	4.01-01	4.04-01	4.30-01	6.97-01	3.36+00	2.95+01	2.44+02	7.16+02	7.28+02
TE130	0.00	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03	1.27+03
XE130	0.00	7.78+01	7.78+01	7.78+01	7.78+01	7.78+01	7.78+01	7.78+01	7.78+01	7.78+01	7.78+01	7.78+01
XE131	0.00	8.94+02	8.94+02	8.94+02	8.94+02	8.94+02	8.94+02	8.94+02	8.94+02	8.94+02	8.94+02	8.94+02
XE132	0.00	3.41+03	3.41+03	3.41+03	3.41+03	3.41+03	3.41+03	3.41+03	3.41+03	3.41+03	3.41+03	3.41+03

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 84.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
CS133	0.00	2.33+03	2.33+03	2.33+03	2.33+03	2.33+03	2.33+03	2.33+03	2.33+03	2.33+03	2.33+03	2.33+03
XE134	0.00	3.86+03	3.86+03	3.86+03	3.86+03	3.86+03	3.86+03	3.86+03	3.86+03	3.86+03	3.86+03	3.86+03
CS134	0.00	4.34+02	3.09+02	1.48+01	9.04-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BA134	0.00	4.77+02	6.01+02	8.96+02	9.11+02	9.11+02	9.11+02	9.11+02	9.11+02	9.11+02	9.11+02	9.11+02
CS135	0.00	7.67+02	7.67+02	7.67+02	7.67+02	7.67+02	7.66+02	7.50+02	6.09+02	7.62+01	7.13-08	0.00
BA135	0.00	4.66-01	4.66-01	4.66-01	4.84-01	6.43-01	2.24+00	1.80+01	1.59+02	6.92+02	7.68+02	7.68+02
XE136	0.00	6.67+03	6.67+03	6.67+03	6.67+03	6.67+03	6.67+03	6.67+03	6.67+03	6.67+03	6.67+03	6.67+03
BA136	0.00	1.02+02	1.02+02	1.02+02	1.02+02	1.02+02	1.02+02	1.02+02	1.02+02	1.02+02	1.02+02	1.02+02
CS137	0.00	3.43+03	3.35+03	2.72+03	3.46+02	3.18-07	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	5.18-04	5.06-04	4.11-04	5.14-05	4.61-14	0.00	0.00	0.00	0.00	0.00	0.00
BA137	0.00	2.43+02	3.21+02	9.50+02	3.33+03	3.67+03	3.67+03	3.67+03	3.67+03	3.67+03	3.67+03	3.67+03
BA138	0.00	3.50+03	3.50+03	3.50+03	3.50+03	3.50+03	3.50+03	3.50+03	3.50+03	3.50+03	3.50+03	3.50+03
LA139	0.00	3.67+03	3.67+03	3.67+03	3.67+03	3.67+03	3.67+03	3.67+03	3.67+03	3.67+03	3.67+03	3.67+03
CE140	0.00	3.91+03	3.91+03	3.91+03	3.91+03	3.91+03	3.91+03	3.91+03	3.91+03	3.91+03	3.91+03	3.91+03
CE141	0.00	5.21-02	2.11-05	6.15-36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR141	0.00	3.85+03	3.85+03	3.85+03	3.85+03	3.85+03	3.85+03	3.85+03	3.85+03	3.85+03	3.85+03	3.85+03
CE142	0.00	4.55+03	4.55+03	4.55+03	4.55+03	4.55+03	4.55+03	4.55+03	4.55+03	4.55+03	4.55+03	4.55+03
ND142	0.00	1.50+02	1.50+02	1.50+02	1.50+02	1.50+02	1.50+02	1.50+02	1.50+02	1.50+02	1.50+02	1.50+02
ND143	0.00	1.61+03	1.61+03	1.61+03	1.61+03	1.61+03	1.61+03	1.61+03	1.61+03	1.61+03	1.61+03	1.61+03
CE144	0.00	3.29+02	1.35+02	4.44-02	6.48-37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	1.39-02	5.71-03	1.88-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND144	0.00	4.66+03	4.87+03	5.01+03	5.01+03	5.01+03	5.01+03	5.01+03	5.01+03	5.01+03	5.01+03	5.01+03
ND145	0.00	1.83+03	1.83+03	1.83+03	1.83+03	1.83+03	1.83+03	1.83+03	1.83+03	1.83+03	1.83+03	1.83+03
ND146	0.00	2.14+03	2.14+03	2.14+03	2.14+03	2.14+03	2.14+03	2.14+03	2.14+03	2.14+03	2.14+03	2.14+03
PM147	0.00	1.57+02	1.21+02	1.12+01	5.13-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM147	0.00	1.59+02	1.95+02	3.05+02	3.16+02	3.16+02	3.16+02	3.16+02	3.16+02	3.16+02	3.16+02	3.16+02
ND146	0.00	9.11+02	9.11+02	9.11+02	9.11+02	9.11+02	9.11+02	9.11+02	9.11+02	9.11+02	9.11+02	9.11+02
PM148M	0.00	1.24-03	2.98-16	8.30-36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	1.28-05	3.08-08	8.57-32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM148	0.00	7.41+02	7.41+02	7.41+02	7.41+02	7.41+02	7.41+02	7.41+02	7.41+02	7.41+02	7.41+02	7.41+02
SM149	0.00	4.52+00	4.52+00	4.52+00	4.52+00	4.52+00	4.52+00	4.52+00	4.52+00	4.52+00	4.52+00	4.52+00
ND150	0.00	3.78+02	3.78+02	3.78+02	3.78+02	3.78+02	3.78+02	3.78+02	3.78+02	3.78+02	3.78+02	3.78+02
SM150	0.00	6.90+02	6.90+02	6.90+02	6.90+02	6.90+02	6.90+02	6.90+02	6.90+02	6.90+02	6.90+02	6.90+02
SM151	0.00	2.20+01	2.18+01	2.03+01	9.90+00	7.62-03	5.60-34	0.00	0.00	0.00	0.00	0.00
EU151	0.00	1.88-01	3.62-01	1.87+00	1.22+01	2.21+01	2.21+01	2.21+01	2.21+01	2.21+01	2.21+01	2.21+01
SM152	0.00	1.64+02	1.64+02	1.64+02	1.64+02	1.64+02	1.64+02	1.64+02	1.64+02	1.64+02	1.64+02	1.64+02
EU152	0.00	1.30-02	1.23-02	7.31-03	4.09-05	1.08-27	0.00	0.00	0.00	0.00	0.00	0.00
GD152	0.00	1.37-01	1.36-01	1.39-01	1.41-01	1.41-01	1.41-01	1.41-01	1.41-01	1.41-01	1.41-01	1.41-01
EU153	0.00	2.08+02	2.08+02	2.08+02	2.08+02	2.08+02	2.08+02	2.08+02	2.08+02	2.08+02	2.08+02	2.08+02
SM154	0.00	3.86+01	3.86+01	3.86+01	3.86+01	3.86+01	3.86+01	3.86+01	3.86+01	3.86+01	3.86+01	3.86+01

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
EU154	0.00	8.35+01	8.00+01	5.42+01	1.10+00	1.29-17	0.00	0.00	0.00	0.00	0.00	0.00
GD154	0.00	8.21+00	1.18+01	3.76+01	9.06+01	9.17+01	9.17+01	9.17+01	9.17+01	9.17+01	9.17+01	9.17+01
EU155	0.00	6.71+00	4.57+00	1.46-01	1.58-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD155	0.00	3.19+00	5.33+00	9.75+00	9.90+00	9.90+00	9.90+00	9.90+00	9.90+00	9.90+00	9.90+00	9.90+00
GD156	0.00	4.69+02	4.69+02	4.69+02	4.69+02	4.69+02	4.69+02	4.69+02	4.69+02	4.69+02	4.69+02	4.69+02
GD157	0.00	3.75-02	3.75-02	3.75-02	3.75-02	3.75-02	3.75-02	3.75-02	3.75-02	3.75-02	3.75-02	3.75-02
GD158	0.00	1.88+01	1.88+01	1.88+01	1.88+01	1.88+01	1.88+01	1.88+01	1.88+01	1.88+01	1.88+01	1.88+01
TB159	0.00	7.54-01	7.54-01	7.54-01	7.54-01	7.54-01	7.54-01	7.54-01	7.54-01	7.54-01	7.54-01	7.54-01
GD160	0.00	2.51-01	2.51-01	2.51-01	2.51-01	2.51-01	2.51-01	2.51-01	2.51-01	2.51-01	2.51-01	2.51-01
TB160	0.00	1.89-03	5.65-05	1.07-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DY160	0.00	2.56-01	2.58-01	2.58-01	2.58-01	2.58-01	2.58-01	2.58-01	2.58-01	2.58-01	2.58-01	2.58-01
DY161	0.00	6.68-02	6.68-02	6.68-02	6.68-02	6.68-02	6.68-02	6.68-02	6.68-02	6.68-02	6.68-02	6.68-02
GD162	0.00	8.25-03	4.13-03	8.07-06	6.61-33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	1.16-07	5.88-08	1.15-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DY162	0.00	6.39-02	6.81-02	7.22-02	7.22-02	7.22-02	7.22-02	7.22-02	7.22-02	7.22-02	7.22-02	7.22-02
DY163	0.00	6.05-02	6.05-02	6.05-02	6.05-02	6.05-02	6.05-02	6.05-02	6.05-02	6.05-02	6.05-02	6.05-02
DY164	0.00	1.24-02	1.24-02	1.24-02	1.24-02	1.24-02	1.24-02	1.24-02	1.24-02	1.24-02	1.24-02	1.24-02
HO165	0.00	4.39-02	4.39-02	4.39-02	4.39-02	4.39-02	4.39-02	4.39-02	4.39-02	4.39-02	4.39-02	4.39-02
HO166M	0.00	6.23-05	6.23-05	6.20-05	5.88-05	3.50-05	1.93-07	5.18-30	0.00	0.00	0.00	0.00
ER166	0.00	1.46-02	1.46-02	1.46-02	1.46-02	1.46-02	1.47-02	1.47-02	1.47-02	1.47-02	1.47-02	1.47-02
ER167	0.00	2.35-03	2.35-03	2.35-03	2.35-03	2.35-03	2.35-03	2.35-03	2.35-03	2.35-03	2.35-03	2.35-03
SUBTOT	0.00	9.90+04	9.90+04	9.90+04	9.90+04	9.90+04	9.90+04	9.90+04	9.90+04	9.90+04	9.90+04	9.90+04
TOTAL	0.00	9.90+04	9.90+04	9.90+04	9.90+04	9.90+04	9.90+04	9.90+04	9.90+04	9.90+04	9.90+04	9.90+04

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 84.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = .MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	1.24+03	1.17+03	7.05+02	4.43+00	4.21-22	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	1.84+00	1.84+00	1.84+00	1.84+00	1.82+00	1.65+00	6.33-01	4.31-05	0.00	0.00	0.00
KR 85	0.00	5.92+04	5.55+04	3.12+04	9.67+01	8.04-24	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	7.45-03	9.86-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	1.09-04	1.09-04	1.09-04	1.09-04	1.09-04	1.09-04	1.09-04	1.09-04	1.09-04	1.09-04	1.07-04
SR 89	0.00	2.25+04	1.73+02	1.63-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	2.84+05	2.76+05	2.22+05	2.42+04	5.54-06	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	2.85+05	2.78+05	2.22+05	2.42+04	5.54-06	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	4.09+04	5.46+02	8.17-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	6.56+00	6.56+00	6.56+00	6.56+00	6.56+00	6.53+00	6.27+00	4.14+00	6.47-02	5.66-20	0.00
NB 93M	0.00	9.25-01	1.25+00	3.16+00	6.53+00	6.56+00	6.53+00	6.27+00	4.14+00	6.47-02	5.66-20	0.00
ZR 95	0.00	6.59+04	1.34+03	8.08-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	1.40+03	2.85+01	1.71-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	1.40+05	2.95+03	1.75-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	3.37+01	3.37+01	3.37+01	3.37+01	3.36+01	3.26+01	2.43+01	1.28+00	2.14-13	0.00	0.00
RU103	0.00	2.02+03	3.39+00	3.52-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	2.03+03	3.39+00	3.53-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	9.50+04	4.77+04	9.61+01	1.06-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	9.50+04	4.77+04	9.61+01	1.06-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	4.49-02	4.49-02	4.49-02	4.49-02	4.49-02	4.49-02	4.45-02	4.07-02	1.67-02	2.26-06	0.00
AG109M	0.00	1.57-05	9.00-06	5.89-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	1.57-05	9.00-06	5.89-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	8.61+01	3.24+01	3.98-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	1.15+01	4.21+00	5.18-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	1.14-01	1.09-01	6.97-02	8.10-04	3.64-23	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	6.77-06	4.29-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	6.53-06	4.14-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	1.88+00	5.21-03	5.12-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	7.92+00	2.88+00	3.17-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	9.23-04	8.15-04	7.51-04	3.31-04	9.02-06	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	2.60+02	3.80+01	4.63-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	5.31-01	6.10-02	2.14-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	2.35+01	3.46-01	1.12-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	1.71+04	1.33+04	1.32+03	1.22-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	7.09+03	5.49+03	5.45+02	5.06-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	9.95-01	9.95-01	9.95-01	9.95-01	9.89-01	9.29-01	4.98-01	9.74-04	0.00	0.00	0.00
SB126M	0.00	9.95-01	9.95-01	9.95-01	9.95-01	9.89-01	9.29-01	4.98-01	9.74-04	0.00	0.00	0.00
SB126	0.00	9.85-01	9.85-01	9.85-01	9.85-01	9.79-01	9.19-01	4.93-01	9.64-04	0.00	0.00	0.00
TE127M	0.00	5.67+03	5.56+02	4.66-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	5.60+03	5.49+02	4.61-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE129M	0.00	1.94+02	1.14-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	1.24+02	7.28-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	1.19-01	1.19-01	1.19-01	1.19-01	1.19-01	1.19-01	1.18-01	1.14-01	7.89-02	2.01-03	2.35-19
CS134	0.00	5.65+05	4.03+05	1.92+04	1.18-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	6.78-01	6.78-01	6.78-01	6.78-01	6.77-01	6.76-01	6.62-01	5.38-01	6.73-02	6.29-11	0.00
CS137	0.00	2.98+05	2.92+05	2.37+05	2.96+04	2.77-05	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	2.79+05	2.73+05	2.21+05	2.77+04	2.59-05	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	7.61-03	1.97-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	8.76-03	2.26-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	1.49+03	6.03-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	3.29-02	3.11-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	1.05+06	4.31+05	1.42+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	1.05+06	4.31+05	1.42+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	1.46+05	1.12+05	1.04+04	4.76-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	2.60+01	6.27-02	1.74-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	2.09+00	5.04-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	5.98+02	5.93+02	5.52+02	2.69+02	2.08-01	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	2.55+00	2.41+00	1.43+00	7.92-03	2.12-25	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	1.21+04	1.16+04	7.86+03	1.59+02	1.88-15	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	8.55+03	5.83+03	1.86+02	2.01-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	3.43-02	1.61-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	2.14+01	6.39-01	1.21-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	1.82+01	9.11+00	1.78-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	1.82+01	9.11+00	1.78-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HO166M	0.00	1.12-04	1.12-04	1.11-04	1.06-04	6.28-05	3.47-07	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	4.55+06	2.69+06	9.75+05	1.06+05	5.25+01	5.09+01	3.98+01	1.02+01	2.92-01	2.12-03	1.07-04
TOTAL	0.00	4.55+06	2.69+06	9.75+05	1.06+05	5.25+01	5.09+01	3.98+01	1.02+01	2.92-01	2.12-03	1.07-04

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	4.41-02	4.17-02	2.51-02	1.57-04	1.50-26	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	6.98-04	6.98-04	6.98-04	6.97-04	6.90-04	6.27-04	2.40-04	1.63-08	0.00	0.00	0.00
KR 85	0.00	9.62+01	9.02+01	5.06+01	1.57-01	1.31-26	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	3.52-05	4.66-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	7.10-08	7.10-08	7.10-08	7.10-08	7.10-08	7.10-08	7.10-08	7.10-08	7.10-08	7.09-08	7.00-08
SR 89	0.00	8.11+01	6.23-01	5.88-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	3.73+02	3.64+02	2.91+02	3.16+01	7.26-09	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	1.67+03	1.63+03	1.31+03	1.42+02	3.26-08	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	1.54+02	2.08+00	3.11-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	7.78-04	7.78-04	7.78-04	7.78-04	7.78-04	7.75-04	7.43-04	4.90-04	7.67-06	6.71-24	0.00
NB 93M	0.00	1.64-04	2.14-04	5.65-04	1.16-03	1.17-03	1.16-03	1.11-03	7.35-04	1.15-05	1.01-23	0.00
ZR 95	0.00	3.45+02	7.02+00	4.23-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	1.95+00	3.97-02	2.39-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	6.74+02	1.43+01	8.43-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	2.28-02	2.28-02	2.28-02	2.28-02	2.27-02	2.20-02	1.64-02	6.66-04	1.45-16	0.00	0.00
RU103	0.00	6.67+00	1.12-02	1.16-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	9.60-01	1.61-03	1.67-28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	5.63+00	2.83+00	5.69-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	9.99+02	5.01+02	1.01+00	1.11-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	3.73-06	3.73-06	3.73-06	3.73-06	3.73-06	3.73-06	3.69-06	3.38-06	1.39-06	1.87-10	0.00
AG109M	0.00	1.64-08	9.39-09	6.15-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	1.57-08	8.96-09	5.87-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	1.49+00	5.46-01	6.73-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	8.31-02	3.06-02	3.76-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	1.51-04	1.44-04	9.22-05	1.07-06	4.81-26	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	7.30-09	4.62-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	3.08-08	1.95-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	6.86-03	1.91-05	1.87-28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	8.35-03	3.04-03	3.35-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	1.04-06	1.03-06	9.53-07	4.19-07	1.14-10	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	1.02+00	1.35-01	1.64-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	1.56-03	1.79-04	6.28-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	3.23-01	4.75-03	1.54-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	6.95+01	5.38+01	5.34+00	4.96-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	1.22+01	9.44+00	9.37-01	6.71-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	1.07-03	1.07-03	1.07-03	1.07-03	1.07-03	1.00-03	5.37-04	1.05-06	0.00	0.00	0.00
SB126M	0.00	6.73-03	6.73-03	6.73-03	6.73-03	6.69-03	6.28-03	3.37-03	6.58-06	0.00	0.00	0.00
SB126	0.00	1.28-02	1.28-02	1.28-02	1.28-02	1.27-02	1.20-02	6.41-03	1.25-05	0.00	0.00	0.00
TE127M	0.00	3.12+00	3.06-01	2.57-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	9.03+00	8.86-01	7.43-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

HIGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE129M	0.00	3.86-01	2.25-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	4.52-01	2.64-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	7.81-05	7.81-05	7.81-05	7.81-05	7.81-05	7.80-05	7.77-05	7.49-05	5.19-05	1.32-06	1.54-22
CS134	0.00	5.98+03	4.27+03	2.04+02	1.25-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	3.29-04	3.29-04	3.29-04	3.29-04	3.29-04	3.29-04	3.22-04	2.61-04	3.27-05	3.06-14	0.00
CS137	0.00	4.88+02	4.77+02	3.87+02	4.85+01	4.53-08	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	1.10+03	1.07+03	8.70+02	1.09+02	1.02-07	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	2.93+00	1.19-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	8.61+02	3.53+02	1.16-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	8.14+03	3.34+03	1.10+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	7.54+01	5.79+01	5.35+00	2.46-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	3.22-01	7.77-04	2.16-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	1.69-02	4.08-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	1.04+00	1.03+00	9.62-01	4.70-01	3.62-04	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	4.57-02	4.32-02	2.57-02	1.42-04	3.80-27	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	9.94+01	9.52+01	6.45+01	1.31+00	1.54-17	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	7.20+00	4.91+00	1.56-01	1.70-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	3.42-04	1.60-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	1.82-01	5.43-03	1.03-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	6.20-02	3.10-02	6.06-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	2.46-01	1.23-01	2.40-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HO166M	0.00	1.20-06	1.20-06	1.20-06	1.14-06	6.75-07	3.74-09	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	2.13+04	1.23+04	3.19+03	3.33+02	4.66-02	4.42-02	2.92-02	2.45-03	1.05-04	1.40-06	7.00-08
TOTAL	0.00	2.13+04	1.23+04	3.19+03	3.33+02	4.66-02	4.42-02	2.92-02	2.45-03	1.05-04	1.40-06	7.00-08

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	6.20+09	5.86+09	3.53+09	2.21+07	2.11-15	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	4.60+08	4.60+08	4.60+08	4.59+08	4.55+08	4.13+08	1.58+08	1.08+04	0.00	0.00	0.00
KR 85	0.00	1.97+11	1.85+11	1.04+11	3.22+08	2.68-17	0.00	0.00	0.00	0.00	0.00	0.00
RB 66	0.00	3.72+06	4.93+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	5.44+04	5.44+04	5.44+04	5.44+04	5.44+04	5.44+04	5.44+04	5.44+04	5.44+04	5.43+04	5.37+04
SR 89	0.00	7.51+13	5.78+11	5.45-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	9.48+15	9.25+15	7.41+15	3.05+14	1.85+05	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	9.48+13	9.25+13	7.41+13	3.05+12	1.85+03	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	4.84+13	5.46+11	8.17-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	1.64+09	1.64+09	1.64+09	1.64+09	1.64+09	1.63+09	1.57+09	1.03+09	1.62+07	1.42-11	0.00
NB 93M	0.00	2.31+06	3.01+04	7.94+00	1.63+09	1.64+09	1.63+09	1.57+09	1.03+09	1.62+07	1.42-11	0.00
ZR 95	0.00	6.59+13	1.34+12	8.63-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	-1.40+03	-2.65+01	-1.71-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	4.67+13	9.93+11	5.64-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	1.68+10	1.68+10	1.68+10	1.68+10	1.68+10	1.63+10	1.21+10	6.41+08	1.07-04	0.00	0.00
RU103	0.00	6.74+11	1.13+09	1.17-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	1.01+09	1.70+06	1.76-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	4.75+14	2.38+14	4.80+11	5.30-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	-9.56+04	-4.77+04	-9.61+01	-1.06-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	2.25+05	2.25+05	2.25+05	2.25+05	2.25+05	2.24+05	2.23+05	2.04+05	8.35+04	1.13+01	0.00
AG109M	0.00	-1.57-05	-9.00-06	-5.89-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	7.67+03	4.50+03	2.95+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	2.94+11	1.08+11	1.33+07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	-1.15+01	-4.21+00	-5.16-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	-1.19-01	-1.09-01	-6.97-02	-5.10-04	-3.64-23	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	9.67+03	6.12+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	-6.53-06	-4.14-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	1.88+09	5.21+06	5.12-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN117M	0.00	-4.00-09	-5.63-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	-7.92+00	-2.80+00	-3.17-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	-8.23-04	-6.15-04	-7.51-04	-3.31-04	-9.02-08	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	-2.88+02	-3.80+01	-4.63-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	-5.31-01	-6.10-02	-2.14-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	3.35+10	4.94+08	1.60-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	1.90+13	1.47+13	1.46+12	1.36+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	1.77+12	1.37+12	1.36+11	1.27+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	4.95+08	4.98+08	4.98+08	4.97+08	4.94+08	4.64+08	2.49+08	4.87+05	0.00	0.00	0.00
SB126M	0.00	-9.95-01	-9.95-01	-9.95-01	-9.95-01	-9.89-01	-9.29-01	-4.98-01	-9.74-04	0.00	0.00	0.00
SB126	0.00	-9.85-01	-9.85-01	-9.85-01	-9.85-01	-9.79-01	-9.19-01	-4.93-01	-9.64-04	0.00	0.00	0.00
TE127M	0.00	5.67+12	5.56+11	4.66+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE127	0.00	1.87+11	1.83+10	1.54+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129M	0.00	1.94+11	1.14+08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	1.24+09	7.28+05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	5.93+09	5.93+09	5.93+09	5.93+09	5.93+09	5.93+09	5.91+09	5.70+09	3.95+09	1.01+08	1.17-08
XE129M	0.00	-3.94-12	-7.17-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	1.41+15	1.01+15	4.80+13	2.94+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	2.26+08	2.26+08	2.26+08	2.26+08	2.26+08	2.25+08	2.21+08	1.79+08	2.24+07	2.10-02	0.00
CS137	0.00	5.97+14	5.83+14	4.74+14	5.92+13	5.54+04	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	-2.79+05	-2.73+05	-2.21+05	-2.77+04	-2.59-05	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	7.61+06	1.97-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	2.19+06	5.66-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	2.98+11	1.21+08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	5.48+06	5.19-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	5.26+15	2.16+15	7.09+11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	-1.05+06	-4.31+05	-1.42+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	7.31+13	5.61+13	5.19+12	2.38+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	-2.60+01	-6.27-02	-1.74-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	-2.09+00	-5.04-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	2.99+11	2.96+11	2.76+11	1.35+11	1.04+08	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	6.38+09	6.02+09	3.58+09	1.98+07	5.30-16	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	1.21+14	1.16+14	7.86+13	1.59+12	1.88-05	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	2.85+12	1.94+12	6.20+10	6.71-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	-3.43-02	-1.61-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	2.14+10	6.39+08	1.21-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	-1.82+01	-9.11+00	-1.78-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	-1.62+01	-9.11+00	-1.78-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HO166M	0.00	5.59+04	5.59+04	5.56+04	5.28+04	3.14+04	1.74+02	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	1.78+16	1.35+16	8.09+15	8.74+14	2.73+10	2.66+10	2.18+10	8.58+09	4.00+09	1.01+08	5.37+04
TOTAL	0.00	1.78+16	1.35+16	8.09+15	8.74+14	2.73+10	2.66+10	2.18+10	8.58+09	4.00+09	1.01+08	5.37+04

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	4.13+05	3.90+05	2.35+05	1.48+03	1.40-19	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	4.60+02	4.60+02	4.60+02	4.59+02	4.55+02	4.13+02	1.58+02	1.08-02	0.00	0.00	0.00
KR 85	0.00	-5.92+04	-5.55+04	-3.12+04	-9.67+01	-8.04-24	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	3.72+02	4.93-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	1.09+00	1.09+00	1.09+00	1.09+00	1.09+00	1.09+00	1.09+00	1.09+00	1.09+00	1.09+00	1.07+00
SR 89	0.00	7.51+09	5.78+07	5.45-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	9.48+11	9.25+11	7.41+11	6.05+10	1.85+01	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	1.42+10	1.39+10	1.11+10	1.21+09	2.77-01	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	1.35+09	1.82+07	2.72-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	8.21+03	8.20+03	8.20+03	8.20+03	8.20+03	8.17+03	7.83+03	5.17+03	8.08+01	7.08-17	0.00
NB 93M	0.00	2.31+03	3.01+03	7.94+03	1.63+04	1.64+04	1.63+04	1.57+04	1.03+04	1.62+02	1.42-16	0.00
ZR 95	0.00	1.10+09	2.24+07	1.35-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	-1.40+03	-2.85+01	-1.71-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	1.40+09	2.98+07	1.75-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	1.68+05	1.68+05	1.68+05	1.68+05	1.68+05	1.63+05	1.21+05	6.41+03	1.07-09	0.00	0.00
RU103	0.00	2.53+07	4.24+04	4.41-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	2.03+05	3.39+02	3.53-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	9.50+09	4.77+09	9.61+06	1.06-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	-9.50+04	-4.77+04	-9.61+01	-1.08-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	4.49+01	4.49+01	4.49+01	4.49+01	4.49+01	4.49+01	4.45+01	4.07+01	1.67+01	2.26-03	0.00
AG109M	0.00	-1.57-05	-9.00-06	-5.89-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	7.87-02	4.50-02	2.95-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	2.94+06	1.08+06	1.33+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	-1.15+01	-4.21+00	-5.16-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113N	0.00	-1.14-01	-1.09-01	-6.97-02	-8.10-04	-3.64-23	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	3.38-01	2.14-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	-6.53-06	-4.14-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	6.25+04	1.74+02	1.71-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN117M	0.00	-4.00-09	-5.63-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	-7.92+00	-2.88+00	-3.17-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	-8.23-04	-8.15-04	-7.51-04	-3.31-04	-9.02-08	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	-2.88+02	-3.80+01	-4.63-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	-5.31-01	-6.10-02	-2.14-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	1.17+06	1.73+04	5.61-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	1.71+08	1.33+08	1.32+07	1.22-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	7.09+07	5.49+07	5.45+06	5.06-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	2.49+03	2.49+03	2.49+03	2.49+03	2.47+03	2.32+03	1.24+03	2.43+00	0.00	0.00	0.00
SB126M	0.00	-9.95-01	-9.95-01	-9.95-01	-9.95-01	-9.89-01	-9.29-01	-4.98-01	-9.74-04	0.00	0.00	0.00
SB126	0.00	-9.85-01	-9.85-01	-9.85-01	-9.85-01	-9.79-01	-9.19-01	-4.93-01	-9.64-04	0.00	0.00	0.00
TE127M	0.00	1.13+08	1.11+07	9.32-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

HTGR SUM OF ALL WASTE STREAMS PROPERTIES AFTER SEPARATION

POWER = 64.57 MW, BURNUP = 94271.MWD, FLUX= 8.05+13N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE127	0.00	2.80+07	2.75+06	2.30-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129M	0.00	9.71+06	5.68+03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	1.56+05	9.10+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I127	0.00	1.98+06	1.98+06	1.98+06	1.98+06	1.98+06	1.98+06	1.97+06	1.90+06	1.32+06	3.36+04	3.91-12
XE129M	0.00	-3.94-12	-7.17-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XE131M	0.00	-7.78-05	-3.76-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	6.27+10	4.47+10	2.13+09	1.31-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	6.78+03	6.78+03	6.78+03	6.78+03	6.77+03	6.76+03	6.62+03	5.38+03	6.73+02	6.29-07	0.00
CS136	0.00	1.11+01	3.88-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS137	0.00	1.49+10	1.46+10	1.18+10	1.48+09	1.39+00	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	-2.79+05	-2.73+05	-2.21+05	-2.77+04	-2.59-05	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	3.01+02	9.83-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	4.38+02	1.13-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	1.65+07	6.70+03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	6.56+02	6.23-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	1.05+11	4.31+10	1.42+07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	-1.05+06	-4.31+05	-1.42+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	2.67+00	3.34-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	7.31+08	5.61+08	5.19+07	2.38-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	-2.60+01	-6.27-02	-1.74-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	-2.09+00	-5.04-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	1.49+06	1.48+06	1.38+06	6.74+05	5.19+02	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	3.19+04	3.01+04	1.79+04	9.90+01	2.65-21	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	6.06+08	5.80+08	3.93+08	7.97+06	9.38-11	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	4.27+07	2.92+07	9.29+05	1.01-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	-3.43-02	-1.61-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	5.35+05	1.60+04	3.03-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	-1.82+01	-9.11+00	-1.78-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	-1.82+01	-9.11+00	-1.78-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HO166M	0.00	2.24-03	2.24-03	2.22-03	2.11-03	1.26-03	6.95-06	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	1.17+12	1.05+12	7.67+11	8.32+10	2.18+06	2.17+06	2.12+06	1.93+06	1.32+06	3.36+04	1.07+00
TOTAL	0.00	1.17+12	1.05+12	7.67+11	8.32+10	2.18+06	2.17+06	2.12+06	1.93+06	1.32+06	3.36+04	1.07+00

APPENDIX 2.F

AI-LMFBR PLANT WASTE

(Power 49 MW/MT, Burnup 37,112 MWD/MT,
Spent Fuel Processed 90 Days After
Discharge with 0.5% Fuel Loss to Waste)

AI-LMFBR PLANT WASTE

Summary Tables

THERMAL POWER

WATTS PER METRIC TON OF FUEL

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	6.89E+03	9.11E+02	1.64E+01	1.40E-02	6.86E-04	1.58E-05	5.49E-35	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00
STRONTIUM	1.26E+03	3.39E+02	2.66E+02	2.89E+01	1.50E-03	6.63E-09	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00
CESIUM	9.37E+02	8.44E+02	5.39E+02	6.63E+01	7.09E-03	6.14E-04	6.13E-04	6.00E-04	4.87E-04	6.10E-05	5.79E-14	.00E+00
SR+CS	2.19E+03	1.18E+03	8.04E+02	9.52E+01	8.59E-03	6.14E-04	6.13E-04	6.00E-04	4.87E-04	6.10E-05	5.79E-14	.00E+00
FP-SR-CS	3.43E+04	1.02E+04	5.88E+01	4.62E+00	1.97E-01	1.64E-02	1.25E-02	9.03E-03	5.95E-04	2.71E-05	4.31E-07	5.41E-23
KR85+I129	1.37E+01	1.28E+01	7.22E+00	2.27E-02	2.52E-05	2.52E-05	2.51E-05	2.51E-05	2.42E-05	1.67E-05	4.30E-07	5.41E-23
FISSION PROD.	3.65E+04	1.14E+04	8.63E+02	9.98E+01	2.06E-01	1.71E-02	1.32E-02	9.63E-03	1.08E-03	8.81E-05	4.31E-07	5.41E-23
U+TH WASTE	1.97E-03	1.97E-03	1.98E-03	1.97E-03	1.96E-03	1.96E-03	1.92E-03	1.58E-03	4.82E-04	3.83E-04	3.69E-04	3.20E-04
PU FUEL WASTE	1.15E+01	1.17E+01	1.24E+01	1.22E+01	9.24E+00	8.02E+00	3.17E+00	6.36E-02	2.25E-02	1.42E-02	1.15E-03	5.34E-05
TRANS PU	3.46E+03	8.69E+02	1.57E+02	1.04E+02	5.19E+01	2.44E+01	1.38E+00	3.43E-01	2.05E-01	1.10E-02	1.10E-04	4.51E-05
TOTAL WASTE	4.69E+04	1.32E+04	1.05E+03	2.16E+02	6.13E+01	3.24E+01	4.56E+00	4.18E-01	2.29E-01	2.57E-02	1.63E-03	4.19E-04

RADIOACTIVITY

CURIES PER METRIC TON OF FUEL
(PARENTS AND DAUGHTERS IN CHAINS ARE INCLUDED IN TOTALS)

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	5.91E+05	1.84E+05	9.30E+03	9.35E+01	1.02E+01	5.96E+00	5.42E+00	2.48E+00	1.01E-03	1.28E-37	.00E+00	.00E+00
STRONTIUM	3.49E+05	9.41E+04	7.38E+04	8.02E+03	4.17E-01	1.84E-06	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00
CESIUM	2.77E+05	2.64E+05	2.00E+05	2.50E+04	3.70E+00	1.26E+00	1.26E+00	1.23E+00	1.00E+00	1.26E-01	1.19E-10	.00E+00
SR+CS	6.26E+05	3.58E+05	2.74E+05	3.30E+04	4.12E+00	1.26E+00	1.26E+00	1.23E+00	1.00E+00	1.26E-01	1.19E-10	.00E+00
FP-SR-CS	8.03E+06	2.37E+06	4.07E+04	2.59E+03	1.26E+02	2.22E+01	1.96E+01	1.45E+01	1.88E+00	1.40E-01	6.67E-04	8.22E-20
KR85+I129	8.43E+03	7.90E+03	4.44E+03	1.40E+01	3.82E-02	3.82E-02	3.82E-02	3.81E-02	3.67E-02	2.55E-02	6.54E-04	8.22E-20
FISSION PROD.	8.66E+06	2.73E+06	3.15E+05	3.56E+04	1.30E+02	2.34E+01	2.08E+01	1.57E+01	2.88E+00	2.66E-01	6.67E-04	8.22E-20
U+TH WASTE	1.21E-01	1.22E-01	1.23E-01	1.21E-01	1.19E-01	1.19E-01	1.17E-01	9.63E-02	3.07E-02	2.49E-02	2.42E-02	2.10E-02
PU FUEL WASTE	2.86E+03	2.74E+03	1.90E+03	2.74E+02	1.30E+02	7.95E+01	2.37E+01	1.65E+00	2.07E-01	2.18E-02	8.18E-03	3.25E-03
TRANS PU	9.78E+04	2.75E+04	8.09E+03	6.04E+03	3.05E+03	1.40E+03	4.80E+01	1.80E+01	1.13E+01	6.06E-01	6.64E-03	2.74E-03
TOTAL WASTE	9.35E+06	2.94E+06	3.34E+05	4.20E+04	3.32E+03	1.51E+03	9.81E+01	3.80E+01	1.44E+01	9.19E-01	3.97E-02	2.70E-02

INGESTION TOXICITY

THE INGESTION TOXICITY INDEX IS THE BASE 10 LOGARITHM OF THE
CUBIC METERS OF WATER PER TON OF FUEL TO DILUTE TO RCG

TIME,YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	9.71	8.39	7.20	6.47	5.24	4.47	4.43	4.09	.70	*****	*****	*****
STRONTIUM	11.38	11.19	11.09	10.13	5.84	.49	*****	*****	*****	*****	*****	*****
CESIUM	9.96	9.91	9.71	8.80	4.87	4.10	4.10	4.09	4.00	3.10	-5.92	*****
SR+CS	11.40	11.21	11.11	10.15	5.89	4.10	4.10	4.09	4.00	3.10	-5.92	*****
FP-SR-CS	11.40	11.01	8.51	6.90	6.00	5.87	5.86	5.85	5.79	5.63	4.04	*****
KR85+I129	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.80	5.79	5.63	4.04	*****
FISSION PROD.	11.70	11.42	11.11	10.15	6.25	5.87	5.87	5.85	5.80	5.63	4.04	*****
U+TH FUEL WASTE	5.55	5.55	5.55	5.55	5.55	5.55	5.54	5.45	4.90	4.80	4.79	4.73
PU FUEL WASTE	7.63	7.63	7.65	7.59	7.32	7.16	6.79	6.16	5.10	3.56	3.28	2.89
TRANS PU	9.75	9.32	9.04	8.90	8.60	8.28	7.23	6.93	6.41	5.07	3.20	2.82
TOTAL WASTE	11.71	11.43	11.11	10.17	8.62	8.31	7.38	7.04	6.53	5.78	4.88	4.74

***** TOXICITY INDEX IS LESS THAN -10
RCG IS RADIONUCLIDE CONCENTRATION GUIDE BASED UPON 10 CFR 20

INHALATION TOXICITY

THE INHALATION TOXICITY INDEX IS THE BASE 10 LOGARITHM OF THE
CUBIC METERS OF AIR TO DILUTE TO RCG PER METRIC TON OF FUEL

TIME,YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	14.52	13.02	12.04	10.64	9.39	8.47	8.43	8.09	4.70	*****	*****	*****
STRONTIUM	15.38	15.19	15.09	14.13	9.84	4.49	*****	*****	*****	*****	*****	*****
CESIUM	14.50	14.46	14.30	13.40	9.46	8.62	8.62	8.61	8.52	7.62	-1.40	*****
SR+CS	15.44	15.26	15.16	14.20	9.99	8.62	8.62	8.61	8.52	7.62	-1.40	*****
FP-SR-CS	16.10	15.71	13.51	12.17	10.81	10.11	10.06	9.95	9.43	9.11	7.51	-8.39
KR85+I129	10.48	10.45	10.22	9.29	9.28	9.28	9.28	9.28	9.26	9.10	7.51	-8.39
FISSION PROD.	16.18	15.84	15.17	14.20	10.87	10.12	10.07	9.97	9.48	9.12	7.51	-8.39
U+TH FUEL WASTE	11.05	11.05	11.05	11.05	11.05	11.05	11.04	10.95	10.41	10.31	10.30	10.24
PU FUEL WASTE	15.49	15.48	15.44	15.25	14.97	14.89	14.59	13.31	11.63	10.56	10.36	9.97
TRANS PU	16.65	16.51	16.43	16.26	15.90	15.57	14.50	13.89	13.59	12.33	10.28	9.90
TOTAL WASTE	16.80	16.62	16.49	16.30	15.95	15.65	14.85	13.99	13.60	12.34	10.79	10.54

***** TOXICITY INDEX IS LESS THAN -10
RCG IS RADIONUCLIDE CONCENTRATION GUIDE BASED UPON 10 CFR 20

AI-LMFBR PLANT WASTE

Actinides

AI FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
HE 4	0.00	2.05+00	2.45+00	2.90+00	5.70+00	1.77+01	2.61+01	3.88+01	7.65+01	1.86+02	2.08+02	3.22+02
TL208	0.00	2.78-11	1.98-11	1.62-12	4.32-13	7.48-17	2.05-18	4.68-17	4.88-16	4.32-15	1.62-14	1.64-14
PB206	0.00	5.00-13	1.07-12	5.36-11	2.41-08	5.24-05	3.31-02	3.71+00	4.12+01	5.04+01	1.02+02	5.78+02
PB207	0.00	5.21-11	1.12-10	1.93-09	7.46-08	1.08-06	4.26-05	1.73-02	4.95-01	5.33+00	5.14+01	3.45+02
PB208	0.00	8.37-06	1.61-05	3.49-05	5.57-05	7.03-05	7.03-05	7.11-05	1.50-04	7.47-03	3.78-01	5.30+00
PB210	0.00	1.69-11	3.14-11	4.20-10	2.07-08	5.20-06	2.45-04	1.93-03	3.65-04	1.78-05	1.75-05	1.52-05
PB212	0.00	1.62-06	1.15-06	9.41-10	2.51-10	4.34-14	1.19-15	2.72-14	2.84-13	2.51-12	9.40-12	9.52-12
BI209	0.00	4.43-09	4.51-09	5.14-09	1.73-08	1.05-05	1.69-02	5.79+00	2.38+02	1.04+03	1.09+03	1.09+03
BI212	0.00	1.54-09	1.10-09	8.96-11	2.39-11	4.14-15	1.13-16	2.59-15	2.70-14	2.39-13	8.96-13	9.07-13
RN220	0.00	2.46-11	1.75-11	1.43-12	3.82-13	6.62-17	1.81-18	4.14-17	4.32-16	3.82-15	1.43-14	1.45-14
RA223	0.00	2.05-12	3.74-12	1.55-11	4.88-11	5.90-11	4.97-10	1.79-06	2.62-08	2.59-08	2.38-08	9.87-09
RA224	0.00	1.41-07	1.00-07	8.19-09	2.19-09	3.78-13	1.04-14	2.37-13	2.47-12	2.19-11	8.19-11	8.29-11
RA225	0.00	9.17-12	4.36-12	4.47-12	1.59-11	2.22-09	3.09-07	7.58-06	1.70-05	8.69-07	2.08-19	0.00
RA226	0.00	2.96-08	4.66-08	2.01-07	2.67-06	4.27-04	2.01-02	1.58-01	3.00-02	1.46-03	1.44-03	1.25-03
AC225	0.00	1.21-11	2.94-12	3.02-12	1.08-11	1.58-09	2.08-07	5.12-06	1.15-05	5.87-07	1.40-19	0.00
AC227	0.00	1.56-09	2.63-09	1.09-08	3.44-08	4.16-06	3.50-07	1.26-05	1.84-05	1.83-05	1.67-05	6.95-06
TH227	0.00	3.36-12	6.00-12	2.48-11	7.82-11	9.45-11	7.97-10	2.87-08	4.19-08	4.16-08	3.81-08	1.58-08
TH228	0.00	2.77-05	1.94-05	1.59-06	4.26-07	7.38-11	2.02-12	4.62-11	4.82-10	4.27-09	1.60-08	1.62-08
TH229	0.00	7.99-07	7.99-07	8.20-07	2.92-06	4.06-04	5.66-02	1.39+00	3.12+00	1.59-01	3.81-14	0.00
TH230	0.00	1.98-03	1.98-03	2.05-03	5.24-03	1.24-01	1.31+00	8.03+00	1.52+00	7.41-02	7.30-02	6.36-02
TH231	0.00	5.17-09	2.59-11	2.62-11	2.94-11	6.25-11	4.31-10	2.38-09	2.54-09	2.51-09	2.30-09	9.57-10
TH232	0.00	1.10-04	1.11-04	1.12-04	1.32-04	4.81-04	1.52-02	3.47-01	3.62+00	3.20+01	1.20+02	1.21+02
TH234	0.00	1.24-05	6.23-08	6.19-08	6.19-08	6.19-08	6.19-08	6.20-08	6.22-08	6.21-08	6.13-08	5.34-08
PA231	0.00	5.44-05	5.44-05	5.45-05	5.49-05	6.36-05	5.36-04	1.93-02	2.82-02	2.80-02	2.56-02	1.06-02
PA233	0.00	9.07-06	9.16-06	9.62-06	1.40-05	3.57-05	4.23-05	4.11-05	3.07-05	1.67-06	3.67-19	0.00
PA234M	0.00	4.18-10	2.10-12	2.09-12	2.09-12	2.09-12	2.09-12	2.09-12	2.10-12	2.10-12	2.07-12	1.80-12
U232	0.00	1.55-05	2.07-05	3.55-05	1.59-05	2.75-09	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	8.44-05	1.78-04	9.58-04	1.08-02	2.38-01	3.69+00	3.13+01	7.04+01	3.60+00	8.57-13	0.00
U234	2.80+02	1.32+00	1.46+00	3.66+00	2.08+01	5.05+01	4.96+01	3.86+01	3.30+00	2.33-01	2.29-01	2.00-01
U235	1.84+03	6.40+00	6.41+00	6.49+00	7.28+00	1.54+01	1.07+02	5.87+02	6.27+02	6.22+02	5.70+02	2.37+02
U236	1.43+03	6.95+00	6.96+00	7.07+00	8.16+00	1.89+01	8.56+01	1.29+02	1.26+02	9.70+01	7.14+00	3.31-11
U237	0.00	2.47-06	7.85-07	5.15-07	7.62-09	1.07-11	5.47-12	6.79-15	0.00	0.00	0.00	0.00
U238	9.08+05	4.31+03	4.31+03	4.31+03	4.31+03	4.31+03	4.31+03	4.31+03	4.32+03	4.32+03	4.26+03	3.71+03
NP237	0.00	2.64+02	2.66+02	2.79+02	4.07+02	1.04+03	1.23+03	1.19+03	8.92+02	4.84+01	1.06-11	0.00
NP239	0.00	2.24-04	2.24-04	2.24-04	2.22-04	2.05-04	9.06-05	2.61-08	1.32-14	9.07-15	2.17-16	0.00
PU236	9.18-03	2.56-05	2.01-05	2.25-06	7.04-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	1.62+03	5.93+00	2.69+01	3.11+01	1.95+01	1.28-01	4.71-32	0.00	0.00	0.00	0.00	0.00
PU239	5.24+04	3.15+02	3.15+02	3.16+02	3.18+02	3.31+02	3.74+02	4.12+01	5.03-08	3.44-08	8.21-10	0.00
PU240	2.12+04	1.09+02	1.10+02	1.14+02	1.23+02	1.13+02	4.48+01	4.40-03	0.00	0.00	0.00	0.00
PU241	9.34+03	2.66+01	2.55+01	1.68+01	2.48-01	3.48-04	1.78-04	2.21-07	1.91-36	0.00	0.00	0.00

AI FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
PU242	3.40+03	1.74+01	1.74+01	1.75+01	1.88+01	2.13+01	2.10+01	1.78+01	3.43+00	2.45-07	0.00	0.00
AM241	4.89+02	9.57+02	9.57+02	9.52+02	8.39+02	1.99+02	5.32-03	6.47-06	0.00	0.00	0.00	0.00
AM242M	0.00	2.22+01	2.21+01	2.13+01	1.41+01	2.33-01	3.52-19	0.00	0.00	0.00	0.00	0.00
AM242	0.00	2.67-04	2.66-04	2.55-04	1.69-04	2.80-06	4.23-24	0.00	0.00	0.00	0.00	0.00
AM243	0.00	2.71+02	2.71+02	2.71+02	2.69+02	2.48+02	1.10+02	3.15-02	1.59-08	1.10-08	2.62-10	0.00
CM242	0.00	2.72+01	5.80+00	5.12-02	3.39-02	5.61-04	0.00	0.00	0.00	0.00	0.00	0.00
CM243	0.00	2.03+00	1.99+00	1.64+00	2.33-01	7.99-10	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	1.57+01	1.51+01	1.07+01	3.41-01	3.70-16	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	2.40-01	2.40-01	2.39-01	2.38-01	2.22-01	1.14-01	1.41-04	1.22-33	0.00	0.00	0.00
CM246	0.00	4.10-03	4.10-03	4.10-03	4.05-03	3.62-03	1.16-03	1.32-08	0.00	0.00	0.00	0.00
CM247	0.00	3.68-05	3.68-05	3.68-05	3.68-05	3.68-05	3.68-05	3.67-05	3.53-05	2.43-05	5.81-07	3.50-23
SUBTOT	1.00+06	6.36+03	6.36+03	6.36+03	6.36+03	6.36+03	6.36+03	6.41+03	6.41+03	6.41+03	6.41+03	6.41+03
TOTAL	1.00+06	6.36+03	6.36+03	6.36+03	6.36+03	6.36+03	6.36+03	6.41+03	6.41+03	6.41+03	6.41+03	6.41+03

AI FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	1.05-07	1.92-07	7.92-07	2.50-06	3.02-06	2.55-05	9.17-04	1.34-03	1.33-03	1.22-03	5.06-04
TL208	0.00	6.12-03	5.78-03	4.72-04	1.26-04	2.18-08	5.97-10	1.37-08	1.42-07	1.26-06	4.72-06	4.78-06
TL209	0.00	1.55-08	3.76-09	3.66-09	1.36-08	1.92-06	2.66-04	6.54-03	1.47-02	7.50-04	1.79-16	0.00
PB209	0.00	7.03-07	1.71-07	1.75-07	6.25-07	8.72-05	1.21-02	2.97-01	6.67-01	3.41-02	8.15-15	0.00
PB210	0.00	1.37-09	2.55-09	3.41-08	1.68-06	4.22-04	1.98-02	1.56-01	2.96-02	1.44-03	1.42-03	1.24-03
PB211	0.00	1.05-07	1.92-07	7.95-07	2.51-06	3.03-06	2.56-05	9.19-04	1.34-03	1.33-03	1.22-03	5.07-04
PB212	0.00	2.26-02	1.61-02	1.31-03	3.50-04	6.06-08	1.66-09	3.80-08	3.96-07	3.50-06	1.31-05	1.33-05
PB214	0.00	2.92-08	4.61-08	1.98-07	2.64-06	4.22-04	1.98-02	1.56-01	2.96-02	1.44-03	1.42-03	1.24-03
BI210	0.00	1.35-09	2.55-09	3.41-08	1.68-06	4.22-04	1.98-02	1.56-01	2.96-02	1.44-03	1.42-03	1.24-03
BI211	0.00	1.05-07	1.92-07	7.95-07	2.51-06	3.03-06	2.56-05	9.19-04	1.34-03	1.33-03	1.22-03	5.07-04
BI212	0.00	2.26-02	1.61-02	1.31-03	3.50-04	6.06-08	1.66-09	3.80-08	3.96-07	3.50-06	1.31-05	1.33-05
BI213	0.00	7.03-07	1.71-07	1.75-07	6.25-07	8.72-05	1.21-02	2.97-01	6.67-01	3.41-02	8.15-15	0.00
BI214	0.00	2.92-08	4.61-08	1.98-07	2.64-06	4.22-04	1.98-02	1.56-01	2.96-02	1.44-03	1.42-03	1.24-03
PO210	0.00	9.83-10	1.89-09	3.41-08	1.68-06	4.22-04	1.98-02	1.56-01	2.96-02	1.44-03	1.42-03	1.24-03
PO211	0.00	3.15-10	5.77-10	2.38-09	7.53-09	9.10-09	7.67-08	2.76-06	4.03-06	4.00-06	3.66-06	1.52-06
PO212	0.00	1.44-02	1.03-02	8.40-04	2.24-04	3.88-08	1.06-09	2.43-06	2.53-07	2.24-06	8.39-06	8.50-06
PO213	0.00	6.87-07	1.67-07	1.72-07	6.11-07	8.53-05	1.18-02	2.91-01	6.53-01	3.33-02	7.97-15	0.00
PO214	0.00	2.92-08	4.61-08	1.98-07	2.64-06	4.22-04	1.98-02	1.56-01	2.96-02	1.44-03	1.42-03	1.24-03
PO215	0.00	1.05-07	1.92-07	7.95-07	2.51-06	3.03-06	2.56-05	9.19-04	1.34-03	1.33-03	1.22-03	5.07-04
PO216	0.00	2.26-02	1.61-02	1.31-03	3.50-04	6.06-08	1.66-09	3.80-08	3.96-07	3.50-06	1.31-05	1.33-05
PO218	0.00	2.92-08	4.61-08	1.98-07	2.64-06	4.22-04	1.98-02	1.56-01	2.96-02	1.44-03	1.42-03	1.24-03
AT217	0.00	7.03-07	1.71-07	1.75-07	6.25-07	8.72-05	1.21-02	2.97-01	6.67-01	3.41-02	8.15-15	0.00
RN219	0.00	1.05-07	1.92-07	7.95-07	2.51-06	3.03-06	2.56-05	9.19-04	1.34-03	1.33-03	1.22-03	5.07-04
RN220	0.00	2.26-02	1.61-02	1.31-03	3.50-04	6.06-08	1.66-09	3.80-08	3.96-07	3.50-06	1.31-05	1.33-05
RN222	0.00	2.92-08	4.61-08	1.98-07	2.64-06	4.22-04	1.98-02	1.56-01	2.96-02	1.44-03	1.42-03	1.24-03
FR221	0.00	7.03-07	1.71-07	1.75-07	6.25-07	8.72-05	1.21-02	2.97-01	6.67-01	3.41-02	8.15-15	0.00
FR223	0.00	1.59-09	2.69-09	1.11-08	3.51-08	4.24-08	3.58-07	1.29-05	1.88-05	1.87-05	1.71-05	7.10-06
RA223	0.00	1.05-07	1.92-07	7.95-07	2.51-06	3.03-06	2.56-05	9.19-04	1.34-03	1.33-03	1.22-03	5.07-04
RA224	0.00	2.26-02	1.61-02	1.31-03	3.50-04	6.06-08	1.66-09	3.80-08	3.96-07	3.50-06	1.31-05	1.33-05
RA225	0.00	3.60-07	1.71-07	1.75-07	6.25-07	8.72-05	1.21-02	2.97-01	6.67-01	3.41-02	8.15-15	0.00
RA226	0.00	2.95-08	4.61-08	1.98-07	2.64-06	4.22-04	1.98-02	1.56-01	2.96-02	1.44-03	1.42-03	1.24-03
AC225	0.00	7.02-07	1.71-07	1.75-07	6.25-07	8.72-05	1.21-02	2.97-01	6.67-01	3.41-02	8.15-15	0.00
AC227	0.00	1.14-07	1.92-07	7.94-07	2.51-06	3.03-06	2.56-05	9.19-04	1.34-03	1.33-03	1.22-03	5.07-04
TH227	0.00	1.07-07	1.90-07	7.83-07	2.47-06	2.99-06	2.52-05	9.07-04	1.33-03	1.31-03	1.20-03	5.00-04
TH228	0.00	2.28-02	1.60-02	1.31-03	3.50-04	6.06-08	1.66-09	3.80-08	3.96-07	3.50-06	1.31-05	1.33-05
TH229	0.00	1.71-07	1.71-07	1.75-07	6.25-07	8.72-05	1.21-02	2.97-01	6.67-01	3.41-02	8.15-15	0.00
TH230	0.00	3.85-05	3.85-05	3.98-05	1.02-04	2.41-03	2.55-02	1.56-01	2.96-02	1.44-03	1.42-03	1.24-03
TH231	0.00	2.74-03	1.37-05	1.39-05	1.56-05	3.31-05	2.28-04	1.26-03	1.34-03	1.33-03	1.22-03	5.07-04
TH232	0.00	1.21-11	1.21-11	1.23-11	1.44-11	5.26-11	1.66-09	3.80-08	3.96-07	3.50-06	1.31-05	1.33-05
TH234	0.00	2.87-01	1.44-03	1.43-03	1.43-03	1.43-03	1.43-03	1.44-03	1.44-03	1.44-03	1.42-03	1.24-03

AI FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
PA231	0.00	2.59-06	2.59-06	2.59-06	2.62-06	3.03-06	2.56-05	9.19-04	1.34-03	1.33-03	1.22-03	5.07-04
PA233	0.00	1.86-01	1.87-01	1.97-01	2.87-01	7.31-01	8.66-01	8.41-01	6.29-01	3.41-02	7.50-15	0.00
PA234M	0.00	2.87-01	1.44-03	1.43-03	1.43-03	1.43-03	1.43-03	1.44-03	1.44-03	1.44-03	1.42-03	1.24-03
PA234	0.00	2.87-04	1.44-06	1.43-06	1.43-06	1.43-06	1.43-06	1.44-06	1.44-06	1.44-06	1.42-06	1.24-06
U232	0.00	3.32-04	4.44-04	7.61-04	3.41-04	5.69-08	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	8.00-07	1.68-06	9.08-06	1.02-04	2.26-03	3.49-02	2.96-01	6.67-01	3.41-02	8.12-15	0.00
U234	1.74+00	8.16-03	9.06-03	2.26-02	1.28-01	3.13-01	3.07-01	2.39-01	2.04-02	1.44-03	1.42-03	1.24-03
U235	3.93-03	1.37-05	1.37-05	1.39-05	1.56-05	3.31-05	2.28-04	1.26-03	1.34-03	1.33-03	1.22-03	5.07-04
U236	9.04-02	4.41-04	4.42-04	4.48-04	5.18-04	1.20-03	5.43-03	8.20-03	7.98-03	6.15-03	4.52-04	2.10-15
U237	0.00	2.02-01	6.41-02	4.21-02	6.23-04	8.72-07	4.47-07	5.54-10	0.00	0.00	0.00	0.00
U238	3.03-01	1.43-03	1.43-03	1.43-03	1.43-03	1.43-03	1.43-03	1.44-03	1.44-03	1.44-03	1.42-03	1.24-03
NP237	0.00	1.86-01	1.87-01	1.97-01	2.87-01	7.31-01	8.66-01	8.41-01	6.29-01	3.41-02	7.50-15	0.00
NP239	0.00	5.21+01	5.21+01	5.21+01	5.17+01	4.76+01	2.11+01	6.07-03	3.06-09	2.11-09	5.04-11	0.00
PU236	4.88+00	1.36-02	1.07-02	1.20-03	3.74-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	2.73+04	1.00+02	4.54+02	5.25+02	3.29+02	2.16+00	0.00	0.00	0.00	0.00	0.00	0.00
PU239	3.21+03	1.93+01	1.93+01	1.94+01	1.95+01	2.03+01	2.29+01	2.52+00	3.08-09	2.11-09	5.04-11	0.00
PU240	4.67+03	2.41+01	2.42+01	2.51+01	2.71+01	2.48+01	9.87+00	9.71-04	0.00	0.00	0.00	0.00
PU241	9.37+05	2.68+03	2.56+03	1.68+03	2.49+01	3.49-02	1.79-02	2.22-05	0.00	0.00	0.00	0.00
PU242	1.33+01	6.77-02	6.78-02	6.84-02	7.34-02	8.30-02	8.18-02	6.94-02	1.34-02	9.55-10	0.00	0.00
PU243	0.00	1.60-11	3.19-09	3.19-09	3.19-09	3.19-09	3.19-09	3.18-09	3.06-09	2.11-09	5.04-11	0.00
AM241	1.68+03	3.28+03	3.28+03	3.26+03	2.88+03	6.81+02	1.82-02	2.22-05	0.00	0.00	0.00	0.00
AM242M	0.00	2.16+02	2.15+02	2.07+02	1.37+02	2.26+00	3.43-18	0.00	0.00	0.00	0.00	0.00
AM242	0.00	2.16+02	2.15+02	2.07+02	1.37+02	2.26+00	3.43-18	0.00	0.00	0.00	0.00	0.00
AM243	0.00	5.21+01	5.21+01	5.21+01	5.17+01	4.76+01	2.11+01	6.07-03	3.06-09	2.11-09	5.04-11	0.00
CM242	0.00	9.01+04	1.92+04	1.69+02	1.12+02	1.86+00	0.00	0.00	0.00	0.00	0.00	0.00
CM243	0.00	9.34+01	9.14+01	7.52+01	1.07+01	3.67-08	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	1.27+03	1.22+03	8.67+02	2.76+01	3.00-14	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	3.75-02	3.75-02	3.75-02	3.72-02	3.48-02	1.78-02	2.21-05	0.00	0.00	0.00	0.00
CM246	0.00	1.09-03	1.09-03	1.09-03	1.08-03	9.60-04	3.07-04	3.51-09	0.00	0.00	0.00	0.00
CM247	0.00	3.19-09	3.19-09	3.19-09	3.19-09	3.19-09	3.19-09	3.18-09	3.06-09	2.11-09	5.04-11	0.00
SUBTOT	9.74+05	9.81+04	2.74+04	7.14+03	3.81+03	8.32+02	7.75+01	8.79+00	7.62+00	4.16-01	3.39-02	2.30-02
TOTAL	9.74+05	9.81+04	2.74+04	7.14+03	3.81+03	8.32+02	7.75+01	8.79+00	7.62+00	4.16-01	3.39-02	2.30-02

AT FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	3.17-10	5.80-10	2.39-09	7.56-09	9.14-09	7.70-08	2.77-06	4.05-06	4.02-06	3.68-06	1.53-06
TL208	0.00	1.89-04	1.35-04	1.10-05	2.93-06	5.06-10	1.39-11	3.18-10	3.32-09	2.94-08	1.10-07	1.11-07
TL209	0.00	2.53-10	6.15-11	6.31-11	2.25-10	3.14-08	4.35-06	1.07-04	2.40-04	1.23-05	2.93-18	0.00
PB209	0.00	8.08-10	1.97-10	2.02-10	7.19-10	1.00-07	1.39-05	3.42-04	7.68-04	3.92-05	9.37-18	0.00
PB211	0.00	3.51-10	6.43-10	2.66-09	8.39-09	1.01-08	8.54-08	3.07-06	4.50-06	4.46-06	4.08-06	1.70-06
PB212	0.00	3.24-05	2.30-05	1.88-06	5.02-07	8.69-11	2.36-12	5.44-11	5.68-10	5.03-09	1.88-08	1.91-08
PB214	0.00	7.12-11	1.12-10	4.62-10	6.44-09	1.03-06	4.83-05	3.81-04	7.22-05	3.51-06	3.46-06	3.01-06
BI210	0.00	3.56-12	6.71-12	8.97-11	4.42-09	1.11-06	5.22-05	4.12-04	7.80-05	3.79-06	3.74-06	3.25-06
BI211	0.00	4.09-09	7.49-09	3.09-08	9.77-08	1.16-07	9.95-07	3.56-05	5.24-05	5.19-05	4.75-05	1.98-05
BI212	0.00	3.92-04	2.79-04	2.28-05	6.08-06	1.05-09	2.68-11	6.59-10	6.87-09	6.08-08	2.28-07	2.31-07
BI213	0.00	4.32-09	1.05-09	1.08-09	3.64-09	5.36-07	7.44-05	1.83-03	4.10-03	2.10-04	5.01-17	0.00
BI214	0.00	4.07-10	6.42-10	2.76-09	3.68-08	5.88-06	2.76-04	2.16-03	4.13-04	2.00-05	1.98-05	1.72-05
PO210	0.00	3.09-11	5.95-11	1.07-09	5.29-08	1.33-05	6.24-04	4.92-03	9.33-04	4.53-05	4.47-05	3.69-05
PO211	0.00	1.39-11	2.55-11	1.09-10	3.32-10	4.02-10	3.39-09	1.22-07	1.78-07	1.77-07	1.62-07	6.72-08
PO212	0.00	7.65-04	5.44-04	4.45-05	1.19-05	2.06-09	5.63-11	1.29-09	1.34-08	1.19-07	4.45-07	4.51-07
PO213	0.00	3.41-08	8.30-09	8.52-09	3.04-08	4.23-06	5.88-04	1.44-02	3.24-02	1.66-03	3.96-16	0.00
PO214	0.00	1.33-09	2.10-09	9.02-09	1.20-07	1.92-05	9.04-04	7.13-03	1.35-03	6.56-05	6.47-05	5.63-05
PO215	0.00	4.60-09	8.42-09	3.48-08	1.10-07	1.33-07	1.12-06	4.03-05	5.89-05	5.84-05	5.35-05	2.22-05
PO216	0.00	9.23-04	6.57-04	5.37-05	1.43-05	2.46-09	6.79-11	1.55-09	1.62-08	1.43-07	5.37-07	5.43-07
PO218	0.00	1.06-09	1.67-09	7.17-09	9.57-08	1.53-05	7.18-04	5.67-03	1.07-03	5.21-05	5.14-05	4.48-05
AT217	0.00	2.94-08	7.17-09	7.35-09	2.62-08	3.65-06	5.07-04	1.25-02	2.80-02	1.43-03	3.41-16	0.00
RN219	0.00	4.25-09	7.78-09	3.22-08	1.02-07	1.23-07	1.03-06	3.72-05	5.44-05	5.39-05	4.94-05	2.05-05
RN220	0.00	8.55-04	6.09-04	4.98-05	1.33-05	2.30-09	6.29-11	1.44-09	1.50-08	1.33-07	4.97-07	5.04-07
RN222	0.00	9.52-10	1.50-09	6.45-09	8.61-08	1.38-05	6.46-04	5.10-03	9.66-04	4.69-05	4.63-05	4.03-05
FR221	0.00	2.61-08	6.36-09	6.53-09	2.33-08	3.24-06	4.50-04	1.11-02	2.48-02	1.27-03	3.03-16	0.00
FR223	0.00	3.73-12	6.30-12	2.60-11	8.23-11	9.94-11	8.38-10	3.01-08	4.41-08	4.37-08	4.00-08	1.66-08
RA223	0.00	3.65-09	6.68-09	2.76-08	8.72-08	1.05-07	8.88-07	3.19-05	4.67-05	4.63-05	4.24-05	1.76-05
RA224	0.00	7.72-04	5.49-04	4.49-05	1.20-05	2.07-09	5.68-11	1.30-09	1.35-08	1.20-07	4.49-07	4.54-07
RA225	0.00	2.37-10	1.13-10	1.15-10	4.11-10	5.74-08	7.96-06	1.96-04	4.39-04	2.24-05	5.36-18	0.00
RA226	0.00	8.34-10	1.31-09	5.60-09	7.48-08	1.19-05	5.61-04	4.43-03	8.39-04	4.07-05	4.02-05	3.50-05
AC225	0.00	2.41-08	5.87-09	6.02-09	2.14-08	2.99-06	4.15-04	1.02-02	2.29-02	1.17-03	2.80-16	0.00
AC227	0.00	5.74-11	9.68-11	4.00-10	1.26-09	1.53-09	1.29-08	4.63-07	6.78-07	6.72-07	6.15-07	2.56-07
TH227	0.00	3.68-09	6.53-09	2.70-08	8.52-08	1.03-07	8.67-07	3.12-05	4.56-05	4.52-05	4.14-05	1.72-05
TH228	0.00	7.46-04	5.23-04	4.29-05	1.15-05	1.98-09	5.43-11	1.24-09	1.30-08	1.15-07	4.30-07	4.35-07
TH229	0.00	5.17-09	5.17-09	5.30-09	1.89-08	2.64-06	3.66-04	8.99-03	2.02-02	1.03-03	2.46-16	0.00
TH230	0.00	1.09-06	1.09-06	1.12-06	2.88-06	6.82-05	7.21-04	4.41-03	8.37-04	4.07-05	4.01-05	3.49-05
TH231	0.00	2.16-06	1.06-08	1.10-08	1.23-08	2.61-08	1.80-07	9.93-07	1.06-06	1.05-06	9.63-07	4.00-07
TH234	0.00	1.02-04	5.13-07	5.10-07	5.10-07	5.10-07	5.10-07	5.11-07	5.12-07	5.12-07	5.05-07	4.40-07
PA231	0.00	7.91-08	7.91-08	7.92-08	7.99-08	9.25-08	7.80-07	2.81-05	4.10-05	4.07-05	3.73-05	1.55-05
PA233	0.00	2.51-04	2.53-04	2.66-04	3.87-04	9.88-04	1.17-03	1.14-03	8.50-04	4.61-05	1.01-17	0.00

AI FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
PA234M	0.00	1.48-03	7.42-06	7.38-06	7.38-06	7.38-06	7.38-06	7.39-06	7.41-06	7.41-06	7.31-06	6.36-06
PA234	0.00	2.61-06	1.31-08	1.30-08	1.30-08	1.30-08	1.30-08	1.30-08	1.31-08	1.31-08	1.29-08	1.12-08
U232	0.00	1.06-05	1.43-05	2.44-05	1.09-05	1.89-09	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	2.33-08	4.91-08	2.64-07	2.98-06	6.57-05	1.02-03	8.63-03	1.94-02	9.93-04	2.36-16	0.00
U234	4.99-02	2.35-04	2.61-04	6.52-04	3.70-03	9.00-03	8.83-03	6.87-03	5.88-04	4.14-05	4.09-05	3.56-05
U235	1.09-04	3.81-07	3.81-07	3.86-07	4.33-07	9.19-07	6.34-06	3.49-05	3.73-05	3.70-05	3.39-05	1.91-05
U236	2.45-03	1.20-05	1.20-05	1.21-05	1.40-05	3.24-05	1.47-04	2.22-04	2.16-04	1.67-04	1.23-05	5.69-17
U237	0.00	1.34-04	4.25-05	2.79-05	4.13-07	5.79-10	2.97-10	3.68-13	0.00	0.00	0.00	0.00
U238	7.65-03	3.63-05	3.63-05	3.63-05	3.63-05	3.63-05	3.63-05	3.63-05	3.64-05	3.64-05	3.59-05	3.13-05
NP237	0.00	5.47-03	5.50-03	5.78-03	8.42-03	2.15-02	2.54-02	2.47-02	1.85-02	1.00-03	2.20-16	0.00
NP239	0.00	7.05-02	7.05-02	7.04-02	6.98-02	6.44-02	2.85-02	8.20-06	4.14-12	2.85-12	6.81-14	0.00
PU236	1.70-01	4.73-04	3.71-04	4.16-05	1.30-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	9.05+02	3.32+00	1.51+01	1.74+01	1.09+01	7.14-02	0.00	0.00	0.00	0.00	0.00	0.00
PU239	9.99+01	6.00-01	6.01-01	6.01-01	6.07-01	6.31-01	7.13-01	7.84-02	9.59-11	6.55-11	1.57-12	0.00
PU240	1.46+02	7.50-01	7.54-01	7.83-01	8.46-01	7.73-01	3.07-01	3.02-05	0.00	0.00	0.00	0.00
PU241	3.89+01	1.11-01	1.06-01	6.97-02	1.03-03	1.45-06	7.41-07	9.20-10	0.00	0.00	0.00	0.00
PU242	3.92-01	2.00-03	2.00-03	2.02-03	2.17-03	2.45-03	2.42-03	2.05-03	3.95-04	2.82-11	0.00	0.00
PU243	0.00	2.26-14	4.52-12	4.52-12	4.52-12	4.52-12	4.52-12	4.51-12	4.34-12	2.99-12	7.14-14	0.00
AM241	5.59+01	1.10+02	1.09+02	1.09+02	9.60+01	2.27+01	6.09-04	7.40-07	0.00	0.00	0.00	0.00
AM242M	0.00	6.15-02	6.13-02	5.88-02	3.90-02	6.44-04	9.75-22	0.00	0.00	0.00	0.00	0.00
AM242	0.00	2.88-01	2.87-01	2.76-01	1.83-01	3.02-03	4.57-21	0.00	0.00	0.00	0.00	0.00
AM243	0.00	1.90+00	1.90+00	1.90+00	1.89+00	1.74+00	7.69-01	2.21-04	1.12-10	7.70-11	1.84-12	0.00
CM242	0.00	3.32+03	7.08+02	6.25+00	4.14+00	6.84-02	0.00	0.00	0.00	0.00	0.00	0.00
CM243	0.00	3.43+00	3.36+00	2.76+00	3.94-01	1.35-09	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	4.45+01	4.28+01	3.03+01	9.67-01	1.05-15	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	1.17-03	1.17-03	1.17-03	1.16-03	1.09-03	5.57-04	6.91-07	0.00	0.00	0.00	0.00
CM246	0.00	3.57-05	3.57-05	3.56-05	3.52-05	3.14-05	1.01-05	1.15-10	0.00	0.00	0.00	0.00
CM247	0.00	9.21-11	9.21-11	9.21-11	9.21-11	9.21-11	9.20-11	9.17-11	8.83-11	6.08-11	1.45-12	0.00
SUBTOT	1.25+03	3.48+03	8.82+02	1.69+02	1.16+02	2.61+01	1.87+00	2.17-01	1.81-01	9.79-03	7.29-04	4.81-04
TOTAL	1.25+03	3.48+03	8.82+02	1.69+02	1.16+02	2.61+01	1.87+00	2.17-01	1.81-01	9.79-03	7.29-04	4.81-04

AI FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT KCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	-1.05-07	-1.92-07	-7.92-07	-2.50-06	-3.02-06	-2.55-05	-9.17-04	-1.34-03	-1.33-03	-1.22-03	-5.06-04
TL208	0.00	-8.12-03	-5.78-03	-4.72-04	-1.26-04	-2.16-08	-5.97-10	-1.37-08	-1.42-07	-1.26-06	-4.72-06	-4.78-06
TL209	0.00	-1.55-08	-3.76-09	-3.86-09	-1.38-08	-1.92-06	-2.66-04	-6.54-03	-1.47-02	-7.50-04	-1.79-16	0.00
PB209	0.00	-7.03-07	-1.71-07	-1.75-07	-6.25-07	-8.72-05	-1.21-02	-2.97-01	-6.67-01	-3.41-02	-8.15-15	0.00
PB210	0.00	3.42+02	6.37+02	8.52+03	4.20+05	1.06+08	4.96+09	3.91+10	7.41+09	3.60+08	3.55+08	3.09+08
PB211	0.00	-1.05-07	-1.92-07	-7.95-07	-2.51-06	-3.03-06	-2.56-05	-9.19-04	-1.34-03	-1.33-03	-1.22-03	-5.07-04
PB212	0.00	3.76+07	2.68+07	2.19+06	5.83+05	1.01+02	2.76+00	6.33+01	6.60+02	5.84+03	2.19+04	2.21+04
PB214	0.00	-2.92-08	-4.61-08	-1.98-07	-2.64-06	-4.22-04	-1.98-02	-1.56-01	-2.96-02	-1.44-03	-1.42-03	-1.24-03
BI210	0.00	6.76+00	1.27+01	1.70+02	8.40+03	2.11+06	9.92+07	7.82+08	1.48+08	7.20+06	7.10+06	6.18+06
BI211	0.00	-1.05-07	-1.92-07	-7.95-07	-2.51-06	-3.03-06	-2.56-05	-9.19-04	-1.34-03	-1.33-03	-1.22-03	-5.07-04
BI212	0.00	7.52+06	5.35+06	4.37+05	1.17+05	2.02+01	5.53-01	1.27+01	1.32+02	1.17+03	4.37+03	4.43+03
BI213	0.00	-7.03-07	-1.71-07	-1.75-07	-6.25-07	-8.72-05	-1.21-02	-2.97-01	-6.67-01	-3.41-02	-8.15-15	0.00
BI214	0.00	-2.92-08	-4.61-08	-1.98-07	-2.64-06	-4.22-04	-1.98-02	-1.56-01	-2.96-02	-1.44-03	-1.42-03	-1.24-03
PO210	0.00	1.40+02	2.70+02	4.67+03	2.40+05	6.03+07	2.83+09	2.23+10	4.23+09	2.06+08	2.03+08	1.77+08
PO211	0.00	-3.15-10	-5.77-10	-2.38-09	-7.53-09	-9.10-09	-7.67-08	-2.76-06	-4.03-06	-4.00-06	-3.66-06	-1.52-06
PO212	0.00	-1.44-02	-1.03-02	-8.40-04	-2.24-04	-3.88-08	-1.06-09	-2.43-08	-2.53-07	-2.24-06	-8.39-06	-8.50-06
PO213	0.00	-8.07-07	-1.67-07	-1.72-07	-6.11-07	-8.53-05	-1.18-02	-2.91-01	-6.53-01	-3.33-02	-7.97-15	0.00
PO214	0.00	-2.92-08	-4.61-08	-1.98-07	-2.64-06	-4.22-04	-1.98-02	-1.56-01	-2.96-02	-1.44-03	-1.42-03	-1.24-03
PO215	0.00	-1.05-07	-1.92-07	-7.95-07	-2.51-06	-3.03-06	-2.56-05	-9.19-04	-1.34-03	-1.33-03	-1.22-03	-5.07-04
PO216	0.00	-2.26-02	-1.61-02	-1.31-03	-3.50-04	-6.06-08	-1.66-09	-3.80-08	-3.96-07	-3.50-06	-1.31-05	-1.33-05
PO218	0.00	-2.92-08	-4.61-08	-1.98-07	-2.64-06	-4.22-04	-1.98-02	-1.56-01	-2.96-02	-1.44-03	-1.42-03	-1.24-03
AT217	0.00	-7.03-07	-1.71-07	-1.75-07	-6.25-07	-8.72-05	-1.21-02	-2.97-01	-6.67-01	-3.41-02	-8.15-15	0.00
RN219	0.00	-1.05-07	-1.92-07	-7.95-07	-2.51-06	-3.03-06	-2.56-05	-9.19-04	-1.34-03	-1.33-03	-1.22-03	-5.07-04
RN220	0.00	2.26+06	1.61+06	1.31+05	3.50+04	6.06+00	1.66-01	3.80+00	3.96+01	3.50+02	1.31+03	1.33+03
RN222	0.00	9.74+00	1.54+01	6.60+01	8.81+02	1.41+05	6.61+06	5.21+07	9.88+06	4.80+05	4.73+05	4.12+05
FR221	0.00	-7.03-07	-1.71-07	-1.75-07	-6.25-07	-8.72-05	-1.21-02	-2.97-01	-6.67-01	-3.41-02	-8.15-15	0.00
FR223	0.00	-1.59-09	-2.69-09	-1.11-08	-3.51-08	-4.24-08	-3.58-07	-1.29-05	-1.88-05	-1.87-05	-1.71-05	-7.10-06
RA223	0.00	1.31+04	2.40+04	9.93+04	3.14+05	3.79+05	3.19+06	1.15+08	1.68+08	1.67+08	1.53+08	6.34+07
RA224	0.00	1.13+09	8.03+08	6.56+07	1.75+07	3.03+03	8.29+01	1.90+03	1.98+04	1.75+05	6.56+05	6.64+05
RA225	0.00	7.20+03	3.42+03	3.51+03	1.25+04	1.74+06	2.42+08	5.95+09	1.33+10	6.82+08	1.63-04	0.00
RA226	0.00	1.47+04	2.31+04	9.89+04	1.32+06	2.11+08	9.92+09	7.82+10	1.48+10	7.20+08	7.10+08	6.18+08
RA228	0.00	1.91+00	2.90+00	8.53+00	1.44+01	5.26+01	1.66+03	3.80+04	3.96+05	3.50+06	1.31+07	1.33+07
AC225	0.00	-7.02-07	-1.71-07	-1.75-07	-6.25-07	-8.72-05	-1.21-02	-2.97-01	-6.67-01	-3.41-02	-8.15-15	0.00
AC227	0.00	1.42+06	2.40+06	9.93+06	3.14+07	3.79+07	3.19+08	1.15+10	1.68+10	1.67+10	1.53+10	6.34+09
AC228	0.00	3.18-03	4.84-03	1.42-02	2.40-02	8.76-02	2.76+00	6.33+01	6.60+02	5.84+03	2.19+04	2.21+04
TH227	0.00	1.78+04	3.16+04	1.31+05	4.12+05	4.98+05	4.20+06	1.51+08	2.21+08	2.19+08	2.01+08	8.34+07
TH228	0.00	1.14+11	7.99+10	6.55+09	1.75+09	3.03+05	8.29+03	1.90+05	1.98+06	1.75+07	6.56+07	6.64+07
TH229	0.00	2.14+06	2.14+06	2.19+06	7.81+06	1.09+09	1.51+11	3.72+12	8.34+12	4.26+11	1.02-01	0.00
TH230	0.00	4.81+08	4.82+08	4.97+08	1.27+09	3.02+10	3.19+11	1.95+12	3.70+11	1.80+10	1.77+10	1.55+10
TH231	0.00	6.86+04	3.43+02	3.48+02	3.90+02	8.28+02	5.71+03	3.15+04	3.36+04	3.33+04	3.05+04	1.27+04

A1 FOLLOW-ON — PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TH232	0.00	1.21+01	1.21+01	1.23+01	1.44+01	5.26+01	1.66+03	3.80+04	3.96+05	3.50+06	1.31+07	1.33+07
TH234	0.00	2.87+08	1.44+06	1.43+06	1.43+06	1.43+06	1.43+06	1.44+06	1.44+06	1.44+06	1.42+06	1.24+06
PA231	0.00	6.48+07	6.48+07	6.49+07	6.54+07	7.58+07	6.39+08	2.30+10	3.36+10	3.33+10	3.05+10	1.27+10
PA233	0.00	3.09+07	3.12+07	3.28+07	4.78+07	1.22+08	1.44+08	1.40+08	1.05+08	5.68+06	1.25-06	0.00
PA234M	0.00	-2.87-01	-1.44-03	-1.43-03	-1.43-03	-1.43-03	-1.43-03	-1.44-03	-1.44-03	-1.44-03	-1.42-03	-1.24-03
PA234	0.00	-2.87-04	-1.44-06	-1.43-06	-1.43-06	-1.43-06	-1.43-06	-1.44-06	-1.44-06	-1.44-06	-1.42-06	-1.24-06
U232	0.00	3.69+08	4.94+08	8.46+08	3.79+08	6.55+04	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	2.00+05	4.21+05	2.27+06	2.56+07	5.64+08	8.73+09	7.41+10	1.67+11	8.52+09	2.03-03	0.00
U234	4.34+11	2.04+09	2.27+09	5.66+09	3.21+10	7.81+10	7.67+10	5.96+10	5.11+09	3.60+08	3.55+08	3.09+08
U235	9.83+08	3.43+06	3.43+06	3.48+06	3.90+06	8.28+06	5.71+07	3.15+08	3.36+08	3.33+08	3.05+08	1.27+08
U236	2.26+10	1.10+08	1.10+08	1.12+08	1.29+08	2.99+08	1.36+09	2.05+09	2.00+09	1.54+09	1.13+08	5.25-04
U237	0.00	-2.02-01	-6.41-02	-4.21-02	-8.23-04	-8.72-07	-4.47-07	-5.54-10	0.00	0.00	0.00	0.00
U238	1.01+11	4.78+08	4.78+08	4.78+08	4.78+08	4.78+08	4.78+08	4.79+08	4.80+08	4.80+08	4.73+08	4.12+08
NP237	0.00	1.86+12	1.87+12	1.97+12	2.87+12	7.31+12	8.66+12	8.41+12	6.29+12	3.41+11	7.50-02	0.00
NP239	0.00	2.61+09	2.61+09	2.60+09	2.58+09	2.38+09	1.05+09	3.03+05	1.53-01	1.05-01	2.52-03	0.00
PU236	-4.88+00	-1.36-02	-1.07-02	-1.20-03	-3.74-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	3.90+17	1.43+15	6.49+15	7.50+15	4.70+15	3.08+13	0.00	0.00	0.00	0.00	0.00	0.00
PU239	5.35+16	3.22+14	3.22+14	3.23+14	3.25+14	3.38+14	3.82+14	4.21+13	5.14+04	3.52+04	8.39+02	0.00
PU240	7.79+16	4.01+14	4.04+14	4.19+14	4.52+14	4.14+14	1.64+14	1.62+10	0.00	0.00	0.00	0.00
PU241	3.12+17	8.94+14	8.53+14	5.60+14	8.29+12	1.16+10	5.96+09	7.39+06	0.00	0.00	0.00	0.00
PU242	2.21+14	1.13+12	1.13+12	1.14+12	1.22+12	1.38+12	1.36+12	1.16+12	2.23+11	1.59+04	0.00	0.00
PU243	0.00	2.66-04	5.32-02	5.32-02	5.32-02	5.32-02	5.32-02	5.30-02	5.11-02	3.52-02	8.39-04	0.00
AM241	8.38+15	1.64+16	1.64+16	1.63+16	1.44+16	3.41+15	9.12+10	1.11+08	0.00	0.00	0.00	0.00
AM242M	0.00	1.08+15	1.08+15	1.03+15	6.85+14	1.13+13	1.71-05	0.00	0.00	0.00	0.00	0.00
AM242	0.00	2.16+11	2.15+11	2.07+11	1.37+11	2.26+09	3.43-09	0.00	0.00	0.00	0.00	0.00
AM243	0.00	2.61+14	2.61+14	2.60+14	2.58+14	2.38+14	1.05+14	3.03+10	1.53+04	1.05+04	2.52+02	0.00
CM242	0.00	2.25+16	4.80+15	4.24+13	2.81+13	4.64+11	0.00	0.00	0.00	0.00	0.00	0.00
CM243	0.00	4.67+14	4.57+14	3.76+14	5.36+13	1.84+05	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	4.24+15	4.08+15	2.89+15	9.21+13	9.98-02	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	1.88+11	1.88+11	1.87+11	1.86+11	1.74+11	8.92+10	1.11+08	0.00	0.00	0.00	0.00
CM246	0.00	5.44+09	5.44+09	5.44+09	5.38+09	4.80+09	1.54+09	1.75+04	0.00	0.00	0.00	0.00
CM247	0.00	1.60+04	1.60+04	1.60+04	1.60+04	1.60+04	1.60+04	1.59+04	1.53+04	1.05+04	2.52+02	0.00
SUBTOT	8.43+17	4.80+16	3.52+16	2.97+16	2.10+16	4.95+15	6.63+14	5.77+13	1.55+13	8.49+11	6.65+10	3.67+10
TOTAL	8.43+17	4.80+16	3.52+16	2.97+16	2.10+16	4.95+15	6.63+14	5.77+13	1.55+13	8.49+11	6.65+10	3.67+10

AI FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	-1.05-07	-1.92-07	-7.92-07	-2.50-06	-3.02-06	-2.55-05	-9.17-04	-1.34-03	-1.33-03	-1.22-03	-5.06-04
TL208	0.00	-8.12-03	-5.78-03	-4.72-04	-1.26-04	-2.18-08	-5.97-10	-1.37-08	-1.42-07	-1.26-06	-4.72-06	-4.78-06
TL209	0.00	-1.55-08	-3.76-09	-3.86-09	-1.38-08	-1.92-06	-2.66-04	-6.54-03	-1.47-02	-7.50-04	-1.79-16	0.00
PB209	0.00	-7.03-07	-1.71-07	-1.75-07	-6.25-07	-8.72-05	-1.21-02	-2.97-01	-6.67-01	-3.41-02	-8.15-15	0.00
PB210	0.00	1.37-02	2.55-02	3.41-01	1.68+01	4.22+03	1.98+05	1.56+06	2.96+05	1.44+04	1.42+04	1.24+04
PB211	0.00	-1.05-07	-1.92-07	-7.95-07	-2.51-06	-3.03-06	-2.56-05	-9.19-04	-1.34-03	-1.33-03	-1.22-03	-5.07-04
PB212	0.00	1.13+03	8.03+02	6.56+01	1.75+01	3.03-03	6.29-05	1.90-03	1.98-02	1.75-01	6.56-01	6.64-01
PB214	0.00	-2.92-08	-4.61-08	-1.98-07	-2.64-06	-4.22-04	-1.98-02	-1.56-01	-2.96-02	-1.44-03	-1.42-03	-1.24-03
BI210	0.00	3.38-05	6.37-05	8.52-04	4.20-02	1.06+01	4.96+02	3.91+03	7.41+02	3.60+01	3.55+01	3.09+01
BI211	0.00	-1.05-07	-1.92-07	-7.95-07	-2.51-06	-3.03-06	-2.56-05	-9.19-04	-1.34-03	-1.33-03	-1.22-03	-5.07-04
BI212	0.00	5.64+01	4.01+01	3.28+00	8.75-01	1.52-04	4.15-06	9.49-05	9.89-04	8.76-03	3.28-02	3.32-02
BI213	0.00	-7.03-07	-1.71-07	-1.75-07	-6.25-07	-8.72-05	-1.21-02	-2.97-01	-6.67-01	-3.41-02	-8.15-15	0.00
BI214	0.00	-2.92-08	-4.61-08	-1.98-07	-2.64-06	-4.22-04	-1.98-02	-1.56-01	-2.96-02	-1.44-03	-1.42-03	-1.24-03
PO210	0.00	1.40-03	2.70-03	4.87-02	2.40+00	6.03+02	2.83+04	2.23+05	4.23+04	2.06+03	2.03+03	1.77+03
PO211	0.00	-3.15-10	-5.77-10	-2.38-09	-7.53-09	-9.10-09	-7.67-08	-2.76-06	-4.03-06	-4.00-06	-3.66-06	-1.52-06
PO212	0.00	-1.44-02	-1.03-02	-6.40-04	-2.24-04	-3.88-08	-1.06-09	-2.43-08	-2.53-07	-2.24-06	-8.39-06	-8.50-06
PO213	0.00	-6.87-07	-1.67-07	-1.72-07	-6.11-07	-8.53-05	-1.18-02	-2.91-01	-6.53-01	-3.33-02	-7.97-15	0.00
PO214	0.00	-2.92-08	-4.61-08	-1.98-07	-2.64-06	-4.22-04	-1.98-02	-1.56-01	-2.96-02	-1.44-03	-1.42-03	-1.24-03
PO215	0.00	-1.05-07	-1.92-07	-7.95-07	-2.51-06	-3.03-06	-2.56-05	-9.19-04	-1.34-03	-1.33-03	-1.22-03	-5.07-04
PO216	0.00	-2.26-02	-1.61-02	-1.31-03	-3.50-04	-6.06-08	-1.66-09	-3.80-08	-3.96-07	-3.50-06	-1.31-05	-1.33-05
PO218	0.00	-2.92-08	-4.61-08	-1.98-07	-2.64-06	-4.22-04	-1.98-02	-1.56-01	-2.96-02	-1.44-03	-1.42-03	-1.24-03
AT217	0.00	-7.03-07	-1.71-07	-1.75-07	-6.25-07	-8.72-05	-1.21-02	-2.97-01	-6.67-01	-3.41-02	-8.15-15	0.00
RN219	0.00	-1.05-07	-1.92-07	-7.95-07	-2.51-06	-3.03-06	-2.56-05	-9.19-04	-1.34-03	-1.33-03	-1.22-03	-5.07-04
RN220	0.00	-2.26-02	-1.61-02	-1.31-03	-3.50-04	-6.06-08	-1.66-09	-3.80-08	-3.96-07	-3.50-06	-1.31-05	-1.33-05
RN222	0.00	-2.92-08	-4.61-08	-1.98-07	-2.64-06	-4.22-04	-1.98-02	-1.56-01	-2.96-02	-1.44-03	-1.42-03	-1.24-03
FR221	0.00	-7.03-07	-1.71-07	-1.75-07	-6.25-07	-8.72-05	-1.21-02	-2.97-01	-6.67-01	-3.41-02	-8.15-15	0.00
FR223	0.00	-1.59-09	-2.69-09	-1.11-08	-3.51-08	-4.24-08	-3.58-07	-1.29-05	-1.88-05	-1.87-05	-1.71-05	-7.10-06
RA223	0.00	1.50-01	2.75-01	1.14+00	3.58+00	4.33+00	3.65+01	1.31+03	1.92+03	1.90+03	1.74+03	7.25+02
RA224	0.00	1.13+04	8.03+03	6.56+02	1.75+02	3.03-02	6.29-04	1.90-02	1.98-01	1.75+00	6.56+00	6.64+00
RA225	0.00	6.00-01	2.85-01	2.92-01	1.04+00	1.45+02	2.02+04	4.96+05	1.11+06	5.68+04	1.36-08	0.00
RA226	0.00	9.82-01	1.54+00	6.60+00	8.81+01	1.41+04	6.61+05	5.21+06	9.88+05	4.80+04	4.73+04	4.12+04
RA228	0.00	6.35-05	9.68-05	2.84-04	4.81-04	1.75-03	5.53-02	1.27+00	1.32+01	1.17+02	4.37+02	4.43+02
AC225	0.00	-7.02-07	-1.71-07	-1.75-07	-6.25-07	-8.72-05	-1.21-02	-2.97-01	-6.67-01	-3.41-02	-8.15-15	0.00
AC227	0.00	5.69-02	9.61-02	3.97-01	1.25+00	1.52+00	1.28+01	4.60+02	6.72+02	6.67+02	6.11+02	2.54+02
AC228	0.00	2.12-08	3.23-08	9.48-06	1.60-07	5.64-07	1.84-05	4.22-04	4.40-03	3.89-02	1.46-01	1.48-01
TH227	0.00	5.34-03	9.48-03	3.92-02	1.24-01	1.49-01	1.26+00	4.53+01	6.63+01	6.57+01	6.02+01	2.50+01
TH228	0.00	3.25+03	2.28+03	1.87+02	5.00+01	8.66-03	2.37-04	5.42-03	5.65-02	5.00-01	1.87+00	1.90+00
TH229	0.00	8.54-02	8.55-02	8.77-02	3.13-01	4.36+01	6.05+03	1.49+05	3.34+05	1.70+04	4.07-09	0.00
TH230	0.00	1.92+01	1.93+01	1.99+01	5.09+01	1.21+03	1.28+04	7.81+04	1.48+04	7.20+02	7.19+02	6.18+02
TH231	0.00	1.37+01	6.87-02	6.95-02	7.81-02	1.66-01	1.14+00	6.30+00	6.72+00	6.67+00	6.11+00	2.54+00

AI FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TH232	0.00	6.03-06	6.04-06	6.14-06	7.21-06	2.63-05	8.29-04	1.90-02	1.98-01	1.75+00	6.56+00	6.64+00
TH234	0.00	1.44+04	7.21+01	7.17+01	7.17+01	7.17+01	7.17+01	7.18+01	7.20+01	7.20+01	7.10+01	6.18+01
PA231	0.00	2.88+00	2.88+00	2.88+00	2.91+00	3.37+00	2.84+01	1.02+03	1.49+03	1.48+03	1.36+03	5.64+02
PA233	0.00	1.86+03	1.87+03	1.97+03	2.87+03	7.31+03	8.66+03	8.41+03	6.29+03	3.41+02	7.50-11	0.00
PA234M	0.00	-2.87-01	-1.44-03	-1.43-03	-1.43-03	-1.43-03	-1.43-03	-1.44-03	-1.44-03	-1.44-03	-1.42-03	-1.24-03
PA234	0.00	-2.87-04	-1.44-06	-1.43-06	-1.43-06	-1.43-06	-1.43-06	-1.44-06	-1.44-06	-1.44-06	-1.42-08	-1.24-06
U232	0.00	1.11+01	1.48+01	2.54+01	1.14+01	1.96-03	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	2.67-02	5.62-02	3.03-01	3.42+00	7.52+01	1.16+03	9.88+03	2.22+04	1.14+03	2.71-10	0.00
U234	5.78+04	2.72+02	3.02+02	7.55+02	4.28+03	1.04+04	1.02+04	7.95+03	6.81+02	4.80+01	4.73+01	4.12+01
U235	1.31+02	4.57-01	4.58-01	4.63-01	5.20-01	1.10+00	7.61+00	4.20+01	4.48+01	4.44+01	4.07+01	1.69+01
U236	3.01+03	1.47+01	1.47+01	1.49+01	1.73+01	3.99+01	1.81+02	2.73+02	2.66+02	2.05+02	1.51+01	7.00-11
U237	0.00	-2.02-01	-6.41-02	-4.21-02	-6.23-04	-8.72-07	-4.47-07	-5.54-10	0.00	0.00	0.00	0.00
U238	7.56+03	3.59+01	3.59+01	3.59+01	3.59+01	3.59+01	3.59+01	3.59+01	3.60+01	3.60+01	3.55+01	3.09+01
NP237	0.00	6.21+04	6.25+04	6.56+04	9.56+04	2.44+05	2.89+05	2.80+05	2.10+05	1.14+04	2.50-09	0.00
NP239	0.00	5.21+05	5.21+05	5.21+05	5.17+05	4.76+05	2.11+05	6.07+01	3.06-05	2.11-05	5.04-07	0.00
PU236	-4.88+00	-1.36-02	-1.07-02	-1.20-03	-3.74-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	5.46+09	2.00+07	9.09+07	1.05+08	6.58+07	4.31+05	0.00	0.00	0.00	0.00	0.00	0.00
PU239	6.43+08	3.86+06	3.86+06	3.87+06	3.90+06	4.06+06	4.59+06	5.05+05	6.17-04	4.22-04	1.01-05	0.00
PU240	9.34+08	4.82+06	4.84+06	5.03+06	5.43+06	4.96+06	1.97+06	1.94+02	0.00	0.00	0.00	0.00
PU241	4.68+09	1.34+07	1.28+07	8.40+06	1.24+05	1.74+02	8.93+01	1.11-01	0.00	0.00	0.00	0.00
PU242	2.65+06	1.35+04	1.36+04	1.37+04	1.47+04	1.66+04	1.64+04	1.39+04	2.68+03	1.91-04	0.00	0.00
PU243	0.00	5.32-08	1.06-05	1.06-05	1.06-05	1.06-05	1.06-05	1.06-05	1.02-05	7.03-06	1.68-07	0.00
AM241	4.19+08	8.20+08	8.20+08	8.16+08	7.19+08	1.70+08	4.56+03	5.54+00	0.00	0.00	0.00	0.00
AM242M	0.00	5.41+07	5.38+07	5.17+07	3.43+07	5.66+05	8.56-13	0.00	0.00	0.00	0.00	0.00
AM242	0.00	2.16+06	2.15+06	2.07+06	1.37+06	2.26+04	3.43-14	0.00	0.00	0.00	0.00	0.00
AM243	0.00	1.30+07	1.30+07	1.30+07	1.29+07	1.19+07	5.27+06	1.52+03	7.66-04	5.27-04	1.26-05	0.00
CM242	0.00	4.50+09	9.60+08	8.47+06	5.62+06	9.29+04	0.00	0.00	0.00	0.00	0.00	0.00
CM243	0.00	1.87+07	1.83+07	1.50+07	2.14+06	7.35-03	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	1.82+08	1.75+08	1.24+08	3.95+06	4.28-09	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	9.38+03	9.38+03	9.37+03	9.31+03	8.71+03	4.46+03	5.53+00	0.00	0.00	0.00	0.00
CM246	0.00	2.72+02	2.72+02	2.72+02	2.69+02	2.40+02	7.69+01	8.77-04	0.00	0.00	0.00	0.00
CM247	0.00	7.98-04	7.98-04	7.98-04	7.98-04	7.98-04	7.98-04	7.95-04	7.66-04	5.27-04	1.26-05	0.00
SUBTOT	1.21+10	5.64+09	2.16+09	1.15+09	8.55+08	1.93+08	1.33+07	8.56+06	3.03+06	1.57+05	6.87+04	5.82+04
TOTAL	1.21+10	5.64+09	2.16+09	1.15+09	8.55+08	1.93+08	1.33+07	8.56+06	3.03+06	1.57+05	6.87+04	5.82+04

AI-LMFBR PLANT WASTE

Fission Products

AI FOLLOW-ON — PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	1.08-01	1.02-01	6.16-02	3.87-04	3.68-26	0.00	0.00	0.00	0.00	0.00	0.00
GE 72	0.00	1.90-04	1.90-04	1.90-04	1.90-04	1.90-04	1.90-04	1.90-04	1.90-04	1.90-04	1.90-04	1.90-04
GE 73	0.00	9.58-04	9.58-04	9.58-04	9.58-04	9.58-04	9.58-04	9.58-04	9.58-04	9.58-04	9.58-04	9.58-04
GE 74	0.00	3.99-03	3.99-03	3.99-03	3.99-03	3.99-03	3.99-03	3.99-03	3.99-03	3.99-03	3.99-03	3.99-03
AS 75	0.00	3.06-02	3.06-02	3.06-02	3.06-02	3.06-02	3.06-02	3.06-02	3.06-02	3.06-02	3.06-02	3.06-02
GE 76	0.00	6.21-02	6.21-02	6.21-02	6.21-02	6.21-02	6.21-02	6.21-02	6.21-02	6.21-02	6.21-02	6.21-02
SE 76	0.00	6.38-04	6.38-04	6.38-04	6.38-04	6.38-04	6.38-04	6.38-04	6.38-04	6.38-04	6.38-04	6.38-04
SE 77	0.00	2.06+00	2.06+00	2.06+00	2.06+00	2.06+00	2.06+00	2.06+00	2.06+00	2.06+00	2.06+00	2.06+00
SE 78	0.00	4.64+00	4.64+00	4.64+00	4.64+00	4.64+00	4.64+00	4.64+00	4.64+00	4.64+00	4.64+00	4.64+00
SE 79	0.00	8.48+00	8.48+00	8.47+00	8.47+00	8.39+00	7.62+00	2.92+00	1.99-04	0.00	0.00	0.00
BR 79	0.00	1.16-04	2.06-04	1.02-03	9.15-03	9.00-02	8.57-01	5.56+00	8.48+00	8.48+00	8.48+00	8.48+00
SE 80	0.00	1.26+01	1.26+01	1.26+01	1.26+01	1.26+01	1.26+01	1.26+01	1.26+01	1.26+01	1.26+01	1.26+01
KR 80	0.00	1.69+00	1.69+00	1.69+00	1.69+00	1.69+00	1.69+00	1.69+00	1.69+00	1.69+00	1.69+00	1.69+00
BR 81	0.00	2.35+01	2.35+01	2.35+01	2.35+01	2.35+01	2.35+01	2.35+01	2.35+01	2.35+01	2.35+01	2.35+01
KR 81	0.00	5.14-03	5.14-03	5.14-03	5.14-03	5.14-03	5.14-03	5.14-03	5.14-03	5.14-03	5.14-03	5.14-03
SE 82	0.00	3.55+01	3.55+01	3.55+01	3.55+01	3.55+01	3.55+01	3.55+01	3.55+01	3.55+01	3.55+01	3.55+01
KR 82	0.00	5.67-01	5.67-01	5.67-01	5.67-01	5.67-01	5.67-01	5.67-01	5.67-01	5.67-01	5.67-01	5.67-01
KR 83	0.00	5.17+01	5.17+01	5.17+01	5.17+01	5.17+01	5.17+01	5.17+01	5.17+01	5.17+01	5.17+01	5.17+01
KR 84	0.00	8.14+01	8.14+01	8.14+01	8.14+01	8.14+01	8.14+01	8.14+01	8.14+01	8.14+01	8.14+01	8.14+01
KR 85	0.00	2.17+01	2.04+01	1.14+01	3.55-02	2.95-27	0.00	0.00	0.00	0.00	0.00	0.00
RB 85	0.00	7.68+01	7.82+01	8.71+01	9.85+01	9.86+01	9.86+01	9.86+01	9.86+01	9.86+01	9.86+01	9.86+01
KR 86	0.00	1.41+02	1.41+02	1.41+02	1.41+02	1.41+02	1.41+02	1.41+02	1.41+02	1.41+02	1.41+02	1.41+02
RB 86	0.00	1.82-03	2.41-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 86	0.00	7.14-01	7.16-01	7.16-01	7.16-01	7.16-01	7.16-01	7.16-01	7.16-01	7.16-01	7.16-01	7.16-01
RB 87	0.00	1.80+02	1.80+02	1.80+02	1.80+02	1.80+02	1.80+02	1.80+02	1.80+02	1.80+02	1.80+02	1.78+02
SR 87	0.00	1.60-03	1.60-03	1.60-03	1.60-03	1.60-03	1.62-03	1.85-03	4.09-03	2.66-02	2.51-01	2.48+00
SR 88	0.00	2.25+02	2.25+02	2.25+02	2.25+02	2.25+02	2.25+02	2.25+02	2.25+02	2.25+02	2.25+02	2.25+02
SR 89	0.00	9.01+00	6.93-02	6.54-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y 89	0.00	2.96+02	3.05+02	3.05+02	3.05+02	3.05+02	3.05+02	3.05+02	3.05+02	3.05+02	3.05+02	3.05+02
SR 90	0.00	3.34+02	3.26+02	2.61+02	2.84+01	6.51-09	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	8.68-02	8.47-02	6.78-02	7.37-03	1.69-12	0.00	0.00	0.00	0.00	0.00	0.00
ZR 90	0.00	1.15+01	1.96+01	8.45+01	3.17+02	3.46+02	3.46+02	3.46+02	3.46+02	3.46+02	3.46+02	3.46+02
Y 91	0.00	1.72+01	2.32-01	3.47-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 91	0.00	4.27+02	4.44+02	4.44+02	4.44+02	4.44+02	4.44+02	4.44+02	4.44+02	4.44+02	4.44+02	4.44+02
ZR 92	0.00	5.21+02	5.21+02	5.21+02	5.21+02	5.21+02	5.21+02	5.21+02	5.21+02	5.21+02	5.21+02	5.21+02
ZR 93	0.00	6.11+02	6.11+02	6.11+02	6.11+02	6.11+02	6.08+02	5.83+02	3.85+02	6.02+00	5.27-18	0.00
NB 93M	0.00	3.61-04	6.18-04	2.43-03	5.51-03	5.54-03	5.51-03	5.29-03	3.49-03	5.46-05	4.78-23	0.00
NB 93	0.00	1.68-05	4.18-05	7.72-04	2.31-02	2.77-01	2.81+00	2.76+01	2.26+02	6.05+02	6.11+02	6.11+02
ZR 94	0.00	7.35+02	7.35+02	7.35+02	7.35+02	7.35+02	7.35+02	7.35+02	7.35+02	7.35+02	7.35+02	7.35+02
ZR 95	0.00	4.04+01	8.22-01	4.95-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

AI FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
NB 95M	0.00	4.94-02	1.01-03	6.06-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	3.60+01	9.75-01	5.66-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MO 95	0.00	7.62+02	8.36+02	8.38+02	8.38+02	8.38+02	8.38+02	8.38+02	8.38+02	8.38+02	8.38+02	8.38+02
ZR 96	0.00	8.43+02	8.43+02	8.43+02	8.43+02	8.43+02	8.43+02	8.43+02	8.43+02	8.43+02	8.43+02	8.43+02
MO 96	0.00	1.33+01	1.33+01	1.33+01	1.33+01	1.33+01	1.33+01	1.33+01	1.33+01	1.33+01	1.33+01	1.33+01
MO 97	0.00	8.29+02	8.29+02	8.29+02	8.29+02	8.29+02	8.29+02	8.29+02	8.29+02	8.29+02	8.29+02	8.29+02
MO 98	0.00	9.17+02	9.17+02	9.17+02	9.17+02	9.17+02	9.17+02	9.17+02	9.17+02	9.17+02	9.17+02	9.17+02
TC 99	0.00	9.64+02	9.64+02	9.64+02	9.63+02	9.61+02	9.33+02	6.95+02	3.67+01	6.13-12	0.00	0.00
RU 99	0.00	4.09-03	7.24-03	3.56-02	3.19-01	3.15+00	3.10+01	2.69+02	9.27+02	9.64+02	9.64+02	9.64+02
MO100	0.00	9.94+02	9.94+02	9.94+02	9.94+02	9.94+02	9.94+02	9.94+02	9.94+02	9.94+02	9.94+02	9.94+02
RU100	0.00	2.25+01	2.25+01	2.25+01	2.25+01	2.25+01	2.25+01	2.25+01	2.25+01	2.25+01	2.25+01	2.25+01
RU101	0.00	9.59+02	9.59+02	9.59+02	9.59+02	9.59+02	9.59+02	9.59+02	9.59+02	9.59+02	9.59+02	9.59+02
RU102	0.00	1.06+03	1.06+03	1.06+03	1.06+03	1.06+03	1.06+03	1.06+03	1.06+03	1.06+03	1.06+03	1.06+03
RU103	0.00	1.59+01	2.66-02	2.77-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	1.59-02	2.66-05	2.77-30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103	0.00	9.84+02	1.00+03	1.00+03	1.00+03	1.00+03	1.00+03	1.00+03	1.00+03	1.00+03	1.00+03	1.00+03
RU104	0.00	9.64+02	9.64+02	9.64+02	9.64+02	9.64+02	9.64+02	9.64+02	9.64+02	9.64+02	9.64+02	9.64+02
PD104	0.00	5.97-03	5.97-03	5.97-03	5.97-03	5.97-03	5.97-03	5.97-03	5.97-03	5.97-03	5.97-03	5.97-03
PD105	0.00	8.26+02	8.26+02	8.26+02	8.26+02	8.26+02	8.26+02	8.26+02	8.26+02	8.26+02	8.26+02	8.26+02
RU106	0.00	3.42+02	1.72+02	3.46-01	3.82-28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	3.24-04	1.62-04	3.27-07	3.61-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD106	0.00	4.57+02	6.27+02	7.99+02	7.99+02	7.99+02	7.99+02	7.99+02	7.99+02	7.99+02	7.99+02	7.99+02
PD107	0.00	5.57+02	5.57+02	5.57+02	5.57+02	5.57+02	5.57+02	5.52+02	5.05+02	2.07+02	2.80-02	0.00
AG107	0.00	7.09-05	1.26-04	6.23-04	5.59-03	5.52-02	5.52-01	5.49+00	5.25+01	3.50+02	5.57+02	5.57+02
PD108	0.00	4.42+02	4.42+02	4.42+02	4.42+02	4.42+02	4.42+02	4.42+02	4.42+02	4.42+02	4.42+02	4.42+02
CD108	0.00	1.40-06	1.40-06	1.40-06	1.40-06	1.40-06	1.40-06	1.40-06	1.40-06	1.40-06	1.40-06	1.40-06
AG109	0.00	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02	2.45+02
CD109	0.00	7.41-09	4.24-09	2.78-11	4.02-33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD110	0.00	1.27+02	1.27+02	1.27+02	1.27+02	1.27+02	1.27+02	1.27+02	1.27+02	1.27+02	1.27+02	1.27+02
AG110M	0.00	1.67-01	6.15-02	7.56-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	2.43-02	8.93-09	1.10-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD110	0.00	1.24+01	1.24+01	1.24+01	1.24+01	1.24+01	1.24+01	1.24+01	1.24+01	1.24+01	1.24+01	1.24+01
CD111	0.00	5.81+01	5.81+01	5.81+01	5.81+01	5.81+01	5.81+01	5.81+01	5.81+01	5.81+01	5.81+01	5.81+01
CD112	0.00	2.89+01	2.89+01	2.89+01	2.89+01	2.89+01	2.89+01	2.89+01	2.89+01	2.89+01	2.89+01	2.89+01
CD113M	0.00	4.12-01	3.92-01	2.51-01	2.92-03	1.31-22	0.00	0.00	0.00	0.00	0.00	0.00
CD113	0.00	1.47+01	1.47+01	1.47+01	1.47+01	1.47+01	1.47+01	1.47+01	1.47+01	1.47+01	1.47+01	1.47+01
IN113	0.00	1.86-02	3.84-02	1.79-01	4.27-01	4.30-01	4.30-01	4.30-01	4.30-01	4.30-01	4.30-01	4.30-01
CD114	0.00	1.91+01	1.91+01	1.91+01	1.91+01	1.91+01	1.91+01	1.91+01	1.91+01	1.91+01	1.91+01	1.91+01
IN114M	0.00	2.15-05	1.36-07	2.23-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	3.46-10	2.19-12	3.58-32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

AI FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
SN114	0.00	3.44-04	3.64-04	3.64-04	3.64-04	3.64-04	3.64-04	3.64-04	3.64-04	3.64-04	3.64-04	3.64-04
CD115M	0.00	2.20-02	6.12-05	6.01-28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN115	0.00	1.52+01	1.52+01	1.52+01	1.52+01	1.52+01	1.52+01	1.52+01	1.52+01	1.52+01	1.52+01	1.52+01
SN115	0.00	7.52-01	7.52-01	7.52-01	7.52-01	7.52-01	7.52-01	7.52-01	7.52-01	7.52-01	7.52-01	7.52-01
CD116	0.00	1.51+01	1.51+01	1.51+01	1.51+01	1.51+01	1.51+01	1.51+01	1.51+01	1.51+01	1.51+01	1.51+01
SN116	0.00	6.16-01	6.16-01	6.16-01	6.16-01	6.16-01	6.16-01	6.16-01	6.16-01	6.16-01	6.16-01	6.16-01
SN117	0.00	1.49+01	1.49+01	1.49+01	1.49+01	1.49+01	1.49+01	1.49+01	1.49+01	1.49+01	1.49+01	1.49+01
SN118	0.00	1.53+01	1.53+01	1.53+01	1.53+01	1.53+01	1.53+01	1.53+01	1.53+01	1.53+01	1.53+01	1.53+01
SN119M	0.00	3.54-02	1.29-02	1.42-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119	0.00	1.50+01	1.50+01	1.50+01	1.50+01	1.50+01	1.50+01	1.50+01	1.50+01	1.50+01	1.50+01	1.50+01
SN120	0.00	1.60+01	1.60+01	1.60+01	1.60+01	1.60+01	1.60+01	1.60+01	1.60+01	1.60+01	1.60+01	1.60+01
SN121M	0.00	2.02-04	2.00-04	1.85-04	8.13-05	2.22-08	0.00	0.00	0.00	0.00	0.00	0.00
SB121	0.00	1.62+01	1.62+01	1.62+01	1.62+01	1.62+01	1.62+01	1.62+01	1.62+01	1.62+01	1.62+01	1.62+01
SN122	0.00	1.76+01	1.76+01	1.76+01	1.76+01	1.76+01	1.76+01	1.76+01	1.76+01	1.76+01	1.76+01	1.76+01
TE122	0.00	3.45-01	3.45-01	3.45-01	3.45-01	3.45-01	3.45-01	3.45-01	3.45-01	3.45-01	3.45-01	3.45-01
SN123M	0.00	1.33+00	1.75-01	2.13-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB123	0.00	1.84+01	1.96+01	1.98+01	1.98+01	1.98+01	1.98+01	1.98+01	1.98+01	1.98+01	1.98+01	1.98+01
TE123M	0.00	2.42-04	2.78-05	9.73-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123	0.00	2.49-03	2.70-03	2.73-03	2.73-03	2.73-03	2.73-03	2.73-03	2.73-03	2.73-03	2.73-03	2.73-03
SN124	0.00	2.39+01	2.39+01	2.39+01	2.39+01	2.39+01	2.39+01	2.39+01	2.39+01	2.39+01	2.39+01	2.39+01
SB124	0.00	2.54-02	3.74-04	1.21-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE124	0.00	3.03-01	3.28-01	3.28-01	3.28-01	3.28-01	3.28-01	3.28-01	3.28-01	3.28-01	3.28-01	3.28-01
SB125	0.00	2.31+01	1.79+01	1.77+00	1.65-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	5.29-01	4.35-01	4.32-02	4.02-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125	0.00	7.96+00	1.33+01	2.98+01	3.16+01	3.16+01	3.16+01	3.16+01	3.16+01	3.16+01	3.16+01	3.16+01
SN126	0.00	4.91+01	4.91+01	4.91+01	4.91+01	4.88+01	4.59+01	2.46+01	4.81-02	3.94-29	0.00	0.00
SB126M	0.00	1.78-08	1.78-08	1.78-08	1.77-08	1.76-08	1.66-08	8.88-09	1.74-11	0.00	0.00	0.00
SB126	0.00	4.72-04	1.67-05	1.67-05	1.66-05	1.65-05	1.55-05	8.33-06	1.63-08	0.00	0.00	0.00
TE126	0.00	2.46+00	2.46+00	2.46+00	2.50+00	2.80+00	5.75+00	2.70+01	5.16+01	5.16+01	5.16+01	5.16+01
TE127M	0.00	2.14+00	2.10-01	1.76-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	7.62-03	7.47-04	6.26-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I127	0.00	7.62+01	7.81+01	7.83+01	7.83+01	7.83+01	7.83+01	7.83+01	7.83+01	7.83+01	7.83+01	7.83+01
TE128	0.00	1.38+02	1.38+02	1.38+02	1.38+02	1.38+02	1.38+02	1.38+02	1.38+02	1.38+02	1.38+02	1.38+02
XE128	0.00	2.34+00	2.34+00	2.34+00	2.34+00	2.34+00	2.34+00	2.34+00	2.34+00	2.34+00	2.34+00	2.34+00
TE129M	0.00	8.60-01	5.03-04	4.01-33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	7.77-04	4.54-07	3.62-36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	2.39+02	2.40+02	2.40+02	2.40+02	2.40+02	2.40+02	2.39+02	2.31+02	1.60+02	4.07+00	4.75-16
XE129	0.00	8.87-03	8.88-03	8.97-03	9.85-03	1.87-02	1.07-01	9.86-01	9.60+00	8.04+01	2.36+02	2.40+02
TE130	0.00	4.77+02	4.77+02	4.77+02	4.77+02	4.77+02	4.77+02	4.77+02	4.77+02	4.77+02	4.77+02	4.77+02
XE130	0.00	8.15+00	8.15+00	8.15+00	8.15+00	8.15+00	8.15+00	8.15+00	8.15+00	8.15+00	8.15+00	8.15+00

AI FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
XE131M	0.00	5.69-03	2.98-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XE131	0.00	7.51+02	7.51+02	7.51+02	7.51+02	7.51+02	7.51+02	7.51+02	7.51+02	7.51+02	7.51+02	7.51+02
XE132	0.00	8.67+02	8.67+02	8.67+02	8.67+02	8.67+02	8.67+02	8.67+02	8.67+02	8.67+02	8.67+02	8.67+02
CS133	0.00	1.23+03	1.23+03	1.23+03	1.23+03	1.23+03	1.23+03	1.23+03	1.23+03	1.23+03	1.23+03	1.23+03
XE134	0.00	1.42+03	1.42+03	1.42+03	1.42+03	1.42+03	1.42+03	1.42+03	1.42+03	1.42+03	1.42+03	1.42+03
CS134	0.00	1.96+01	1.40+01	6.68-01	4.09-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BA134	0.00	6.99+00	1.26+01	2.59+01	2.66+01	2.66+01	2.66+01	2.66+01	2.66+01	2.66+01	2.66+01	2.66+01
CS135	0.00	1.43+03	1.43+03	1.43+03	1.43+03	1.43+03	1.43+03	1.40+03	1.14+03	1.42+02	1.33-07	0.00
BA135	0.00	3.71-03	4.04-03	7.01-03	3.67-02	3.34-01	3.30+00	3.27+01	2.95+02	1.29+03	1.43+03	1.43+03
XE136	0.00	1.49+03	1.49+03	1.49+03	1.49+03	1.49+03	1.49+03	1.49+03	1.49+03	1.49+03	1.49+03	1.49+03
CS136	0.00	1.43-02	4.99-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BA136	0.00	4.95+01	4.96+01	4.96+01	4.96+01	4.96+01	4.96+01	4.96+01	4.96+01	4.96+01	4.96+01	4.96+01
CS137	0.00	1.44+03	1.41+03	1.15+03	1.43+02	1.34-07	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	2.16-04	2.13-04	1.73-04	2.16-05	2.03-14	0.00	0.00	0.00	0.00	0.00	0.00
BA137	0.00	4.46+01	7.75+01	3.42+02	1.34+03	1.49+03	1.49+03	1.49+03	1.49+03	1.49+03	1.49+03	1.49+03
BA138	0.00	1.40+03	1.40+03	1.40+03	1.40+03	1.40+03	1.40+03	1.40+03	1.40+03	1.40+03	1.40+03	1.40+03
LA139	0.00	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03
BA140	0.00	2.26-01	5.64-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	3.40-02	6.79-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE140	0.00	1.22+03	1.22+03	1.22+03	1.22+03	1.22+03	1.22+03	1.22+03	1.22+03	1.22+03	1.22+03	1.22+03
CE141	0.00	9.35+00	3.78-03	1.10-33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR141	0.00	1.02+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03
CE142	0.00	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03	1.24+03
ND142	0.00	4.52+00	4.52+00	4.52+00	4.52+00	4.52+00	4.52+00	4.52+00	4.52+00	4.52+00	4.52+00	4.52+00
PR143	0.00	3.31-01	3.13-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND143	0.00	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03
CE144	0.00	3.16+02	1.30+02	4.26-02	6.21-37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	1.34-02	5.48-03	1.80-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND144	0.00	5.91+02	7.77+02	9.07+02	9.07+02	9.07+02	9.07+02	9.07+02	9.07+02	9.07+02	9.07+02	9.07+02
ND145	0.00	7.18+02	7.18+02	7.18+02	7.18+02	7.18+02	7.18+02	7.18+02	7.18+02	7.18+02	7.18+02	7.18+02
ND146	0.00	6.71+02	6.71+02	6.71+02	6.71+02	6.71+02	6.71+02	6.71+02	6.71+02	6.71+02	6.71+02	6.71+02
ND147	0.00	4.10-02	5.13-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	3.54+02	2.72+02	2.52+01	1.15-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM147	0.00	1.37+02	2.19+02	4.66+02	4.92+02	4.92+02	4.92+02	4.92+02	4.92+02	4.92+02	4.92+02	4.92+02
ND148	0.00	4.22+02	4.22+02	4.22+02	4.22+02	4.22+02	4.22+02	4.22+02	4.22+02	4.22+02	4.22+02	4.22+02
PM148M	0.00	5.65-01	1.36-03	3.80-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	5.84-03	1.41-05	3.92-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM148	0.00	3.89+01	3.95+01	3.95+01	3.95+01	3.95+01	3.95+01	3.95+01	3.95+01	3.95+01	3.95+01	3.95+01
SM149	0.00	3.59+02	3.59+02	3.59+02	3.59+02	3.59+02	3.59+02	3.59+02	3.59+02	3.59+02	3.59+02	3.59+02
ND150	0.00	2.40+02	2.40+02	2.40+02	2.40+02	2.40+02	2.40+02	2.40+02	2.40+02	2.40+02	2.40+02	2.40+02

A1 FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
SM150	0.00	2.78+01	2.78+01	2.78+01	2.78+01	2.78+01	2.78+01	2.78+01	2.78+01	2.78+01	2.78+01	2.78+01
SM151	0.00	2.07+02	2.06+02	1.92+02	9.36+01	7.21-02	5.29-33	0.00	0.00	0.00	0.00	0.00
EU151	0.00	2.07+00	3.71+00	1.80+01	1.16+02	2.09+02	2.10+02	2.10+02	2.10+02	2.10+02	2.10+02	2.10+02
SM152	0.00	1.88+02	1.88+02	1.88+02	1.88+02	1.88+02	1.88+02	1.88+02	1.88+02	1.88+02	1.88+02	1.88+02
EU152	0.00	8.82-02	8.32-02	4.95-02	2.74-04	7.33-27	0.00	0.00	0.00	0.00	0.00	0.00
GD152	0.00	4.58-02	4.72-02	5.67-02	7.04-02	7.05-02	7.05-02	7.05-02	7.05-02	7.05-02	7.05-02	7.05-02
EU153	0.00	1.07+02	1.07+02	1.07+02	1.07+02	1.07+02	1.07+02	1.07+02	1.07+02	1.07+02	1.07+02	1.07+02
GD153	0.00	1.80-04	6.31-05	5.15-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM154	0.00	8.46+01	8.46+01	8.46+01	8.46+01	8.46+01	8.46+01	8.46+01	8.46+01	8.46+01	8.46+01	8.46+01
EU154	0.00	9.79+00	9.37+00	6.35+00	1.29-01	1.51-18	0.00	0.00	0.00	0.00	0.00	0.00
GD154	0.00	4.30-01	8.45-01	3.87+00	1.01+01	1.02+01	1.02+01	1.02+01	1.02+01	1.02+01	1.02+01	1.02+01
EU155	0.00	3.91+01	2.67+01	8.51-01	9.22-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD155	0.00	2.17+01	3.41+01	6.00+01	6.08+01	6.08+01	6.08+01	6.08+01	6.08+01	6.08+01	6.08+01	6.08+01
EU156	0.00	2.27-02	1.06-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD156	0.00	4.58+01	4.58+01	4.58+01	4.58+01	4.58+01	4.58+01	4.58+01	4.58+01	4.58+01	4.58+01	4.58+01
GD157	0.00	2.64+01	2.64+01	2.64+01	2.64+01	2.64+01	2.64+01	2.64+01	2.64+01	2.64+01	2.64+01	2.64+01
GD158	0.00	1.92+01	1.92+01	1.92+01	1.92+01	1.92+01	1.92+01	1.92+01	1.92+01	1.92+01	1.92+01	1.92+01
TB159	0.00	9.73+00	9.73+00	9.73+00	9.73+00	9.73+00	9.73+00	9.73+00	9.73+00	9.73+00	9.73+00	9.73+00
GD160	0.00	5.51+00	5.51+00	5.51+00	5.51+00	5.51+00	5.51+00	5.51+00	5.51+00	5.51+00	5.51+00	5.51+00
TB160	0.00	1.06-01	3.17-03	6.01-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DY160	0.00	1.02+00	1.12+00	1.12+00	1.12+00	1.12+00	1.12+00	1.12+00	1.12+00	1.12+00	1.12+00	1.12+00
DY161	0.00	3.24+00	3.24+00	3.24+00	3.24+00	3.24+00	3.24+00	3.24+00	3.24+00	3.24+00	3.24+00	3.24+00
GD162	0.00	1.10-06	5.48-07	1.07-09	8.77-37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	1.56-11	7.81-12	1.53-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DY162	0.00	1.69-01	1.69-01	1.69-01	1.69-01	1.69-01	1.69-01	1.69-01	1.69-01	1.69-01	1.69-01	1.69-01
DY163	0.00	1.26-03	1.26-03	1.26-03	1.26-03	1.26-03	1.26-03	1.26-03	1.26-03	1.26-03	1.26-03	1.26-03
DY164	0.00	3.78-05	3.78-05	3.78-05	3.78-05	3.78-05	3.78-05	3.78-05	3.78-05	3.78-05	3.78-05	3.78-05
HO165	0.00	2.15-07	2.15-07	2.15-07	2.15-07	2.15-07	2.15-07	2.15-07	2.15-07	2.15-07	2.15-07	2.15-07
ER166	0.00	6.97-09	6.97-09	6.97-09	6.97-09	6.97-09	6.97-09	6.97-09	6.97-09	6.97-09	6.97-09	6.97-09
ER167	0.00	3.71-11	3.71-11	3.71-11	3.71-11	3.71-11	3.71-11	3.71-11	3.71-11	3.71-11	3.71-11	3.71-11
SUBTOT	0.00	3.81+04	3.81+04	3.81+04	3.81+04	3.81+04	3.81+04	3.81+04	3.81+04	3.81+04	3.81+04	3.81+04
TOTAL	0.00	3.81+04	3.81+04	3.81+04	3.81+04	3.81+04	3.81+04	3.81+04	3.81+04	3.81+04	3.81+04	3.81+04

AI FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	1.05+03	9.92+02	5.97+02	3.75+00	3.57-22	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	5.90-01	5.90-01	5.90-01	5.90-01	5.84-01	5.31-01	2.03-01	1.38-05	0.00	0.00	0.00
KR 85	0.00	8.46+03	7.94+03	4.45+03	1.38+01	1.15-24	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	1.48+02	1.96-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	1.48-05	1.48-05	1.48-05	1.48-05	1.48-05	1.48-05	1.48-05	1.48-05	1.48-05	1.48-05	1.48-05
SR 89	0.00	2.54+05	1.96+03	1.84-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	4.72+04	4.61+04	3.69+04	4.01+03	9.20-07	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	4.73+04	4.61+04	3.69+04	4.01+03	9.20-07	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	4.20+05	5.67+03	8.48-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	1.57+00	1.57+00	1.57+00	1.57+00	1.57+00	1.56+00	1.50+00	9.87-01	1.54-02	1.35-20	0.00
NB 93M	0.00	1.02-01	1.75-01	6.86-01	1.56+00	1.57+00	1.56+00	1.50+00	9.87-01	1.54-02	1.35-20	0.00
ZR 95	0.00	8.54+05	1.74+04	1.05-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	1.81+04	3.69+02	2.22-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	1.41+06	3.83+04	2.22-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	1.64+01	1.64+01	1.64+01	1.64+01	1.64+01	1.59+01	1.18+01	6.25-01	1.04-13	0.00	0.00
RU103	0.00	5.09+05	8.53+02	8.87-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	5.09+05	8.54+02	8.88-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	1.15+06	5.77+05	1.16+03	1.28-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	1.15+06	5.77+05	1.16+03	1.28-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	2.66-01	2.66-01	2.66-01	2.66-01	2.66-01	2.66-01	2.64-01	2.41-01	9.89-02	1.34-05	0.00
AG109M	0.00	1.96-05	1.12-05	7.35-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	1.96-05	1.12-05	7.35-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	7.85+02	2.89+02	3.55-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	1.02+02	3.75+01	4.61-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	9.31+01	8.86+01	5.67+01	6.59-01	2.96-20	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	4.93-01	3.12-03	5.11-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	4.76-01	3.01-03	4.93-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	5.82+02	1.62+00	1.59-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN117M	0.00	1.65-01	2.32-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	1.56+02	5.65+01	6.24-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	7.87-03	7.80-03	7.18-03	3.16-03	8.63-07	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	1.13+04	1.49+03	1.81-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	2.19+00	2.52-01	8.83-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	4.46+02	6.57+00	2.13-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN125	0.00	7.97+01	1.61-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	2.45+04	1.89+04	1.88+03	1.75-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	9.54+03	7.84+03	7.79+02	7.24-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	1.40+00	1.40+00	1.39+00	1.39+00	1.39+00	1.30+00	6.98-01	1.36-03	0.00	0.00	0.00
SB126M	0.00	1.40+00	1.40+00	1.39+00	1.39+00	1.39+00	1.30+00	6.98-01	1.36-03	0.00	0.00	0.00
SB126	0.00	3.92+01	1.38+00	1.38+00	1.38+00	1.37+00	1.29+00	6.91-01	1.35-03	0.00	0.00	0.00

AI FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE127M	0.00	2.02+04	1.98+03	1.66-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	2.00+04	1.96+03	1.64-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129M	0.00	2.56+04	1.50+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	1.64+04	9.60+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	3.90-02	3.92-02	3.92-02	3.92-02	3.92-02	3.91-02	3.90-02	3.76-02	2.60-02	6.64-04	7.75-20
I131	0.00	2.30+03	5.10-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XE131M	0.00	4.81+02	2.52-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	2.55+04	1.82+04	8.69+02	5.32-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	1.26+00	1.26+00	1.26+00	1.26+00	1.26+00	1.26+00	1.23+00	1.00+00	1.25-01	1.17-10	0.00
CS136	0.00	1.05+03	3.69-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS137	0.00	1.26+05	1.23+05	9.97+04	1.25+04	1.17-05	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	1.17+05	1.15+05	9.32+04	1.17+04	1.09-05	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	1.65+04	4.26-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	1.90+04	4.90-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	2.67+05	1.08+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	2.21+04	2.09-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	1.01+06	4.14+05	1.36+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	1.01+06	4.14+05	1.36+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	3.29+03	4.11-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	3.29+05	2.53+05	2.34+04	1.07-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	1.19+04	2.87+01	7.98-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	9.55+02	2.30+00	6.41-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	5.65+03	5.60+03	5.22+03	2.55+03	1.96+00	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	1.73+01	1.63+01	9.70+00	5.37-02	1.44-24	0.00	0.00	0.00	0.00	0.00	0.00
GD153	0.00	6.34-01	2.23-01	1.82-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	1.42+03	1.36+03	9.21+02	1.87+01	2.20-16	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	4.99+04	3.40+04	1.08+03	1.18-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	1.27+03	5.94-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	1.20+03	3.58+01	6.80-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	2.42-03	1.21-03	2.37-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	2.42-03	1.21-03	2.37-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	9.53+06	2.73+06	3.09+05	3.48+04	2.78+01	2.50+01	1.87+01	3.88+00	2.81-01	6.93-04	1.46-05
TOTAL	0.00	9.53+06	2.73+06	3.09+05	3.48+04	2.78+01	2.50+01	1.87+01	3.88+00	2.81-01	6.93-04	1.46-05

A1 FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	3.73-02	3.53-02	2.12-02	1.33-04	1.27-26	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	2.24-04	2.24-04	2.24-04	2.24-04	2.22-04	2.01-04	7.71-05	5.25-09	0.00	0.00	0.00
KR 85	0.00	1.37+01	1.29+01	7.23+00	2.25-02	1.67-27	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	6.99-01	9.25-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	9.66-09	9.66-09	9.66-09	9.66-09	9.66-09	9.66-09	9.66-09	9.66-09	9.66-09	9.65-09	9.53-09
SR 89	0.00	9.15+02	7.04+00	6.64-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	6.19+01	6.04+01	4.84+01	5.25+00	1.21-09	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	2.78+02	2.71+02	2.17+02	2.36+01	5.42-09	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	1.60+03	2.16+01	3.23-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	1.86-04	1.86-04	1.86-04	1.86-04	1.86-04	1.85-04	1.77-04	1.17-04	1.83-06	1.60-24	0.00
NB 93M	0.00	1.81-05	3.11-05	1.22-04	2.77-04	2.78-04	2.77-04	2.66-04	1.75-04	2.74-06	2.40-24	0.00
ZR 95	0.00	4.47+03	9.10+01	5.48-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	2.52+01	5.14-01	3.09-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	6.80+03	1.84+02	1.07-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	1.11-02	1.11-02	1.11-02	1.11-02	1.11-02	1.07-02	8.60-03	4.22-04	7.06-17	0.00	0.00
RU103	0.00	1.68+03	2.81+00	2.92-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	2.42+02	4.05-01	4.21-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	6.81+01	3.42+01	6.89-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	1.21+04	6.06+03	1.22+01	1.35-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	2.21-05	2.21-05	2.21-05	2.21-05	2.21-05	2.21-05	2.19-05	2.00-05	8.21-06	1.11-09	0.00
AG109M	0.00	2.05-08	1.17-08	7.66-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	1.95-08	1.12-08	7.31-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	1.33+01	4.88+00	6.60-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	7.41-01	2.72-01	3.35-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	1.23-01	1.17-01	7.50-02	8.71-04	3.91-23	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	5.32-04	3.37-06	5.51-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	2.24-03	1.42-05	2.32-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	2.13+00	5.91-03	5.81-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN117M	0.00	6.22-04	8.74-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	1.64-01	5.96-02	6.58-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	9.98-06	9.89-06	9.11-06	4.01-06	1.09-09	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	3.99+01	5.26+00	6.41-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	6.45-03	7.41-04	2.60-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	6.13+00	9.03-02	2.93-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN125	0.00	5.06-01	1.02-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	9.93+01	7.68+01	7.62+00	7.08-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	1.64+01	1.35+01	1.34+00	1.24-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	1.50-03	1.50-03	1.50-03	1.50-03	1.49-03	1.40-03	7.53-04	1.47-06	0.00	0.00	0.00
SB126M	0.00	9.44-03	9.44-03	9.43-03	9.43-03	9.37-03	8.80-03	4.72-03	9.23-06	0.00	0.00	0.00
SB126	0.00	5.10-01	1.80-02	1.80-02	1.80-02	1.76-02	1.68-02	8.99-03	1.76-05	0.00	0.00	0.00

A1 FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE127M	0.00	1.12+01	1.09+00	9.17-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	3.22+01	3.16+00	2.65-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129M	0.00	5.09+01	2.97-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	5.97+01	3.49-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	2.57-05	2.58-05	2.58-05	2.58-05	2.58-05	2.58-05	2.57-05	2.47-05	1.71-05	4.37-07	5.10-23
XE131M	0.00	9.35-01	4.89-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	2.71+02	1.93+02	9.21+00	5.64-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	6.14-04	6.14-04	6.14-04	6.14-04	6.14-04	6.12-04	6.00-04	4.87-04	6.09-05	5.70-14	0.00
CS136	0.00	1.45+01	5.06-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS137	0.00	2.05+02	2.01+02	1.63+02	2.04+01	1.91-08	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	4.62+02	4.51+02	3.66+02	4.58+01	4.29-08	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	5.50+01	1.42-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	3.34+02	8.63-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	5.26+02	2.13-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	4.78+01	4.53-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	8.26+02	3.39+02	1.11-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	7.81+03	3.20+03	1.05+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	1.07+01	1.33-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	1.70+02	1.30+02	1.21+01	5.53-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	1.47+02	3.56-01	9.90-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	7.74+00	1.87-02	5.20-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	9.84+00	9.77+00	9.09+00	4.44+00	3.42-03	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	3.10-01	2.92-01	1.74-01	9.61-04	2.57-26	0.00	0.00	0.00	0.00	0.00	0.00
GD153	0.00	9.13-04	3.21-04	2.62-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	1.17+01	1.12+01	7.56+00	1.53-01	1.80-18	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	4.20+01	2.86+01	9.13-01	9.89-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	1.26+01	5.91-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	1.02+01	3.04-01	5.78-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	8.23-06	4.11-06	8.05-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	3.26-05	1.63-05	3.19-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	3.95+04	1.14+04	8.64+02	9.97+01	4.45-02	3.90-02	2.36-02	1.27-03	9.09-05	4.48-07	9.53-09
TOTAL	0.00	3.96+04	1.14+04	8.64+02	9.97+01	4.45-02	3.90-02	2.36-02	1.27-03	9.09-05	4.48-07	9.53-09

A1 FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	5.25+09	4.96+09	2.99+09	1.87+07	1.78-15	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	1.48+08	1.46+08	1.46+08	1.47+08	1.46+08	1.33+08	5.08+07	3.46+03	0.00	0.00	0.00
KR 85	0.00	2.82+10	2.65+10	1.48+10	4.61+07	3.83-18	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	7.40+10	9.79+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	7.41+03	7.41+03	7.41+03	7.41+03	7.41+03	7.41+03	7.41+03	7.41+03	7.41+03	7.40+03	7.31+03
SR 89	0.00	8.46+14	6.52+12	6.15-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	1.57+15	1.54+15	1.23+15	1.34+14	3.07+04	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	1.58+13	1.54+13	1.23+13	1.34+12	3.07+02	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	4.20+14	5.67+12	8.48-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	3.92+08	3.92+08	3.92+08	3.91+08	3.91+08	3.90+08	3.74+08	2.47+08	3.86+06	3.38-12	0.00
NB 93M	0.00	2.55+07	4.37+07	1.72+08	3.89+08	3.91+08	3.90+08	3.74+08	2.47+08	3.86+06	3.38-12	0.00
ZR 95	0.00	8.54+14	1.74+13	1.05-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	-1.81+04	-3.69+02	-2.22-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	4.71+14	1.28+13	7.41-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	8.21+09	8.21+09	8.21+09	8.21+09	8.16+09	7.95+09	5.92+09	3.12+08	5.22-05	0.00	0.00
RU103	0.00	1.70+14	2.84+11	2.96-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	2.55+11	4.27+08	4.44-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	5.75+15	2.88+15	5.81+12	6.41-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	-1.15+06	-5.77+05	-1.16+03	-1.28-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	1.33+06	1.33+06	1.33+06	1.33+06	1.33+06	1.33+06	1.32+06	1.21+06	4.94+05	6.68+01	0.00
AG109M	0.00	-1.96-05	-1.12-05	-7.35-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	9.81+03	5.61+03	3.67+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	2.62+12	9.63+11	1.18+08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	-1.02+02	-3.75+01	-4.61-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	-9.31+01	-8.86+01	-5.67+01	-6.59-01	-2.96-20	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	7.05+08	4.46+06	7.29-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	-4.76-01	-3.01-03	-4.93-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	5.62+11	1.62+09	1.59-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN117M	0.00	-1.65-01	-2.32-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	-1.56+02	-5.65+01	-6.24-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	-7.87-03	-7.80-03	-7.18-03	-3.16-03	-8.63-07	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	-1.13+04	-1.49+03	-1.81-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	-2.19+00	-2.52-01	-8.83-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	6.37+11	9.38+09	3.04-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN125	0.00	2.66+10	5.37-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	2.72+13	2.10+13	2.09+12	1.94+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	2.38+12	1.96+12	1.95+11	1.81+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	6.98+08	6.96+08	6.97+08	6.97+08	6.93+08	6.51+08	3.49+08	6.82+05	0.00	0.00	0.00
SB126M	0.00	-1.40+00	-1.40+00	-1.39+00	-1.39+00	-1.39+00	-1.30+00	-6.98-01	-1.36-03	0.00	0.00	0.00
SB126	0.00	-3.92+01	-1.38+00	-1.38+00	-1.38+00	-1.37+00	-1.29+00	-6.91-01	-1.35-03	0.00	0.00	0.00

A1 FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE127M	0.00	2.02+13	1.98+12	1.66+03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	6.67+11	6.54+10	5.48+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129M	0.00	2.56+13	1.50+10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	1.64+11	9.60+07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	1.95+09	1.96+09	1.96+09	1.96+09	1.96+09	1.96+09	1.95+09	1.88+09	1.30+09	3.32+07	3.87-09
I131	0.00	2.30+13	5.10-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XE131M	0.00	1.20+09	6.29-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	6.39+13	4.55+13	2.17+12	1.33-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	4.21+08	4.21+08	4.21+08	4.21+08	4.21+08	4.20+08	4.11+08	3.34+08	4.18+07	3.91-02	0.00
CS136	0.00	1.76+11	6.15+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS137	0.00	2.51+14	2.45+14	1.99+14	2.49+13	2.33+04	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	-1.17+05	-1.15+05	-9.32+04	-1.17+04	-1.09-05	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	1.65+13	4.26+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	4.74+12	1.22+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	5.35+13	2.16+10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	3.68+12	3.48+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	5.05+15	2.07+15	6.80+11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	-1.01+06	-4.14+05	-1.36+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	4.11+11	5.13+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	1.65+14	1.26+14	1.17+13	5.36+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	-1.19+04	-2.87+01	-7.98-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	-9.55+02	-2.30+00	-6.41-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	2.82+12	2.80+12	2.61+12	1.27+12	9.81+08	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	4.32+10	4.08+10	2.43+10	1.34+08	3.59-15	0.00	0.00	0.00	0.00	0.00	0.00
GD153	0.00	2.11+08	7.43+07	6.06+03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	1.42+13	1.36+13	9.21+12	1.87+11	2.20-06	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	1.66+13	1.13+13	3.62+11	3.92-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	-1.27+03	-5.94-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	1.20+12	3.58+10	6.80-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB161	0.00	-6.78-01	-7.94-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	-2.42-03	-1.21-03	-2.37-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	-2.42-03	-1.21-03	-2.37-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	1.58+16	7.02+15	1.48+15	1.61+14	1.32+10	1.19+10	9.43+09	3.02+09	1.35+09	3.32+07	7.31+03
TOTAL	0.00	1.58+16	7.02+15	1.48+15	1.61+14	1.32+10	1.19+10	9.43+09	3.02+09	1.35+09	3.32+07	7.31+03

AI FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	3.50+05	3.31+05	1.99+05	1.25+03	1.19-19	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	1.48+02	1.46+02	1.46+02	1.47+02	1.46+02	1.33+02	5.08+01	3.46-03	0.00	0.00	0.00
KR 85	0.00	-8.46+03	-7.94+03	-4.45+03	-1.38+01	-1.15-24	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	7.40+06	9.79+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	1.48-01	1.48-01	1.48-01	1.48-01	1.48-01	1.48-01	1.48-01	1.48-01	1.48-01	1.48-01	1.48-01
SR 89	0.00	8.48+10	6.52+08	6.15-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	1.57+11	1.54+11	1.23+11	1.34+10	3.07+00	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	2.36+09	2.30+09	1.85+09	2.01+08	4.60-02	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	1.40+10	1.89+08	2.83-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	1.96+03	1.96+03	1.96+03	1.96+03	1.96+03	1.95+03	1.87+03	1.23+03	1.93+01	1.69-17	0.00
NB 93M	0.00	2.55+02	4.37+02	1.72+03	3.89+03	3.91+03	3.90+03	3.74+03	2.47+03	3.86+01	3.38-17	0.00
ZR 95	0.00	1.42+10	2.90+08	1.74-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	-1.81+04	-3.69+02	-2.22-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	1.41+10	3.83+08	2.22-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	5.21+04	8.21+04	8.21+04	8.21+04	8.18+04	7.95+04	5.92+04	3.12+03	5.22-10	0.00	0.00
RU103	0.00	6.36+09	1.07+07	1.11-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	5.09+07	8.54+04	8.88-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	1.15+11	5.77+10	1.16+08	1.28-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	-1.15+06	-5.77+05	-1.16+03	-1.28-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	2.66+02	2.66+02	2.66+02	2.66+02	2.66+02	2.66+02	2.64+02	2.41+02	9.89+01	1.34-02	0.00
AG109M	0.00	-1.96-05	-1.12-05	-7.35-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	9.81-02	5.61-02	3.67-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	2.62+07	9.63+06	1.18+03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	-1.02+02	-3.75+01	-4.61-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG111	0.00	9.03+05	1.99-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	-9.31+01	-8.86+01	-5.67+01	-6.59-01	-2.96-20	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	2.47+04	1.56+02	2.55-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	-4.76-01	-3.01-03	-4.93-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	1.94+07	5.39+04	5.29-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN117M	0.00	-1.65-01	-2.32-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	-1.56+02	-5.65+01	-6.24-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	-7.87-03	-7.80-03	-7.18-03	-3.16-03	-8.63-07	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	-1.13+04	-1.49+03	-1.81-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	-2.19+00	-2.52-01	-8.83-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	2.23+07	3.28+05	1.07-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN125	0.00	3.98+06	8.05-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	2.45+08	1.89+08	1.88+07	1.75-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	9.54+07	7.84+07	7.79+06	7.24-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	3.49+03	3.49+03	3.49+03	3.49+03	3.46+03	3.25+03	1.74+03	3.41+00	0.00	0.00	0.00
SB126M	0.00	-1.40+00	-1.40+00	-1.39+00	-1.39+00	-1.39+00	-1.30+00	-6.98-01	-1.36-03	0.00	0.00	0.00

AI FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 49.27 MW, BURNUP = 37112.MWD, FLUX= 2.32+15N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
SB126	0.00	-3.92+01	-1.38+00	-1.38+00	-1.38+00	-1.37+00	-1.29+00	-6.91-01	-1.35-03	0.00	0.00	0.00
TE127M	0.00	4.05+08	3.97+07	3.33-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	1.00+09	9.81+06	8.22-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129M	0.00	1.28+09	7.49+05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	2.05+07	1.20+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	6.50+05	6.53+05	6.53+05	6.53+05	6.53+05	6.52+05	6.50+05	6.27+05	4.34+05	1.11+04	1.29-12
I131	0.00	7.68+09	1.70-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XE131M	0.00	-4.81+02	-2.52-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XE133	0.00	-2.08+01	-2.88-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	2.84+09	2.02+09	9.66+07	5.91-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	1.26+04	1.26+04	1.26+04	1.26+04	1.26+04	1.26+04	1.23+04	1.00+04	1.25+03	1.17-06	0.00
CS136	0.00	1.76+07	6.15-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS137	0.00	6.28+09	6.14+09	4.98+09	6.23+08	5.83-01	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	-1.17+05	-1.15+05	-9.32+04	-1.17+04	-1.09-05	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	8.24+08	2.13+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	9.48+08	2.45+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	2.97+09	1.20+06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	4.41+08	4.18+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	1.01+11	4.14+10	1.36+07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	-1.01+06	-4.14+05	-1.36+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	5.48+07	6.84-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	1.65+09	1.26+09	1.17+08	5.36-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	-1.19+04	-2.87+01	-7.98-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	-9.55+02	-2.30+00	-6.41-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	1.41+07	1.40+07	1.30+07	6.37+06	4.90+03	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	2.16+05	2.04+05	1.21+05	6.71+02	1.80-20	0.00	0.00	0.00	0.00	0.00	0.00
GD153	0.00	3.17+03	1.11+03	9.09-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	7.10+07	6.80+07	4.61+07	9.34+05	1.10-11	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	2.50+08	1.70+08	5.42+06	5.88-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	-1.27+03	-5.94-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	3.00+07	8.96+05	1.70-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB161	0.00	-6.78-01	-7.94-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	-2.42-03	-1.21-03	-2.37-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	-2.42-03	-1.21-03	-2.37-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	5.36+11	2.67+11	1.30+11	1.42+10	7.62+05	7.54+05	7.29+05	6.44+05	4.36+05	1.11+04	1.46-01
TOTAL	0.00	5.36+11	2.67+11	1.30+11	1.42+10	7.62+05	7.54+05	7.29+05	6.44+05	4.36+05	1.11+04	1.46-01

APPENDIX 2.G

GE LMFBR PLANT WASTE

(Power 49 MW/MT, Burnup 41,493 MWD/MT,
Spent Fuel Processed 90 Days After
Discharge with 0.5% Fuel Loss to Waste)

GE LMFBR PLANT WASTE

Summary Tables

THERMAL POWER

WATTS PER METRIC TON OF FUEL

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	8.31E+03	1.14E+03	2.18E+01	1.88E-02	9.21E-04	2.13E-05	7.37E-35	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00
STRONTIUM	1.29E+03	3.81E+02	2.99E+02	3.25E+01	1.69E-03	7.46E-09	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00
CESIUM	1.19E+03	1.04E+03	6.09E+02	7.44E+01	7.95E-03	6.78E-04	6.76E-04	6.62E-04	5.38E-04	6.74E-05	6.39E-14	.00E+00
SR+CS	2.48E+03	1.42E+03	9.09E+02	1.07E+02	9.64E-03	6.78E-04	6.76E-04	6.62E-04	5.38E-04	6.74E-05	6.39E-14	.00E+00
FP-SR-CS	3.49E+04	1.05E+04	6.55E+01	5.08E+00	2.15E-01	1.81E-02	1.39E-02	9.98E-03	6.59E-04	2.96E-05	4.74E-07	5.94E-23
KR85+I129	1.52E+01	1.43E+01	8.03E+00	2.53E-02	2.76E-05	2.76E-05	2.76E-05	2.75E-05	2.65E-05	1.84E-05	4.73E-07	5.94E-23
FISSION PROD.	3.74E+04	1.20E+04	9.74E+02	1.12E+02	2.24E-01	1.88E-02	1.45E-02	1.06E-02	1.20E-03	9.70E-05	4.74E-07	5.94E-23
U+TH WASTE	1.93E-03	1.93E-03	1.93E-03	1.93E-03	1.92E-03	1.92E-03	1.88E-03	1.55E-03	4.86E-04	3.90E-04	3.76E-04	3.26E-04
PU FUEL WASTE	7.87E+00	7.94E+00	8.35E+00	8.22E+00	6.42E+00	5.67E+00	2.31E+00	4.89E-02	1.55E-02	1.00E-02	8.30E-04	4.51E-05
TRANS PU	3.06E+03	7.69E+02	1.31E+02	6.71E+01	3.24E+01	1.56E+01	1.33E+00	2.35E-01	1.25E-01	6.74E-03	1.16E-04	4.71E-05
TOTAL WASTE	4.87E+04	1.39E+04	1.14E+03	1.87E+02	3.90E+01	2.13E+01	3.65E+00	2.96E-01	1.42E-01	1.73E-02	1.32E-03	4.18E-04

RADIOACTIVITY

CURIES PER METRIC TON OF FUEL
(PARENTS AND DAUGHTERS IN CHAINS ARE INCLUDED IN TOTALS)

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	7.31E+05	2.37E+05	1.23E+04	1.25E+02	1.36E+01	7.95E+00	7.23E+00	3.31E+00	1.35E-03	1.71E-37	.00E+00	.00E+00
STRONTIUM	3.59E+05	1.06E+05	8.31E+04	9.03E+03	4.69E-01	2.07E-06	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00	.00E+00
CESIUM	3.23E+05	3.05E+05	2.25E+05	2.80E+04	4.13E+00	1.39E+00	1.39E+00	1.36E+00	1.11E+00	1.39E-01	1.32E-10	.00E+00
SR+CS	6.83E+05	4.11E+05	3.08E+05	3.71E+04	4.60E+00	1.39E+00	1.39E+00	1.36E+00	1.11E+00	1.39E-01	1.32E-10	.00E+00
FP-SR-CS	8.17E+06	2.46E+06	4.40E+04	2.82E+03	1.37E+02	2.45E+01	2.16E+01	1.60E+01	2.09E+00	1.52E-01	7.33E-04	9.03E-20
KR85+I129	9.37E+03	8.79E+03	4.94E+03	1.56E+01	4.20E-02	4.20E-02	4.20E-02	4.18E-02	4.03E-02	2.80E-02	7.19E-04	9.03E-20
FISSION PROD.	8.85E+06	2.87E+06	3.52E+05	3.99E+04	1.42E+02	2.59E+01	2.30E+01	1.74E+01	3.20E+00	2.91E-01	7.33E-04	9.03E-20
U+TH WASTE	1.18E-01	1.19E-01	1.20E-01	1.18E-01	1.17E-01	1.17E-01	1.15E-01	9.47E-02	3.10E-02	2.53E-02	2.47E-02	2.14E-02
PU FUEL WASTE	1.65E+03	1.58E+03	1.10E+03	1.66E+02	8.28E+01	5.36E+01	1.87E+01	1.27E+00	1.28E-01	1.58E-02	6.85E-03	2.74E-03
TRANS PU	8.56E+04	2.34E+04	6.00E+03	3.82E+03	1.88E+03	8.71E+02	4.38E+01	1.20E+01	6.86E+00	3.70E-01	6.97E-03	2.86E-03
TOTAL WASTE	9.67E+06	3.13E+06	3.72E+05	4.40E+04	2.12E+03	9.59E+02	9.28E+01	3.41E+01	1.02E+01	7.03E-01	3.92E-02	2.70E-02

INGESTION TOXICITY

THE INGESTION TOXICITY INDEX IS THE BASE 10 LOGARITHM OF THE
CUBIC METERS OF WATER PER TON OF FUEL TO DILUTE TO RCG

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	9.80	8.50	7.33	6.60	5.36	4.59	4.56	4.22	.83	*****	*****	*****
STRONTIUM	11.42	11.24	11.14	10.18	5.89	.54	*****	*****	*****	*****	*****	*****
CESIUM	10.07	10.01	9.76	8.85	4.92	4.14	4.14	4.13	4.04	3.14	-5.88	*****
SR+CS	11.44	11.26	11.16	10.20	5.94	4.14	4.14	4.13	4.04	3.14	-5.88	*****
FP-SR-CS	11.41	11.02	8.56	6.96	6.04	5.91	5.90	5.89	5.83	5.67	4.08	*****
KR85+I129	5.85	5.85	5.85	5.85	5.85	5.85	5.85	5.84	5.83	5.67	4.08	*****
FISSION PROD.	11.73	11.46	11.16	10.20	6.29	5.91	5.91	5.90	5.84	5.67	4.08	*****
U+TH FUEL WASTE	5.54	5.54	5.54	5.54	5.54	5.54	5.53	5.44	4.91	4.80	4.80	4.74
PU FUEL WASTE	7.42	7.43	7.44	7.38	7.14	7.00	6.66	5.96	4.88	3.43	3.20	2.82
TRANS PU	9.68	9.25	8.92	8.72	8.40	8.09	7.19	6.83	6.23	4.86	3.22	2.84
TOTAL WASTE	11.74	11.46	11.16	10.21	8.43	8.13	7.33	6.94	6.40	5.78	4.89	4.75

***** TOXICITY INDEX IS LESS THAN -10
RCG IS RADIONUCLIDE CONCENTRATION GUIDE BASED UPON 10 CFR 20

INHALATION TOXICITY

THE INHALATION TOXICITY INDEX IS THE BASE 10 LOGARITHM OF THE
CUBIC METERS OF AIR TO DILUTE TO RCG PER METRIC TON OF FUEL

TIME, YEARS AFTER YR 2000	0	1	10	100	500	1000	1.00E+04	1.00E+05	1.00E+06	1.00E+07	1.00E+08	1.00E+09
CLADDING	14.61	13.13	12.16	10.77	9.52	8.59	8.56	8.22	4.83	*****	*****	*****
STRONTIUM	15.42	15.24	15.14	14.18	9.89	4.54	*****	*****	*****	*****	*****	*****
CESIUM	14.59	14.54	14.36	13.45	9.51	8.67	8.67	8.66	8.57	7.66	-1.36	*****
SR+CS	15.48	15.32	15.21	14.25	10.04	8.67	8.67	8.66	8.57	7.66	-1.36	*****
FP-SR-CS	16.11	15.73	13.57	12.22	10.85	10.15	10.10	10.00	9.47	9.15	7.56	-8.35
KR85+I129	10.52	10.50	10.27	9.33	9.32	9.32	9.32	9.32	9.30	9.15	7.56	-8.35
FISSION PROD.	16.20	15.87	15.22	14.26	10.91	10.16	10.12	10.02	9.52	9.16	7.56	-8.35
U+TH FUEL WASTE	11.04	11.04	11.04	11.04	11.04	11.04	11.03	10.94	10.42	10.32	10.31	10.24
PU FUEL WASTE	15.29	15.28	15.25	15.07	14.83	14.76	14.49	13.23	11.45	10.45	10.28	9.90
TRANS PU	16.58	16.43	16.33	16.09	15.70	15.38	14.51	13.76	13.37	12.11	10.30	9.92
TOTAL WASTE	16.75	16.56	16.39	16.14	15.76	15.47	14.80	13.87	13.38	12.13	10.78	10.53

***** TOXICITY INDEX IS LESS THAN -10
RCG IS RADIONUCLIDE CONCENTRATION GUIDE BASED UPON 10 CFR 20

GE LMFBR PLANT WASTE

Actinides

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
HE 4	0.00	2.00+00	2.34+00	2.74+00	4.74+00	1.24+01	1.92+01	3.10+01	5.94+01	1.40+02	1.60+02	2.73+02
TL208	0.00	2.15-11	1.53-11	1.22-12	3.20-13	5.54-17	1.73-18	3.88-17	4.04-16	3.57-15	1.34-14	1.36-14
PB207	0.00	3.56-11	9.79-11	2.18-09	8.72-08	1.25-06	4.05-05	1.62-02	4.68-01	5.04+00	4.86+01	3.26+02
PB208	0.00	7.30-06	1.33-05	2.77-05	4.31-05	5.39-05	5.40-05	5.45-05	1.20-04	6.17-03	3.12-01	4.38+00
PB210	0.00	1.18-11	2.58-11	4.23-10	2.05-08	4.49-06	2.11-04	1.66-03	3.17-04	1.81-05	1.78-05	1.55-05
PB212	0.00	1.25-08	8.86-09	7.09-10	1.86-10	3.22-14	1.00-15	2.25-14	2.35-13	2.08-12	7.77-12	7.87-12
BI209	0.00	5.66-09	5.75-09	6.47-09	2.02-08	9.34-06	1.26-02	4.24+00	1.74+02	7.63+02	7.96+02	7.96+02
BI212	0.00	1.19-09	8.44-10	6.76-11	1.77-11	3.07-15	9.56-17	2.14-15	2.23-14	1.98-13	7.41-13	7.50-13
RN220	0.00	1.90-11	1.35-11	1.08-12	2.83-13	4.90-17	1.53-18	3.43-17	3.57-16	3.16-15	1.18-14	1.20-14
RA223	0.00	2.04-12	4.04-12	1.79-11	5.72-11	6.68-11	4.55-10	1.69-08	2.48-08	2.45-08	2.25-08	9.34-09
RA224	0.00	1.09-07	7.72-08	6.17-09	1.62-09	2.80-13	8.73-15	1.96-13	2.04-12	1.81-11	6.77-11	6.85-11
RA225	0.00	1.02-11	4.95-12	5.08-12	1.77-11	1.89-09	2.28-07	5.54-06	1.24-05	6.35-07	1.52-19	0.00
RA226	0.00	2.78-08	4.54-08	2.06-07	2.60-06	3.69-04	1.73-02	1.36-01	2.60-02	1.48-03	1.46-03	1.27-03
AC225	0.00	1.33-11	3.34-12	3.43-12	1.19-11	1.28-09	1.54-07	3.75-06	8.40-06	4.29-07	1.03-19	0.00
AC227	0.00	1.58-09	2.84-09	1.26-08	4.03-08	4.70-08	3.20-07	1.19-05	1.74-05	1.73-05	1.58-05	6.58-06
TH227	0.00	3.39-12	6.48-12	2.86-11	9.16-11	1.07-10	7.29-10	2.70-08	3.97-08	3.93-08	3.60-08	1.50-08
TH228	0.00	2.14-05	1.50-05	1.20-06	3.16-07	5.47-11	1.70-12	3.82-11	3.98-10	3.53-09	1.32-08	1.34-08
TH229	0.00	9.07-07	9.07-07	9.32-07	3.24-06	3.47-04	4.18-02	1.02+00	2.28+00	1.16-01	2.78-14	0.00
TH230	0.00	2.07-03	2.07-03	2.13-03	4.85-03	1.07-01	1.13+00	6.92+00	1.32+00	7.53-02	7.43-02	6.47-02
TH231	0.00	5.00-09	2.50-11	2.53-11	2.80-11	5.63-11	3.86-10	2.24-09	2.40-09	2.38-09	2.18-09	9.05-10
TH232	0.00	1.17-04	1.17-04	1.19-04	1.38-04	4.58-04	1.28-02	2.87-01	2.99+00	2.65+01	9.92+01	1.00+02
TH234	0.00	1.26-05	6.34-08	6.31-08	6.31-08	6.31-08	6.31-08	6.31-08	6.33-08	6.32-08	6.23-08	5.43-08
PA231	0.00	6.38-05	6.38-05	6.39-05	6.43-05	7.20-05	4.91-04	1.82-02	2.67-02	2.65-02	2.42-02	1.01-02
PA233	0.00	1.08-05	1.09-05	1.12-05	1.38-05	2.69-05	3.09-05	3.00-05	2.25-05	1.22-06	2.68-19	0.00
PA234M	0.00	4.26-10	2.14-12	2.13-12	2.13-12	2.13-12	2.13-12	2.13-12	2.13-12	2.13-12	2.10-12	1.83-12
U232	0.00	1.12-05	1.52-05	2.63-05	1.18-05	2.04-09	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	9.46-05	2.06-04	1.12-03	1.15-02	1.93-01	2.71+00	2.29+01	5.14+01	2.63+00	6.26-13	0.00
U234	2.91+02	1.29+00	1.41+00	3.24+00	1.76+01	4.35+01	4.27+01	3.32+01	2.88+00	2.37-01	2.33-01	2.03-01
U235	1.89+03	6.18+00	6.19+00	6.26+00	6.93+00	1.39+01	9.56+01	5.55+02	5.93+02	5.88+02	5.39+02	2.24+02
U236	1.47+03	7.07+00	7.07+00	7.15+00	8.02+00	1.68+01	7.12+01	1.07+02	1.04+02	8.02+01	5.90+00	2.74-11
U237	0.00	2.25-06	4.50-07	2.96-07	4.40-09	2.47-11	1.27-11	1.57-14	0.00	0.00	0.00	0.00
U238	9.35+05	4.39+03	4.39+03	4.39+03	4.39+03	4.39+03	4.39+03	4.39+03	4.40+03	4.39+03	4.33+03	3.77+03
NP237	0.00	3.14+02	3.15+02	3.24+02	4.01+02	7.81+02	8.97+02	8.72+02	6.51+02	3.53+01	7.78-12	0.00
NP239	0.00	2.34-04	2.34-04	2.34-04	2.32-04	2.14-04	9.46-05	2.72-08	7.26-14	5.00-14	1.19-15	0.00
PU236	6.35-03	1.92-05	1.51-05	1.69-06	5.29-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	1.12+03	3.54+00	2.21+01	2.59+01	1.65+01	1.15-01	4.23-32	0.00	0.00	0.00	0.00	0.00
PU239	3.64+04	2.66+02	2.66+02	2.67+02	2.70+02	2.85+02	3.44+02	3.93+01	2.76-07	1.90-07	4.53-09	0.00
PU240	1.47+04	7.74+01	7.83+01	8.51+01	1.00+02	9.19+01	3.65+01	3.59-03	0.00	0.00	0.00	0.00
PU241	6.50+03	1.54+01	1.47+01	9.62+00	1.43-01	8.05-04	4.12-04	5.12-07	4.43-36	0.00	0.00	0.00
PU242	2.36+03	1.18+01	1.18+01	1.20+01	1.32+01	1.54+01	1.52+01	1.29+01	2.49+00	1.77-07	0.00	0.00

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
AM241	3.32+02	5.80+02	5.80+02	5.76+02	5.08+02	1.20+02	1.21-02	1.50-05	0.00	0.00	0.00	0.00
AM242M	0.00	2.02+01	2.01+01	1.93+01	1.28+01	2.11-01	3.19-19	0.00	0.00	0.00	0.00	0.00
AM242	0.00	2.42-04	2.41-04	2.31-04	1.53-04	2.53-06	3.83-24	0.00	0.00	0.00	0.00	0.00
AM243	0.00	2.83+02	2.83+02	2.83+02	2.80+02	2.58+02	1.14+02	3.29-02	8.78-08	6.04-08	1.44-09	0.00
CM242	0.00	2.41+01	5.13+00	4.69-02	3.08-02	5.08-04	0.00	0.00	0.00	0.00	0.00	0.00
CM243	0.00	2.93+00	2.87+00	2.36+00	3.36-01	1.15-09	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	2.47+01	2.38+01	1.69+01	5.38-01	5.83-16	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	5.55-01	5.54-01	5.54-01	5.50-01	5.15-01	2.64-01	3.27-04	2.83-33	0.00	0.00	0.00
CM246	0.00	1.47-02	1.47-02	1.47-02	1.45-02	1.30-02	4.16-03	4.74-08	0.00	0.00	0.00	0.00
CM247	0.00	2.03-04	2.03-04	2.03-04	2.03-04	2.03-04	2.03-04	2.02-04	1.95-04	1.34-04	3.20-06	1.93-22
SUBTOT	1.00+06	6.03+03	6.03+03	6.03+03	6.03+03	6.03+03	6.03+03	6.07+03	6.04+03	6.04+03	5.98+03	5.50+03
TOTAL	1.00+06	6.03+03	6.03+03	6.03+03	6.03+03	6.03+03	6.03+03	6.08+03	6.08+03	6.08+03	6.08+03	6.08+03

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	1.04-07	2.07-07	9.16-07	2.93-06	3.42-06	2.33-05	8.65-04	1.27-03	1.26-03	1.15-03	4.78-04
TL208	0.00	6.26-03	4.45-03	3.56-04	9.34-05	1.62-08	5.04-10	1.13-08	1.18-07	1.04-06	3.90-06	3.95-06
TL209	0.00	1.70-08	4.27-09	4.39-09	1.53-08	1.63-06	1.97-04	4.78-03	1.07-02	5.48-04	1.31-16	0.00
PB209	0.00	7.72-07	1.94-07	1.99-07	6.93-07	7.43-05	6.95-03	2.17-01	4.88-01	2.49-02	5.95-15	0.00
PB210	0.00	9.54-10	2.10-09	3.43-08	1.66-06	3.64-04	1.71-02	1.35-01	2.57-02	1.46-03	1.44-03	1.26-03
PB211	0.00	1.05-07	2.08-07	9.19-07	2.94-06	3.43-06	2.34-05	8.67-04	1.27-03	1.26-03	1.15-03	4.80-04
PB212	0.00	1.74-02	1.24-02	9.89-04	2.59-04	4.49-08	1.40-09	3.14-08	3.27-07	2.90-06	1.08-05	1.10-05
PB214	0.00	2.73-08	4.49-08	2.03-07	2.58-06	3.64-04	1.71-02	1.35-01	2.57-02	1.46-03	1.44-03	1.26-03
BI210	0.00	9.37-10	2.10-09	3.43-08	1.66-06	3.64-04	1.71-02	1.35-01	2.57-02	1.46-03	1.44-03	1.26-03
BI211	0.00	1.05-07	2.08-07	9.19-07	2.94-06	3.43-06	2.34-05	8.67-04	1.27-03	1.26-03	1.15-03	4.80-04
BI212	0.00	1.74-02	1.24-02	9.89-04	2.59-04	4.49-08	1.40-09	3.14-08	3.27-07	2.90-06	1.08-05	1.10-05
BI213	0.00	7.72-07	1.94-07	1.99-07	6.93-07	7.43-05	8.95-03	2.17-01	4.88-01	2.49-02	5.95-15	0.00
BI214	0.00	2.73-08	4.49-08	2.03-07	2.58-06	3.64-04	1.71-02	1.35-01	2.57-02	1.46-03	1.44-03	1.26-03
PO210	0.00	6.04-10	1.46-09	3.43-08	1.66-06	3.64-04	1.71-02	1.35-01	2.57-02	1.46-03	1.44-03	1.26-03
PO211	0.00	3.14-10	6.23-10	2.76-09	8.82-09	1.03-08	7.01-08	2.60-06	3.82-06	3.78-06	3.46-06	1.44-06
PO212	0.00	1.11-02	7.91-03	6.33-04	1.66-04	2.67-08	8.95-10	2.01-08	2.09-07	1.85-06	6.94-06	7.03-06
PO213	0.00	7.55-07	1.90-07	1.95-07	6.78-07	7.27-05	8.75-03	2.13-01	4.77-01	2.44-02	5.82-15	0.00
PO214	0.00	2.73-08	4.49-08	2.03-07	2.58-06	3.64-04	1.71-02	1.35-01	2.57-02	1.46-03	1.44-03	1.26-03
PO215	0.00	1.05-07	2.08-07	9.19-07	2.94-06	3.43-06	2.34-05	8.67-04	1.27-03	1.26-03	1.15-03	4.80-04
PO216	0.00	1.74-02	1.24-02	9.89-04	2.59-04	4.49-08	1.40-09	3.14-08	3.27-07	2.90-06	1.08-05	1.10-05
PO218	0.00	2.73-08	4.49-08	2.03-07	2.58-06	3.64-04	1.71-02	1.35-01	2.57-02	1.46-03	1.44-03	1.26-03
AT217	0.00	7.72-07	1.94-07	1.99-07	6.93-07	7.43-05	8.95-03	2.17-01	4.88-01	2.49-02	5.95-15	0.00
RN219	0.00	1.05-07	2.08-07	9.19-07	2.94-06	3.43-06	2.34-05	8.67-04	1.27-03	1.26-03	1.15-03	4.80-04
RN220	0.00	1.74-02	1.24-02	9.89-04	2.59-04	4.49-08	1.40-09	3.14-08	3.27-07	2.90-06	1.08-05	1.10-05
RN222	0.00	2.73-08	4.49-08	2.03-07	2.58-06	3.64-04	1.71-02	1.35-01	2.57-02	1.46-03	1.44-03	1.26-03
FR221	0.00	7.72-07	1.94-07	1.99-07	6.93-07	7.43-05	8.95-03	2.17-01	4.88-01	2.49-02	5.95-15	0.00
FR223	0.00	1.61-09	2.90-09	1.29-08	4.11-08	4.00-08	3.27-07	1.21-05	1.78-05	1.77-05	1.62-05	6.72-06
RA223	0.00	1.05-07	2.08-07	9.19-07	2.94-06	3.43-06	2.34-05	8.67-04	1.27-03	1.26-03	1.15-03	4.80-04
RA224	0.00	1.74-02	1.24-02	9.89-04	2.59-04	4.49-08	1.40-09	3.14-08	3.27-07	2.90-06	1.08-05	1.10-05
RA225	0.00	3.99-07	1.94-07	1.99-07	6.93-07	7.43-05	8.95-03	2.17-01	4.88-01	2.49-02	5.95-15	0.00
RA226	0.00	2.75-08	4.49-08	2.03-07	2.58-06	3.64-04	1.71-02	1.35-01	2.57-02	1.46-03	1.44-03	1.26-03
AC225	0.00	7.71-07	1.94-07	1.99-07	6.93-07	7.43-05	8.95-03	2.17-01	4.88-01	2.49-02	5.95-15	0.00
AC227	0.00	1.15-07	2.07-07	9.18-07	2.94-06	3.43-06	2.34-05	8.67-04	1.27-03	1.26-03	1.15-03	4.80-04
TH227	0.00	1.07-07	2.05-07	9.06-07	2.90-06	3.38-06	2.30-05	8.55-04	1.25-03	1.24-03	1.14-03	4.73-04
TH228	0.00	1.76-02	1.23-02	9.87-04	2.59-04	4.49-08	1.40-09	3.14-08	3.27-07	2.90-06	1.08-05	1.10-05
TH229	0.00	1.94-07	1.94-07	1.99-07	6.93-07	7.43-05	8.95-03	2.17-01	4.88-01	2.49-02	5.95-15	0.00
TH230	0.00	4.02-05	4.03-05	4.14-05	9.43-05	2.08-03	2.20-02	1.35-01	2.57-02	1.46-03	1.44-03	1.26-03
TH231	0.00	2.65-03	1.33-05	1.34-05	1.49-05	2.98-05	2.05-04	1.19-03	1.27-03	1.26-03	1.15-03	4.80-04
TH232	0.00	1.27-11	1.28-11	1.30-11	1.51-11	5.00-11	1.40-09	3.14-08	3.27-07	2.90-06	1.08-05	1.10-05
TH234	0.00	2.92-01	1.47-03	1.46-03	1.46-03	1.46-03	1.46-03	1.46-03	1.47-03	1.46-03	1.44-03	1.26-03

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
PA231	0.00	3.04-06	3.04-06	3.04-06	3.06-06	3.43-06	2.34-05	8.67-04	1.27-03	1.26-03	1.15-03	4.80-04
PA233	0.00	2.22-01	2.22-01	2.28-01	2.82-01	5.51-01	6.33-01	6.15-01	4.59-01	2.49-02	5.48-15	0.00
PA234M	0.00	2.92-01	1.47-03	1.46-03	1.46-03	1.46-03	1.46-03	1.46-03	1.47-03	1.46-03	1.44-03	1.26-03
PA234	0.00	2.92-04	1.47-06	1.46-06	1.46-06	1.46-06	1.46-06	1.46-06	1.47-06	1.46-06	1.44-06	1.26-06
U232	0.00	2.40-04	3.25-04	5.63-04	2.52-04	4.37-08	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	8.96-07	1.95-06	1.06-05	1.09-04	1.83-03	2.57-02	2.17-01	4.87-01	2.49-02	5.93-15	0.00
U234	1.80+00	8.01-03	8.73-03	2.01-02	1.09-01	2.69-01	2.64-01	2.06-01	1.78-02	1.46-03	1.44-03	1.26-03
U235	4.04-03	1.33-05	1.33-05	1.34-05	1.49-05	2.98-05	2.05-04	1.19-03	1.27-03	1.26-03	1.15-03	4.80-04
U236	9.31-02	4.48-04	4.49-04	4.53-04	5.09-04	1.06-03	4.51-03	6.77-03	6.60-03	5.08-03	3.74-04	1.74-15
U237	0.00	1.84-01	3.68-02	2.41-02	3.59-04	2.02-06	1.03-06	1.28-09	0.00	0.00	0.00	0.00
U238	3.12-01	1.46-03	1.46-03	1.46-03	1.46-03	1.46-03	1.46-03	1.46-03	1.47-03	1.46-03	1.44-03	1.26-03
NP237	0.00	2.22-01	2.22-01	2.28-01	2.82-01	5.51-01	6.33-01	6.15-01	4.59-01	2.49-02	5.48-15	0.00
NP239	0.00	5.44+01	5.44+01	5.44+01	5.39+01	4.97+01	2.20+01	6.33-03	1.69-08	1.16-08	2.78-10	0.00
PU236	3.38+00	1.02-02	8.00-03	8.97-04	2.81-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	1.89+04	5.98+01	3.74+02	4.38+02	2.79+02	1.94+00	0.00	0.00	0.00	0.00	0.00	0.00
PU239	2.23+03	1.63+01	1.63+01	1.63+01	1.66+01	1.75+01	2.11+01	2.41+00	1.69-08	1.16-08	2.78-10	0.00
PU240	3.24+03	1.71+01	1.73+01	1.88+01	2.21+01	2.03+01	8.05+00	7.92-04	0.00	0.00	0.00	0.00
PU241	6.51+05	1.54+03	1.47+03	9.64+02	1.43+01	8.08-02	4.14-02	5.13-05	0.00	0.00	0.00	0.00
PU242	9.19+00	4.61-02	4.62-02	4.68-02	5.13-02	6.00-02	5.92-02	5.03-02	9.69-03	6.91-10	0.00	0.00
PU243	0.00	8.80-11	1.76-08	1.76-08	1.76-08	1.76-08	1.76-08	1.75-08	1.69-08	1.16-08	2.78-10	0.00
AM241	1.14+03	1.99+03	1.99+03	1.98+03	1.74+03	4.12+02	4.16-02	5.13-05	0.00	0.00	0.00	0.00
AM242M	0.00	1.96+02	1.95+02	1.87+02	1.24+02	2.05+00	3.10-18	0.00	0.00	0.00	0.00	0.00
AM242	0.00	1.96+02	1.95+02	1.87+02	1.24+02	2.05+00	3.10-18	0.00	0.00	0.00	0.00	0.00
AM243	0.00	5.44+01	5.44+01	5.44+01	5.39+01	4.97+01	2.20+01	6.33-03	1.69-08	1.16-08	2.78-10	0.00
CM242	0.00	7.97+04	1.70+04	1.54+02	1.02+02	1.68+00	0.00	0.00	0.00	0.00	0.00	0.00
CM243	0.00	1.35+02	1.32+02	1.09+02	1.55+01	5.31-08	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	2.00+03	1.93+03	1.37+03	4.35+01	4.72-14	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	8.69-02	8.68-02	8.68-02	8.62-02	8.06-02	4.13-02	5.12-05	0.00	0.00	0.00	0.00
CM246	0.00	3.91-03	3.91-03	3.90-03	3.86-03	3.44-03	1.10-03	1.26-08	0.00	0.00	0.00	0.00
CM247	0.00	1.76-08	1.76-08	1.76-08	1.76-08	1.76-08	1.76-08	1.75-08	1.69-08	1.16-08	2.78-10	0.00
SUBTOT	6.77+05	8.60+04	2.34+04	5.53+03	2.59+03	5.59+02	7.51+01	7.24+00	5.62+00	3.14-01	3.34-02	2.30-02
TOTAL	6.77+05	8.60+04	2.34+04	5.53+03	2.59+03	5.59+02	7.51+01	7.24+00	5.62+00	3.14-01	3.34-02	2.30-02

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	3.16-10	6.26-10	2.77-09	8.86-09	1.03-08	7.05-08	2.61-06	3.83-06	3.80-06	3.48-06	1.45-06
TL208	0.00	1.46-04	1.04-04	8.29-06	2.17-06	3.76-10	1.17-11	2.63-10	2.74-09	2.43-08	9.09-08	9.20-08
TL209	0.00	2.78-10	6.98-11	7.17-11	2.49-10	2.67-08	3.22-06	7.82-05	1.75-04	8.96-06	2.14-18	0.00
PB209	0.00	8.87-10	2.23-10	2.29-10	7.97-10	8.54-08	1.03-05	2.50-04	5.61-04	2.86-05	6.85-18	0.00
PB211	0.00	3.50-10	6.94-10	3.07-09	9.82-09	1.15-08	7.81-08	2.90-06	4.25-06	4.22-06	3.86-06	1.60-06
PB212	0.00	2.49-05	1.77-05	1.42-06	3.72-07	6.44-11	2.01-12	4.50-11	4.69-10	4.15-09	1.56-08	1.58-08
PB214	0.00	6.64-11	1.09-10	4.95-10	6.27-09	8.68-07	4.16-05	3.28-04	6.27-05	3.57-06	3.52-06	3.06-06
BI210	0.00	2.47-12	5.52-12	9.04-11	4.37-09	9.59-07	4.50-05	3.55-04	6.78-05	3.85-06	3.80-06	3.31-06
BI211	0.00	4.08-09	8.09-09	3.58-08	1.14-07	1.34-07	9.10-07	3.36-05	4.95-05	4.91-05	4.50-05	1.87-05
BI212	0.00	3.02-04	2.15-04	1.72-05	4.50-06	7.80-10	2.43-11	5.45-10	5.66-09	5.03-08	1.88-07	1.91-07
BI213	0.00	4.74-09	1.19-09	1.23-09	4.20-09	4.57-07	5.50-05	1.34-03	3.06-03	1.53-04	3.66-17	0.00
BI214	0.00	3.60-10	6.26-10	2.83-09	3.59-08	5.08-06	2.38-04	1.88-03	3.59-04	2.04-05	2.01-05	1.75-05
PO210	0.00	1.98-11	4.61-11	1.08-09	5.23-08	1.15-05	5.38-04	4.24-03	8.10-04	4.61-05	4.55-05	3.96-05
PO211	0.00	1.39-11	2.75-11	1.22-10	3.97-10	4.55-10	3.10-09	1.15-07	1.69-07	1.67-07	1.53-07	6.36-08
PO212	0.00	5.90-04	4.19-04	3.35-05	8.84-06	1.52-09	4.75-11	1.07-09	1.11-08	9.82-08	3.68-07	3.72-07
PO213	0.00	3.75-06	9.43-09	7.68-09	3.37-08	3.61-06	4.35-04	1.06-02	2.37-02	1.21-03	2.89-16	0.00
PO214	0.00	1.29-09	2.05-09	9.26-09	1.17-07	1.66-05	7.79-04	6.14-03	1.17-03	6.67-05	6.58-05	5.73-05
PO215	0.00	4.59-09	9.10-09	4.02-08	1.29-07	1.50-07	1.02-06	3.60-05	5.57-05	5.52-05	5.06-05	2.10-05
PO216	0.00	7.11-04	5.06-04	4.05-05	1.20-05	1.04-09	5.72-11	1.28-09	1.34-08	1.18-07	4.44-07	4.49-07
PO218	0.00	5.86-10	1.63-09	7.37-09	9.33-08	1.32-05	6.19-04	4.88-03	9.33-04	5.30-05	5.23-05	4.56-05
AT217	0.00	3.23-06	8.19-09	8.35-09	2.91-08	3.11-06	3.75-04	9.11-03	2.04-02	1.04-03	2.49-16	0.00
RN219	0.00	4.24-09	8.41-09	3.72-08	1.19-07	1.39-07	9.46-07	3.51-05	5.15-05	5.10-05	4.67-05	1.94-05
RN220	0.00	6.59-04	4.69-04	3.75-05	9.83-06	1.70-09	5.30-11	1.19-09	1.24-08	1.10-07	4.11-07	4.16-07
RN222	0.00	8.89-10	1.46-09	6.63-09	8.39-08	1.19-05	5.57-04	4.39-03	8.39-04	4.77-05	4.71-05	4.10-05
FR221	0.00	2.87-06	7.22-09	7.42-09	2.58-08	2.76-06	3.33-04	8.09-03	1.81-02	9.27-04	2.21-16	0.00
FR223	0.00	3.77-12	6.80-12	3.01-11	9.63-11	1.12-10	7.66-10	2.84-08	4.17-08	4.13-08	3.79-08	1.57-08
RA223	0.00	3.64-09	7.22-09	3.19-08	1.02-07	1.19-07	8.12-07	3.01-05	4.42-05	4.38-05	4.01-05	1.67-05
RA224	0.00	5.95-04	4.23-04	3.38-05	8.87-06	1.54-09	4.79-11	1.07-09	1.12-08	9.91-08	3.71-07	3.76-07
RA225	0.00	2.63-10	1.28-10	1.31-10	4.56-10	4.89-08	5.89-06	1.43-04	3.21-04	1.64-05	3.92-18	0.00
RA226	0.00	7.79-10	1.27-09	5.75-09	7.29-08	1.03-05	4.84-04	3.82-03	7.29-04	4.14-05	4.09-05	3.56-05
AC225	0.00	2.65-08	6.66-09	6.84-09	2.38-08	2.55-06	3.07-04	7.46-03	1.67-02	8.55-04	2.04-16	0.00
AC227	0.00	5.80-11	1.05-10	4.63-10	1.48-09	1.73-09	1.18-08	4.37-07	6.41-07	6.35-07	5.82-07	2.42-07
TH227	0.00	3.66-09	7.05-09	3.12-08	9.97-08	1.16-07	7.93-07	2.94-05	4.32-05	4.28-05	3.92-05	1.63-05
TH228	0.00	5.75-04	4.03-04	3.23-05	8.49-06	1.47-09	4.58-11	1.03-09	1.07-08	9.48-08	3.55-07	3.60-07
TH229	0.00	5.86-09	5.67-09	6.03-09	2.10-08	2.25-06	2.71-04	6.57-03	1.47-02	7.53-04	1.80-16	0.00
TH230	0.00	1.14-06	1.14-06	1.17-06	2.66-06	5.68-05	6.21-04	3.80-03	7.28-04	4.14-05	4.08-05	3.55-05
TH231	0.00	2.09-06	1.05-08	1.06-08	1.17-08	2.35-08	1.62-07	9.38-07	1.00-06	9.94-07	9.10-07	3.78-07
TH234	0.00	1.04-04	5.23-07	5.20-07	5.20-07	5.20-07	5.20-07	5.20-07	5.21-07	5.21-07	5.14-07	4.47-07
PA231	0.00	9.28-08	9.28-08	9.29-08	9.35-08	1.05-07	7.13-07	2.65-05	3.88-05	3.85-05	3.52-05	1.46-05
PA233	0.00	3.00-04	3.01-04	3.06-04	3.82-04	7.45-04	8.55-04	8.31-04	6.21-04	3.37-05	7.41-18	0.00

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
PA234M	0.00	1.50-03	7.56-06	7.52-06	7.52-06	7.52-06	7.52-06	7.52-06	7.54-06	7.53-06	7.43-06	6.47-06
PA234	0.00	2.66-06	1.34-08	1.33-08	1.33-08	1.33-08	1.33-08	1.33-08	1.33-08	1.33-08	1.31-08	1.14-08
U232	0.00	7.71-06	1.04-05	1.81-05	8.10-06	1.40-09	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	2.61-08	5.67-08	3.09-07	3.18-06	5.33-05	7.48-04	6.31-03	1.42-02	7.25-04	1.73-16	0.00
U234	5.19-02	2.31-04	2.51-04	5.77-04	3.14-03	7.75-03	7.61-03	5.92-03	5.13-04	4.21-05	4.16-05	3.62-05
U235	1.12-04	3.68-07	3.68-07	3.72-07	4.12-07	8.28-07	5.69-06	3.30-05	3.53-05	3.50-05	3.20-05	1.33-05
U236	2.52-03	1.21-05	1.22-05	1.23-05	1.38-05	2.88-05	1.22-04	1.84-04	1.79-04	1.38-04	1.01-05	4.71-17
U237	0.00	1.22-04	2.44-05	1.60-05	2.38-07	1.34-09	6.86-10	8.52-13	0.00	0.00	0.00	0.00
U238	7.88-03	3.70-05	3.70-05	3.70-05	3.70-05	3.70-05	3.70-05	3.70-05	3.71-05	3.70-05	3.65-05	3.18-05
NP237	0.00	6.51-03	6.53-03	6.70-03	8.30-03	1.62-02	1.86-02	1.81-02	1.35-02	7.32-04	1.61-16	0.00
NP239	0.00	7.36-02	7.36-02	7.35-02	7.29-02	6.72-02	2.97-02	8.56-06	2.28-11	1.57-11	3.75-13	0.00
PU236	1.18-01	3.55-04	2.79-04	3.12-05	9.78-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	6.28+02	1.98+00	1.24+01	1.45+01	9.25+00	6.41-02	0.00	0.00	0.00	0.00	0.00	0.00
PU239	6.93+01	5.07-01	5.07-01	5.08-01	5.15-01	5.43-01	6.55-01	7.50-02	5.26-10	3.61-10	8.63-12	0.00
PU240	1.01+02	5.32-01	5.38-01	5.84-01	6.88-01	6.31-01	2.51-01	2.47-05	0.00	0.00	0.00	0.00
PU241	2.70+01	6.39-02	6.10-02	4.00-02	5.95-04	3.35-06	1.72-06	2.13-09	0.00	0.00	0.00	0.00
PU242	2.71-01	1.36-03	1.36-03	1.38-03	1.51-03	1.77-03	1.75-03	1.48-03	2.86-04	2.04-11	0.00	0.00
PU243	0.00	1.25-13	2.49-11	2.49-11	2.49-11	2.49-11	2.49-11	2.48-11	2.39-11	1.65-11	3.93-13	0.00
AM241	3.80+01	6.63+01	6.63+01	6.59+01	5.81+01	1.30+01	1.39-03	1.71-06	0.00	0.00	0.00	0.00
AM242M	0.00	5.58-02	5.55-02	5.33-02	3.53-02	5.84-04	8.83-22	0.00	0.00	0.00	0.00	0.00
AM242	0.00	2.61-01	2.60-01	2.50-01	1.66-01	2.74-03	4.14-21	0.00	0.00	0.00	0.00	0.00
AM243	0.00	1.99+00	1.99+00	1.99+00	1.97+00	1.82+00	8.03-01	2.31-04	6.17-10	4.25-10	1.01-11	0.00
CM242	0.00	2.94+03	6.26+02	5.66+00	3.75+00	6.20-02	0.00	0.00	0.00	0.00	0.00	0.00
CM243	0.00	4.96+00	4.85+00	3.99+00	5.69-01	1.95-09	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	7.01+01	6.74+01	4.78+01	1.52+00	1.65-15	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	2.71-03	2.71-03	2.71-03	2.69-03	2.52-03	1.29-03	1.60-06	0.00	0.00	0.00	0.00
CM246	0.00	1.26-04	1.28-04	1.28-04	1.26-04	1.13-04	3.61-05	4.12-10	0.00	0.00	0.00	0.00
CM247	0.00	5.08-10	5.08-10	5.08-10	5.08-10	5.08-10	5.07-10	5.06-10	4.87-10	3.35-10	8.01-12	0.00
SUBTOT	8.63+02	3.08+03	7.81+02	1.41+02	7.66+01	1.70+01	1.78+00	1.82-01	1.33-01	7.36-03	7.16-04	4.79-04
TOTAL	8.63+02	3.08+03	7.81+02	1.41+02	7.66+01	1.70+01	1.78+00	1.82-01	1.33-01	7.36-03	7.16-04	4.80-04

4.6.10

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	-1.04-07	-2.07-07	-9.16-07	-2.93-06	-3.42-06	-2.33-05	-8.65-04	-1.27-03	-1.26-03	-1.15-03	-4.78-04
TL208	0.00	-6.26-03	-4.45-03	-3.56-04	-9.34-05	-1.62-08	-5.04-10	-1.13-08	-1.18-07	-1.04-06	-3.90-06	-3.95-06
TL209	0.00	-1.70-08	-4.27-09	-4.39-09	-1.53-08	-1.63-06	-1.97-04	-4.78-03	-1.07-02	-5.48-04	-1.31-16	0.00
PB209	0.00	-7.72-07	-1.94-07	-1.99-07	-6.93-07	-7.43-05	-8.95-03	-2.17-01	-4.88-01	-2.49-02	-5.95-15	0.00
PB210	0.00	2.38+02	5.24+02	8.58+03	4.16+05	9.11+07	4.27+09	3.37+10	6.44+09	3.66+08	3.61+08	3.14+08
PB211	0.00	-1.05-07	-2.08-07	-9.19-07	-2.94-06	-3.43-06	-2.34-05	-8.67-04	-1.27-03	-1.26-03	-1.15-03	-4.80-04
PB212	0.00	2.90+07	2.06+07	1.65+06	4.32+05	7.49+01	2.33+00	5.23+01	5.45+02	4.83+03	1.81+04	1.83+04
PB214	0.00	-2.73-08	-4.49-08	-2.03-07	-2.58-06	-3.64-04	-1.71-02	-1.35-01	-2.57-02	-1.46-03	-1.44-03	-1.26-03
BI210	0.00	4.68+00	1.05+01	1.72+02	8.31+03	1.82+06	8.55+07	6.74+08	1.29+08	7.32+06	7.22+06	6.29+06
BI211	0.00	-1.05-07	-2.08-07	-9.19-07	-2.94-06	-3.43-06	-2.34-05	-8.67-04	-1.27-03	-1.26-03	-1.15-03	-4.80-04
BI212	0.00	5.80+06	4.12+06	3.30+05	8.64+04	1.50+01	4.66-01	1.05+01	1.09+02	9.65+02	3.61+03	3.66+03
BI213	0.00	-7.72-07	-1.94-07	-1.99-07	-6.93-07	-7.43-05	-8.95-03	-2.17-01	-4.88-01	-2.49-02	-5.95-15	0.00
BI214	0.00	-2.73-08	-4.49-08	-2.03-07	-2.58-06	-3.64-04	-1.71-02	-1.35-01	-2.57-02	-1.46-03	-1.44-03	-1.26-03
PO210	0.00	8.63+01	2.09+02	4.91+03	2.37+05	5.21+07	2.44+09	1.93+10	3.68+09	2.09+08	2.06+08	1.80+08
PO211	0.00	-3.14-10	-6.23-10	-2.76-09	-8.82-09	-1.03-08	-7.01-08	-2.60-06	-3.82-06	-3.78-06	-3.46-06	-1.44-06
PO212	0.00	-1.11-02	-7.91-03	-6.33-04	-1.66-04	-2.87-08	-8.95-10	-2.01-08	-2.09-07	-1.85-06	-6.94-06	-7.03-06
PO213	0.00	-7.55-07	-1.90-07	-1.95-07	-6.76-07	-7.27-05	-8.75-03	-2.13-01	-4.77-01	-2.44-02	-5.82-15	0.00
PO214	0.00	-2.73-08	-4.49-08	-2.03-07	-2.58-06	-3.64-04	-1.71-02	-1.35-01	-2.57-02	-1.46-03	-1.44-03	-1.26-03
PO215	0.00	-1.05-07	-2.08-07	-9.19-07	-2.94-06	-3.43-06	-2.34-05	-8.67-04	-1.27-03	-1.26-03	-1.15-03	-4.80-04
PO216	0.00	-1.74-02	-1.24-02	-9.89-04	-2.59-04	-4.49-08	-1.40-09	-3.14-08	-3.27-07	-2.90-06	-1.08-05	-1.10-05
PO218	0.00	-2.73-08	-4.49-08	-2.03-07	-2.58-06	-3.64-04	-1.71-02	-1.35-01	-2.57-02	-1.46-03	-1.44-03	-1.26-03
AT217	0.00	-7.72-07	-1.94-07	-1.99-07	-6.93-07	-7.43-05	-8.95-03	-2.17-01	-4.88-01	-2.49-02	-5.95-15	0.00
RN219	0.00	-1.05-07	-2.08-07	-9.19-07	-2.94-06	-3.43-06	-2.34-05	-8.67-04	-1.27-03	-1.26-03	-1.15-03	-4.80-04
RN220	0.00	1.74+06	1.24+06	9.89+04	2.59+04	4.49+00	1.40-01	3.14+00	3.27+01	2.90+02	1.08+03	1.10+03
RN222	0.00	9.09+00	1.50+01	6.78+01	8.59+02	1.21+05	5.70+06	4.49+07	8.58+06	4.88+05	4.81+05	4.19+05
FR221	0.00	-7.72-07	-1.94-07	-1.99-07	-6.93-07	-7.43-05	-8.95-03	-2.17-01	-4.88-01	-2.49-02	-5.95-15	0.00
FR223	0.00	-1.61-09	-2.90-09	-1.29-08	-4.11-08	-4.80-08	-3.27-07	-1.21-05	-1.78-05	-1.77-05	-1.62-05	-6.72-06
RA223	0.00	1.31+04	2.60+04	1.15+05	3.67+05	4.29+05	2.92+06	1.08+08	1.59+08	1.58+08	1.44+08	6.00+07
RA224	0.00	8.70+08	6.18+08	4.95+07	1.30+07	2.25+03	7.00+01	1.57+03	1.64+04	1.45+05	5.42+05	5.49+05
RA225	0.00	7.98+03	3.88+03	3.99+03	1.39+04	1.49+06	1.79+08	4.35+09	9.75+09	4.98+08	1.19-04	0.00
RA226	0.00	1.38+04	2.25+04	1.02+05	1.29+06	1.82+08	8.55+09	6.74+10	1.29+10	7.32+08	7.22+08	6.29+08
RA228	0.00	1.84+00	2.91+00	8.95+00	1.51+01	5.00+01	1.40+03	3.14+04	3.27+05	2.90+06	1.08+07	1.10+07
AC225	0.00	-7.71-07	-1.94-07	-1.99-07	-6.93-07	-7.43-05	-8.95-03	-2.17-01	-4.88-01	-2.49-02	-5.95-15	0.00
AC227	0.00	1.44+06	2.59+06	1.15+07	3.67+07	4.29+07	2.92+08	1.08+10	1.59+10	1.58+10	1.44+10	6.00+09
AC228	0.00	3.06-03	4.85-03	1.49-02	2.52-02	8.34-02	2.33+00	5.23+01	5.45+02	4.83+03	1.81+04	1.83+04
TH227	0.00	1.78+04	3.41+04	1.51+05	4.83+05	5.64+05	3.84+06	1.43+08	2.09+08	2.07+08	1.90+08	7.88+07
TH228	0.00	8.78+10	6.15+10	4.93+09	1.30+09	2.25+05	7.00+03	1.57+05	1.64+06	1.45+07	5.42+07	5.49+07
TH229	0.00	2.43+06	2.43+06	2.49+06	8.67+06	9.29+08	1.12+11	2.72+12	6.10+12	3.11+11	7.44-02	0.00
TH230	0.00	5.02+08	5.03+08	5.17+08	1.18+09	2.60+10	2.75+11	1.68+12	3.22+11	1.83+10	1.81+10	1.57+10
TH231	0.00	6.63+04	3.32+02	3.35+02	3.72+02	7.46+02	5.12+03	2.98+04	3.18+04	3.15+04	2.89+04	1.20+04

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TH232	0.00	1.27+01	1.26+01	1.30+01	1.51+01	5.00+01	1.40+03	3.14+04	3.27+05	2.90+06	1.08+07	1.10+07
TH234	0.00	2.92+06	1.47+06	1.46+06	1.46+06	1.46+06	1.46+06	1.46+06	1.47+06	1.46+06	1.44+06	1.26+06
PA231	0.00	7.60+07	7.60+07	7.61+07	7.66+07	8.57+07	5.84+08	2.17+10	3.18+10	3.15+10	2.89+10	1.20+10
PA233	0.00	3.70+07	3.71+07	3.80+07	4.71+07	9.18+07	1.05+08	1.02+06	7.66+07	4.15+06	9.14-07	0.00
PA234M	0.00	-2.92-01	-1.46-03	-1.46-03	-1.46-03	-1.46-03	-1.46-03	-1.46-03	-1.47-03	-1.46-03	-1.44-03	-1.26-03
PA234	0.00	-2.92-01	-1.47-06	-1.46-06	-1.46-06	-1.46-06	-1.46-06	-1.46-06	-1.47-06	-1.46-06	-1.44-06	-1.26-06
U232	0.00	2.67+08	3.61+08	6.26+08	2.81+09	4.85+09	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	2.40+07	4.87+07	2.66+08	2.23+09	8.38+09	5.92+10	5.92+11	1.22+11	6.23+09	1.49-03	0.00
U234	0.00	3.00+07	1.18+08	9.01+08	2.18+10	2.72+11	6.41+11	5.10+11	4.45+09	3.44+07	3.61+06	3.14+04
U235	1.14+05	1.21+04	6.22+04	3.25+06	3.76+08	7.46+09	2.12+10	2.98+09	3.18+08	3.15+07	2.85+06	2.29+04
U236	2.23+04	1.11+03	1.13+04	1.13+05	2.18+07	1.13+09	1.69+09	1.86+09	1.27+08	9.35+07	7.38-01	0.00
U238	1.00	1.00+00	1.00+00	1.00+00	1.00+00	1.00+00	1.00+00	1.00+00	1.00+00	1.00+00	1.00+00	1.00+00
NP237	1.38+11	8.13+10	8.27+10	8.27+10	8.27+10	8.27+10	8.27+10	8.27+10	8.28+10	8.28+10	8.81+08	1.49+07
NP238	1.00	2.22+00	1.13+01	1.13+02	1.13+03	1.13+04	1.13+05	1.13+06	4.59+12	2.48+11	5.49-01	0.00
NP239	1.00	1.72+00	1.72+00	1.72+00	1.72+00	1.72+00	1.72+00	1.72+00	5.45-01	5.81-03	1.39-07	0.00
PU236	1.38+07	-1.11+07	-1.11+07	-1.11+07	-2.11+11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	2.21+17	1.75+17	1.76+17	1.76+17	2.72+17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU239	1.42+16	1.42+16	1.42+16	1.42+16	2.76+16	2.81+16	3.51+16	4.02+16	2.82+05	1.34+03	9.63+03	0.00
PU240	2.13+16	2.13+16	2.13+16	2.13+16	3.38+16	3.38+16	1.34+16	1.22+01	0.00	0.00	0.00	0.00
PU241	1.03+15	1.03+15	1.03+15	1.03+15	2.72+15	1.38+15	1.71+07	0.00	0.00	0.00	0.00	0.00
PU242	2.63+13	2.63+13	2.63+13	2.63+13	8.81+13	1.08+12	9.87+11	8.38+11	1.42+11	1.15+09	0.00	0.00
PU243	0.00	2.93-01	2.93-01	2.93-01	2.93-01	2.93-01	2.93-01	2.93-01	2.93-01	1.98-03	9.69-03	0.00
AM241	1.63+15	9.99+15	9.98+15	9.86+15	6.38+15	2.06+15	2.08+11	3.67+08	0.00	0.00	0.00	0.00
AM242M	0.00	5.89+13	5.76+13	5.36+13	6.21+13	1.03+13	1.55-05	0.00	0.00	0.00	0.00	0.00
AM243	0.00	1.96+11	1.95+11	1.87+11	1.29+11	2.05+09	3.16-05	0.00	0.00	0.00	0.00	0.00
AM245	0.00	2.72+14	2.72+14	2.72+14	2.70+14	2.49+14	1.10+14	3.17+10	6.45+04	5.81+04	1.39+03	0.00
CM242	0.00	7.99+16	4.25+15	3.84+13	2.55+13	4.21+11	0.00	0.00	0.00	0.00	0.00	0.00
CM243	0.00	6.75+14	6.60+14	5.43+14	7.74+13	2.65+05	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	6.68+15	6.43+15	4.55+15	1.45+14	1.57-01	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	4.34+11	4.34+11	4.34+11	4.31+11	4.03+11	2.06+11	2.56+08	0.00	0.00	0.00	0.00
CM246	0.00	1.95+10	1.95+10	1.95+10	1.93+10	1.72+10	5.52+09	6.29+04	0.00	0.00	0.00	0.00
CM247	0.00	8.80+04	8.80+04	8.80+04	8.80+04	8.80+04	8.80+04	8.77+04	8.45+04	5.81+04	1.39+03	0.00
SUBTOT	5.85+17	4.04+16	2.89+16	2.34+16	1.45+16	2.98+15	6.04+14	5.19+13	1.14+13	6.37+11	6.43+10	3.59+10
TOTAL	5.85+17	4.04+16	2.89+16	2.34+16	1.45+16	2.98+15	6.04+14	5.19+13	1.14+13	6.37+11	6.43+10	3.59+10

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TL207	0.00	-1.04-07	-2.07-07	-9.16-07	-2.93-06	-3.42-06	-2.33-05	-8.65-04	-1.27-03	-1.26-03	-1.15-03	-4.78-04
TL208	0.00	-6.26-03	-4.45-03	-3.56-04	-9.34-05	-1.62-08	-5.04-10	-1.13-08	-1.18-07	-1.04-06	-3.90-06	-3.95-06
TL209	0.00	-1.70-06	-4.27-09	-4.39-09	-1.53-08	-1.63-06	-1.97-04	-4.78-03	-1.07-02	-5.48-04	-1.31-16	0.00
PB209	0.00	-7.72-07	-1.94-07	-1.99-07	-6.93-07	-7.43-05	-8.95-03	-2.17-01	-4.88-01	-2.49-02	-5.95-15	0.00
PB210	0.00	9.54-03	2.10-02	3.43-01	1.66+01	3.64+03	1.71+05	1.35+06	2.57+05	1.46+04	1.44+04	1.26+04
PB211	0.00	-1.05-07	-2.08-07	-9.19-07	-2.94-06	-3.43-06	-2.34-05	-8.67-04	-1.27-03	-1.26-03	-1.15-03	-4.80-04
PB212	0.00	8.70+02	6.18+02	4.95+01	1.30+01	2.25-03	7.00-05	1.57-03	1.64-02	1.45-01	5.42-01	5.49-01
PB214	0.00	-2.73-08	-4.49-08	-2.03-07	-2.58-06	-3.64-04	-1.71-02	-1.35-01	-2.57-02	-1.46-03	-1.44-03	-1.26-03
BI210	0.00	2.34-05	5.24-05	8.59-04	4.16-02	9.11+00	4.27+02	3.37+03	6.44+02	3.66+01	3.61+01	3.14+01
BI211	0.00	-1.05-07	-2.08-07	-9.19-07	-2.94-06	-3.43-06	-2.34-05	-8.67-04	-1.27-03	-1.26-03	-1.15-03	-4.80-04
BI212	0.00	4.35+01	3.09+01	2.47+00	6.48-01	1.12-04	3.50-06	7.85-05	8.18-04	7.24-03	2.71-02	2.75-02
BI213	0.00	-7.72-07	-1.94-07	-1.99-07	-6.93-07	-7.43-05	-8.95-03	-2.17-01	-4.88-01	-2.49-02	-5.95-15	0.00
BI214	0.00	-2.73-08	-4.49-08	-2.03-07	-2.58-06	-3.64-04	-1.71-02	-1.35-01	-2.57-02	-1.46-03	-1.44-03	-1.26-03
PO210	0.00	8.63-04	2.09-03	4.91-02	2.37+00	5.21+02	2.44+04	1.93+05	3.66+04	2.09+03	2.06+03	1.80+03
PO211	0.00	-3.14-10	-6.23-10	-2.76-09	-8.82-09	-1.03-08	-7.01-08	-2.60-06	-3.82-06	-3.78-06	-3.46-06	-1.44-06
PO212	0.00	-1.11-02	-7.91-03	-6.33-04	-1.66-04	-2.87-08	-8.95-10	-2.01-08	-2.09-07	-1.85-06	-6.94-06	-7.03-06
PO213	0.00	-7.55-07	-1.90-07	-1.95-07	-6.78-07	-7.27-05	-8.75-03	-2.13-01	-4.77-01	-2.44-02	-5.82-15	0.00
PO214	0.00	-2.73-08	-4.49-08	-2.03-07	-2.56-06	-3.64-04	-1.71-02	-1.35-01	-2.57-02	-1.46-03	-1.44-03	-1.26-03
PO215	0.00	-1.05-07	-2.08-07	-9.19-07	-2.94-06	-3.43-06	-2.34-05	-8.67-04	-1.27-03	-1.26-03	-1.15-03	-4.80-04
PO216	0.00	-1.74-02	-1.24-02	-9.89-04	-2.59-04	-4.49-08	-1.40-09	-3.14-08	-3.27-07	-2.90-06	-1.08-05	-1.10-05
PO218	0.00	-2.73-06	-4.49-08	-2.03-07	-2.58-06	-3.64-04	-1.71-02	-1.35-01	-2.57-02	-1.46-03	-1.44-03	-1.26-03
AT217	0.00	-7.72-07	-1.94-07	-1.99-07	-6.93-07	-7.43-05	-8.95-03	-2.17-01	-4.88-01	-2.49-02	-5.95-15	0.00
RN219	0.00	-1.05-07	-2.08-07	-9.19-07	-2.94-06	-3.43-06	-2.34-05	-8.67-04	-1.27-03	-1.26-03	-1.15-03	-4.80-04
RN220	0.00	-1.74-02	-1.24-02	-9.89-04	-2.59-04	-4.49-08	-1.40-09	-3.14-08	-3.27-07	-2.90-06	-1.08-05	-1.10-05
RN222	0.00	-2.73-08	-4.49-08	-2.03-07	-2.58-06	-3.64-04	-1.71-02	-1.35-01	-2.57-02	-1.46-03	-1.44-03	-1.26-03
FR221	0.00	-7.72-07	-1.94-07	-1.99-07	-6.93-07	-7.43-05	-8.95-03	-2.17-01	-4.88-01	-2.49-02	-5.95-15	0.00
FR223	0.00	-1.61-09	-2.90-09	-1.29-08	-4.11-08	-4.80-08	-3.27-07	-1.21-05	-1.78-05	-1.77-05	-1.62-05	-6.72-06
RA223	0.00	1.50-01	2.97-01	1.31+00	4.20+00	4.90+00	3.34+01	1.24+03	1.82+03	1.80+03	1.65+03	6.85+02
RA224	0.00	8.70+03	6.18+03	4.95+02	1.30+02	2.25-02	7.00-04	1.57-02	1.64-01	1.45+00	5.42+00	5.49+00
RA225	0.00	6.65-01	3.24-01	3.32-01	1.16+00	1.24+02	1.49+04	3.62+05	8.13+05	4.15+04	9.92-09	0.00
RA226	0.00	9.18-01	1.50+00	6.78+00	8.59+01	1.21+04	5.70+05	4.49+06	8.58+05	4.88+04	4.81+04	4.19+04
RA228	0.00	6.12-05	9.70-05	2.98-04	5.03-04	1.67-03	4.66-02	1.05+00	1.09+01	9.65+01	3.61+02	3.66+02
AC225	0.00	-7.71-07	-1.94-07	-1.99-07	-6.93-07	-7.43-05	-8.95-03	-2.17-01	-4.88-01	-2.49-02	-5.95-15	0.00
AC227	0.00	5.75-02	1.04-01	4.59-01	1.47+00	1.72+00	1.17+01	4.34+02	6.36+02	6.30+02	5.77+02	2.40+02
AC228	0.00	2.04-08	3.23-08	9.95-08	1.68-07	5.56-07	1.55-05	3.49-04	3.64-03	3.22-02	1.20-01	1.22-01
TH227	0.00	5.35-03	1.02-02	4.53-02	1.45-01	1.69-01	1.15+00	4.28+01	6.27+01	6.22+01	5.69+01	2.37+01
TH228	0.00	2.51+03	1.76+03	1.41+02	3.70+01	6.41-03	2.00-04	4.49-03	4.67-02	4.14-01	1.55+00	1.57+00
TH229	0.00	9.70-02	9.71-02	9.97-02	3.47-01	3.71+01	4.47+03	1.09+05	2.44+05	1.25+04	2.98-09	0.00
TH230	0.00	2.01+01	2.01+01	2.07+01	4.71+01	1.04+03	1.10+04	6.73+04	1.29+04	7.32+02	7.22+02	6.29+02
TH231	0.00	1.33+01	6.63-02	6.71-02	7.43-02	1.49-01	1.02+00	5.95+00	6.36+00	6.30+00	5.77+00	2.40+00

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TH232	0.00	6.37-06	6.38-06	6.48-06	7.55-06	2.50-05	7.00-04	1.57-02	1.64-01	1.45+00	5.42+00	5.49+00
TH234	0.00	1.46+04	7.35+01	7.31+01	7.31+01	7.31+01	7.31+01	7.31+01	7.33+01	7.32+01	7.22+01	6.29+01
PA231	0.00	3.38+00	3.38+00	3.38+00	3.40+00	3.81+00	2.60+01	9.64+02	1.41+03	1.40+03	1.28+03	5.33+02
PA233	0.00	2.22+03	2.22+03	2.28+03	2.82+03	5.51+03	6.33+03	6.15+03	4.59+03	2.49+02	5.48-11	0.00
PA234M	0.00	-2.92-01	-1.47-03	-1.46-03	-1.46-03	-1.46-03	-1.46-03	-1.46-03	-1.47-03	-1.46-03	-1.44-03	-1.26-03
PA234	0.00	-2.92-04	-1.47-06	-1.46-06	-1.46-06	-1.46-06	-1.46-06	-1.46-06	-1.47-06	-1.46-06	-1.44-06	-1.26-06
U232	0.00	8.01+00	1.08+01	1.88+01	8.42+00	1.46-03	0.00	0.00	0.00	0.00	0.00	0.00
U233	0.00	2.99-02	6.50-02	3.54-01	3.64+00	6.10+01	8.56+02	7.22+03	1.62+04	8.30+02	1.98-10	0.00
U234	6.01+04	2.67+02	2.91+02	6.68+02	3.64+03	8.97+03	8.81+03	6.85+03	5.94+02	4.88+01	4.81+01	4.19+01
U235	1.35+02	4.42-01	4.42-01	4.47-01	4.95-01	9.94-01	6.83+00	3.97+01	4.24+01	4.20+01	3.85+01	1.60+01
U236	3.10+03	1.49+01	1.50+01	1.51+01	1.70+01	3.54+01	1.50+02	2.26+02	2.20+02	1.69+02	1.25+01	5.79-11
U237	0.00	-1.84-01	-3.68-02	-2.41-02	-3.59-04	-2.02-06	-1.03-06	-1.28-09	0.00	0.00	0.00	0.00
U238	7.79+03	3.65+01	3.65+01	3.65+01	3.65+01	3.65+01	3.65+01	3.66+01	3.66+01	3.66+01	3.61+01	3.14+01
NP237	0.00	7.39+04	7.41+04	7.61+04	9.42+04	1.84+05	2.11+05	2.05+05	1.53+05	8.30+03	1.83-09	0.00
NP239	0.00	5.44+05	5.44+05	5.44+05	5.39+05	4.97+05	2.20+05	6.33+01	1.69-04	1.16-04	2.78-06	0.00
PU236	-3.38+00	-1.02-02	-8.00-03	-8.97-04	-2.81-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PU238	3.79+09	1.20+07	7.47+07	8.76+07	5.59+07	3.87+05	0.00	0.00	0.00	0.00	0.00	0.00
PU239	4.46+08	3.26+06	3.26+06	3.27+06	3.31+06	3.49+06	4.21+06	4.82+05	3.38-03	2.33-03	5.55-05	0.00
PU240	6.48+08	3.41+06	3.45+06	3.75+06	4.42+06	4.05+06	1.61+06	1.58+02	0.00	0.00	0.00	0.00
PU241	3.26+09	7.70+06	7.35+06	4.82+06	7.17+04	4.04+02	2.07+02	2.57-01	0.00	0.00	0.00	0.00
PU242	1.84+06	9.23+03	9.24+03	9.35+03	1.03+04	1.20+04	1.18+04	1.01+04	1.94+03	1.38-04	0.00	0.00
PU243	0.00	2.93-07	5.87-05	5.87-05	5.87-05	5.87-05	5.87-05	5.85-05	5.63-05	3.88-05	9.26-07	0.00
AM241	2.84+08	4.97+08	4.97+08	4.94+08	4.35+08	1.03+08	1.04+04	1.28+01	0.00	0.00	0.00	0.00
AM242M	0.00	4.90+07	4.88+07	4.68+07	3.11+07	5.13+05	7.76-13	0.00	0.00	0.00	0.00	0.00
AM242	0.00	1.96+06	1.95+06	1.87+06	1.24+06	2.05+04	3.10-14	0.00	0.00	0.00	0.00	0.00
AM243	0.00	1.36+07	1.36+07	1.36+07	1.35+07	1.24+07	5.50+06	1.58+03	4.22-03	2.91-03	6.94-05	0.00
CM242	0.00	3.99+09	8.50+08	7.68+06	5.09+06	8.41+04	0.00	0.00	0.00	0.00	0.00	0.00
CM243	0.00	2.70+07	2.64+07	2.17+07	3.09+06	1.06-02	0.00	0.00	0.00	0.00	0.00	0.00
CM244	0.00	2.86+08	2.75+08	1.95+08	6.22+06	6.74-09	0.00	0.00	0.00	0.00	0.00	0.00
CM245	0.00	2.17+04	2.17+04	2.17+04	2.16+04	2.02+04	1.03+04	1.28+01	0.00	0.00	0.00	0.00
CM246	0.00	9.77+02	9.77+02	9.76+02	9.65+02	8.61+02	2.76+02	3.15-03	0.00	0.00	0.00	0.00
CM247	0.00	4.40-03	4.40-03	4.40-03	4.40-03	4.40-03	4.40-03	4.38-03	4.22-03	2.91-03	6.94-05	0.00
SUBTOT	8.43+09	4.89+09	1.80+09	8.81+08	5.59+08	1.25+08	1.26+07	7.30+06	2.40+06	1.34+05	6.96+04	5.90+04
TOTAL	8.43+09	4.89+09	1.80+09	8.81+08	5.59+08	1.25+08	1.26+07	7.30+06	2.40+06	1.34+05	6.96+04	5.90+04

GE LMFBR PLANT WASTE

Fission Products

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	1.20-01	1.13-01	6.82-02	4.28-04	4.07-26	0.00	0.00	0.00	0.00	0.00	0.00
GE 72	0.00	2.35-04	2.35-04	2.35-04	2.35-04	2.35-04	2.35-04	2.35-04	2.35-04	2.35-04	2.35-04	2.35-04
GE 73	0.00	1.18-03	1.18-03	1.18-03	1.18-03	1.18-03	1.18-03	1.18-03	1.18-03	1.18-03	1.18-03	1.18-03
GE 74	0.00	4.80-03	4.80-03	4.80-03	4.80-03	4.80-03	4.80-03	4.80-03	4.80-03	4.80-03	4.80-03	4.80-03
AS 75	0.00	3.59-02	3.59-02	3.59-02	3.59-02	3.59-02	3.59-02	3.59-02	3.59-02	3.59-02	3.59-02	3.59-02
GE 76	0.00	7.38-02	7.38-02	7.38-02	7.38-02	7.38-02	7.38-02	7.38-02	7.38-02	7.38-02	7.38-02	7.38-02
SE 76	0.00	9.98-04	9.98-04	9.98-04	9.98-04	9.98-04	9.98-04	9.98-04	9.98-04	9.98-04	9.98-04	9.98-04
SE 77	0.00	2.21+00	2.21+00	2.21+00	2.21+00	2.21+00	2.21+00	2.21+00	2.21+00	2.21+00	2.21+00	2.21+00
SE 78	0.00	5.16+00	5.16+00	5.16+00	5.16+00	5.16+00	5.16+00	5.16+00	5.16+00	5.16+00	5.16+00	5.16+00
SE 79	0.00	9.32+00	9.32+00	9.32+00	9.31+00	9.23+00	8.38+00	3.21+00	2.18-04	0.00	0.00	0.00
BR 79	0.00	1.35-04	2.34-04	1.13-03	1.01-02	9.90-02	9.43-01	6.11+00	9.32+00	9.32+00	9.32+00	9.32+00
SE 80	0.00	1.39+01	1.39+01	1.39+01	1.39+01	1.39+01	1.39+01	1.39+01	1.39+01	1.39+01	1.39+01	1.39+01
KR 80	0.00	2.09+00	2.09+00	2.09+00	2.09+00	2.09+00	2.09+00	2.09+00	2.09+00	2.09+00	2.09+00	2.09+00
BR 81	0.00	2.60+01	2.60+01	2.60+01	2.60+01	2.60+01	2.60+01	2.60+01	2.60+01	2.60+01	2.60+01	2.60+01
KR 81	0.00	8.56-03	8.56-03	8.56-03	8.56-03	8.56-03	8.56-03	8.56-03	8.56-03	8.56-03	8.56-03	8.56-03
SE 82	0.00	3.96+01	3.96+01	3.96+01	3.96+01	3.96+01	3.96+01	3.96+01	3.96+01	3.96+01	3.96+01	3.96+01
KR 82	0.00	8.91-01	8.91-01	8.91-01	8.91-01	8.91-01	8.91-01	8.91-01	8.91-01	8.91-01	8.91-01	8.91-01
KR 83	0.00	5.72+01	5.72+01	5.72+01	5.72+01	5.72+01	5.72+01	5.72+01	5.72+01	5.72+01	5.72+01	5.72+01
KR 84	0.00	9.25+01	9.25+01	9.25+01	9.25+01	9.25+01	9.25+01	9.25+01	9.25+01	9.25+01	9.25+01	9.25+01
KR 85	0.00	2.41+01	2.26+01	1.27+01	3.94-02	3.27-27	0.00	0.00	0.00	0.00	0.00	0.00
RB 85	0.00	8.59+01	8.74+01	9.73+01	1.10+02	1.10+02	1.10+02	1.10+02	1.10+02	1.10+02	1.10+02	1.10+02
KR 86	0.00	1.59+02	1.59+02	1.59+02	1.59+02	1.59+02	1.59+02	1.59+02	1.59+02	1.59+02	1.59+02	1.59+02
RB 86	0.00	2.74-03	3.63-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 86	0.00	1.21+00	1.21+00	1.21+00	1.21+00	1.21+00	1.21+00	1.21+00	1.21+00	1.21+00	1.21+00	1.21+00
RB 87	0.00	2.03+02	2.03+02	2.03+02	2.03+02	2.03+02	2.03+02	2.03+02	2.03+02	2.03+02	2.03+02	2.00+02
SR 87	0.00	4.30-03	4.30-03	4.30-03	4.30-03	4.30-03	4.33-03	4.58-03	7.11-03	3.24-02	2.85-01	2.80+00
SR 88	0.00	2.53+02	2.53+02	2.53+02	2.53+02	2.53+02	2.53+02	2.53+02	2.53+02	2.53+02	2.53+02	2.53+02
SR 89	0.00	8.97+00	6.90-02	6.50-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Y 89	0.00	3.37+02	3.45+02	3.45+02	3.45+02	3.45+02	3.45+02	3.45+02	3.45+02	3.45+02	3.45+02	3.45+02
SR 90	0.00	3.76+02	3.67+02	2.94+02	3.19+01	7.32-09	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	9.77-02	9.53-02	7.63-02	8.29-03	1.90-12	0.00	0.00	0.00	0.00	0.00	0.00
ZR 90	0.00	1.38+01	2.30+01	9.60+01	3.58+02	3.90+02	3.90+02	3.90+02	3.90+02	3.90+02	3.90+02	3.90+02
Y 91	0.00	1.71+01	2.31-01	3.45-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 91	0.00	4.85+02	5.01+02	5.02+02	5.02+02	5.02+02	5.02+02	5.02+02	5.02+02	5.02+02	5.02+02	5.02+02
ZR 92	0.00	5.87+02	5.87+02	5.87+02	5.87+02	5.87+02	5.87+02	5.87+02	5.87+02	5.87+02	5.87+02	5.87+02
ZR 93	0.00	6.85+02	6.85+02	6.85+02	6.85+02	6.84+02	6.82+02	6.54+02	4.31+02	6.75+00	5.90-18	0.00
NB 93M	0.00	4.30-04	7.17-04	2.74-03	6.17-03	6.20-03	6.18-03	5.93-03	3.91-03	6.12-05	5.35-23	0.00
NB 93	0.00	1.97-05	4.90-05	8.76-04	2.59-02	3.10-01	3.15+00	3.09+01	2.53+02	6.78+02	6.85+02	6.85+02
ZR 94	0.00	8.25+02	8.25+02	8.25+02	8.25+02	8.25+02	8.25+02	8.25+02	8.25+02	8.25+02	8.25+02	8.25+02
ZR 95	0.00	3.98+01	8.11-01	4.88-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
NB 95M	0.00	4.68-02	9.93-04	5.98-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	3.55+01	9.62-01	5.56-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MO 95	0.00	8.58+02	9.31+02	9.33+02	9.33+02	9.33+02	9.33+02	9.33+02	9.33+02	9.33+02	9.33+02	9.33+02
ZR 96	0.00	9.44+02	9.44+02	9.44+02	9.44+02	9.44+02	9.44+02	9.44+02	9.44+02	9.44+02	9.44+02	9.44+02
MO 96	0.00	2.27+01	2.27+01	2.27+01	2.27+01	2.27+01	2.27+01	2.27+01	2.27+01	2.27+01	2.27+01	2.27+01
MO 97	0.00	9.18+02	9.18+02	9.18+02	9.18+02	9.18+02	9.18+02	9.18+02	9.18+02	9.18+02	9.18+02	9.18+02
MO 98	0.00	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03	1.03+03
TC 99	0.00	1.07+03	1.07+03	1.07+03	1.07+03	1.07+03	1.04+03	7.71+02	4.07+01	6.80-12	0.00	0.00
RU 99	0.00	4.80-03	8.29-03	3.98-02	3.54-01	3.50+00	3.44+01	2.98+02	1.03+03	1.07+03	1.07+03	1.07+03
MO100	0.00	1.11+03	1.11+03	1.11+03	1.11+03	1.11+03	1.11+03	1.11+03	1.11+03	1.11+03	1.11+03	1.11+03
RU100	0.00	3.79+01	3.79+01	3.79+01	3.79+01	3.79+01	3.79+01	3.79+01	3.79+01	3.79+01	3.79+01	3.79+01
RU101	0.00	1.05+03	1.05+03	1.05+03	1.05+03	1.05+03	1.05+03	1.05+03	1.05+03	1.05+03	1.05+03	1.05+03
RU102	0.00	1.21+03	1.21+03	1.21+03	1.21+03	1.21+03	1.21+03	1.21+03	1.21+03	1.21+03	1.21+03	1.21+03
RU103	0.00	1.59+01	2.67-02	2.77-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	1.59-02	2.67-05	2.77-30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103	0.00	1.11+03	1.12+03	1.12+03	1.12+03	1.12+03	1.12+03	1.12+03	1.12+03	1.12+03	1.12+03	1.12+03
RU104	0.00	1.08+03	1.08+03	1.08+03	1.08+03	1.08+03	1.08+03	1.08+03	1.08+03	1.08+03	1.08+03	1.08+03
PD104	0.00	9.01-03	9.01-03	9.01-03	9.01-03	9.01-03	9.01-03	9.01-03	9.01-03	9.01-03	9.01-03	9.01-03
PD105	0.00	8.99+02	8.99+02	8.99+02	8.99+02	8.99+02	8.99+02	8.99+02	8.99+02	8.99+02	8.99+02	8.99+02
RU106	0.00	3.94+02	1.73+02	3.53-01	3.95-28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	3.35-04	1.58-04	3.39-07	3.74-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD106	0.00	9.51+02	7.20+02	9.06+02	9.06+02	9.06+02	9.06+02	9.06+02	9.06+02	9.06+02	9.06+02	9.06+02
PD107	0.00	6.02+02	6.02+02	6.02+02	6.02+02	6.02+02	6.02+02	5.96+02	5.46+02	2.24+02	3.62-02	0.00
AG107	0.00	8.25-05	1.42-04	6.79-04	6.05-03	5.97-02	5.96-01	5.93+00	5.68+01	3.79+02	6.02+02	6.02+02
PD108	0.00	4.99+02	4.99+02	4.99+02	4.99+02	4.99+02	4.99+02	4.99+02	4.99+02	4.99+02	4.99+02	4.99+02
CD108	0.00	2.63-06	2.63-06	2.63-06	2.63-06	2.63-06	2.63-06	2.63-06	2.63-06	2.63-06	2.63-06	2.63-06
AG109	0.00	2.65+02	2.65+02	2.65+02	2.65+02	2.65+02	2.65+02	2.65+02	2.65+02	2.65+02	2.65+02	2.65+02
CD109	0.00	2.21-08	1.27-08	8.29-11	1.20-32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD110	0.00	1.39+02	1.39+02	1.39+02	1.37+02	1.39+02	1.39+02	1.39+02	1.39+02	1.39+02	1.39+02	1.39+02
AG110M	0.00	2.54-01	9.34-02	1.15-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	3.66-08	1.35-08	1.67-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD110	0.00	2.07+01	2.08+01	2.09+01	2.09+01	2.09+01	2.09+01	2.09+01	2.09+01	2.09+01	2.09+01	2.09+01
CD111	0.00	6.28+01	6.28+01	6.28+01	6.28+01	6.28+01	6.28+01	6.28+01	6.28+01	6.28+01	6.28+01	6.28+01
CD112	0.00	3.39+01	3.39+01	3.39+01	3.39+01	3.39+01	3.39+01	3.39+01	3.39+01	3.39+01	3.39+01	3.39+01
CD113M	0.00	7.22-01	6.87-01	4.40-01	5.11-03	2.30-22	0.00	0.00	0.00	0.00	0.00	0.00
CD113	0.00	1.58+01	1.58+01	1.58+01	1.58+01	1.58+01	1.58+01	1.58+01	1.58+01	1.58+01	1.58+01	1.58+01
IN113	0.00	3.47-02	6.95-02	3.16-01	7.50-01	7.56-01	7.56-01	7.56-01	7.56-01	7.56-01	7.56-01	7.56-01
CD114	0.00	2.14+01	2.14+01	2.14+01	2.14+01	2.14+01	2.14+01	2.14+01	2.14+01	2.14+01	2.14+01	2.14+01
IN114M	0.00	6.01-05	3.81-07	6.22-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	9.67-10	6.12-12	1.00-31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
SN114	0.00	1.06-03	1.11-03	1.11-03	1.11-03	1.11-03	1.11-03	1.11-03	1.11-03	1.11-03	1.11-03	1.11-03
CD115M	0.00	2.19-02	6.08-05	5.97-28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN115	0.00	1.66+01	1.66+01	1.66+01	1.66+01	1.66+01	1.66+01	1.66+01	1.66+01	1.66+01	1.66+01	1.66+01
SN115	0.00	8.24-01	8.24-01	8.24-01	8.24-01	8.24-01	8.24-01	8.24-01	8.24-01	8.24-01	8.24-01	8.24-01
CD116	0.00	1.67+01	1.67+01	1.67+01	1.67+01	1.67+01	1.67+01	1.67+01	1.67+01	1.67+01	1.67+01	1.67+01
SN116	0.00	1.04+00	1.04+00	1.04+00	1.04+00	1.04+00	1.04+00	1.04+00	1.04+00	1.04+00	1.04+00	1.04+00
SN117	0.00	1.63+01	1.63+01	1.63+01	1.63+01	1.63+01	1.63+01	1.63+01	1.63+01	1.63+01	1.63+01	1.63+01
SN118	0.00	1.70+01	1.70+01	1.70+01	1.70+01	1.70+01	1.70+01	1.70+01	1.70+01	1.70+01	1.70+01	1.70+01
SN119M	0.00	4.82-02	1.75-02	1.93-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119	0.00	1.65+01	1.65+01	1.65+01	1.65+01	1.65+01	1.65+01	1.65+01	1.65+01	1.65+01	1.65+01	1.65+01
SN120	0.00	1.77+01	1.77+01	1.77+01	1.77+01	1.77+01	1.77+01	1.77+01	1.77+01	1.77+01	1.77+01	1.77+01
SN121M	0.00	3.46-04	3.43-04	3.16-04	1.39-04	3.80-08	0.00	0.00	0.00	0.00	0.00	0.00
SB121	0.00	1.77+01	1.77+01	1.77+01	1.77+01	1.77+01	1.77+01	1.77+01	1.77+01	1.77+01	1.77+01	1.77+01
SN122	0.00	1.94+01	1.94+01	1.94+01	1.94+01	1.94+01	1.94+01	1.94+01	1.94+01	1.94+01	1.94+01	1.94+01
TE122	0.00	5.83-01	5.83-01	5.83-01	5.83-01	5.83-01	5.83-01	5.83-01	5.83-01	5.83-01	5.83-01	5.83-01
SN123M	0.00	1.30+00	1.72-01	2.09-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB123	0.00	2.03+01	2.14+01	2.16+01	2.16+01	2.16+01	2.16+01	2.16+01	2.16+01	2.16+01	2.16+01	2.16+01
TE123M	0.00	5.99-04	6.89-05	2.41-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123	0.00	6.67-03	7.20-03	7.27-03	7.27-03	7.27-03	7.27-03	7.27-03	7.27-03	7.27-03	7.27-03	7.27-03
SN124	0.00	2.63+01	2.63+01	2.63+01	2.63+01	2.63+01	2.63+01	2.63+01	2.63+01	2.63+01	2.63+01	2.63+01
SB124	0.00	3.90-02	5.74-04	1.86-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE124	0.00	5.22-01	5.60-01	5.61-01	5.61-01	5.61-01	5.61-01	5.61-01	5.61-01	5.61-01	5.61-01	5.61-01
SB125	0.00	2.47+01	1.91+01	1.90+00	1.76-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	5.69-01	4.65-01	4.62-02	4.29-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125	0.00	9.39+00	1.51+01	3.27+01	3.46+01	3.46+01	3.46+01	3.46+01	3.46+01	3.46+01	3.46+01	3.46+01
SN126	0.00	5.41+01	5.41+01	5.41+01	5.40+01	5.37+01	5.05+01	2.70+01	5.29-02	4.33-29	0.00	0.00
SB126M	0.00	1.95-08	1.95-08	1.95-08	1.95-08	1.94-08	1.82-08	9.77-09	1.91-11	0.00	0.00	0.00
SB126	0.00	5.32-04	1.83-05	1.83-05	1.83-05	1.82-05	1.71-05	9.16-06	1.79-08	0.00	0.00	0.00
TE126	0.00	3.07+00	3.07+00	3.07+00	3.11+00	3.44+00	6.69+00	3.01+01	5.71+01	5.71+01	5.71+01	5.71+01
TE127M	0.00	2.09+00	2.05-01	1.72-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	7.43-03	7.29-04	6.11-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I127	0.00	8.29+01	8.48+01	8.50+01	8.50+01	8.50+01	8.50+01	8.50+01	8.50+01	8.50+01	8.50+01	8.50+01
TE128	0.00	1.53+02	1.53+02	1.53+02	1.53+02	1.53+02	1.53+02	1.53+02	1.53+02	1.53+02	1.53+02	1.53+02
XE128	0.00	3.98+00	3.98+00	3.98+00	3.98+00	3.98+00	3.98+00	3.98+00	3.98+00	3.98+00	3.98+00	3.98+00
TE129M	0.00	8.45-01	4.94-04	3.94-33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	7.63-04	4.46-07	3.56-36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	2.63+02	2.63+02	2.63+02	2.63+02	2.63+02	2.63+02	2.62+02	2.53+02	1.75+02	4.47+00	5.21-16
XE129	0.00	2.39-02	2.40-02	2.41-02	2.50-02	3.47-02	1.31-01	1.10+00	1.05+01	8.82+01	2.59+02	2.63+02
TE130	0.00	5.31+02	5.31+02	5.31+02	5.31+02	5.31+02	5.31+02	5.31+02	5.31+02	5.31+02	5.31+02	5.31+02
XE130	0.00	1.28+01	1.28+01	1.28+01	1.28+01	1.28+01	1.28+01	1.28+01	1.28+01	1.28+01	1.28+01	1.28+01

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
XE131M	0.00	5.62-03	2.94-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XE131	0.00	8.28+02	8.28+02	8.28+02	8.28+02	8.28+02	8.28+02	8.28+02	8.28+02	8.28+02	8.28+02	8.28+02
XE132	0.00	9.79+02	9.79+02	9.79+02	9.79+02	9.79+02	9.79+02	9.79+02	9.79+02	9.79+02	9.79+02	9.79+02
CS133	0.00	1.36+03	1.36+03	1.36+03	1.36+03	1.36+03	1.36+03	1.36+03	1.36+03	1.36+03	1.36+03	1.36+03
XE134	0.00	1.58+03	1.58+03	1.58+03	1.58+03	1.58+03	1.58+03	1.58+03	1.58+03	1.58+03	1.58+03	1.58+03
CS134	0.00	3.18+01	2.27+01	1.08+00	6.62-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BA134	0.00	1.24+01	2.15+01	4.31+01	4.41+01	4.41+01	4.41+01	4.41+01	4.41+01	4.41+01	4.41+01	4.41+01
CS135	0.00	1.59+03	1.59+03	1.59+03	1.59+03	1.58+03	1.58+03	1.55+03	1.26+03	1.57+02	1.47-07	0.00
BA135	0.00	1.01-02	1.05-02	1.38-02	4.67-02	3.76-01	3.67+00	3.62+01	3.27+02	1.43+03	1.59+03	1.59+03
XE136	0.00	1.64+03	1.64+03	1.64+03	1.64+03	1.64+03	1.64+03	1.64+03	1.64+03	1.64+03	1.64+03	1.64+03
CS136	0.00	1.81-02	6.35-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BA136	0.00	6.62+01	6.62+01	6.62+01	6.62+01	6.62+01	6.62+01	6.62+01	6.62+01	6.62+01	6.62+01	6.62+01
CS137	0.00	1.62+03	1.58+03	1.29+03	1.61+02	1.51-07	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	2.45-04	2.39-04	1.94-04	2.43-05	2.28-14	0.00	0.00	0.00	0.00	0.00	0.00
BA137	0.00	5.37+01	9.07+01	3.88+02	1.51+03	1.68+03	1.68+03	1.68+03	1.68+03	1.68+03	1.68+03	1.68+03
BA138	0.00	1.57+03	1.57+03	1.57+03	1.57+03	1.57+03	1.57+03	1.57+03	1.57+03	1.57+03	1.57+03	1.57+03
LA139	0.00	1.39+03	1.39+03	1.39+03	1.39+03	1.39+03	1.39+03	1.39+03	1.39+03	1.39+03	1.39+03	1.39+03
BA140	0.00	2.23-01	5.76-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	3.36-02	6.67-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE140	0.00	1.37+03	1.37+03	1.37+03	1.37+03	1.37+03	1.37+03	1.37+03	1.37+03	1.37+03	1.37+03	1.37+03
CE141	0.00	9.27+00	3.75-03	1.09-33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR141	0.00	1.15+03	1.16+03	1.16+03	1.16+03	1.16+03	1.16+03	1.16+03	1.16+03	1.16+03	1.16+03	1.16+03
CE142	0.00	1.38+03	1.38+03	1.38+03	1.38+03	1.38+03	1.38+03	1.38+03	1.38+03	1.38+03	1.38+03	1.38+03
ND142	0.00	7.79+00	7.79+00	7.79+00	7.79+00	7.79+00	7.79+00	7.79+00	7.79+00	7.79+00	7.79+00	7.79+00
PR143	0.00	3.32-01	3.14-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND143	0.00	1.14+03	1.14+03	1.14+03	1.14+03	1.14+03	1.14+03	1.14+03	1.14+03	1.14+03	1.14+03	1.14+03
CE144	0.00	3.26+02	1.34+02	4.39-02	6.41-37	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	1.38-02	5.66-03	1.86-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND144	0.00	7.11+02	9.03+02	1.04+03	1.04+03	1.04+03	1.04+03	1.04+03	1.04+03	1.04+03	1.04+03	1.04+03
ND145	0.00	7.87+02	7.87+02	7.87+02	7.87+02	7.87+02	7.87+02	7.87+02	7.87+02	7.87+02	7.87+02	7.87+02
ND146	0.00	7.71+02	7.71+02	7.71+02	7.71+02	7.71+02	7.71+02	7.71+02	7.71+02	7.71+02	7.71+02	7.71+02
ND147	0.00	4.14-02	5.17-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	3.78+02	2.91+02	2.69+01	1.23-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM147	0.00	1.59+02	2.47+02	5.10+02	5.37+02	5.37+02	5.37+02	5.37+02	5.37+02	5.37+02	5.37+02	5.37+02
ND148	0.00	4.69+02	4.69+02	4.69+02	4.69+02	4.69+02	4.69+02	4.69+02	4.69+02	4.69+02	4.69+02	4.69+02
PM148M	0.00	7.86-01	1.90-03	5.28-27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	8.12-03	1.96-05	5.46-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM148	0.00	6.33+01	6.41+01	6.41+01	6.41+01	6.41+01	6.41+01	6.41+01	6.41+01	6.41+01	6.41+01	6.41+01
SM149	0.00	3.97+02	3.97+02	3.97+02	3.97+02	3.97+02	3.97+02	3.97+02	3.97+02	3.97+02	3.97+02	3.97+02
ND150	0.00	2.65+02	2.65+02	2.65+02	2.65+02	2.65+02	2.65+02	2.65+02	2.65+02	2.65+02	2.65+02	2.65+02

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE CONCENTRATIONS, GRAMS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
SM150	0.00	4.55+01	4.55+01	4.55+01	4.55+01	4.55+01	4.55+01	4.55+01	4.55+01	4.55+01	4.55+01	4.55+01
SM151	0.00	2.25+02	2.23+02	2.08+02	1.01+02	7.81-02	5.73-33	0.00	0.00	0.00	0.00	0.00
EU151	0.00	2.32+00	4.10+00	1.95+01	1.26+02	2.27+02	2.27+02	2.27+02	2.27+02	2.27+02	2.27+02	2.27+02
SM152	0.00	2.18+02	2.18+02	2.18+02	2.18+02	2.18+02	2.18+02	2.18+02	2.18+02	2.18+02	2.18+02	2.18+02
EU152	0.00	1.34-01	1.27-01	7.53-02	4.17-04	1.12-26	0.00	0.00	0.00	0.00	0.00	0.00
GD152	0.00	8.08-02	8.29-02	9.72-02	1.18-01	1.18-01	1.18-01	1.18-01	1.18-01	1.18-01	1.18-01	1.18-01
EU153	0.00	1.14+02	1.14+02	1.14+02	1.14+02	1.14+02	1.14+02	1.14+02	1.14+02	1.14+02	1.14+02	1.14+02
GD153	0.00	5.04-04	1.77-04	1.44-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM154	0.00	9.32+01	9.32+01	9.32+01	9.32+01	9.32+01	9.32+01	9.32+01	9.32+01	9.32+01	9.32+01	9.32+01
EU154	0.00	1.38+01	1.32+01	8.95+00	1.81-01	2.14-18	0.00	0.00	0.00	0.00	0.00	0.00
GD154	0.00	6.71-01	1.26+00	5.52+00	1.43+01	1.45+01	1.45+01	1.45+01	1.45+01	1.45+01	1.45+01	1.45+01
EU155	0.00	4.36+01	2.97+01	9.47-01	1.03-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD155	0.00	2.53+01	3.92+01	6.80+01	6.89+01	6.89+01	6.89+01	6.89+01	6.89+01	6.89+01	6.89+01	6.89+01
EU156	0.00	2.40-02	1.13-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD156	0.00	5.33+01	5.33+01	5.33+01	5.33+01	5.33+01	5.33+01	5.33+01	5.33+01	5.33+01	5.33+01	5.33+01
GD157	0.00	2.83+01	2.83+01	2.83+01	2.83+01	2.83+01	2.83+01	2.83+01	2.83+01	2.83+01	2.83+01	2.83+01
GD158	0.00	2.26+01	2.26+01	2.26+01	2.26+01	2.26+01	2.26+01	2.26+01	2.26+01	2.26+01	2.26+01	2.26+01
TB159	0.00	1.05+01	1.05+01	1.05+01	1.05+01	1.05+01	1.05+01	1.05+01	1.05+01	1.05+01	1.05+01	1.05+01
GD160	0.00	5.98+00	5.98+00	5.98+00	5.98+00	5.98+00	5.98+00	5.98+00	5.98+00	5.98+00	5.98+00	5.98+00
TB160	0.00	1.47-01	4.41-03	8.36-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DY160	0.00	1.56+00	1.70+00	1.70+00	1.70+00	1.70+00	1.70+00	1.70+00	1.70+00	1.70+00	1.70+00	1.70+00
DY161	0.00	3.66+00	3.66+00	3.66+00	3.66+00	3.66+00	3.66+00	3.66+00	3.66+00	3.66+00	3.66+00	3.66+00
GD162	0.00	1.56-06	7.80-07	1.53-09	1.25-36	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	2.22-11	1.11-11	2.18-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DY162	0.00	2.93-01	2.93-01	2.93-01	2.93-01	2.93-01	2.93-01	2.93-01	2.93-01	2.93-01	2.93-01	2.93-01
DY163	0.00	3.39-03	3.39-03	3.39-03	3.39-03	3.39-03	3.39-03	3.39-03	3.39-03	3.39-03	3.39-03	3.39-03
DY164	0.00	1.61-04	1.61-04	1.61-04	1.61-04	1.61-04	1.61-04	1.61-04	1.61-04	1.61-04	1.61-04	1.61-04
HO165	0.00	1.44-06	1.44-06	1.44-06	1.44-06	1.44-06	1.44-06	1.44-06	1.44-06	1.44-06	1.44-06	1.44-06
ER166	0.00	7.39-08	7.39-08	7.39-08	7.39-08	7.39-08	7.39-08	7.39-08	7.39-08	7.39-08	7.39-08	7.39-08
ER167	0.00	6.21-10	6.21-10	6.21-10	6.21-10	6.21-10	6.21-10	6.21-10	6.21-10	6.21-10	6.21-10	6.21-10
SUBTOT	0.00	4.26+04	4.26+04	4.26+04	4.26+04	4.26+04	4.26+04	4.26+04	4.26+04	4.26+04	4.26+04	4.26+04
TOTAL	0.00	4.26+04	4.26+04	4.26+04	4.26+04	4.26+04	4.26+04	4.26+04	4.26+04	4.26+04	4.26+04	4.26+04

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 46.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	1.16+03	1.10+03	6.61+02	4.15+00	3.95-22	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	6.49-01	6.49-01	6.49-01	6.49-01	6.43-01	5.84-01	2.24-01	1.52-05	0.00	0.00	0.00
KR 85	0.00	9.39+03	8.81+03	4.94+03	1.53+01	1.28-24	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	2.23+02	2.95-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	1.67-05	1.67-05	1.67-05	1.67-05	1.67-05	1.67-05	1.67-05	1.67-05	1.67-05	1.67-05	1.64-05
SR 89	0.00	2.53+05	1.95+03	1.84-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	5.32+04	5.19+04	4.15+04	4.51+03	1.04-06	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	5.32+04	5.19+04	4.15+04	4.51+03	1.04-06	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	4.18+05	5.64+03	8.43-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	1.76+00	1.76+00	1.76+00	1.76+00	1.75+00	1.75+00	1.68+00	1.11+00	1.73-02	1.51-20	0.00
NB 93M	0.00	1.22-01	2.03-01	7.74-01	1.75+00	1.75+00	1.75+00	1.68+00	1.11+00	1.73-02	1.51-20	0.00
ZR 95	0.00	8.43+05	1.72+04	1.03-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	1.79+04	3.64+02	2.19-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	1.39+06	3.78+04	2.19-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	1.82+01	1.82+01	1.82+01	1.82+01	1.82+01	1.76+01	1.31+01	6.93-01	1.16-13	0.00	0.00
RU103	0.00	5.09+05	8.54+02	8.87-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	5.10+05	8.54+02	8.88-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	1.19+06	5.97+05	1.20+03	1.33-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	1.19+06	5.97+05	1.20+03	1.33-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	2.88-01	2.88-01	2.88-01	2.88-01	2.88-01	2.87-01	2.85-01	2.61-01	1.07-01	1.44-05	0.00
AG109M	0.00	5.86-05	3.35-05	2.19-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	5.86-05	3.35-05	2.19-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	1.19+03	4.38+02	5.39-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	1.55+02	5.70+01	7.00-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	1.63+02	1.55+02	9.94+01	1.16+00	5.19-20	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	1.38+00	8.73-03	1.43-22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	1.33+00	8.42-03	1.38-22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	5.78+02	1.61+00	1.58-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN117M	0.00	3.91-01	5.49-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	2.12+02	7.69+01	8.48-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	1.35-02	1.33-02	1.23-02	5.41-03	1.46-06	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	1.11+04	1.46+03	1.78-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	5.44+00	6.25-01	2.19-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	6.85+02	1.01+01	3.27-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN125	0.00	7.79+01	1.57-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	2.62+04	2.02+04	2.01+03	1.87-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	1.02+04	8.38+03	8.32+02	7.73-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	1.53+00	1.53+00	1.53+00	1.53+00	1.52+00	1.43+00	7.68-01	1.50-03	0.00	0.00	0.00
SB126M	0.00	1.53+00	1.53+00	1.53+00	1.53+00	1.52+00	1.43+00	7.68-01	1.50-03	0.00	0.00	0.00
SB126	0.00	4.41+01	1.52+00	1.52+00	1.52+00	1.51+00	1.42+00	7.60-01	1.49-03	0.00	0.00	0.00

2.6.21

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE RADIOACTIVITY, CURIES
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE127M	0.00	1.97+04	1.94+03	1.62-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	1.95+04	1.91+03	1.61-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129M	0.00	2.52+04	1.47+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	1.61+04	9.43+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	4.28-02	4.30-02	4.30-02	4.30-02	4.30-02	4.30-02	4.28-02	4.13-02	2.86-02	7.29-04	8.50-20
I131	0.00	2.28+03	5.04-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XE131M	0.00	4.75+02	2.49-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	4.14+04	2.95+04	1.41+03	8.62-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	1.40+00	1.40+00	1.40+00	1.40+00	1.40+00	1.40+00	1.37+00	1.11+00	1.39-01	1.30-10	0.00
CS136	0.00	1.34+03	4.69-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS137	0.00	1.41+05	1.38+05	1.12+05	1.40+04	1.31-05	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	1.32+05	1.29+05	1.05+05	1.31+04	1.23-05	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	1.63+04	4.20-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	1.87+04	4.83-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	2.65+05	1.07+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	2.21+04	2.10-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	1.04+06	4.27+05	1.40+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	1.04+06	4.27+05	1.40+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	3.31+03	4.14-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	3.51+05	2.70+05	2.50+04	1.14-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	1.65+04	3.99+01	1.11-22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	1.33+03	3.20+00	8.92-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	6.12+03	6.07+03	5.65+03	2.76+03	2.13+00	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	2.63+01	2.48+01	1.48+01	8.17-02	2.19-24	0.00	0.00	0.00	0.00	0.00	0.00
GD153	0.00	1.78+00	6.24-01	5.10-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	2.00+03	1.92+03	1.30+03	2.63+01	3.10-16	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	5.55+04	3.79+04	1.21+03	1.31-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	1.34+03	6.28-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	1.67+03	4.99+01	9.47-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	3.44-03	1.72-03	3.37-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	3.44-03	1.72-03	3.37-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	9.73+06	2.87+06	3.46+05	3.90+04	3.07+01	2.77+01	2.07+01	4.32+00	3.09-01	7.60-04	1.64-05
TOTAL	0.00	9.73+06	2.87+06	3.46+05	3.90+04	3.07+01	2.77+01	2.07+01	4.32+00	3.09-01	7.60-04	1.64-05

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	4.13-02	3.91-02	2.35-02	1.40-04	1.40-26	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	2.46-04	2.46-04	2.46-04	2.46-04	2.44-04	2.21-04	8.46-05	5.77-09	0.00	0.00	0.00
KR 85	0.00	1.52+01	1.43+01	8.03+00	2.49-02	2.07-27	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	1.05+00	1.39-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	1.09-08	1.09-08	1.09-08	1.09-08	1.09-08	1.09-08	1.09-08	1.09-08	1.09-08	1.09-08	1.07-08
SR 89	0.00	9.11+02	7.00+00	6.60-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	6.96+01	6.79+01	5.44+01	5.91+00	1.36-09	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	3.13+02	3.05+02	2.45+02	2.66+01	6.10-09	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	1.59+03	2.15+01	3.21-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	2.08-04	2.08-04	2.08-04	2.08-04	2.08-04	2.07-04	1.99-04	1.31-04	2.05-06	1.79-24	0.00
NB 93M	0.00	2.16-05	3.61-05	1.38-04	3.10-04	3.12-04	3.11-04	2.98-04	1.97-04	3.08-06	2.69-24	0.00
ZR 95	0.00	4.41+03	8.98+01	5.40-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	2.49+01	5.07-01	3.05-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	6.71+03	1.82+02	1.06-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	1.23-02	1.23-02	1.23-02	1.23-02	1.23-02	1.19-02	8.88-03	4.69-04	7.84-17	0.00	0.00
RU103	0.00	1.66+03	2.81+01	2.92-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	2.42+02	4.05-01	4.21-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	7.06+01	3.54+01	7.13-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	1.25+04	6.28+03	1.27+01	1.40-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	2.39-05	2.39-05	2.39-05	2.39-05	2.39-05	2.38-05	2.36-05	2.16-05	8.87-06	1.20-09	0.00
AG109M	0.00	6.11-06	3.50-08	2.29-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	5.83-08	3.34-08	2.18-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	2.01+01	7.40+00	9.10-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	1.12+00	4.13-01	5.08-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	2.16-01	2.05-01	1.31-01	1.53-03	6.86-23	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	1.49-03	9.41-06	1.54-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	6.27-03	3.97-05	6.49-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	2.12+00	5.86-03	5.77-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN117M	0.00	1.47-03	2.07-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	2.23-01	8.11-02	8.95-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	1.71-05	1.69-05	1.56-05	6.86-06	1.87-09	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	3.91+01	5.16+00	6.28-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	1.60-02	1.84-03	6.44-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	9.41+00	1.39-01	4.50-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN125	0.00	4.95-01	1.00-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	1.06+02	8.21+01	8.14+00	7.56-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	1.76+01	1.44+01	1.43+00	1.33-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	1.66-03	1.66-03	1.66-03	1.65-03	1.64-03	1.54-03	8.28-04	1.62-06	0.00	0.00	0.00
SB126M	0.00	1.04-02	1.04-02	1.04-02	1.04-02	1.03-02	9.69-03	5.19-03	1.02-05	0.00	0.00	0.00
SB126	0.00	5.74-01	1.98-02	1.98-02	1.98-02	1.96-02	1.84-02	9.89-03	1.93-05	0.00	0.00	0.00

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE THERMAL POWER, WATTS
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE127M	0.00	1.09+01	1.07+00	8.95-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	3.15+01	3.09+00	2.59-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129M	0.00	5.00+01	2.92-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	5.86+01	3.43-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	2.82-05	2.83-05	2.83-05	2.83-05	2.83-05	2.83-05	2.82-05	2.71-05	1.88-05	4.80-07	5.59-23
XE131M	0.00	9.24-01	4.83-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	4.38+02	3.12+02	1.49+01	9.13-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	6.80-04	6.80-04	6.80-04	6.80-04	6.80-04	6.79-04	6.65-04	5.40-04	6.75-05	6.32-14	0.00
CS136	0.00	1.84+01	6.44-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS137	0.00	2.31+02	2.26+02	1.83+02	2.29+01	2.14-08	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	5.18+02	5.07+02	4.12+02	5.15+01	4.81-08	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	5.43+01	1.40-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	3.30+02	8.52-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	5.21+02	2.11-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	4.80+01	4.55-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	8.52+02	3.49+02	1.15-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	8.06+03	3.31+03	1.09+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	1.08+01	1.35-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	1.81+02	1.39+02	1.29+01	5.90-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	2.05+02	4.94-01	1.38-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	1.08+01	2.60-02	7.23-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	1.07+01	1.06+01	9.85+00	4.81+00	3.71-03	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	4.71-01	4.45-01	2.65-01	1.46-03	3.92-26	0.00	0.00	0.00	0.00	0.00	0.00
GD153	0.00	2.56-03	8.99-04	7.34-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	1.64+01	1.57+01	1.07+01	2.16-01	2.54-18	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	4.68+01	3.19+01	1.02+00	1.10-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	1.33+01	6.25-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	1.42+01	4.24-01	8.04-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	1.17-05	5.86-06	1.15-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	4.64-05	2.32-05	4.54-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	4.05+04	1.20+04	9.75+02	1.12+02	4.91-02	4.31-02	2.61-02	1.42-03	1.00-04	4.92-07	1.07-08
TOTAL	0.00	4.05+04	1.20+04	9.75+02	1.12+02	4.91-02	4.31-02	2.61-02	1.42-03	1.00-04	4.92-07	1.07-08

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	5.81+09	5.49+09	3.31+09	2.08+07	1.97-15	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	1.62+08	1.62+08	1.62+08	1.62+08	1.61+08	1.46+08	5.59+07	3.80+03	0.00	0.00	0.00
KR 85	0.00	3.13+10	2.94+10	1.65+10	5.11+07	4.25-18	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	1.11+11	1.46+05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	8.34+03	8.34+03	8.34+03	8.34+03	8.34+03	8.34+03	8.34+03	8.34+03	8.34+03	8.33+03	8.22+03
SR 89	0.00	8.44+14	6.49+12	6.12-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	1.77+15	1.73+15	1.38+15	1.50+14	3.45+04	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	1.77+13	1.73+13	1.38+13	1.50+12	3.45+02	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	4.18+14	5.64+12	8.43-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	4.39+08	4.39+08	4.39+08	4.39+08	4.39+08	4.37+08	4.19+08	2.76+08	4.32+06	3.78-12	0.00
NB 93M	0.00	3.04+07	5.07+07	1.93+08	4.36+08	4.39+08	4.37+08	4.19+08	2.76+08	4.32+06	3.78-12	0.00
ZR 95	0.00	8.43+14	1.72+13	1.03-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	-1.79+04	-3.64+02	-2.19-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	4.65+14	1.26+13	7.31-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	9.11+09	9.11+09	9.11+09	9.11+09	9.08+09	8.82+09	6.57+09	3.47+08	5.80-05	0.00	0.00
RU103	0.00	1.70+14	2.85+11	2.96-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	2.55+11	4.27+08	4.44-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	5.95+15	2.99+15	6.02+12	6.64-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	-1.19+06	-5.97+05	-1.20+03	-1.33-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	1.44+06	1.44+06	1.44+06	1.44+06	1.44+06	1.44+06	1.42+06	1.30+06	5.34+05	7.22+01	0.00
AG109M	0.00	-5.86-05	-3.35-05	-2.19-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	2.93+04	1.68+04	1.10+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	3.97+12	1.46+12	1.80+08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	-1.55+02	-5.70+01	-7.00-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	-1.63+02	-1.55+02	-9.94+01	-1.16+00	-5.19-20	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	1.97+09	1.25+07	2.04-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	-1.33+00	-8.42-03	-1.38-22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	5.78+11	1.61+09	1.58-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN117M	0.00	-3.91-01	-5.49-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	-2.12+02	-7.69+01	-8.48-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	-1.35-02	-1.33-02	-1.23-02	-5.41-03	-1.48-06	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	-1.11+04	-1.46+03	-1.78-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	-5.44+00	-6.25-01	-2.19-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	9.79+11	1.44+10	4.67-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN125	0.00	2.60+10	5.25-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	2.91+13	2.25+13	2.23+12	2.07+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	2.56+12	2.09+12	2.08+11	1.93+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	7.67+08	7.67+08	7.67+08	7.67+08	7.62+08	7.16+08	3.84+08	7.50+05	0.00	0.00	0.00
SB126M	0.00	-1.53+00	-1.53+00	-1.53+00	-1.53+00	-1.52+00	-1.43+00	-7.68-01	-1.50-03	0.00	0.00	0.00
SB126	0.00	-4.41+01	-1.52+00	-1.52+00	-1.52+00	-1.51+00	-1.42+00	-7.60-01	-1.49-03	0.00	0.00	0.00

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE INHALATION HAZARD, M**3 OF AIR AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
TE127M	0.00	1.97+13	1.94+12	1.62+03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	6.51+11	6.38+10	5.35+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129M	0.00	2.52+13	1.47+10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	1.61+11	9.43+07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	2.14+09	2.15+09	2.15+09	2.15+09	2.15+09	2.15+09	2.14+09	2.06+09	1.43+09	3.65+07	4.25-09
I131	0.00	2.28+13	5.04-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XE131M	0.00	1.19+09	6.21-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	1.03+14	7.37+13	3.52+12	2.15-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	4.67+08	4.67+08	4.67+08	4.67+08	4.67+08	4.66+08	4.56+08	3.70+08	4.63+07	4.33-02	0.00
CS136	0.00	2.23+11	7.82+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS137	0.00	2.82+14	2.76+14	2.24+14	2.80+13	2.62+04	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	-1.32+05	-1.29+05	-1.05+05	-1.31+04	-1.23-05	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	1.63+13	4.20+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	4.68+12	1.21+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	5.30+13	2.14+10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	3.69+12	3.49+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	5.21+15	2.13+15	7.01+11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	-1.04+06	-4.27+05	-1.40+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	4.14+11	5.18+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	1.76+14	1.35+14	1.25+13	5.72+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	-1.65+04	-3.99+01	-1.11-22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	-1.33+03	-3.20+00	-8.92-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	3.06+12	3.04+12	2.83+12	1.38+12	1.06+09	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	6.58+10	6.21+10	3.69+10	2.04+08	5.47-15	0.00	0.00	0.00	0.00	0.00	0.00
GD153	0.00	5.92+08	2.08+08	1.70+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	2.00+13	1.92+13	1.30+13	2.63+11	3.10-06	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	1.85+13	1.26+13	4.02+11	4.36-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	-1.34+03	-6.28-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	1.67+12	4.99+10	9.47-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB161	0.00	-7.21-01	-8.45-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	-3.44-03	-1.72-03	-3.37-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	-3.44-03	-1.72-03	-3.37-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	1.65+16	7.46+15	1.66+15	1.82+14	1.46+10	1.32+10	1.04+10	3.33+09	1.48+09	3.65+07	8.22+03
TOTAL	0.00	1.65+16	7.46+15	1.66+15	1.82+14	1.46+10	1.32+10	1.04+10	3.33+09	1.48+09	3.65+07	8.22+03

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+15N/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
H 3	0.00	3.87+05	3.66+05	2.20+05	1.38+03	1.32-19	0.00	0.00	0.00	0.00	0.00	0.00
SE 79	0.00	1.62+02	1.62+02	1.62+02	1.62+02	1.61+02	1.46+02	5.59+01	3.80-03	0.00	0.00	0.00
KR 85	0.00	-9.39+03	-8.81+03	-4.94+03	-1.53+01	-1.28-24	0.00	0.00	0.00	0.00	0.00	0.00
RB 86	0.00	1.11+07	1.48+01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RB 87	0.00	1.67-01	1.67-01	1.67-01	1.67-01	1.67-01	1.67-01	1.67-01	1.67-01	1.67-01	1.67-01	1.64-01
SR 89	0.00	8.44+10	6.49+08	6.12-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SR 90	0.00	1.77+11	1.73+11	1.38+11	1.50+10	3.45+00	0.00	0.00	0.00	0.00	0.00	0.00
Y 90	0.00	2.66+09	2.59+09	2.08+09	2.26+08	5.18-02	0.00	0.00	0.00	0.00	0.00	0.00
Y 91	0.00	1.39+10	1.88+08	2.81-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZR 93	0.00	2.19+03	2.19+03	2.19+03	2.19+03	2.19+03	2.18+03	2.10+03	1.38+03	2.16+01	1.89-17	0.00
NB 93M	0.00	3.04+02	5.07+02	1.93+03	4.36+03	4.39+03	4.37+03	4.19+03	2.76+03	4.32+01	3.78-17	0.00
ZR 95	0.00	1.40+10	2.86+08	1.72-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95M	0.00	-1.79+04	-3.64+02	-2.19-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NB 95	0.00	1.39+10	3.78+08	2.19-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TC 99	0.00	9.11+04	9.11+04	9.11+04	9.11+04	9.08+04	8.82+04	6.57+04	3.47+03	5.80-10	0.00	0.00
RU103	0.00	6.37+09	1.07+07	1.11-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH103M	0.00	5.10+07	8.54+04	8.88-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RU106	0.00	1.19+11	5.97+10	1.20+08	1.33-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RH106	0.00	-1.19+06	-5.97+05	-1.20+03	-1.33-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PD107	0.00	2.88+02	2.88+02	2.88+02	2.88+02	2.88+02	2.87+02	2.85+02	2.61+02	1.07+02	1.44-02	0.00
AG109M	0.00	-5.86-05	-3.35-05	-2.19-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD109	0.00	2.93-01	1.68-01	1.10-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110M	0.00	3.97+07	1.46+07	1.80+03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG110	0.00	-1.55+02	-5.70+01	-7.00-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AG111	0.00	8.98+05	1.98-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD113M	0.00	-1.63+02	-1.55+02	-9.94+01	-1.16+00	-5.19-20	0.00	0.00	0.00	0.00	0.00	0.00
IN114M	0.00	6.89+04	4.36+02	7.13-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IN114	0.00	-1.33+00	-8.42-03	-1.38-22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CD115M	0.00	1.93+07	5.36+04	5.26-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN117M	0.00	-3.91-01	-5.49-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN119M	0.00	-2.12+02	-7.69+01	-8.48-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN121M	0.00	-1.35-02	-1.33-02	-1.23-02	-5.41-03	-1.48-06	0.00	0.00	0.00	0.00	0.00	0.00
SN123M	0.00	-1.11+04	-1.46+03	-1.78-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE123M	0.00	-5.44+00	-6.25-01	-2.19-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB124	0.00	3.42+07	5.04+05	1.64-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN125	0.00	3.89+06	7.87-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SB125	0.00	2.62+08	2.02+08	2.01+07	1.87-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE125M	0.00	1.02+08	8.38+07	8.32+06	7.73-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SN126	0.00	3.84+03	3.84+03	3.84+03	3.83+03	3.81+03	3.58+03	1.92+03	3.75+00	0.00	0.00	0.00
SB126M	0.00	-1.53+00	-1.53+00	-1.53+00	-1.53+00	-1.52+00	-1.43+00	-7.68-01	-1.50-03	0.00	0.00	0.00

GE FOLLOW-ON PROPERTIES AFTER SEPARATION

POWER = 48.52 MW, BURNUP = 41493.MWD, FLUX= 2.59+ISN/CM**2-SEC

NUCLIDE INGESTION HAZARD, M**3 OF WATER AT RCG
BASIS = MT HEAVY METAL CHARGED TO REACTOR

	CHARGE	SEPARATION	1.0+00 YR	1.0+01 YR	1.0+02 YR	1.0+03 YR	1.0+04 YR	1.0+05 YR	1.0+06 YR	1.0+07 YR	1.0+08 YR	1.0+09 YR
SB126	0.00	-4.41+01	-1.52+00	-1.52+00	-1.52+00	-1.51+00	-1.42+00	-7.60-01	-1.49-03	0.00	0.00	0.00
TE127M	0.00	3.95+08	3.87+07	3.25-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE127	0.00	9.76+07	9.57+06	8.03-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129M	0.00	1.26+09	7.36+05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TE129	0.00	2.02+07	1.18+04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I129	0.00	7.14+05	7.16+05	7.16+05	7.16+05	7.16+05	7.16+05	7.13+05	6.88+05	4.76+05	1.22+04	1.42-12
I131	0.00	7.59+09	1.68-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XE131M	0.00	-4.75+02	-2.49-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XE133	0.00	-2.06+01	-2.85-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS134	0.00	4.60+09	3.28+09	1.56+08	9.58-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS135	0.00	1.40+04	1.40+04	1.40+04	1.40+04	1.40+04	1.40+04	1.37+04	1.11+04	1.39+03	1.30-06	0.00
CS136	0.00	2.23+07	7.82-02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CS137	0.00	7.05+09	6.89+09	5.60+09	7.00+08	6.55-01	0.00	0.00	0.00	0.00	0.00	0.00
BA137M	0.00	-1.32+05	-1.29+05	-1.05+05	-1.31+04	-1.23-05	0.00	0.00	0.00	0.00	0.00	0.00
BA140	0.00	8.13+08	2.10+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LA140	0.00	9.36+08	2.42+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE141	0.00	2.94+09	1.19+06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR143	0.00	4.43+08	4.19+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CE144	0.00	1.04+11	4.27+10	1.40+07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PR144	0.00	-1.04+06	-4.27+05	-1.40+02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ND147	0.00	5.52+07	6.90-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM147	0.00	1.76+09	1.35+09	1.25+08	5.72-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148M	0.00	-1.65+04	-3.99+01	-1.11-22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PM148	0.00	-1.33+03	-3.20+00	-8.92-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SM151	0.00	1.53+07	1.52+07	1.41+07	6.90+06	5.32+03	0.00	0.00	0.00	0.00	0.00	0.00
EU152	0.00	3.29+05	3.10+05	1.85+05	1.02+03	2.73-20	0.00	0.00	0.00	0.00	0.00	0.00
GD153	0.00	8.88+03	3.12+03	2.55-01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU154	0.00	1.00+08	9.59+07	6.49+07	1.32+06	1.55-11	0.00	0.00	0.00	0.00	0.00	0.00
EU155	0.00	2.78+08	1.89+08	6.04+06	6.54-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EU156	0.00	-1.34+03	-6.28-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB160	0.00	4.17+07	1.25+06	2.37-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB161	0.00	-7.21-01	-8.45-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GD162	0.00	-3.44-03	-1.72-03	-3.37-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TB162M	0.00	-3.44-03	-1.72-03	-3.37-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUBTOT	0.00	5.65+11	2.92+11	1.47+11	1.60+10	8.37+05	8.29+05	8.01+05	7.07+05	4.78+05	1.22+04	1.64-01
TOTAL	0.00	5.65+11	2.92+11	1.47+11	1.60+10	8.37+05	8.29+05	8.01+05	7.07+05	4.78+05	1.22+04	1.64-01

APPENDIX

SECTION 3: EVALUATION METHODOLOGY

APPENDIX 3.A

Specimen Dose Calculation Program

APPENDIX 3.A Specimen Dose Calculation Program

FILE NAME = FOODW PROCESSED ON 17 JUL 73 AT 17:33:00

NO PCF ELEMENT REQUESTED

```
100 ' *******  THIS PROGRAM CALCULATES DOSES AND DOSE  COMMITMENTS FROM FOODS FROM IRRIGATED FARMS.
110 '  * * *   FOR ALAP STUDY.  APRIL 1973.
120 '  FOR HELP CALL DA BAKER 946-2211
130
140 '*************   ARRAY  DIMENSIONS   ************,*****
150
160  DIM  A(200,5), B(200)          ' ADULT DOSE FACTORS,  PLANT CONC. FACTORS
165  DIM  C(200)                    ' MILK CONC.
170  DIM  D(200),   E(200)          ' DECAY CONST.,  EGG BURDENS
180  DIM  G(200,5), I(200,5)        ' % DOSE,  TAUS
190  DIM  J(200),   L(200)          ' EGG TRANS. FACTORS,  WATER CONC.
200  DIM  M(200),   N(200,5)        ' MILK TRANS. COEF.,  DOSE COMMITMENTS
210  DIM  O(200,5), Q(200,5)        ' % DOSE COMMIT.,  ADULT DOSE
220  DIM  R(200),   S(200)          ' RELEASES,  SOIL FACTORS
230  DIM  T(5,5),   U(5,5)          ' DOSE TOTALS,  DOSE COMMIT. TOTALS
240  DIM  V(200),   W(200)          ' RECYCLE FRACTION,  LEAF FACTORS
250  DIM  X(200),   Y(15)           ' PLANT CONC.,  YIELDS
260  DIM  Z(200)                    ' RECONCENTRATIONS
270
280  DIM  H(5)$(5),  N(200)$(8)     ' INDIV. NAMES,  ISOTOPE NAMES
290  DIM  S(15)$(12)                ' FOOD NAMES
340
350 'NON-DIMENSIONED VARIABLES USED IN THIS PROGRAM:
360 ' A5 C D1 D2 D3 E F F1 F2 F3 F4 F5 G1 H1 I J K K1  K3 K4 K5 M1 M2 N N1 Q1 Q2 Q3 Q4
370 ' R R3 R5 R7 S1 T T1 T2 T3 T4 T5 T6 U1 U2 V V1 W1 X
380 ' A$ B$ C$ D$ F$  I$ K$ P$ Q$ R$ T$ W$ X$
390
400 REM ********************READ INITAL CONSTANTS*****************
410
430 N1=62   ' NUMBER OF NUCLIDES IN ARGIN FILE
440 T6=50   ' YEARS OF DOSE ACCUMULATION
450 T4=25   ' YEARS ACCUMULATION IN SOIL
460 T2=30   ' DAYS COW CYCLES BETWEEN GRAZING SITES
470 R5=110  ' IRRIGATION RATE IN L/M^2/MO
475 D3=0.25 ' DEPOSITION FRACTION TO PLANT
480 U2=365  ' MILK CONSUMPTION IN L/YR
490 Q1=55   'FORAGE CONSUMPTION IN KG/DAY
500 Q2=50   ' COW WATER IN L/DAY
```

```
510 G1=.75  ' GRAZING FACTOR
512 Q3=0.12 ' CHICKEN GRAIN CONSUMPTION IN KG/DAY
515 Q4=0.3  ' CHICKEN WATER CONSUMPTION IN  L/DAY
560
570 DATA "LEAFY-VEG.","O.A.G.-VEG.","SPUDS","ROOT-VEG.","BERRIES
580 DATA MELONS,"ORCH.-FRUIT","WHEAT","OTHER-GRAIN","EGGS","MILK
590 READ S(1)$,S(2)$,S(3)$,S(4)$,S(5)$,S(6)$,S(7)$,S(8)$,S(9)$,S,10)$,S(11)$
600 DATA ADULT, TEEN, CHILD
610 READ B(1)$,B(2)$,B(3)$
620 DATA BODY, GI-LLI, THYROID, BONE,LIVER
630 READ G(1)$,G(2)$,G(3)$,G(4)$,G(5)$
640 DATA 1.5, .7, 1.8, 4, 2.7, .83, 1.7, .34, .35, .35, 1.3
650 MAT READ Y(11)      ' YIELD IN KG/M^2
660
670 FILE #1=TAUS2, #2=ARGIN2, #3=RELW, #4=FOOIN3
680
690 GET#2, I$,I$          'SPACE PAST TITLES
700 GET #1, I$, I$        ' SPACE PAST TITLES
701
710 FOR I=1 TO N1      'READ ISOTOPE NAME, DECAY CONST AND DOSE FACTORS FROM 'ARGIN'
720 INPUT#2, N(I)$,D(I),A(I,1),A(I,2),A(I,3),A(I,4),A(I,5),I$,I$,I$,I$
730 INPUT#1, X$, I(I,1), I(I,4),I(I,5)         ' TAUS FOR T-B AND BONE AND LIVER IN DAYS
740 I(I,3)=138        '  TAUS FOR THYROID
750 I(I,2)=10       ' TAU IN DAYS FOR GI-LLI
760 NEXT I
770
780  GET#4, I$, I$       '  SPACE PAST TITLES
790
800 FOR I=1 TO N1
810 IF I=1 GOTO 830
820 IF N(I)$(1,2)=N(I-1)$(1,2) GOTO 850
830 INPUT#4, I$, B(I), J(I), M(I)
840 GOTO 860
850 B(I)=B(I-1)
860 J(I)=J(I-1)
870 M(I)=M(I-1)
880 CONTINUE
890 NEXT I
900
910 WIDTH 132
920 ON ERROR GOTO 1990
930 ON ATTENTION GOTO 2000
931
940 REM ******************GET USER INPUT*****************************
950
960 PRINT "TITLE  ";
970 GET A$
980 'FIND OUT REACTOR NAME FROM USER
990 PRINT
```

```
1000 OUTPUT "REACTOR NAME";
1010 GET R$
1020 '**GET REACTOR RELEASES FROM FILE 'REL'
1030 IF END#3 GOTO 1080
1040 GET#3, Q$      'TRY TO MATCH THIS LINE OF 'REL' WITH REACTOR NAME
1050 IF LEN(Q$)<1+LEN(R$)  GOTO 1030
1060 IF Q$(2,LEN(R$))<>R$  GOTO 1030
1070 GOTO 1110
1080 OUTPUT "**NO ";R$;" RELEASES ON FILE 'REL'**"
1090 RESTORE#3
1100 GOTO 1000
1110 INPUT#3, W$          ' INPUT WATER TYPE
1120 MAT INPUT#3, R(200)      'INPUT REACTOR RELEASES
1130 RESTORE#3
1140 IF NUM=N1  GOTO 1170
1150 OUTPUT "I NEED TO EAT";N1;"RELEASES, BUT WAS FED";STR(NUM," ###.")
1160 GOTO 3360
1170 K1=K1+1       '  CASE NO.
1180 PRINT "ENTER FOOD TYPE, 1 TO 11";
1190 INPUT X
1210 IF X=1 GOTO 1255
1215 E=.1       ' TRANS. FACTOR FOR ALL OTHERS
1220 IF X=11 GOTO 1440
1250 IF X=10 GOTO 1285
1252 GOTO 1260
1255 E=1    ' TRANS FACTOR FOR LEAFY VEG.
1260 PRINT "ENTER CONSUMPTION RATE IN KG/YR,  CONTAMINATED FRACTION,  AND GROWING SEASON IN DAYS";
1270 INPUT U1, F4, T2
1280 GOTO 1440
1285 E=.1      ' TRANS. FACTOR FOR GRAIN
1290 PRINT "ENTER CONSUMPTION RATE IN EGGS/DAY  &  TIME IN DAYS BETWEEN LAYING AND EATING";
1300 INPUT U1, T5
1310 PRINT "ENTER GRAIN GROWING SEASON IN DAYS";
1320 INPUT T2
1324 PRINT "ENTER CONTAMINATED FRACTION";
1326 INPUT F4
1430
1440 PRINT "ENTER HOLDUP IN HRS  AND  MIX. RATIO ";
1450 INPUT M1,M2
1460 '**INPUT COOLING FLOW AND RECONCENTRATION CONSTANTS
1470 OUTPUT "COOLING FLOW IN CFS=";
1480 INPUT W
1500 OUTPUT "WHICH RECONCENTRATION FORMULA";
1510 INPUT R
1520 ON R GOTO 1600,1710,1550
1530 OUTPUT "**ENTER ONE OF THE NUMBERS 1, 2, OR 3**"
1540 GOTO 1500
1550
1560 C=1    '  RECONC. FACTOR
```

```
1570 1850 OUTPUT R$;"   FLOW=";W;"  CONSTANT RECONCENTRATION=";C
1580 2060 Z(I)=C
1590 GOTO 1760
1600 PRINT "ENTER COOLING POND VOLUME IN CUBIC FEET AN"
1610 PRINT "      FRACTIONAL TURNOVER RATE IN 1/DAY"
1620 INPUT V,M1
1630 PRINT "ENTER MAKEUP FLOW IN CFS AND CYCLE TIME IN HOURS"
1640 INPUT M,C
1650 IF M>W GOTO 1990
1660 1850 OUTPUT R$;"   FLOWS ARE";W;"&";M;"  VOLUME=";V;"  CYCLE=";C
1670 1860 OUTPUT R$;"      TURNOVER RATE=";M1
1680 2070 V(I)=(W-M)/(W+V*M1/86400)   'RECYCLE FRACTION
1690 2060 Z(I)=1/(1-V(I)*EXP(-D(I)*C))
1700 GOTO 1780
1710 OUTPUT "ENTER RECYCLE FRACTION, CYCLE TIME IN HOURS"
1720 INPUT V,C
1730 1850 OUTPUT R$;"   FLOW=";W;"  FRACTION=";V;"  CYCLE=";C
1740 2060 Z(I)=(1-(V*EXP(-D(I)*C))^(T4*8766/C+1))/(1-V*EXP(-D(I)*C))
1750
1760 '**PRINT CONSTANTS AT TELETYPE
1770
1780 PRINT
1790 IF X=11 GOTO 1831
1830 PRINT "CONSUMP. RATE=";U1;"   CONTAMINATED FRACTION=";F4;"   GROWING SEASON=";T2
1831 PRINT "TRANSLOCATION=";E;"    YIELD=";Y(X)
1840 PRINT
1850 OUTPUT R$;"   FLOW=";W;"  CONSTANT RECONCENTRATION=";C
1860 'PUT IN AT RUN
1870 OUTPUT
1880 PRINT "HOLDUP=";H1,"MIXING RATIO=";M2
1890 PRINT
1920 ON ATTENTION
1930 OUTPUT "CONSTANTS OK"
1940 GET A$
1950 IF A$(1,1)="N" GOTO 1180
1960 IF A$(1,1)="Y" GOTO 2025
1970 OUTPUT "**TYPE Y FOR YES OR N FOR NO**"
1980 GOTO 1930
1990 PRINT "ERROR ON INPUT - - - SAY AGAIN . ."
2000 T=ESL
2010 JUMP T
2020 ON ERROR
2025 IF K1>1 GOTO 2040
2026 PRINT
2027 LIST NN 440-513
2030
2040 REM ********************CALCULATE RESULTS**********************
2050 FOR I=1 TO N1
2060  IF R(I)=0  GOTO 2090
```

```
2070 'PUT IN AT RUN
2080 Z(I)=C
2090 NEXT I
2100
2130 ' * * * * *  DOSE  CALCULATION  * * * *
2140
2145 DISABLE
2150 MAT T=ZER
2160 MAT U=ZER
2170 FOR F=1 TO 5
2180  FOR I=1 TO N1
2190  IF R(I)=0 GOTO 2410
2200  L(I)=R(I)*Z(I)*M2*EXP(-D(I)*H1)/(W*8.937E8)*1E12     ' PCI/L
2210 D1=0.693/14+24*D(I)          ' EFFECTIVE DECAY CONST IN 1/DAY
2230 IF X<>11 GOTO 2250
2240 T2=30
2250 W(I)=D5*E/Y(X)*(1-EXP(-D1*T2))/(D1*30.44)       ' WATER THRU LEAF PATH
2260 S(I)=B(I)*(1-EXP(-D(I)*T4*8766))/(D(I)*224*730.5)      'SOIL TO ROOT PATH
2270 X(I)=L(I)*R5*(W(I)+S(I))                ' PLANT CONC. IN PCI/KG
2280  Q(I,F)=X(I)*F4*U1*A(I,F)               'ADULT DOSE
2285 GOSUB 3370
2290 N(I,F)=Q(I,F)*F5          '  VEG. DOSE  COMMITMANT.
2291
2295 IF X=11 GOTO 2350
2297 IF X<10 GOTO 2380
2300 E(I)=(X(I)*Q3*EXP(-D(I)*T5*24) + Q4*L(I)) * J(I)      ' EGG BURDEN IN PCI/EGG
2320 Q(I,F)=A(I,F)*U1*E(I)*F4*365       '  EGG DOSE
2330 N(I,F)=Q(I,F)*F5      '  EGG DOSE  COMMITMENT
2340 GOTO 2380
2345
2350 C(I)=M(I)*G1*X(I)/EXP(-D(I)*T1*24) + M(I)*L(I)*Q2      ' MILK CONC. IN PCI/L
2360 Q(I,F)=A(I,F)*U2*G1*C(I)          '  MILK DOSE
2370 N(I,F)=Q(I,F)*F5      '  MILK DOSE  COMMITMENT
2371
2380 T(I,F)=T(I,F) + Q(I,F)            ' TOTAL DOSE
2390 U(I,F)=U(I,F) + N(I,F)            ' TOTAL DOSE COMMITMENT
2410  NEXT I
2420 NEXT F
2430 ENABLE
2440
2450 '  * * * * *  PRINT RESULTS AT TTY  * * * * *
2460 PRINT
2470 PRINT
2480 PRINT " * * *  DOSES AND DOSE COMMITMENTS TO AN INDIVIDUAL CONSUMING ";S(X)$;" IN MREM/YEAR AND MREM    * * *"
2490 PRINT
2500 PRINT TAB(9);" BODY      GI-LLI     THYROID    BONE     LIVER"
2510 PRINT
2520 FOR J=1 TO 3
2530 IF J>1 GOTO 2570
```

```
2540 PRINT USING 2590, B(J)$,T(J,1),T(J,2),T(J,3),T(J,4),T(J,5)
2550 PRINT
2560 PRINT USING 2590, B(J)$,U(J,1),U(J,2),U(J,3),U(J,4),U(J,5)
2570 NEXT J
2580
2590 : #####  #.#!!!!   #.#!!!!   #.#!!!!   #.#!!!!   #.#!!!!
2600
2630 PRINT
2640 IF K1>1 GOTO 2755
2650 PRINT ¤DO YOU WANT DOSES PUT ON FILE¤;
2660 GET C$
2670 IF C$=¤N¤ GOTO 2880
2672
2674 ' * * * WRITE DOSES TO FILE * * *
2675
2680 PRINT ¤ENTER FILE NAME¤;
2690 GET K$
2700 PRINT ¤ENTER FILE TITLE¤;
2710 GET T$
2720 FILE CLOSE #1
2730 FILE SCRATCH#1=K$
2740 OUTPUT #1, R$; T$
2750 GOTO 2770
2755 IF C$=¤N¤ GOTO 2880
2760 FILE APPEND #1=K$
2770 OUTPUT #1, S(X)$, N1, K1
2780 FOR I=1 TO N1
2790 OUTPUT #1, N(I)$;
2820 OUTPUT #1, Q(I,1),Q(I,2),Q(I,3),Q(I,4),Q(I,5)
2830 NEXT I
2840
2850 FILES
2860
2870 ON ATTENTION GOTO 3260
2880 PRINT
2884 PRINT ¤WHAT % ***¤;
2885 INPUT J1
2886 PRINT
2890 PRINT ¤      * * *  CONTRIBUTIONS TO ADULT DOSE >¤;J1;¤%   *  *  *¤
2900 PRINT
2910 IF X=11 GOTO 2990
2920 IF X=10 GOTO 2960
2930 PRINT ¤ISOTOPE   H.L.    RELEASE   CONC.   PATH  FACTOR  PLANT CONC.  DOSE      %        TAU   DOSE COMMIT   %¤
2940 PRINT ¤          YEAR     CI/YR    PCI/L    LEAF  ROOT     PCI/KG    MREM/YR                DAY      MREM¤
2950 GOTO 2980
2960 PRINT ¤ISOTOPE    H.L.    RELEASE   CONC.   GRAIN CONC.  EGG CONC.    DOSE       %        TAU   DOSE COMMIT   %¤
2970 PRINT ¤           YEAR     CI/YR    PCI/L     PCI/KG      PCI/EGG    MREM/YR               DAY      MREM¤
2980 GOTO 3020
2990 CONTINUE
```

```
3000 PRINT #ISOTOPE    H.L.    RELEASE   CONC.   GRASS CONC.  MILK CONC.   DOSE      %       TAU   DOSE COMMIT   %#
3010 PRINT #           YEAR    CI/YR     PCI/L     PCI/KG       PCI/L     MREM/YR             DAY      MREM#
3020 FOR F=1 TO 5
3030 PRINT
3040 PRINT G(F)$
3050 PRINT
3060 FOR I=1 TO N1
3070 IF R(I)=0 GOTO 3220
3080 A5=0.693/(D(I)*8766)       ' HALF LIFE IN YRS
3085 IF T(1,F) =0 GOTO 3110
3090 G(I,F)=Q(I,F)/T(1,F)*100     '  % DOSE
3100 O(I,F)=N(I,F)/U(1,F)*100     '  % DOSE COMMITMENT
3110 IF G(I,F)>U1 OR O(I,F)>U1 GOTO 3130
3120 GOTO 3220
3130 IF X=11 GOTO 3210
3140 IF X=10 GOTO 3190
3150 K3=W(I)/(W(I)+S(I))
3160 K4=S(I)/(W(1)+S(I))
3170 PRINTUSING3240,N(I)$,A5,R(I),L(I),K3,K4,X(I),Q(I,F),G(I,F),I(I,F),N(I,F),O(I,F)
3180 GOTO 3220
3190 PRINT USING 3250,N(I)$,A5,R(I),L(I),X(I),E(I),Q(I,F),G(I,F),I(I,F),N(I,F),O(I,F)
3200 GOTO 3220
3210 PRINT USING 3250, N(I)$,A5,R(I),L(I),X(I),C(I),Q(I,F),G(I,F),I(I,F),N(I,F),O(I,F)
3220 NEXT I
3230 NEXT F
3240 :&&&&&&&& #.#!!!!  #.#!!!!  #.#!!!!   #.##  #.##    #.#!!!!   #.##!!!!   ###.#    ######   #.##!!!!   ###.#
3250 :&&&&&&&& #.#!!!!  #.#!!!!  #.#!!!!   #.#!!!!     #.#!!!!   #.##!!!!   ###.#    ######   #.##!!!!   ###.#
3260 :&&&&&&&& #.#!!!!     #.#!!!!  #.#!!!!     #.#!!!!      #.#!!!!  ###.##       #.#!!!!     ###.##     ######
3270 PRINT
3280 CONTINUE
3290 ON ATTENTION
3300 ON ATTENTION GOTO 3320
3305 IF C$=##  GOTO 3320
3310  ' LLLLLLL
3320 PRINT
3330 PRINT
3340 ON ATTENTION
3350 GOTO 1170
3360 STOP
3370 '**********   SUB TO CALC FACTOR FOR DOSE COMMITMENT AFTER T6 YEARS.   ********
3380 F5=0
3390 FOR P=1 TO T6
3400 F5= F5 + 1 + (T6-P)*EXP(-P*253/I(I,F))
3410 NEXT P
3420 RETURN

*_**********END OF FILE
```

APPENDIX 3.B

3.B.1 External Radiation Dose Factors

3.B.2 Adult Radiation Dose Factors - Ingestion

3.B.3 Adult Radiation Dose Factors - Inhalation

APPENDIX 3.B.1 External Radiation Dose Factors

ISOTOPE	Submersion in Air (mrem/yr per pCi/m^3) WHOLE BODY	Standing on Shoreline (mrem/hr per pCi/m^2) WHOLE BODY
C-14	1.4E-11	0.0
Ca-41	1.3E-10	0.0
Co-60	2.0E-6	2.0E-8
Ni-59	9.6E-6	0.0
Ni-63	0.0	0.0
Se-79	1.2E-7	0.0
Rb-87	4.4E-7	0.0
Sr-90	2.4E-10	0.0
Zr-93+D	0.0	0.0
Nb-93m	0.0	0.0
Mo-93	2.0E-11	0.0
Tc-99	5.1E-7	0.0
Pd-107	0.0	0.0
Cd-113m	4.9E-10	2.2E-12
Sn-126+D	7.3E-5	9.0E-9
Sb-126	9.6E-3	8.9E-9
I-129	9.6E-6	7.0E-12
Cs-135	2.5E-7	0.0
Cs-137	4.7E-7	4.9E-9
Sm-151	1.1E-6	4.8E-11
Eu-154	9.8E-7	9.0E-9
Ho-166m	9.6E-3	8.9E-9
Pb-210+D	1.2E-5	1.3E-11
Bi-210+D	1.4E-5	0.0
Po-210	5.9E-8	5.4E-14
Rn-222+D	7.1E-3	6.4E-9
Ra-223+D	1.6E-3	1.5E-9
Ra-224+D	1.1E-2	8.9E-9
Ra-225+D	7.6E-5	8.4E-11
Ra-226+D	7.2E-3	6.4E-9
Ra-228+D	3.4E-3	1.2E-8
Ac-225	1.7E-3	1.6E-9
Ac-227+D	1.8E-3	2.0E-9
Th-227+D	5.2E-4	5.1E-10
Th-228+D	1.5E-5	8.9E-9
Th-229	2.3E-3	2.2E-9
Th-230+D	7.2E-3	6.5E-9
Th-232+D	3.4E-3	3.0E-9
Th-234	1.1E-4	1.1E-10
Pa-231+D	2.0E-3	2.2E-9
Pa-233	1.3E-3	1.3E-9
U-233	2.4E-3	2.3E-9
U-234	6.9E-7	7.4E-13
U-235+D	1.1E-3	3.2E-9
U-236	1.5E-5	4.3E-9
U-238+D	1.1E-4	8.8E-7
Np-237+D	1.4E-3	4.5E-7
Np-239	9.6E-4	3.7E-7
Pu-238	6.0E-7	4.0E-9
Pu-239	4.9E-7	1.7E-9
Pu-240	5.7E-7	4.0E-9
Pu-241	2.5E-7	9.5E-11
Pu-242	4.5E-7	3.6E-9
Am-241	1.6E-4	6.1E-8
Am-242m	2.1E-5	1.6E-7
Am-243+D	1.3E-3	4.6E-7
Cm-242	1.4E-6	4.7E-9
Cm-243	1.1E-7	2.9E-9
Cm-244	1.2E-10	1.8E-9
Cm-245+D	3.9E-4	1.3E-7
Cm-246	4.2E-7	3.3E-9
Cm-247+D	1.8E-3	7.5E-7

APPENDIX 3.B.2 Adult Radiation Dose Factors - Ingestion

	mrem/pCi Intake				
Isotope	Whole Body	GI-LLI	Thyroid	Bone	Liver
C-14	5.29E-7	3.20E-7	5.29E-7	2.64E-6	5.29E-7
Ca-41	5.74E-5	1.84E-7	0.0	0.0	0.0
Co-60	4.70E-6	3.94E-5	0.0	0.0	2.11E-6
Ni-59	5.14E-7	6.90E-7	0.0	2.65E-6	1.33E-6
Ni-63	1.20E-6	1.61E-6	0.0	3.02E-5	3.10E-6
Se-79	4.40E-7	5.38E-7	0.0	0.0	2.63E-6
Rb-87	4.27E-6	5.76E-7	0.0	0.0	1.21E-5
Sr-90	8.95E-5	1.23E-4	0.0	3.3E-4	0.0
Zr-93+D	4.71E-10	2.43E-6	0.0	9.36E-9	1.10E-10
Nb-93m	6.66E-10	3.84E-6	0.0	6.84E-9	2.51E-9
Mo-93	2.07E-7	1.25E-6	0.0	0.0	7.65E-6
Tc-99	4.44E-8	5.38E-6	0.0	1.11E-7	1.65E-7
Pd-107	9.41E-9	9.11E-7	0.0	0.0	1.47E-7
Cd-113m	6.69E-8	2.30E-5	0.0	0.0	2.09E-6
Sn-126+D	2.40E-6	2.43E-5	4.79E-7	7.78E-5	1.63E-6
Sb-126	4.17E-7	9.40E-5	6.99E-9	1.16E-6	2.36E-8
I-129	6.01E-6	3.07E-7	6.18E-3	2.49E-6	1.76E-6
Cs-135	5.64E-6	3.71E-7	0.0	1.44E-5	1.49E-5
Cs-137	5.60E-5	2.05E-6	0.0	6.37E-5	9.96E-5
Sm-151	9.29E-10	5.25E-6	0.0	1.12E-8	8.84E-9
Eu-154	2.81E-8	8.83E-5	0.0	2.34E-7	1.01E-7
Ho-166m	1.84E-8	2.56E-5	0.0	6.05E-8	2.12E-8
Pb-210+D	1.01E-4	5.42E-5	0.0	1.47E-3	6.49E-4
Bi-210+D	3.96E-8	4.75E-5	0.0	4.57E-7	3.23E-6
Po-210	8.62E-5	6.36E-5	0.0	3.58E-4	7.57E-4
Rn-222+D	0.0	0.0	0.0	0.0	0.0
Ra-223+D	5.15E-4	3.21E-4	0.0	4.98E-3	0.0
Ra-224+D	2.04E-4	3.40E-4	0.0	1.62E-3	0.0
Ra-225+D	1.31E-3	3.06E-4	0.0	6.57E-3	0.0
Ra-226+D	7.69E-3	3.32E-4	0.0	1.17E-2	0.0
Ra-228+D	1.12E-2	5.64E-5	0.0	1.91E-2	0.0
Ac-225	2.96E-7	4.07E-4	0.0	4.41E-6	6.09E-6
Ac-227+D	5.24E-6	7.94E-5	0.0	7.88E-5	3.19E-5
Th-227+D	3.85E-7	5.39E-4	0.0	1.33E-5	2.42E-7
Th-228+D	5.15E-6	5.63E-4	0.0	1.52E-4	2.57E-6
Th-229	8.73E-6	5.12E-4	0.0	3.06E-4	8.79E-6
Th-230+D	1.28E-6	6.02E-5	0.0	4.52E-5	2.66E-6
Th-232+D	1.09E-6	1.28E-4	0.0	3.92E-5	2.26E-6
Th-234	2.32E-9	1.13E-4	0.0	8.03E-8	4.73E-9
Pa-231+D	3.73E-6	6.27E-4	0.0	9.01E-5	3.46E-6
Pa-233	9.13E-10	1.64E-5	0.0	5.27E-9	1.06E-9
U-233	4.86E-7	6.27E-5	0.0	4.97E-6	0.0
U-234	4.77E-7	6.14E-5	0.0	4.77E-6	0.0
U-235+D	4.48E-7	7.81E-5	0.0	4.57E-6	0.0
U-236	4.57E-7	5.76E-5	0.0	4.57E-6	0.0
U-238+D	4.18E-7	1.66E-4	0.0	4.37E-6	0.0
Np-237+D	1.31E-6	7.94E-5	0.0	3.00E-5	2.70E-6
Np-239	6.46E-11	2.40E-5	0.0	1.20E-9	1.18E-10
Pu-238	4.39E-7	7.30E-5	0.0	1.76E-5	2.70E-6
Pu-239	4.12E-7	6.66E-5	0.0	1.65E-5	2.54E-6
Pu-240	4.16E-7	6.78E-5	0.0	1.65E-5	2.57E-6
Pu-241	4.21E-10	6.78E-7	0.0	1.44E-8	2.60E-9
Pu-242	3.92E-7	6.53E-5	0.0	1.57E-5	2.42E-6
Am-241	1.46E-6	7.42E-5	0.0	1.83E-5	2.04E-5
Am-242m	1.62E-6	9.34E-5	0.0	2.01E-5	2.12E-5
Am-243+D	1.41E-6	9.73E-5	0.0	1.77E-5	1.97E-5
Cm-242	8.26E-7	7.92E-5	0.0	1.25E-5	1.32E-5
Cm-243	1.58E-6	7.81E-5	0.0	2.38E-5	2.51E-5
Cm-244	1.51E-6	6.55E-5	0.0	2.28E-5	2.40E-5
Cm-245+D	1.49E-6	7.04E-5	0.0	2.24E-5	2.36E-5
Cm-246	1.49E-6	6.91E-5	0.0	2.23E-5	2.36E-5
Cm-247+D	1.46E-6	9.09E-5	0.0	2.16E-5	2.32E-5

APPENDIX 3.B.3 Adult Radiation Dose Factors - Inhalation

	mrem/pCi Intake					
Isotope	GI-LLI	Lungs	Whole Body	Thyroid	Bone	Liver
C-14	1.64E-7	3.97E-7	4.11E-7		2.05E-6	3.97E-7
Ca-41	2.88E-7	3.42E-6				
Co-60	3.49E-5	6.55E-4				
Ni-59	6.11E-7	7.21E-6			3.53E-6	
Ni-63	1.43E-6	1.69E-5				
Se-79	3.33E-6	3.93E-5				
Rb-87	2.88E-7	0.0	3.20E-6			
Sr-90	9.04E-5	1.05E-3				
Zr-93+D	3.89E-6	1.87E-5				
Nb-93m	2.32E-6	2.81E-5				
Mo-93	3.90E-6	4.56E-5				
Tc-99	6.66E-6	7.86E-5				
Pd-107	7.06E-7	8.33E-6				
Cd-113m	1.43E-5	1.66E-4				
Sn-126+D	1.59E-5	1.03E-3				
Sb-126	6.01E-5	9.63E-5				
I-129	1.54E-7	0.0	4.50E-6	4.74E-3	1.88E-6	1.32E-6
Cs-135	1.86E-7	1.04E-6	4.23E-6		1.08E-5	1.07E-5
Cs-137	1.03E-6	6.99E-6	4.21E-5		4.78E-5	7.11E-5
Sm-151	3.25E-6	3.93E-5				
Eu-154	5.48E-5	7.96E-4				
Ho-166m	1.59E-5	3.46E-4				
Pb-210+D	3.65E-5	2.31E-2				
Bi-210+D	2.95E-5	1.11E-3				
Po-210	4.19E-5	3.08E-2				
Rn-222+D	0.0	0.0				
Ra-223+D	2.84E-4	2.54E-2				
Ra-224+D	3.01E-4	8.78E-3				
Ra-225+D	2.71E-4	3.28E-2				
Ra-226+D	2.94E-4	0.0				
Ra-228+D	5.00E-5	1.44E-1				
Ac-225	2.52E-4	2.29E-2				
Ac-227+D	4.92E-5	2.10E-1				
Th-227+D	3.34E-4	3.23E-2				
Th-228+D	3.49E-4	2.00E-1				
Th-229	3.17E-4	2.50E-1				
Th-230+D	3.73E-5	4.49E-2				
Th-232+D	7.94E-5	3.84E-2				
Th-234	7.03E-5	1.61E-4				
Pa-231+D	3.89E-4	5.06E-2				
Pa-233	1.02E-5	3.52E-5				
U-233	3.89E-5	4.68E-2				
U-234	3.81E-5	4.59E-2				
U-235+D	4.84E-5	4.31E-2				
U-236	3.57E-5	4.40E-2				
U-238+D	1.03E-4	4.03E-2				
Np-237+D	4.92E-5	4.59E-2				
Np-239	1.49E-5	4.70E-6				
Pu-238	4.52E-5	5.15E-2				
Pu-239	4.13E-5	4.82E-2				
Pu-240	4.21E-5	4.87E-2				
Pu-241	4.21E-7	3.24E-5				
Pu-242	4.05E-5	4.59E-2				
Am-241	4.60E-5	5.15E-2				
Am-242m	5.79E-5	2.15E-2				
Am-243+D	6.03E-5	4.96E-2				
Cm-242	4.91E-5	3.64E-2				
Cm-243	4.84E-5	5.62E-2				
Cm-244	4.68E-5	5.37E-2				
Cm-245+D	4.36E-5	5.15E-2				
Cm-246	4.29E-5	5.24E-2				
Cm-247+D	5.63E-5	5.15E-2				

APPENDIX 3.C

Radionuclide Transfer Factors Used in Dose Calculations for Selected Media

APPENDIX 3.C Radionuclide Transfer Factors for Selected Media Used in Dose Calculations

ELEMENT	CROPS	MILK	FRESH WATER FISH	MARINE FISH
	pCi/kg of Plant / pCi/kg in Soil	pCi/ℓ of Milk / pCi/d of Intake	pCi/kg of Fish / pCi/ℓ in River	pCi/kg of Fish / pCi/ℓ in River
C	5.5	7.5E-3	4.6E+3	1.
Ca	3.6E-2	8.0E-3	4.	1.0E+1
Co	9.4E-3	5.0E-4	5.0E+1	1.0E+2
Ni	1.9	3.4E-3	1.0E+2	5.0E+2
Se	1.3	2.3E-2	1.7E+2	1.0E+1
Rb	1.3E-1	1.5E-2	1.0E+3	3.0E+1
Sr	1.7E-2	1.0E-3	1.0E+2	1.
Zr	1.7E-4	2.5E-6	3.	3.0E+1
Nb	9.4E-3	1.3E-3	3.0E+4	1.0E+2
Mo	1.3E-1	3.7E-3	1.0E+1	1.0E+1
Tc	2.5E-1	1.3E-2	1.5E+1	1.0E+1
Pd	5.0	5.0E-3	1.0E+1	1.0E+1
Cd	3.0E-1	6.2E-5	2.0E+2	1.0E+2
Sn	2.5E-3	1.3E-3	3.0E+3	3.
Sb	1.1E-2	8.0E-4	1.	1.0E+3
I	2.0E-2	1.0E-2	1.5E+1	2.0E+1
Cs	1.9E-2	7.0E-3	2.0E+3	3.0E+1
Sm	2.5E-3	2.5E-6	2.5E+1	1.0E+2
Ho	2.6E-3	2.5E-6	2.5E+1	1.0E+2
Eu	2.5E-3	2.5E-6	2.5E+1	1.0E+2
Pb	6.8E-2	3.1E-4	1.0E+2	3.0E+2
Bi	1.5E-1	2.5E-4	1.5E+1	1.5E+1
Po	1.	1.5E-3	5.0E+2	3.0E+2
Rn	0.0	1.0E-2	5.7E+1	1.
Ra	3.1E-4	8.0E-3	5.0E+1	5.0E+1
Ac	2.5E-3	2.5E-6	2.5E+1	2.5E+1
Th	4.2E-3	2.5E-6	3.0E+1	1.0E+4
Pa	2.5E-3	2.5E-6	1.1E+1	1.0E+1
U	2.5E-3	2.5E-4	2.	1.0E+1
Np	2.5E-3	2.5E-6	1.0E+1	1.0E+1
Pu	2.5E-4	2.5E-6	3.5	3.
Am	2.5E-4	2.5E-6	2.5E+1	2.5E+1
Cm	2.5E-3	2.5E-6	2.5E+1	2.5E+1

APPENDIX 3.D

Radioactivity in Waste Accumulated Through Year 2000

APPENDIX 3.D

RADIOACTIVITY IN WASTE ACCUMULATED THROUGH YEAR 2000

(Curies)

ISOTOPE	Years' Storage				
	10^2	10^3	10^4	10^5	10^6
C-14	5.63E+5	0.0	0.0	0.0	0.0
Ca-41	7.33E+2	0.0	0.0	0.0	0.0
Co-60	3.15E+2	0.0	0.0	0.0	0.0
Ni-59	1.95E+5	3.33E+4	3.08E-4	1.40E+4	5.43
Ni-63	3.05E+6	1.23E+3	0.0	0.0	0.0
Se-79	9.69E+4	9.60E+4	8.72E+4	3.34E+4	2.26
Rb-87	4.70	4.67	4.67	4.67	4.67
Sr-90	1.10E+9	0.0	0.0	0.0	0.0
Zr-93	4.03E+5	3.88E+5	3.87E+5	3.71E+5	2.45E+5
Nb-93m	4.05E+5	3.88E+5	3.87E+5	3.71E+5	2.45E+5
Mo-93	5.22E+3	0.0	0.0	0.0	0.0
Tc-99	2.83E+6	2.82E+6	2.74E+6	2.04E+6	1.08E+5
Pd-107	2.28E+4	2.28E+4	2.27E+4	2.25E+4	2.06E+4
Cd-113m	3.13E+4	0.0	0.0	0.0	0.0
Sn-126	1.27E+5	1.26E+5	1.19E+5	6.35E+4	1.24E+2
Sb-126	0.0	1.25E+5	1.17E+5	6.29E+4	1.23E+2
I-129	7.97E+3	7.97E+3	7.96E+3	7.94E+3	7.65E+3
Cs-135	8.46E+4	8.46E+4	8.44E+4	8.27E+4	6.71E+4
Cs-137	1.84E+9	0.0	0.0	0.0	0.0
Sm-151	1.40E+8	1.08E+5	0.0	0.0	0.0
Eu-154	1.07E+7	0.0	0.0	0.0	0.0
Ho-166m	9.33E+1	5.55E+1	3.06E-1	0.0	0.0
Pb-210	8.73E-1	1.88E+2	8.89E+3	7.03E+4	1.28E+4
Bi-210	8.73E-1	1.88E+2	8.89E+3	7.03E+4	1.28E+4
Po-210	8.73E-1	1.88E+2	8.89E+3	7.03E+4	1.28E+4
Rn-222	1.32	1.88E+2	8.89E+3	7.03E+4	1.28E+4
Ra-223	1.34E+4	1.36E+4	1.12E+4	1.74E+3	1.30E+2
Ra-224	9.64E+3	9.46	7.79	7.83	8.16
Ra-225	1.95E+2	1.73E+3	1.25E+4	4.02E+4	6.78E+4
Ra-226	1.32	1.88E+2	8.89E+3	7.03E+4	1.28E+4
Ra-228	7.80	7.79	7.79	7.83	8.16
Ac-225	1.95E+2	1.73E+3	1.25E+4	4.02E+4	6.78E+4
Ac-227	1.34E+4	1.36E+4	1.12E+4	1.74E+3	1.30E+2
Th-227	1.34E+4	1.34E+4	1.11E+4	1.71E+3	1.29E+2
Th-228	9.64E+3	9.46	7.79	7.83	8.16
Th-229	1.95E+2	1.73E+3	1.25E+4	4.02E+4	6.78E+4
Th-230	5.22E+1	1.08E+3	1.14E+4	7.00E+4	1.28E+4
Th-232	7.80	7.79	7.79	7.83	8.16
Th-234	2.42E+2	2.42E+2	2.42E+2	2.42E+2	2.43E+2
Pa-231	1.39E+4	1.36E+4	1.12E+4	1.74E+3	1.30E+2
Pa-233	7.29E+4	8.34E+4	8.70E+4	8.50E+4	6.35E+4
U-233	1.88E+4	1.90E+4	2.16E+4	4.22E+4	6.76E+4
U-234	8.38E+4	1.41E+5	1.37E+5	1.07E+5	8.77E+3
U-235	2.14E+1	2.23E+1	3.60E+1	1.22E+2	1.30E+2
U-236	6.18E+3	6.30E+3	7.08E+3	7.57E+3	7.38E+3
U-238	2.42E+2	2.42E+2	2.42E+2	2.42E+2	2.43E+2
Np-237	7.29E+4	8.34E+4	8.70E+4	8.50E+4	6.35E+4
Np-239	7.16E+6	6.60E+6	2.92E+6	8.38E+2	0.0
Pu-238	1.55E+8	2.42E+5	0.0	0.0	0.0
Pu-239	9.31E+5	1.08E+6	1.84E+6	2.46E+5	1.94E-6
Pu-240	4.95E+6	4.56E+5	1.81E+6	1.78E+2	0.0
Pu-241	2.33E+6	2.85E+5	1.34E+5	7.10E+1	0.0
Pu-242	9.85E+3	1.02E+4	1.04E+4	9.00E+3	1.74E+3
Am-241	6.74E+7	1.62E+7	1.34E+5	7.10E+1	0.0
Am-242m	3.30E+6	5.45E+4	0.0	0.0	0.0
Am-243	7.16E+6	6.60E+6	2.92E+6	8.38E+2	0.0
Cm-242	2.71E+6	4.47E+4	0.0	0.0	0.0
Cm-243	2.28E+5	0.0	0.0	0.0	0.0
Cm-244	1.84E+7	0.0	0.0	0.0	0.0
Cm-245	3.07E+5	2.85E+5	1.34E+5	7.09E+1	0.0
Cm-246	5.73E+4	5.02E+4	1.34E+4	2.37E-2	0.0

APPENDIX 3.E

Assumed Rural Population Distribution for Geologic Disposal

APPENDIX 3.E Assumed Rural Population Distribution for Geologic Disposal

RANGE / SECTOR	.5 MI	1.5 MI	2.5 MI	3.5 MI	4.5 MI	7.5 MI	15 MI	25 MI	35 MI	45 MI	TOTALS
N	0	0	0	0	0	0	30	260	275	14,200	14,765
NNE	0	0	0	0	0	0	350	4,382	1,300	354	6,386
NE	0	0	0	0	0	4	384	620	356	840	2,204
ENE	0	0	0	0	20	96	608	1,165	411	364	2,664
E	0	0	0	0	0	96	510	254	328	1,239	2,427
ESE	0	0	0	0	0	52	670	270	822	5,280	7,094
SE	0	0	0	0	0	24	1,900	13,900	2,160	1,062	19,046
SSE	0	0	0	0	0	36	20,377	15,876	690	2,193	39,172
S	0	0	0	0	0	12	21,635	300	140	7,060	29,147
SSW	0	0	0	0	0	140	3,158	80	110	1,593	5,081
SW	0	0	0	0	0	4	150	3,140	274	354	3,922
WSW	0	0	0	0	0	0	12	1,320	17,790	708	19,830
W	0	0	0	0	0	0	0	200	4,345	21,400	25,945
WNW	0	0	0	0	0	0	0	90	205	354	649
NW	0	0	0	0	0	0	0	10	90	310	410
NNW	0	0	0	0	0	0	0	20	300	530	850
TOTALS	0	0	0	0	20	464	49,784	41,887	29,596	57,841	179,592
CUM TOTL	0	0	0	0	20	484	50,268	92,155	121,751	179,592	179,592

APPENDIX 3.F

Assumed Meteorological Data - Western Region

APPENDIX 3.F Assumed Meteorological Data - Western Region

Hanford Very Stable Category
Percent of all Occurrences

(Wind Speed in Miles per Hour)

	-3	4-7	8-12	13-18	19+	TOTALS
N	.28	.22	.10	.02	.01	.64
NNE	.24	.21	.11	.03	.02	.62
NE	.29	.35	.23	.11	.03	1.02
ENE	.28	.44	.55	.25	.04	1.57
E	.50	.93	1.07	.41	.03	2.95
ESE	.42	1.03	1.80	1.05	.04	4.35
SE	.57	1.04	1.88	1.64	.20	5.34
SSE	.45	.65	.55	.22	.00	1.88
S	.41	.35	.20	.07	.00	1.04
SSE	.20	.18	.12	.04	.00	.55
SW	.24	.19	.10	.03	.00	.57
WSW	.18	.11	.08	.02	.00	.40
W	.26	.15	.09	.02	.01	.54
WNW	.28	.16	.05	.00	.00	.50
NW	.45	.31	.14	.05	.01	.97
NWN	.25	.22	.20	.08	.01	.77
TOTALS	5.37	6.56	7.27	4.04	.40	23.64

N.B. Directions are those <u>toward</u> which wind is blowing.

Hanford Moderately Stable Category
Percent of all Occurrences

(Wind Speed in Miles per Hour)

	1-3	4-7	8-12	13-18	19+	TOTALS
N	.27	.18	.15	.14	.17	.91
NNE	.18	.18	.21	.26	.56	1.39
NE	.22	.22	.33	.80	1.16	2.53
ENE	.21	.26	.46	.84	.74	2.53
E	.28	.46	.90	1.07	.43	3.14
ESE	.34	.59	1.62	2.81	1.85	7.20
SE	.45	.61	1.89	2.71	2.53	8.39
SSE	.42	.49	.35	.18	.05	1.49
S	.46	.33	.16	.12	.01	1.08
SSW	.24	.16	.11	.08	.03	.62
SW	.30	.12	.09	.03	.03	.57
WSW	.24	.12	.02	.02	.01	.41
W	.27	.16	.07	.01	.00	.51
WNW	.49	.22	.07	.02	.00	.80
NW	.53	.40	.19	.09	.03	1.24
NNW	.27	.22	.19	.13	.09	.90
TOTALS	5.18	4.92	6.83	9.11	7.69	33.71

N.B. Directions are those <u>toward</u> which wind is blowing.

Hanford Neutral Category
Percent of all Occurrences

(Wind Speed in Miles per Hour)

	1-3	4-7	8-12	13-18	19+	TOTALS
N	.22	.11	.05	.05	.04	.47
NNE	.17	.07	.06	.07	.13	.50
NE	.18	.10	.08	.15	.27	.78
ENE	.16	.12	.12	.20	.21	.81
E	.27	.18	.12	.14	.07	.78
ESE	.26	.30	.36	.28	.28	1.48
SE	.48	.66	.87	.51	.57	3.09
SSE	.54	.31	.17	.07	.01	1.10
S	.54	.16	.09	.04	.02	.85
SSW	.31	.10	.06	.06	.01	.54
SW	.42	.13	.06	.01	.02	.63
WSW	.32	.10	.03	.01	.00	.46
W	.40	.10	.03	.01	.00	.54
WNW	.44	.15	.03	.00	.00	.62
NW	.51	.25	.06	.03	.01	.86
NNW	.26	.13	.08	.03	.01	.49
TOTALS	5.49	2.99	2.24	1.66	1.65	14.03

N.B. Directions are those toward which wind is blowing.

Hanford Unstable Category
Percent of all Occurrences

(Wind Speed in Miles per Hour)

	1-3	4-7	8-12	13-18	19+	TOTALS
N	.25	.49	.12	.04	.02	.92
NNE	.15	.48	.28	.19	.17	1.27
NE	.21	.61	.00	.53	.67	1.92
ENE	.13	.40	.54	.64	.71	2.42
E	.17	.41	.33	.26	.19	1.36
ESE	.19	.24	.49	.59	.37	2.08
SE	.33	1.11	1.33	1.00	1.08	4.85
SSE	.43	.99	.47	.10	.02	2.01
S	.67	1.22	.49	.12	.03	2.53
SSW	.41	.72	.47	.25	.07	1.92
SW	.66	.70	.35	.15	.06	2.03
WSW	.43	.45	.11	.04	.01	1.04
W	.48	.52	.06	.00	.00	1.06
WNW	.39	.45	.07	.00	.00	.91
NW	.29	.58	.09	.03	.00	.99
NNW	.14	.37	.10	.03	.01	.65
TOTALS	5.38	9.89	5.30	3.97	3.41	27.95

N.B. Directions are those <u>toward</u> which wind is blowing.

APPENDIX 3.G

Questionnaire - Pilot Public Attitude Study

BATTELLE
HUMAN AFFAIRS RESEARCH CENTERS
SPECIAL PROJECTS

Fellow HARC Employees:

We are asking for your help in conducting a study of public opinion about some proposed methods for disposing of nuclear waste materials.

Large amounts of radioactive wastes are currently being held in temporary storage. In addition, rapidly increasing quantities of high-level radioactive wastes from commercial nuclear power plants are being forecast.

Experts are now considering several methods for permanent storage of nuclear waste. You may recall that nuclear waste disposal was the topic of a conference held at BSRC in October, 1972.

Aside from the technology involved in various disposal methods, one very important issue to be taken into account is the acceptability of these methods by the public. This survey is being administered to HARC staff as a first step toward determining how people feel about some of the issues connected with nuclear waste disposal.

There are two parts to the study:

Part I deals with the questionnaire form you have before you now. On the following pages, you will find (1) very brief descriptions of five proposed disposal methods, (2) a list of categories to use in evaluating each method, and (3) questions about each method. We realize that you are being asked to answer questions, given very limited and incomplete information about nuclear waste disposal. Later today, however, a thirty-minute videotape will be shown which describes nuclear waste disposal in considerably more detail; questions like those presented here will be asked again following the videotape.

Since the study deals with opinions and attitudes, there really are not any "right" or "wrong" answers to the questions. We are mainly interested in your own judgments and reactions to the questions. Your individual answers will be kept confidential and only group averages will be presented in the final report. It is not necessary for you to identify yourself by name.

The group results and conclusions from this survey of HARC employees will be included in a larger report to be submitted to the Atomic Energy Commission. A brief summary of the group results will be made available to any participants who are interested. Thank you for your cooperation.

Sincerely,

Dr. S.M. Nealey
W.S. Maynard

GENERAL INSTRUCTIONS:

In this survey, you will answer most of the questions by circling a number, as in the example below. You are to circle the number that best describes how you feel about the statement.

EXAMPLE 1. Read the statement below and answer the question by circling the number which best describes your feeling.

How do you feel about driving a car on snow-covered, icy Seattle streets?

VERY UNSAFE: 1 2 3 4 5 6 7 : VERY SAFE

If you feel very uneasy about these driving conditions, you would circle "1". If you are undecided or "neutral", you would circle "4". If you feel moderately at ease, you would circle "5", or perhaps "6".

DESCRIPTIONS:

Experts say that there are five general methods of permanent storage of nuclear waste materials. More details regarding these methods will be found in the following pages but briefly they are:

1. Geologic Disposal
2. Icecap Disposal
3. Ocean Disposal
4. Stable Earth Orbit
5. Retrievable Surface Storage

In judging each method, there are several things to consider. These are:

1. Distance - How far from the nearest person is the material (how deep in the earth, how high an orbit?)

2. Population Density - Aside from emplacement distance, how far from population centers is the disposal site?

3. Emplacement Operations - What is the nature of the transportation needed to get the material to the disposal site? What is the state of development of the emplacement technology? How likely are mishaps during the transportation and emplacement operations?

4. Stability - Once stored, how would the wastes be affected by such phenomena as earthquakes, volcanos, hurricanes or floods?

5. Detectability - If there is any dispersal of the radioactivity, how well can it be detected?

6. Retrievability - Once the material is in its final storage location, how easily can it be recovered for further treatment or for emergency procedures?

7. Protective Reaction - If nuclear waste escaped into man's environment, how effectively could the population be protected?

DIRECTIONS: PLEASE CONSIDER EACH PROPOSED METHOD SEPARATELY. Read each description of a proposed method of disposal and then answer each question by circling the number which best describes how you feel.

METHOD 1: GEOLOGIC DISPOSAL

This method would dispose of nuclear wastes by placing the material in sealed containers which are buried in specially prepared holes in the earth's surface.

Think specifically of the GEOLOGIC DISPOSAL method and answer the following questions.

1. (Distance) What do you think about the distance that the nuclear waste would be from the nearest person?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

2. (Population Density) What do you think about the distance the nuclear waste would be from population centers?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

3. (Emplacement Operations) What do you think about the feasibility of the operations and procedures involved in transporting the waste to its storage location?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

4. (Stability) What do you think about the stability of the method being affected by "natural occurrences" (e.g., earthquakes, etc.) once it is stored?

   VERY DANGEROUS: 1 2 3 4 5. 6 7 : VERY SAFE

5. (Detectability) What do you think about the ability to supervise the waste over time regarding radiation leakage?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

6. (Retrievability) What do you think about the ease with which the nuclear waste could be recovered, once in its final storage location

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

7. (Protective Reaction) What do you think about the procedures for protecting humanity and controlling the dispersal, should the nuclear waste escape from its container?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

Listed below are the seven issues concerning the disposal of nuclear waste. Rank these from 1 to 7 as you think they contribute to the overall level of risk involved in the GEOLOGIC DISPOSAL method. For example, if you think the issue of "Distance" is the most important feature to consider in evaluating total risk, you would put a "1" beside "Distance". Similarly, if you think that "Detectability" is the second most important contributor to total risk, you would place a "2" beside it, etc., until all lines have a number beside them.

_____ Distance

_____ Population Density

_____ Emplacement Operations

_____ Stability

_____ Detectability

_____ Retrievability

_____ Protective Reaction

Taking all factors into consideration, how would you evaluate the overall level of risk involved in the GEOLOGIC DISPOSAL method?

VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

METHOD 2: ICECAP DISPOSAL

This method would dispose of nuclear wastes by allowing sealed containers of waste to sink into the ice of largely uninhabited, ice capped land masses (Antarctica and Greenland).

Think specifically of the ICECAP DISPOSAL method and answer the following questions.

1. (Distance) What do you think about the distance that the nuclear waste would be from the nearest person?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

2. (Population Density) What do you think about the distance the nuclear waste would be from population centers?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

3. (Emplacement Operations) What do you think about the feasibility of the operations and procedures involved in transporting the waste to its storage location?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

4. (Stability) What do you think about the stability of the method being affected by "natural occurrences" (e.g., earthquakes, etc.) once it is stored?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

5. (Detectability) What do you think about the ability to supervise the waste over time regarding radiation leakage?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

6. (Retrievability) What do you think about the ease with which the nuclear waste could be recovered, once in its final storage location

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

7. (Protective Reaction) What do you think about the procedures for protecting humanity and controlling the dispersal, should the nuclear waste escape from its container?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

As you did with the first disposal method presented, rank the seven issues in order of their importance as contributors to the overall level of risk involved in the ICECAP DISPOSAL method.

_____ Distance

_____ Population Density

_____ Emplacement Operations

_____ Stability

_____ Detectability

_____ Retrievability

_____ Protective Reaction

Taking all factors into consideration, how would you evaluate the overall level of risk involved in the ICECAP DISPOSAL method?

VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

METHOD 3: OCEAN DISPOSAL

This method would dispose of nuclear waste by placing sealed containers of the waste on the bottom of the ocean.

Think specifically of the OCEAN DISPOSAL method and answer the following questions.

1. (Distance) What do you think about the distance that the nuclear waste would be from the nearest person?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

2. (Population Density) What do you think about the distance the nuclear waste would be from population centers?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

3. (Emplacement Operations) What do you think about the feasibility of the operations and procedures involved in transporting the waste to its storage location?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

4. (Stability) What do you think about the stability of the method being affected by "natural occurrences" (e.g., earthquakes, etc.) once it is stored?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

5. (Detectability) What do you think about the ability to supervise the waste over time regarding radiation leakage?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

6. (Retrievability) What do you think about the ease with which the nuclear waste could be recovered, once in its final storage location

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

7. (Protective Reaction) What do you think about the procedures for protecting humanity and controlling the dispersal, should the nuclear waste escape from its container?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

Rank the seven issues in order of their importance as contributors to the overall level of risk involved in the OCEAN DISPOSAL method of waste disposal.

_____ Distance

_____ Population Density

_____ Emplacement Operations

_____ Stability

_____ Detectability

_____ Retrievability

_____ Protective Reaction

Taking all factors into consideration, how would you evaluate the overall level of risk involved in the OCEAN DISPOSAL method?

VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

METHOD 4: STABLE EARTH ORBIT

This method would dispose of nuclear wastes by specially encapsulating the materials and placing the sealed containers in orbit around the earth.

Think specifically of the EARTH ORBIT method and answer the following questions.

1. (Distance) What do you think about the distance that the nuclear waste would be from the nearest person?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

2. (Population Density) What do you think about the distance the nuclear waste would be from population centers?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

3. (Emplacement Operations) What do you think about the feasibility of the operations and procedures involved in transporting the waste to its storage location?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

4. (Stability) What do you think about the stability of the method being affected by "natural occurrences" (e.g., earthquakes, etc.) once it is stored?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

5. (Detectability) What do you think about the ability to supervise the waste over time regarding radiation leakage?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

6. (Retrievability) What do you think about the ease with which the nuclear waste could be recovered, once in its final storage location?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

7. (Protective Reaction) What do you think about the procedures for protecting humanity and controlling the dispersal, should the nuclear waste escape from its container?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

Rank the seven issues in order of their importance as contributors to the overall level of risk involved in the STABLE EARTH ORBIT method of waste disposal.

_____ Distance

_____ Population Density

_____ Emplacement Operations

_____ Stability

_____ Detectability

_____ Retrievability

_____ Protective Reaction

Taking all factors into consideration, how would you evaluate the overall level of risk involved in the STABLE EARTH ORBIT method?

VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

METHOD 5: RETRIEVABLE SURFACE STORAGE

This method would dispose of nuclear wastes by placing sealed containers of waste in specially designed buildings on the surface of the earth.

Think specifically of the RETRIEVABLE SURFACE STORAGE method and answer the following questions.

1. (Distance) What do you think about the distance that the nuclear waste would be from the nearest person?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

2. (Population Density) What do you think about the distance the nuclear waste would be from population centers?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

3. (Emplacement Operations) What do you think about the feasibility of the operations and procedures involved in transporting the waste to its storage location?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

4. (Stability) What do you think about the stability of the method being affected by "natural occurrences" (e.g., earthquakes, etc.) once it is stored?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

5. (Detectability) What do you think about the ability to supervise the waste over time regarding radiation leakage?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

6. (Retrievability) What do you think about the ease with which the nuclear waste could be recovered, once in its final storage location?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

7. (Protective Reaction) What do you think about the procedures for protecting humanity and controlling the dispersal, should the nuclear waste escape from its container?

   VERY DANGEROUS: 1 2 3 4 5 6 7 : VERY SAFE

Rank the seven issues in order of their importance as contributors to the overall level of risk involved in the RETRIEVABLE SURFACE STORAGE method of waste disposal.

_____ Distance

_____ Population Density

_____ Emplacement Operations

_____ Stability

_____ Detectability

_____ Retrievability

_____ Protective Reaction

Taking all factors into consideration, how would you evaluate the overall level of risk involved in the RETRIEVABLE SURFACE STORAGE method?

VERY DANGEROUS: 1 2 3 4 .5 6 7 : VERY SAFE

Consider the topic of nuclear waste disposal in general and rank the seven issues as you think they contribute to the total risk in nuclear waste disposal. Place a "1" beside the issue you think contributes the most to total risk, a "2" beside the second highest contributor to total risk, etc.

_____ Distance

_____ Population Density

_____ Emplacement Operations

_____ Stability

_____ Detectability

_____ Retrievability

_____ Protective Reaction

Taking all factors into consideration, rank the five proposed methods in order of their acceptability to you. Place a "1" by the most acceptable method, a "2" by the next most acceptable method, etc.

_____ Geologic Disposal

_____ Icecap Disposal

_____ Ocean Disposal

_____ Stable Earth Orbit

_____ Retrievable Surface Storage

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P. O. Box 1541
Juneau, AK 99801

Arizona State Library
Dept. of Library & Archives,
Regional
Phoenix, AZ 85007

Arkansas Supreme Court Library
Little Rock, AR 72201

California State Library,
Regional
Sacramento, CA 95809

Colorado State Library
Denver, CO 80203

Connecticut State Library
Hartford, CT 06103

Delaware State Law Library
Dover, DE 19901

Florida State Library
Tallahassee, FL 32304

Georgia State Library
Atlanta, GA 30303

Hawaii State Library
Honolulu, HI 96813

Idaho State Law Library
Boise, ID 83706

Illinois State Library,
Regional
Springfield, IL 62706

Indiana State Library,
Regional
Indianapolis, IN 46204

Iowa State Traveling Library
Des Moines, IA 50319

Kansas State Historical Society,
Library
Topeka, KS 66612

Kentucky State Law Library
Frankfort, KY 40601

Louisiana State Library
Baton Rouge, LA 70803

Maine State Library
Augusta, ME 04330

Maryland State Library
Annapolis, MD 21404

Massachusetts State Library
Regional
Boston, MA 02133

Michigan State Library
Regional
Lansing, MI 48913

Minnesota State Law Library
Historical Society Library
St. Paul MN

Mississippi State Library
Jackson, MS 39210

Missouri State Library
Jefferson City, MO 65102

Montana State Library
Helena, MT 59601

Nebraska State Library
Lincoln, NB 68508

Nevada State Library
Carson City, NV 89701

New Hampshire State Library
Concord, NH 03302

New Jersey State Library
Dept. of Education
Law & Reference Bureau
Trenton, NJ 08625

New Mexico State Library
Regional
Santa Fe, NM 87501

New York State Library
Regional
Albany, NY 12224

North Carolina State Library
Raleigh, NC 27602

North Dakota State
Historical Library
Bismarck, ND 58501

Ohio State Library
Regional
Columbus, OH 43215

STATE CAPITAL LIBRARIES

Oklahoma State Library
Regional
Oklahoma City, OK 73105

Oregon State Library
Salem, OR 97310

Pennsylvania State Library
Harrisburg, PA 17126

Rhode Island State Library
Providence, RI 02903

South Carolina State Library
Columbia, SC 29201

South Dakota State Library
Commission
Pierre, SD 57501

Tennessee State Library
and Archives
Nashville, TN 37219

Texas State Library
Regional
Austin, TX 78711

Utah State Library
Salt Lake City, UT 84102

Vermont State Library
Montpelier, VT 05601

Virginia State Library
Richmond, VA 23219

Washington State Library
Regional
Olympia, WA 98502

West Virginia State Library
Dept. of Archives & History
Charleston, WV 25305

Wisconsin State Library
Madison, WI 53702

Wyoming State Library
Cheyenne, WY 82001

MAJOR CITY LIBRARIES

Birmingham Public Library
2020 Seventh Avenue North
Birmingham, AL 35203

Alaska State Court Libraries
941-4th Avenue
Anchorage, AK 99501

University of Arizona
Institute of Atmospheric Physics
Library
Tucson, AZ 85721

Arkansas (State) Library Commission
506-1/2 Center Street
Little Rock, AR 72201

Los Angeles Public Library
630 West Fifth Street
Los Angeles, CA 90017

San Francisco Public Library
Civic Center
San Francisco, CA 94102

Academy Library
U.S. Air Force Academy, CO 80840

Hartford Public Library
Hartford, CT 06103

Wilmington Institute Free Library
Wilmington, DE 19801

Washington Public Library
Washington, DC 20001

Miami Public Library
Miami, FL 33132

University of Tampa Library
Tampa, FL 33606

Savannah Public Library
Savannah, GA 31401

Municipal Reference Library
Honolulu, Hawaii 96813

Boise Public Library
Boise, ID 83706

Chicago Public Library
78 East Washington Street
Chicago, IL 60602

John Crerar Library
Chicago, IL 60616

Fort Wayne Public Library
Fort Wayne, IL 46802

Des Moines Public Library
Des Moines, IA 50309

Wichita State University Library
Wichita, KS 67208

Louisville Free Public Library
Louisville, KY 40203

New Orleans Public Library
New Orleans, LA 70140

Portland Public Library
Portland, ME 04101

Johns Hopkins University Library
Baltimore, MD 21218

Massachusetts Institute of
Technology Library
Cambridge, MA 02138

Detroit Public Library
Detroit, MI 48208

Minneapolis Public Library
Minneapolis, MN 55401

Mississippi Library Commission
Jackson, MS 39201

Kansas City Public Library
Kansas City, MO 64110

St. Louis Public Library
St. Louis, MO 63103

Eastern Montana College Library
Billings, MT 59101

Omaha Public Library
Omaha, NB 68102

Manchester City Library
Manchester, NH 03104

Newark Public Library
Newark, NJ 07101

New Mexico State University
Library
University Park, NM 88070

New York Public Library
New York, NY 10018

Public Library of Charlotte
Charlotte, NC 28202

Fargo Public Library
Fargo, ND 58103

HANFORD TECHNICAL LIBRARY
3 3679 00062 5386

MAJOR CITY LIBRARIES

Cleveland Public Library
Cleveland, OH 44114

Cincinnati Public Library
Cincinnati, OH 45202

Toledo Public Library
Toledo, OH 43624

University of Tulsa Library
Tulsa, OK 74104

Reed College Library
Portland, OR 97202

Carnegie Library of Pittsburgh
Pittsburgh, PA 15213

Providence Public Library
Providence, RI 02903

Charleston College Library
Charleston, SC 29401

Carnegie Free Public Library
Sioux Falls, SD 57101

Public Library of Nashville &
Davidson County
222 Eighth Avenue North
Nashville, TN 37203

Dallas Public Library
Dallas, TX 75201

Houston Public Library
Houston, TX 77002

Brigham Young University Library
Provo, Utah 84601

Virginia Polytechnic Institute
Carol Newman Library
Blacksburg, VA 24061

Seattle Public Library
Seattle, WA 98104

Spokane Public Library
Spokane, WA 99201

Marshall University Library
Huntington, WV 25701

Milwaukee Public Library,
Regional
Milwaukee, WI 53233

Natrona County Public Library
Casper, WY 82601