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Y/OWI/TM-36/2

TECHNICAL SUPPORT FOR GEIS: RADIOACTIVE WASTE ISOLATION IN GEOLOGIC FORMATIONS

MASTER

Volume 2

Commercial Waste Forms, Packaging and Projections for Preconceptual Repository Design Studies

April 1978

Prepared By

Science Applications, Inc.
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UNION CARBIDE

OFFICE OF WASTE ISOLATION
OAK RIDGE, TENNESSEE

prepared for the U.S. DEPARTMENT OF ENERGY *under* U.S. GOVERNMENT *Contract W-7405 eng 26*

This report was prepared by Science Applications, Inc. under Subcontract 62Y-45700 with Union Carbide Corporation, Nuclear Division. The subcontract was administered by the Office of Waste Isolation.

DISCLAIMER

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TECHNICAL SUPPORT FOR GEIS:
RADIOACTIVE WASTE ISOLATION
IN GEOLOGIC FORMATIONS

Volume No.	Volume Title	Prepared by*
TM-36/1	Executive Summary	SAI
TM-36/2	Commercial Waste Forms, Packaging and Projections for Preconceptual Repository Design Studies	SAI
TM-36/3	Stratigraphies of Salt, Granite, Shale, and Basalt	D&M
TM-36/4	Baseline Rock Properties-Salt	D&M
TM-36/5	Baseline Rock Properties-Granite	D&M
TM-36/6	Baseline Rock Properties-Shale	D&M
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TM-36/21	Ground Water Movement and Nuclide Transport	D&M
TM-36/22	Nuclear Considerations for Repository Design	SAI
TM-36/23	Environmental Effluent Analyses	SAI

*These documents were prepared by Science Applications, Inc. (SAI), 800 Oak Ridge Turnpike, Oak Ridge, Tennessee 37830; Dames & Moore (D&M), 20 Haarlem Avenue, White Plains, New York 10603; and Parsons Brinckerhoff Quade & Douglas, Inc. (PBQD), 1 Penn Plaza, New York, New York 10001.

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ABSTRACT

This volume, Y/OWI/TM-36/2, "Commercial Waste Forms, Packaging and Projections for Preconceptual Repository Design Studies," is one of a 23-volume series, "Technical Support for GEIS: Radioactive Waste Isolation in Geologic Formations," Y/OWI/TM-36, which supplements the "Contribution to Draft Generic Environmental Impact Statement on Commercial Waste Management: Radioactive Waste Isolation in Geologic Formations," Y/OWI/TM-44. The series provides a more complete technical basis for the preconceptual designs, resource requirements, and environmental source terms associated with isolating commercial LWR wastes in underground repositories in salt, granite, shale and basalt. Wastes are considered from three fuel cycles: uranium and plutonium recycling, no recycling of spent fuel and uranium-only recycling.

This volume contains the data base for waste forms, packages, and projections from the commercial waste defined by the Office of Waste Isolation in "Nuclear Waste Projections and Source Term Data for FY 1977," Y/OWI/TM-34. Also, as an alternative data base for repository design and analysis, waste forms, packages, and projections for commercial waste defined by Battelle Pacific Northwest Laboratory (BPNL) have been included. This data base consists of a reference case for use in the alternative design study and a definition of combustible wastes for use in mine fire and hydrogen generation analyses.

PREFACE

Project Background

One of the major problems related to the production of electricity by light-water nuclear reactors is the management of radioactive wastes generated by the use of nuclear fuel. However, the subject is considered amenable to a rational solution, and the technology involved is considered to be well within the capabilities of our present-day technological base.

An important step toward the realization of an effective waste management program is the preparation of the generic environmental impact statement for commercial waste management. A pivotal issue in waste management is the means of providing long-term, permanent storage of these wastes in a manner that best assures their isolation from the biosphere. Analyses spanning two decades have generated the widely supported concept for providing final isolation of these nuclear wastes in deep geologic formations. Therefore, the Office of Waste Isolation* was assigned the responsibility for preparation of those sections of this generic statement dealing with deep geologic waste isolation.

The original concept for deep geologic disposal was first advanced in 1957 when a National Research Council Advisory Committee of the National Academy of Sciences suggested the burial of solid radioactive wastes in salt deposits. To date, most of the research, development, and most demonstration (RD&D) activities have been in salt. The current United States Department of Energy (DOE) National Waste Terminal Storage (NWTS) program calls for the selection of two sites overlying suitable salt formations by 1979, followed by the construction and start-up in 1985 of one NRC-licensed repository designed for the permanent disposal/isolation of commercial nuclear wastes in a salt formation at one of these two sites. In addition to this activity in salt, vigorous RD&D programs have been initiated to determine the appropriateness of various hard rocks as host media for a repository.

*Operated by Union Carbide Corporation, Nuclear Division, for the Department of Energy.

The deep-geologic-isolation portion of the generic statement considers repositories located in salt, granite, shale, or basalt. The repositories are designed to handle wastes from the nuclear fuel cycle in which the spent fuel is considered a waste (no reprocessing), or from either of two fuel cycles that include reprocessing--the cycle with uranium and plutonium recycle and that with only uranium recycle. To prepare this contribution, the Office of Waste Isolation contracted with Dames & Moore, Parsons Brinckerhoff Quade & Douglas, Inc., and Science Applications, Inc. In order to prepare this description, generic sites were defined, preconceptual repository designs completed, and resource requirements and effluents from the repositories identified. The preconceptual repository designs for the salt host formation were based on more than two decades of analysis and in situ experimentation. The data base upon which the repository design for the non-salt host formations were based is more more sparse since repository-oriented analyses of these formations have been proceeding only for the last couple of years. For each of the host rocks additional analyses were performed during the conduct of these studies. Details of this additional technical work are described within the twenty-three volumes of this report.

For an overview of these preconceptual repository design studies, the study objectives and scope, and the major study assumptions, the reader is referred to Volume 1 of this series, the "Executive Summary" (Y/OWI/TM-36/1).

Volume Summary (Y/OWI/TM-36/2)

Alternative repository studies were performed using four generic geologic media as well as two sets of nuclear waste data. The first set of data was defined and documented by the Office of Waste Isolation (Y/OWI/TM-34) for purposes of the generic design study as well as for other on-going studies associated with nuclear waste management. The second data set was developed by Battelle Pacific Northwest Laboratories (BPNL) for general use in nuclear waste management research and has been chosen to serve as an alternative to the OWI waste data in this generic repository design study.

Both data sets have been defined for the same fuel cycles (total recycle, SURF, U-only recycle), consist of the same basic waste types, and pertain to all four alternative geologic media. Slight variations, however, exist between the actual data values in the two sets and are summarized here.

- Waste Forms: OWI considers HLW in vitrified and calcined forms while BPNL considers the vitrified HLW form only. Radioactive source terms vary slightly due to the assumed hold-up time for the waste. For OWI waste, HLW and spent fuel are buried 10 years after reactor discharge. Reprocessing cladding waste, ILW, and LLW, are 5 years old at burial, and SURF-LLW is 1 year old. For BPNL waste, HLW is buried at 6.5 years after reactor discharge, or 5 years after reprocessing. The same is true for all cladding waste, ILW and LLW. Spent fuel is buried 5.5 years after reactor discharge. All other waste-form considerations among the two sets are consistent.

- Packages: OWI specified cylindrical canisters for spent fuel assemblies, while BPNL uses square (cross sectional) canisters. The ILW and cladding of OWI are all in 12 in. diameter canisters, but BPNL employs 30 in. diameter canisters and 55-gallon drums for ILW and 30 in. canisters for cladding. The LLW of OWI is packaged in 55-gallon drums, while BPNL employs both 55-gallon drums and 4 ft x 6 ft x 6 ft boxes.

- Projections: The projected quantities of waste generated in the two data sets were based on different nuclear power growth curves. The OWI projections represent the growth of installed nuclear capacity to 480 GWe by the year 2000 while BPNL projects 400 GWe by the year 2000. OWI projections pertain to the four alternative rock types: salt, granite, shale, and basalt. To meet thermal criteria, OWI waste stored in the nonsalt rocks was assumed to be packaged in a less dense form than was used for storage in salt. This practice resulted in an increase in the number of HLW canisters received at the repository. BPNL projections pertain to salt only. HLW projections from this alternative waste design required adjustments to meet thermal criteria after the year 2010.

This document is divided into two parts: OWI waste and BPNL waste. The OWI data presented here (Part I) are those which cannot be found in the sections of Y/OWI/TM-34 that are associated with this design study. The BPNL data were incorporated as part of this report in the form of transmittals between BPNL and OWI, thus serving as the reference. The parts of the transmittals containing waste data have been included here (Part II).

All of the data can be found in simplified form in the GEIS (Chapter 3 and Section 9.3.2).

PART I OWI WASTE DATA

The baseline waste data set upon which the preconceptual repository design studies were based was supplied by the Office of Waste Isolation (OWI). The waste data required for the reference repository design includes definition of waste forms, isotopic contents, packaging, radioactive and thermal characteristics, and projected waste receipt rates. Detailed descriptions of these data, in the form used for design studies have been presented in Section 3.0 of the GEIS. This part of the technical support document identifies the source of these data and the modifications required for use in the design studies.

The basic waste data resulted from studies conducted at the Office of Waste Isolation and are now documented in the OWI report Y/OWI/TM-34.[1] This OWI report gives a detailed description of wastes generated by the light-water-reactor (LWR) fuel cycle as applied to the evaluation of terminal waste disposal facilities. Wastes from the alternative cycles (Total Recycle, SURF, U-Only Recycle) are described in terms of form, volume, radioactivity, heat generation, and mass. Also included are descriptions of the containers assumed for the shipment and geologic disposal of the various waste types.

Projected quantities of LWR fuel cycle wastes requiring disposal were based on a modification of ERDA's "mid-case" forecast of 1976 for nuclear power growth in the United States. In this modified case, the installed nuclear electric capacity rises from a nominal 50 GWe in year 1977 to a nominal 480 GWe in the year 2000. The power reactor grid is assumed to consist entirely of LWR's. The three basic fuel cycle alternatives considered follow the same growth curve. Due to the preliminary nature of the data from the draft of Y/OWI/TM-34 at the time of these analyses, the spent-fuel projections used for the SURF Cycle differ from the final projections by about 7 percent. This is not expected to impact the repository design significantly, perhaps altering the repository lifetime for Cycle II by approximately one year.

Rather than reproduce the information contained in TM-34 and incorporate it into this support document, specific cross references have been provided which identify the source of the data presented in Section 3.0

of the GEIS. These cross references are contained in Table I-1, in terms of section and table numbers.

For the most part, the data contained within this OWI report were used in its original form in the design studies. However, in the case of projected waste quantities of HLW received at the repository for the Total Recycle and U-Only Recycle options, modifications were required due to thermal constraints. As described in Section 3.3.1 of the GEIS, the thermal characteristics of the OWI waste were such that bulking of the HLW (addition of inert material to lower the canister heat load) was required in canisters designed to be stored in the non-salt media under consideration (granite, shale, and basalt). For storage in salt, the projected receipt rates given in Y/OWI/TM-34 could be applied without alteration. For storage in the other three media, the bulking resulted in an increase in the number of canisters received by an amount equivalent to the ratio of their specific volumes. These specific volumes were 3.0 ft^3/MTHM for HLW in salt, 5.0 ft^3/MTHM for HLW in granite, and 7.0 ft^3/MTHM for HLW in shale or basalt. Hence, projections for a granite repository were increased by a factor of 5.0/3.0 or 1.67 (7.0/3.0 or 2.33 for shale or basalt). The tables presented in Section 3.0 of the GEIS reflect this modification of projected receipt rates. Thermal constraints did not impact the other waste types in this manner; therefore, these wastes were left in their original assumed density.

In addition to the data in Y/OWI/TM-34, radioactive source terms for individual nuclides in the waste were needed for certain aspects of the design analysis. The following appendix (Appendix A) includes these data for spent fuel, HLW, and cladding wastes.

REFERENCES

1. Kisner, R. A., Marshall, J. R., Turner, D. W., and Vath, J. E., "Nuclear Waste Projections and Source Term Data for FY 1977," Y/OWI/TM-34, April, 1978.

Table I-1

OWI WASTE DATA SET CROSS REFERENCES

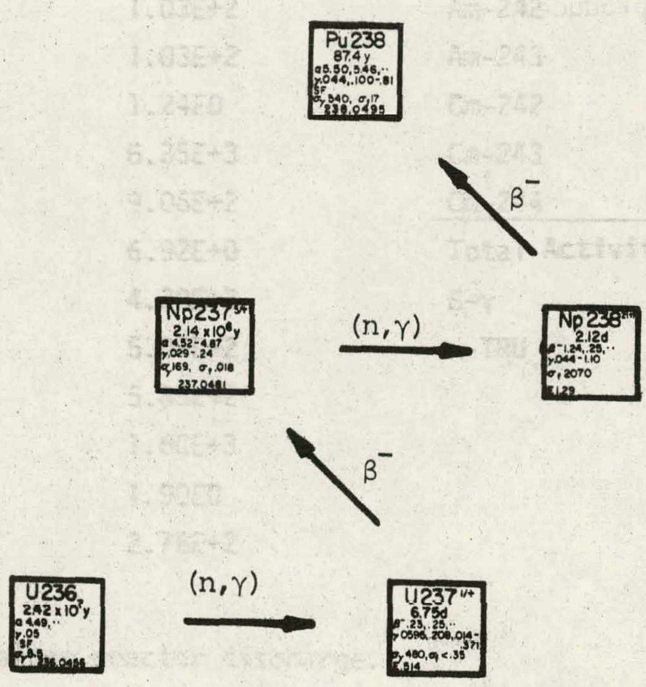
DATA	GEIS Section Numbers	Y/OWI/TM-34 Section and Table Numbers
Forms and Packages (Total Recycle)	3.1.1, 3.2	2.2, 4.2, 4.5, 4.6, 4.7
Forms and Packages (SURF Recycle)	3.1.2, 3.2	2.1, 4.1, 4.7
Forms and Packages (U-Only Recycle)	3.1.3, 3.2	2.3, 4.3, 4.5, 4.6, 4.7
Thermal Characteristics	3.3.1	3.2.1, 3.2.3, Tables A.3, A.17, A.18, A.22, A.23, A.31, A.32, A.33
Waste Projections	3.4	1.0, 3.2.2, Tables A.1, A.16, A.21, A.30, A.38, A.39, A.40, A.41, A.42

APPENDIX A

RADIOACTIVE SOURCE TERMS

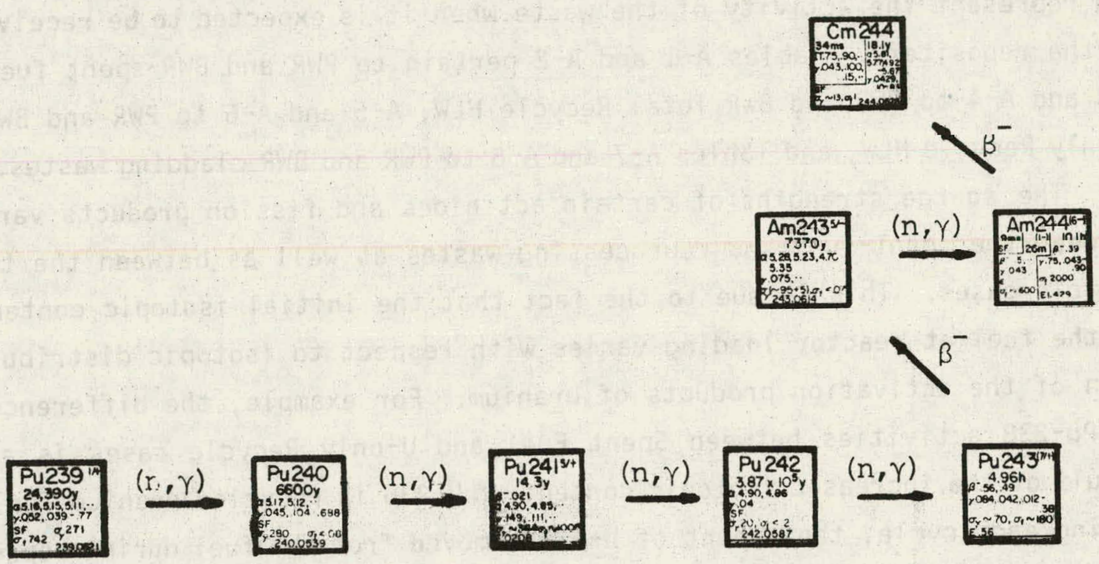
These source terms were extracted from the results of ORIGEN code runs supplied by the Office of Waste Isolation. They are stated in terms of curies per metric tonne of heavy metal charged to the reactor (Ci/MTHM) and represent the activity of the waste when it is expected to be received at the repository. Tables A-1 and A-2 pertain to PWR and BWR spent fuel, A-3 and A-4 to PWR and BWR Total Recycle HLW, A-5 and A-6 to PWR and BWR U-Only Recycle HLW, and Tables A-7 and A-8 to PWR and BWR cladding wastes.

The source strengths of certain actinides and fission products vary between the spent-fuel and reprocessing wastes as well as between the two recycle cases. This is due to the fact that the initial isotopic content of the fuel at reactor loading varies with respect to isotopic distribution of the activation products of uranium. For example, the difference in Pu-238 activities between Spent Fuel and U-only Recycle cases is a result of the increased isotopic content of U-236 in recycled uranium fuel. During each cycle, the amount of U-236 removed from the fuel during reprocessing and refabricated into new fuel increases. This increase results in increased production of Pu-238 via the following chain:



This increase in production is subsequently observed in the waste arising from the recycled fuel.

Similarly, for the differences observed in the amounts of Cm-244 in HLW from U-only Recycle and Total Recycle cases, the following explanation applies. In the total recycle case, Pu-239 is returned to the reactor as a fuel, and in the burnup process it also undergoes the following nuclear interactions,



resulting in the production of Cm-244. In U-only recycled fuel, this chain also occurs, but because of the smaller amounts of Pu-239 involved, much less Cm-244 is produced.

TABLE A-1

WASTE SOURCE STRENGTHS: Spent Fuel - PWR

ISOTOPE	CURIES/MTHM 10 Yr.[a]	ISOTOPE	CURIES/MTHM 10 Yr.
H-3	3.07E+2	U-232	1.94E-2
C-14	1.80E-1	U-233	6.77E-5
Kr-85	4.90E+3	U-234	1.04E0
Sr-90	6.01E+4	U-235	1.72E-2
Y-90	6.01E+4	U-236	2.60E-1
Zr-93	2.91E0	U-237	1.90E0
Tc-99	1.44E+1	U-238	3.14E-1
Ru-106	5.57E+2	Np-237	3.29E-1
Rh-106	5.57E+2	Np-239	1.72E+1
Cd-113m	2.13E+1	Pu-238	2.21E+3
Sb-125	7.99E+2	Pu-239	3.31E+2
Te-125m	1.95E+2	Pu-240	4.88E+2
I-129	3.39E-2	Pu-241	7.89E+4
Cs-134	9.16E+3	Pu-242	1.73E0
Cs-137	8.65E+4	Am-241	1.75E+3
Ba-137m	8.19E+4	Am-242m	6.96E0
Ce-144	1.47E+2	Am-242	6.96E0
Pr-144	1.47E+2	Am-243	1.72E+1
Pr-144m	1.76E0	Cm-242	5.72E0
Pm-147	7.30E+3	Cm-243	2.35E0
Sm-151	1.04E+3	Cm-244	1.35E+3
Eu-152	5.90E0	Total Activity	4.06E+5
Eu-154	5.67E+3	β-γ	4.00E+5
Eu-155	6.38E+2	α-TRU	6.15E+3
Fe-55	5.59E+2		
Co-60	1.38E+2		
Ni-59	3.50E0		
Ni-63	5.09E+2		

[a] Time after reactor discharge.

TABLE A-2

WASTE SOURCE STRENGTHS: Spent Fuel - BWR

ISOTOPE	CURIES/MTHM 10Yr.[a]	ISOTOPE	CURIES/MTHM 10 Yr.
H-3	2.54E+2	U-232	1.43E-2
C-14	1.31E-5	U-233	5.32E-5
Kr-85	3.95E+3	U-234	8.28E-1
Sr-90	4.89E+4	U-235	1.43E-2
Y-90	4.89E+4	U-236	2.00E-1
Zr-93	2.41E0	U-237	1.64E0
Tc-99	1.21E+1	U-238	3.17E-1
Ru-106	4.27E+2	Np-237	2.59E-1
Rh-106	4.27E+2	Np-239	1.36E+1
Cd-113m	1.74E+1	Pu-238	1.91E+3
Sb-125	6.39E+2	Pu-239	3.05E+2
Te-125m	1.56E+2	Pu-240	4.67E+2
I-129	2.87E-2	Pu-241	6.83E+4
Cs-134	6.61E+3	Pu-242	1.42E0
Cs-137	7.17E+4	Am-241	1.57E+3
Ba-137m	6.78E+4	Am-242m	1.14E+1
Ce-144	1.03E+2	Am-242	1.14E+1
Pr-144	1.03E+2	Am-243	1.36E+1
Pr-144m	1.24E0	Cm-242	9.36E0
Pm-147	6.35E+3	Cm-243	1.66E0
Sm-151	9.06E+2	Cm-244	1.05E+3
Eu-152	6.92E+0	Total Activity	3.38E+5
Eu-154	4.39E+3	β-γ	3.33E+5
Eu-155	5.08E+2	α-TRU	5.30E+3
Fe-55	5.85E+2		
Co-60	1.60E+3		
Ni-59	1.90E0		
Ni-63	2.76E+2		

[a] Time after reactor discharge.

TABLE A-3

WASTE SOURCE STRENGTHS: HLW from Total Recycle - PWR @ 10 years
Ratio of UO_2 fuel to MOX fuel is 3 to 1

ISOTOPE	CURIES/MTHM
H-3	0
C-14	0
Kr-85	0
Sr-90	5.38E+4
Y-90	5.38E+4
Zr-93	2.75E0
Nb-93m	1.28E0
Tc-99	1.44E+1
Ru-106	6.41E+2
Rh-106	6.41E+2
Ag-110m	2.18E-1
Cd-113m	2.54E+1
Sb-125	9.09E+2
Te-125m	2.22E+2
I-129	3.74E-5
Cs-134	9.00E+3
Cs-137	8.71E+4
Ba-137m	8.24E+4
Ce-144	1.42E+2
Pr-144	1.42E+2
Pr-144m	1.70E0
Pm-147	7.40E+3
Sm-151	1.12E+3
Eu-152	8.43E0
Eu-154	6.21E+3
Eu-155	7.10E+2

ISOTOPE	CURIES/MTHM
U-232	8.80E-5
U-233	1.19E-5
U-234	8.40E-3
U-235	7.29E-5
U-236	1.03E-3
U-237	1.85E-2
U-238	1.56E-3
Np-237	3.10E-1
Np-239	8.09E+1
Pu-238	1.38E+2
Pu-239	2.11E0
Pu-240	1.58E+1
Pu-241	9.28E+2
Pu-242	3.00E-2
Am-241	8.97E+2
Am-242m	9.35E+1
Am-242	9.35E+1
Am-243	8.09E+1
Cm-242	7.68E+1
Cm-243	7.26E0
Cm-244	1.04E+4
Total Activity	3.17E+5
β-γ	3.05E+5
α-TRU	1.16E+4

TABLE A-4

WASTE SOURCE STRENGTHS: HLW from Total Recycle - BWR @ 10 Years
No fuel blend, assumes pure MOX fuel.

ISOTOPE	Ci/MTHM	ISOTOPE	Ci/MTHM
H-3	0	U-232	5.83E-5
C-14	0	U-233	4.91E-6
Kr-85	0	U-234	1.44E-2
Sr-90	2.95E+4	U-235	3.52E-5
Y-90	2.95E+4	U-236	2.31E-4
Zr-93	1.9E0	U-237	3.81E-2
Tc-99	1.21E+1	U-238	1.56E-3
Ru-106	6.37E+2	Np-237	1.13E-1
Rh-106	6.37E+2	Np-239	2.17E+2
Ag-110m	2.42E-1	Pu-238	3.29E+2
Cd-113m	2.96E+1	Pu-239	2.98E0
Sb-125	9.48E+2	Pu-240	3.94E+1
Te-125m	2.31E+2	Pu-241	1.59E+3
I-129	3.89E-5	Pu-242	7.56E-2
Cs-134	6.33E+3	Am-241	2.68E+3
Cs-137	7.32E+4	Am-242m	2.21E+2
Ba-137m	6.93E+4	Am-242	2.21E+2
Ce-144	9.09E+1	Am-243	2.17E+2
Pr-144	9.09E+1	Cm-242	1.82E+2
Pr-144m	1.09E0	Cm-243	1.42E+1
Pm-147	6.48E+3	Cm-244	2.72E+4
Sm-151	1.13E+3	Total Activity	2.58E+5
Eu-152	1.71E+1	β-γ	2.27E+5
Eu-154	6.01E+3	α-TRU	3.07E+4
Eu-155	7.29E+2		

TABLE A-5

WASTE SOURCE STRENGTHS: HLW from U-Only Recycle
Pu in HLW - PWR @ 10 years

ISOTOPE	Ci/MTHM
H-3	0
C-14	0
Kr-85	0
Sr-90	6.08E+4
Y-90	6.08E+4
Zr-93	2.92E0
Nb-93m	1.36E0
Tc-99	1.44E+1
Ru-106	5.41E+2
Rh-106	5.41E+2
Ag-110m	1.62E-1
Cd-113m	2.05E+1
Sb-125	7.80E+2
Te-125m	1.91E+2
I-129	3.36E-5
Cs-134	8.88E+3
Cs-137	8.63E+4
Ba-137m	8.16E+4
Ce-144	1.47E+2
Pr-144	1.47E+2
Pr-144m	1.76E0
Pm-147	7.49E+3
Sm-151	1.05E+3
Eu-152	6.15E0
Eu-154	5.46E+3
Eu-155	6.18E+2

ISOTOPE	Ci/MTHM
U-232	2.40E-2
U-233	2.90E-5
U-234	1.27E-1
U-235	9.77E-5
U-236	2.59E-3
U-237	1.85E0
U-238	1.56E-3
Np-237	6.82E-1
Np-239	1.53E+1
Pu-238	4.65E+3
Pu-239	3.39E+2
Pu-240	4.88E+2
Pu-241	7.70E+4
Pu-242	1.61E0
Am-241	1.71E+3
Am-242m	6.71E0
Am-242	6.71E0
Am-243	1.53E+1
Cm-242	5.52E0
Cm-243	2.12E0
Cm-244	1.14E+3
Total Activity	4.00E+5
β-γ	3.92E+5
α-TRU	8.33E+3

TABLE A-6

WASTE SOURCE STRENGTHS: HLW from U-Only Recycle
Pu in HLW - BWR @ 10 years

ISOTOPE	Ci/MTHM
H-3	0
C-14	0
Kr-85	0
Sr-90	4.97E+4
Y-90	4.97E+4
Zr-93	2.43E0
Nb-93m	1.15E0
Tc-99	1.21E+1
Ru-106	4.13E+2
Rh-106	4.13E+2
Ag-110m	1.14E-1
Cd-113m	1.67E+1
Sb-125	6.22E+2
Te-125m	1.52E+2
I-129	2.83E-5
Cs-134	6.93E+3
Cs-137	7.15E+4
Ba-137m	6.76E+4
Ce-144	1.04E+2
Pr-144	1.04E+2
Pr-144m	1.24E0
Pm-147	6.53E+3
Sm-151	9.13E+2
Eu-152	7.23E0
Eu-154	4.20E+3
Eu-155	4.90E+2

ISOTOPE	Ci/MTHM
U-232	1.92E-2
U-233	2.64E-5
U-234	1.28E-1
U-235	8.24E-5
U-236	2.29E-3
U-237	1.60E0
U-238	1.58E-3
Np-237	6.21E-1
Np-239	1.20E+1
Pu-238	4.73E+3
Pu-239	3.13E+2
Pu-240	4.66E+2
Pu-241	6.65E+4
Pu-242	1.31E0
Am-241	1.53E+3
Am-242m	1.07E+1
Am-242	1.07E+1
Am-243	1.20E+1
Cm-242	8.82E0
Cm-243	1.47E0
Cm-244	8.90E+2
Total Activity	3.38E+5
β-γ	3.30E+5
α-TRU	7.93E+3

TABLE A-7

SOURCE STRENGTHS: Cladding Wastes - PWR @ 5 Years

ISOTOPE	Ci/MTHM	ISOTOPE	Ci/MTHM
H-3	0	Mn-54	1.53E+1
C-14	0	Fe-55	2.12E+3
Kr-85	0	Co-60	2.67E+2
Sr-90	3.40E+1	Ni-59	3.50E0
Y-90	3.40E+1	Ni-63	5.25E+2
Zr-93	0	U-232	8.59E-6
Tc-99	0	U-233	2.98E-8
Ru-106	8.61E0	U-234	5.06E-4
Rh-106	8.61E0	U-235	8.62E-6
Ag-110m	0	U-236	1.30E-4
Cd-113m	0	U-237	1.30E-3
Sb-125	1.51E+1	U-238	1.57E-4
Te-125m	6.01E0	Np-237	1.63E-4
I-129	1.70E-5	Np-239	8.58E-3
Cs-134	2.46E+1	Pu-238	1.15E0
Cs-137	4.85E+1	Pu-239	1.65E-1
Ba-137m	4.59E+1	Pu-240	2.44E-1
Ce-144	6.28E0	Pu-241	5.00E+1
Pr-144	6.28E0	Pu-242	8.65E-4
Pr-144m	0	Am-241	5.25E-1
Pm-147	1.37E+1	Am-242m	5.63E-3
Sm-151	5.42E-1	Am-242	5.63E-3
Eu-152	0	Am-243	8.58E-3
Eu-154	4.24E0	Cm-242	8.61E-3
Eu-155	6.57E-1	Cm-243	1.31E-3
		Cm-244	8.15E-1
		Total Activity	3.19E+3
		β-γ	3.19E+3
		α-TRU	2.90E0

TABLE A-8

SOURCE STRENGTHS: Cladding Wastes - BWR @ 5 Years

ISOTOPE	Ci/MTHM	ISOTOPE	Ci/MTHM
H-3	0	Mn-54	1.47E+1
C-14	0	Fe-55	2.22+3
Kr-85	0	Co-60	3.10E+3
Sr-90	2.76E+1	Ni-59	1.90E0
Y-90	2.76E+1	Ni-63	2.87E+2
Zr-93	0	U-232	6.38E-6
Tc-99	0	U-233	2.34E-8
Ru-106	6.59E0	U-234	4.01E-4
Rh-106	6.59E0	U-235	7.14E-6
Ag-110m	0	U-236	1.00E-4
Cd-113m	0	U-237	1.04E-3
Sb-125	1.74E+1	U-238	1.59E-4
Te-125m	7.02E0	Np-237	1.28E-4
I-129	1.43E-5	Np-239	6.81E-3
Cs-134	1.78E+1	Pu-238	9.90E-1
Cs-137	4.02E+1	Pu-239	1.52E-1
Ba-137m	3.72E+1	Pu-240	2.33E-1
Ce-144	4.42E0	Pu-241	4.33E+1
Pr-144	4.42E0	Pu-242	7.10E-4
Pr-144m	0	Am-241	4.81E-1
Pm-147	1.19E+1	Am-242m	5.83E-3
Sm-151	4.70E-1	Am-242	5.83E-3
Eu-152	0	Am-243	6.81E-3
Eu-154	3.29E0	Cm-242	9.03E-3
Eu-155	5.23E-1	Cm-243	9.25E-4
		Cm-244	6.33E-1
		Total Activity	5.84E+3
		β-γ	5.84E+3
		α-TRU	2.49E0

PART II BPNL WASTE DATA PACKAGE

The information received from Battelle Pacific Northwest Laboratories (BPNL) for the purpose of the alternate repository design study was in the form of transmittals between BPNL and the staff at OWI. In this form, the data cannot be referenced conventionally. Therefore, this section of the technical support document is designed to present the BPNL waste data as they were received and thereby make them more easily accessible.

The information contained in the following appendices is reproduced in the original form as received, changing only the figure and table numbers to facilitate order within this document. In some cases, iteration, adjustments, and clarification of these data were required prior to use. Where this was the case, details of the data processing have been supplied, either in this document or in the GEIS (Section 9.3.2).

To facilitate use of this document, the data used in the design study were separated in terms of specific topic areas. The data in each area are contained in an individual appendix as specified below.

The appendices are:

Appendix A - Nuclear Generating Capacity
B - Description of Waste Forms
C - Waste Package Descriptions
D - Waste Projections
E - Source Terms
F - Heat Generation Rates
G - Waste Thermal History

In each appendix, the source of the information is supplied and reference made to the final form of the data used. The transmittals referred to in each appendix correspond to the following:

November, 1976 - ORIGEN runs from BPNL to A. Quist, Office of Waste Isolation (OWI), Union Carbide Corporation, Nuclear Division (UCC-ND)

May 27, 1977 - Memorandum from R. W. McKee, Manager, Waste Management Technology, Commercial Waste Management Statement (CWMS), BPNL, to R. K. Kibbe, Project Manager, OWI, UCC-ND.

September 28, 1977- Memorandum entitled "Waste Packaging Descriptions for Impact Statement on Commercial Radioactive Waste Management," from C. M. Unruh, Manager, CWMS, BPNL, to Dr. C. D. Zerby, Director, OWI, UCC-ND.

November 1, 1977 - Memorandum from R. W. McKee, Manager, Waste Management Technology, CWMS, BPNL, to R. K. Kibbe, Project Manager, OWI, UCC-ND.

November 11, 1977 - Memorandum entitled "Waste Package Descriptions for Impact Statement on Commercial Radioactive Waste Management," from R. W. McKee, Manager, Waste Management Technology, CWMS, BPNL, to R. K. Kibbe, Project Manager, OWI, UCC-ND.

November 17, 1977 - Memorandum entitled "Waste Description Data for Impact Statement on Commercial Radioactive Waste Management," from R. W. McKee, Manager, Waste Management Technology, CWMS, BPNL, to R. K. Kibbe, Project Manager, OWI, UCC-ND.

November 28, 1977 - Memorandum entitled "Waste Package Quantities for Case 2, CWMS," from R. W. McKee, Manager, Waste Management Technology, CWMS, BPNL, to R. K. Kibbe, Project Manager, OWI, UCC-ND.

In using the original BPNL information, it must be noted that the fuel cycle cases 1, 2 and 3 correspond to the OWI reference cycles SURF

(II), U-Only Recycle (III), and Total Recycle (I), respectively. In addition, the lower-case letters following the cycle numbers in the BPNL data refer to particular alternative waste forms within each cycle. The only forms of concern in this study were 1, 2a, and 3a for the alternative design, and case 3d for the analysis of combustible wastes. The descriptions of these forms are as follows:

Case a - Reference case - Incineration of combustible wastes and cementation of wet wastes and incinerator products.

Case d - Minimum treatment of combustible wastes (packaging only) and bitumenization of wet wastes.

APPENDIX A - NUCLEAR GENERATING CAPACITY

The following information was obtained from the September 28 transmittal from C. M. Unruh to Dr. C. D. Zerby. The table describes the projected growth of installed nuclear capacity used in determining the quantities of BPNL waste generated (Appendix D).

The data in terms of PWR, BWR and total generating capacity are presented in Table 9-11 of the GEIS.

TABLE A-1

Installed U.S. Nuclear Generation Capacity Projection for CWMS

Year	PWR Capacity GWe	PWR Capacity Factor %	PWR Generation GWe Yr	BWR Capacity GWe	BWR Capacity Factor %	BWR Generation GWe Yr	Total LWR Capacity GWe	Total LWR Capacity Factor %	Total LWR Generation GWe Yr
1977	30	61	19	17	68	11	47	65	30
1980	41	67	28	19	67	13	60	67	40
1985	86	65	56	41	64	26	127	65	82
1990	131	67	88	63	17	42	194	67	130
1995	197	67	132	96	67	64	293	67	195
2000	268	67	181	132	67	89	400	67	269
2005	268	68	183	132	68	90	399	68	272
2010	265	66	176	129	66	86	395	65	261
2015	247	64	156	117	65	76	364	65	235
2020	227	60	137	113	60	68	340	60	205
2025	182	56	101	91	56	51	274	56	152
2030	137	49	68	69	49	34	206	49	101
2035	72	44	31	36	44	16	108	44	47
2039	14	40	5	7	40	3	20	40	8

As provided by [redacted]
9/28/77 as Table 1

APPENDIX B - DESCRIPTION OF WASTE FORMS

The tables included in this appendix describe the waste forms associated with the BPNL repository design. These data were obtained from the September 28 transmittal from C. M. Unruh to Dr. C. D. Zerby (for Tables B-1, B-2 and B-3 describing solidified HLW, cladding waste and spent LWR fuel, respectively) and the November 11 transmittal from R. W. McKee to R. K. Kibbe (for Table B-4 describing ILW and LLW for Case 3a). This information was used to identify the waste form and specific volumes (waste containers/MTHM processed) of each waste type. The radioactivity characteristics described in these tables were not used in the form given (see Appendix F for source term data). The basic description for HLW (Table B-1), although only given for Fuel Cycle 3 (Total Recycle), was also used to describe the HLW from the U-only Recycle case. Packaged ILW and LLW waste descriptions given in the tables for Case 3a (Total Recycle) were also used for the Uranium-Only Recycle case by deleting any description of wastes arising from PuO_2 conversion or from a MOX FFP (mixed oxide fuel fabrication plant). Tables 9-7 and 9-8 of the GEIS contain this waste form information.

In the analysis of the impacts of combustible waste storage, combustible-waste data were obtained from the November 11 transmittal from R. W. McKee to R. K. Kibbe (Table B-5 for Case 3d). Further assumptions concerning these data are discussed in Section 4.2.2 of TM-36/23.

TABLE B-1

Solidified High-Level Waste

Fuel Cycle 3

High-Level Liquid Waste → Glass-Melt and Package → Shipment 12 in. x 10 ft Canister >10 R/hr, 0.3285 Canisters/MTHM

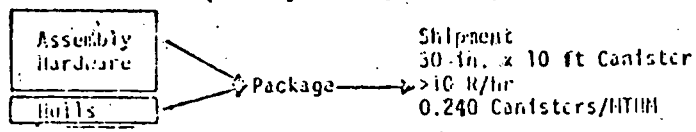
Source	Years After Chemical Separation							
	0	5	10	50	100	10^3	10^4	10^6
Irradiated fuel								
Impurities/MTHM								
Grams	3.5×10^2	3.5×10^2	3.5×10^2	3.5×10^2	3.5×10^2	3.5×10^2	3.5×10^2	3.5×10^2
Curies	2.9×10^1	8.4	3.6	1.4	9.8×10^{-1}	2.4×10^{-2}	2.2×10^{-2}	1.0×10^{-3}
Watts	5.7×10^{-2}	1.2×10^{-2}	4.1×10^{-3}	2.5×10^{-4}	1.7×10^{-4}	2.0×10^{-5}	1.9×10^{-5}	1.9×10^{-6}
Actinides/MTHM								
Grams	6.0×10^3	6.0×10^3	6.0×10^3	6.0×10^3	6.0×10^3	6.0×10^3	6.0×10^3	6.0×10^3
Curies	1.9×10^4	7.6×10^3	6.5×10^3	2.1×10^3	1.1×10^3	2.7×10^2	5.9×10^1	4.8
Watts	6.4×10^2	2.4×10^2	2.0×10^2	6.6×10^1	3.2×10^1	7.5	1.3	1.1×10^{-1}
Fission products/MTHM								
Grams	2.6×10^4	2.6×10^4	2.6×10^4	2.6×10^4	2.6×10^4	2.6×10^4	2.6×10^4	2.6×10^4
Curies	1.4×10^6	3.3×10^5	2.5×10^5	9.4×10^4	2.9×10^4	1.9×10^1	1.8×10^1	2.9
Watts	6.5×10^3	1.2×10^3	8.2×10^2	2.9×10^2	8.8×10^1	2.1×10^{-2}	2.0×10^{-2}	7.7×10^{-4}
Total/MTHM								
Grams	3.2×10^4	3.2×10^4	3.2×10^4	3.2×10^4	3.2×10^4	3.2×10^4	3.2×10^4	3.2×10^4
Curies	1.4×10^6	3.4×10^5	2.5×10^5	9.6×10^4	3.0×10^4	2.9×10^2	7.7×10^1	7.6
Watts	7.1×10^3	1.5×10^3	1.0×10^3	3.6×10^2	1.2×10^2	7.6	1.4	1.1×10^{-1}
Total/container								
Grams	9.7×10^4	9.7×10^4	9.7×10^4	9.7×10^4	9.7×10^4	9.7×10^4	9.7×10^4	9.7×10^4
Curies	4.3×10^6	1.0×10^6	7.9×10^5	2.9×10^5	9.1×10^4	8.7×10^2	2.3×10^2	2.3×10^1
Watts	2.2×10^4	4.4×10^3	3.1×10^3	1.1×10^3	3.6×10^2	2.3×10^1	4.1	3.5×10^{-1}

As provided by ORNL on 9/26/77 as Table A-1

TABLE B-2

Hulls and Hardware Wastes

(Fuel Cycles 2a, b and 3)



Source	Years After Chemical Separation: 0	10	50	10^2	10^3	10^4	10^6
Assembly hardware and hulls							
Activation products/MTHM							
Grams	3.2×10^5	3.2×10^5	3.2×10^5	3.2×10^5	3.2×10^5	3.2×10^5	3.2×10^6
Curies	9.4×10^3	1.8×10^3	3.0×10^2	2.1×10^2	3.2	2.7	1.2×10^{-1}
Watts	7.2×10^1	1.7×10^1	1.4×10^{-1}	3.3×10^{-2}	1.4×10^{-4}	7.4×10^{-5}	2.9×10^{-5}
Hulls, residual fuel							
Fission products/MTHM							
Grams	1.5×10^1	1.5×10^1	1.5×10^1	1.5×10^1	1.5×10^1	1.5×10^1	1.5×10^1
Curies	7.0×10^2	1.3×10^2	4.8×10^1	1.5×10^1	9.4×10^{-3}	9.0×10^{-3}	1.4×10^{-3}
Watts	3.2	4.3×10^{-1}	1.5×10^{-1}	4.5×10^{-2}	1.1×10^{-5}	9.9×10^{-6}	3.8×10^{-7}
Actinides/MTHM							
Grams	4.8×10^2		4.8×10^2	4.8×10^2	4.8×10^2	4.8×10^2	4.8×10^2
Curies	1.0×10^2		1.5×10^1	5.8	1.3	3.0×10^{-1}	1.1×10^{-2}
Watts	4.3×10^{-1}		2.0×10^{-1}	1.6×10^{-1}	4.0×10^{-2}	9.1×10^{-3}	2.6×10^{-4}
Total/MTHM							
Grams	3.2×10^5	3.2×10^5	3.2×10^5	3.2×10^5	3.2×10^5	3.2×10^5	3.2×10^5
Curies	1.0×10^4	1.9×10^3	3.6×10^2	2.3×10^2	4.5	3.0	1.3×10^{-1}
Watts	7.6×10^1	1.8×10^1	4.9×10^{-1}	2.4×10^{-1}	4.0×10^{-2}	9.2×10^{-3}	2.9×10^{-4}
Total contents/container[(a)]							
Noncompacted							
Grams	1.3×10^6	1.3×10^6	1.3×10^6	1.3×10^6	1.3×10^6	1.3×10^6	1.3×10^6
Curies	4.2×10^4	7.9×10^3	1.5×10^3	9.6×10^2	1.9×10^1	1.3×10^1	5.4×10^{-1}
Watts	3.2×10^2	7.5×10^1	2.0	1.0	1.7×10^{-1}	3.8×10^{-2}	1.2×10^{-3}

a. Assumed assembly hardware and cladding (hulls) packaged in same proportion as in original fuel rod assembly.

As provided by BPNL on 9/20/77 as Table A-2

TABLE B-3

Radioactive Content of Spent LWR Fuel

(Fuel Cycle 1)

Source	Years After Reactor Discharge										
	0.5	1.0	1.5	5.0	10	10^2	3×10^2	5×10^2	10^3	10^4	10^5
Pressurized water reactor											
Radioactive contents/assembly[(a)]											
Grams	6.7×10^5	6.7×10^5		6.7×10^5	6.7×10^5	6.7×10^5	6.7×10^5				
Curies	1.8×10^6	1.1×10^6		2.7×10^5	1.9×10^5	1.9×10^4	2.1×10^3				
Watts	8.5×10^3	5.1×10^3		9.7×10^2	5.9×10^2	1.4×10^2	6.1×10^1				
Radioactive contents/MTHM											
Grams	1.5×10^6	1.5×10^6		1.5×10^6	1.5×10^6	1.5×10^6	1.5×10^6				
Curies	4.0×10^6	2.4×10^6		5.9×10^5	4.1×10^5	4.2×10^4	4.5×10^3				
Watts	1.8×10^4	1.1×10^4		2.1×10^3	1.3×10^3	3.0×10^2	1.3×10^2				
Boiling water reactor											
Radioactive content/assembly[(b)]											
Grams	2.8×10^5	2.8×10^5		2.8×10^5	2.8×10^5	2.8×10^5	2.8×10^5				
Curies	5.0×10^5	3.1×10^5		8.6×10^4	6.1×10^4	6.3×10^3	6.7×10^2				
Watts	2.3×10^3	1.4×10^3		2.9×10^2	1.9×10^2	4.5×10^1	1.9×10^1				
Radioactive content/MTHM											
Grams	1.5×10^6	1.5×10^6		1.5×10^6	1.5×10^6	1.5×10^6	1.5×10^6				
Curies	2.7×10^6	1.6×10^6		4.6×10^5	3.2×10^5	3.4×10^4	3.5×10^3				
Watts	1.2×10^4	7.3×10^3		1.5×10^3	9.9×10^2	2.4×10^2	1.0×10^2				
Composite fuel[(c)]											
Content/MTHM											
Grams	1.5×10^6	1.5×10^6		1.5×10^5	1.5×10^6	1.5×10^6	1.5×10^6				
Curies	3.4×10^6	2.1×10^6	1.5×10^6	5.2×10^5	3.6×10^5	3.7×10^4	4.1×10^3	2.7×10^3	1.6×10^3	4.3×10^2	1.8×10^1
Watts	1.6×10^4	9.6×10^3	6.7×10^3	1.8×10^3	1.1×10^3	2.7×10^2	1.2×10^2	8.6×10^1	5.0×10^1	1.2×10^1	3.5 x 10[illegible]

a. PWR fuel assemblies contain 461.5 kg uranium.
b. BWR fuel assemblies contain 188.6 kg uranium.
c. Composite fuel denotes the mix of spent fuel that results from PWR's supplying 2/3 and BWR's 1/3 of the total electrical energy produced.

As provided by BPNL on 9/28/77 as Table A-10

TABLE B-4

Case 3a   page 1 of 3   11/7/77

PACKAGED INTERMEDIATE AND LOW-LEVEL TRU WASTES FROM FRP

Plutonium and Uranium Recycle

Waste Treatment: Incinerate Combustibles, Cementation, Packaging

Packaged Waste Description	Container	Containers/ 2000 MTHM	Packaged Density g/cc	γ Radioactivity, Ci/Container			Surface Dose[1] R/hr	Treated Waste Composition
				FPs	Actinides	Activation		
Incinerator Blowdown	55 gal drum	2230	1.8	9.6×10^{-2}	4.1	8.5×10^{-6}	< 0.2 (0.05)	Cement, Blowdown Solution
Noncombustible General Trash	55 gal drums	431	0.25	1.6×10^{-2}	2.3×10^{-3}		< 0.2 (0.12)	Ferrous Metal 90% Glass 10%
Noncombustible Trash PuO_2 Conversion	55 gal drums	52	0.25		4.4×10^{2}		< 0.2 (.01 - 0.015)	Ferrous Metal 90% Glass 10%
Failed Equipment General	4'x6'x6' boxes	50	0.5	7.5×10^{-2}	1.1×10^{-2}		< 0.2 (0.1)	100% Metal
Failed Equipment PuO_2 Conversion	4'x6'x6' boxes	10	0.5		2.0×10^{2}		< 0.2 (6×10^{-4})	100% Metal
Noncombustible General Trash	55 gal drums	1500	0.25	8.9×10^{-2}	1.3×10^{-3}		0.2 - 1.0 (0.5)	Ferrous Metals 90% Glass 10%
Noncombustible Trash PuO_2 Con.	55 gal drums	6	0.25		2.7×10^{-3}		0.2 - 1.0 (0.6)	Ferrous Metals 90% Glass 10%
Failed Equipment	55 gal drums	445	0.4	1.0×10^{-2}	1.5×10^{-2}		0.2 - 1.0 (0.7)	100% Ferrous Alloys
Failed Equipment	30"x 10' canisters	67	0.4	6.9×10^{-1}	9.7×10^{-2}		0.2 - 1.0 (0.7)	100% Ferrous Alloys
Noncombustible Trash	55 gal drums	1940	0.25	1.3	1.9×10^{-2}		1 - 10 (7.3)	90% Metal 10% Glass

As provided by BPNL on 11/11/77

TABLE B-4 (cont'd)

Case 3 a | page 2 of 2 | 11/7/77

PACKAGED INTERMEDIATE AND LOW-LEVEL TRU WASTES FROM FRP

Plutonium and Uranium Recycle

Waste Treatment: Incinerate Combustibles, Cementation, Packaging

Packaged Waste Description	Container	Containers/ 2000 MTHM	Packaged Density g/cc	γ Radioactivity, Ci/Container			Surface Dose[1] R/hr	Treated Waste Composition
				FPs	Actinides	Activation		
Failed Equipment	55 gal drums	26	0.5	9.1×10^{-2}	1.3×10^{-1}		1 - 10 (2.4)	100% Ferrous Alloys
Failed Equipment	30" x 10' canisters	4	0.5	5.5	7.9×10^{-1}		1 - 10 (7.1)	100% Ferrous Alloys
Cemented Incinerator Ash	55 gal drums	829	1.8	14	2.5×10^{2}	2.3×10^{-2}	>10 (10.6)	Cement + Ashes from incinerator
Noncombustible Trash	55 gal drums	500	0.25	56	8.2	3.8	>10 (310)	90% Metal 10% Glass
Cemented Wet Wastes	55 gal drums	2526	1.5	3.2×10^{2}	1.5×10^{2}	7.5×10^{-1}	>10 (280)	Cement, Misc. salts, Resins, Filter Sludge
HEPA Filter Media	55 gal drums	415	0.7	68	1.8×10^{3}		>10 (130)	Compacted Glass Fiber

(1) The surface dose rate is divided into four classes, < 0.2, 0.2 - 1.0, 1 - 10, and > 10 R/hr. The numbers in parenthesis are the calculated average dose rates. A distribution of dose rates about the average is to be expected.

TABLE B-4 (cont'd)

 11/7/77

Case 3a

PACKAGED INTERMEDIATE AND LOW-LEVEL TRU WASTES FROM MOX FFP

Plutonium and Uranium Recycle

Waste Treatment: Incinerate Combustibles, Cementation, Packaging

Packaged Waste Description	Container	Containers/ 400 MTHM	Packaged Density g/cc	γ Radioactivity, Ci/Container			Surface Dose (1) R/hr	Treated Waste Composition
				FPs	Actinides	Activation		
Noncombustible Trash	55 gal drum	394	0.25		62		< 0.2 (0.001)	90% Metal 10% Glass
Failed Equipment	4'x6'x6' boxes	20	1.0		18		< 0.2 (5×10^{-5})	80% Metal 20% Insulating Brick
Filter Media	55 gal drums	200	0.2		8.4×10^{2}		< 0.2 (0.01)	60% Metal 40% Glass Fiber
Cemented Incinerator Ash & Blowdown	55 gal drums	1070	1.8		67		< 0.2 (0.002)	Cement, Ash, Blowdown
Cemented Wet Waste	55 gal drums	584	1.8		28		< 0.2 (1×10^{-4})	Cement, Inorganic Salts

As provided by BPNL on 11/11/77

TABLE B-5

Case 3 d — page 1 of 3 — 11/7/77

PACKAGED INTERMEDIATE AND LOW-LEVEL TRU WASTES FROM FRP

Plutonium and Uranium Recycle

Waste Treatment: Minimum Treatment, Bitumen Fixation, Packaging

Packaged Waste Description	Container	Containers/ 2000 MTHM	Packaged Density g/cc	γ Radioactivity, Ci/Container			Surface Dose[(1)] R/hr	Treated Waste Composition
				FPs	Actinides	Activation		
LLW Combustible Trash	55 gal drums	12,000	0.12	2.3×10^{-4}	3.4×10^{-5}		< 0.2 (0.003)	Paper, rags, PVC neoprene, latex, wooc
LLW Combustible Trash	55 gal drums	700	0.12	1.0×10^{-2}	2.6×10^{2}	3.5×10^{-4}	< 0.2 (0.12)	Paper, rags, PVC neoprene, latex, wood
Noncombustible Trash - General	55 gal drums	431	0.25	1.6×10^{-2}	2.3×10^{-3}		< 0.2 (0.1)	90% Ferrous Metals 10% Glass
Noncombustible Trash, PuO_2 Conversion	55 gal drums	52	0.25		4.4×10^{2}		< 0.2 (0.01 - .015)	90% Ferrous Metals 10% Glass
Failed Equipment General	4'x6'x6' boxes	50	0.5	7.5×10^{-2}	1.1×10^{-2}		< 0.2 (0.1)	100% Metal
Failed Equipment PuO_2 Conversion	4'x6'x6' boxes	10	0.5		2.0×10^{2}		< 0.2 (6.10^{-4})	100% Metal
Bitumenized Wet Wastes	55 gal drums	42	0.8	5.2×10^{-2}	8.9×10^{-1}		< 0.2 (0.13)	Bitumen, Silica Gel
Noncombustible General Trash	55 gal drums	1500	0.25	8.9×10^{-2}	1.3×10^{-3}		0.2 - 1.0 (0.5)	90% Ferrous Metals 10% Glass
Noncombustible Trash, PuO_2 Conversion	55 gal drums	6	0.25		2.7×10^{3}		0.2 - 1.0 (0.6)	90% Ferrous Metals 10% Glass

As provided by BPNL on 11/11/77

TABLE B-5 (cont'd)

Case 3 d page 2 of 3 11/7/77

PACKAGED INTERMEDIATE AND LOW-LEVEL TRU WASTES FROM FRP

Plutonium and Uranium Recycle

Waste Treatment: Minimum Treatment, Bitumen Fixation, Packaging

Packaged Waste Description	Container	Containers/ 2000 MTHM	Packaged Density g/cc	γ Radioactivity, Ci/Container			Surface Dose[1] R/hr	Treated Waste Composition
				FPs	Actinides	Activation		
Failed Equipment	55 gal drums	445	0.4	1.0×10^{-1}	1.5×10^{-2}		0.2 - 1.0 (0.7)	100% Ferrous Alloys
Failed Equipment	30" x 10' canisters	67	0.4	6.9×10^{-1}	9.7×10^{-2}		0.2 - 10 (0.7)	100% Ferrous Alloys
Bitumenized Wet Wastes	55 gal drums	659	1.3	1.3	6.6×10^{-1}		0.2 - 1.0 (0.35)	Bitumen, Fluorinator Fines, (Al_2O_3, CaF_2)
Noncombustible Trash	55 gal drums	1940	0.25	1.3	1.9×10^{-2}		1 - 10 (7.3)	90% Metal 10% Glass
Failed Equipment	55 gal drums	26	0.5	9.1×10^{-1}	1.3×10^{-1}		1 - 10 (2.4)	100% Ferrous Alloys
Failed Equipment	4'x6'x6' boxes	4	0.5	5.5	7.9×10^{-1}		1 - 10 (7.1)	100% Ferrous Alloys
ILW Combustible Trash	55 gal drums	6500	0.12	5.2×10^{-1}	7.3×10^{-2}	2.9×10^{-3}	1.0 - 10 (6.0)	Paper, rags, PVC neoprene, latex, wood
Filters	80 gal drums	2900	0.16	17	2.5×10^{2}		> 10 (142)	60% Metal 40% Glass Fiber
Noncombustible Trash	55 gal drums	500	0.25	56	8.2	3.8	10 >(310)	90% Metal 10% Glass
Bitumenized Wet Wastes	55 gal drums	685	1.1	1.1×10^{3}	5.5×10^{2}	2.8	10 >(1370)	Bitumen, Misc. salts resins, filter sludge

As provided by BPNL on 11/11/77

Case 3d page 3 of 3 11/7/77

PACKAGED INTERMEDIATE AND LOW-LEVEL TRU WASTES FROM MOX FFP

Plutonium and Uranium Recycle

Waste Treatment: Minimum Treatment, Bitumen Fixation, Packaging

Packaged Waste Description	Container	Containers/ 400 MTHM	Packaged Density g/cc	Y Radioactivity, Ci/Container FPs	Actinides	Activation	Surface Dose (1) R/hr	Treated Waste Composition
Combustible Trash	55 gal drum	1050	0.12		68		< 0.2 (0.001)	Cellulosics, PVC Polyethylene, Latex, Neoprene, Polystyrene
Noncombustible Trash	55 gal drums	394	0.25		62		< 0.2 (0.001)	90% Metal 10% Glass
Failed Equipment	4'x6'x6' boxes	20	1.0		18		< 0.2 (5×10^{-5})	80% Metal 20% Insulating Brick
Filters	80 gal drums	350	0.16		4.8×10^{2}		< 0.2	60% Metal 40% Glass Fiber
Bitumenized Wet Wastes	55 gal drums	460	1.0		35		< 0.2 (2×10^{-4})	Bitumen, Inorganic Salts

(1) The surface dose rate is divided into four classes, < 0.2, 012 - 1.0, 1 - 10, and > 10 R/hr. The numbers in parenthesis are the calculated average dose rates. A distribution of dose rates about the average is to be expected.

As provided by BP on 11/11/77

APPENDIX C - WASTE PACKAGE DESCRIPTIONS

This appendix describes the BPNL waste packages used for the alternate repository design study. Individual waste container information was obtained from the September 28 transmittal of C. M. Unruh to Dr. C. D. Zerby (Table C-1). Waste shipping-container descriptions and shipment modes were obtained from the November 1 transmittal of R. W. McKee to R. K. Kibbe (Table C-2 and text). More HLW shipping casks have been described than were actually specified in the repository design in order to give an overall picture of what types of casks are available. In the GEIS, individual waste data are presented in Table 9-9 and shipping containers are discussed in Section 9.3.2.2.2.

TABLE C-1 CWMS Waste Container Characteristics

Container	Dimensions	Construction	Application	Closure
canisters	12" dia. x 10' long	Sch. 40 SS pipe .41" wall thickness	HLW	welded head
	30" dia. x 10' long	Sch. 20 SS pipe .5" wall thickness	FRW[a] and failed equipment	welded head
	6.5" sq. x 16' long	SS or carbon steel plate .25" thick	BWR elements	welded head
	9.5" sq. x 16' long	SS or carbon steel plate .25" thick	PWR elements	welded head
drums	55 gal 22.5" dia. x 34.8" long	carbon steel DOT spec. 17C	ILW and LLW	ring clamps and gasket
boxes	4' x 6' x 6'	carbon steel DOT spec. 7A	LLW failed equipment	gasket or welded head

a. FRW = Fuel Residue Waste (fuel hulls and hardware)

As provided by [illegible] on 9/[illegible]/77 as Table 2

As provided by APRL on 11/1/77 as Table 3

TABLE C-2. Packages per Shipment for CWMS Reference System

1. Spent Fuel From Reactor To Interim Storage

   45% via NLI 10/24 rail cask with 10 PWR or 24 BWR assemblies/cask.

   45% via IF-300 rail cask with 7 PWR or 18 BWR assemblies/cask.

   10% via truck cask with 1 PWR or 2 BWR assemblies/cask.

2. Packaged Spent Fuel From Interim Storage To Permanent Disposal

   All shipments via modified rail cask with 7 PWR or 17 BWR assemblies/shipment.

3. Solidified High Level Waste From Fuel Reprocessing Plant To Federal Repository

   All shipments by rail. Vitrified waste will be in 12 in. dia. by 10 ft. long canisters with 9 canisters per cask.

4. Fuel Bundle Residues From Fuel Reprocessing Plant to Federal Repository

   Waste package in 30 in. dia. by 10 ft. long canisters. All shipments by rail. Rail casks will carry 3 canisters.

5. Plutonium From Fuel Reprocessing Plant To Federal Repository

   All shipments by truck. 32 kg of plutonium oxide/cask, 10 casks/truck shipmen

6. Non-high Level TRU Waste From Fuel Reprocessing Plants and MOX Plants To Federal Repository

   All shipments by truck. Waste will be packaged in 55-gal drums, 4'x6'x5' boxes or 30 in. dia. x 10' long canisters (fuel bundle residue canisters).
   30 in. dia. canisters will be shipped in fuel bundle residue casks.
   Steel boxes will be shipped in a Super Tiger with 3 boxes/overpack.
   Shipment mode for 55-gal drums will depend on surface dose rate as follows:

Surface Dose Rate	Shipment Mode
<200 mr/hr	36 drums per Super Tiger
200 mr/hr - 1 R/hr	36 drums per shielded van
1 R/hr - 10 R/hr	14 drums per cask
>10 R/hr	6 drums per cask

   Truck shipments will consist of 1 Super Tiger or 1 cask.

6.2.1.1 Rail Casks for Shipment of Spent Fuel

As indicated in Table 6.2.1, two rail casks, the IF-300 and the NLI 10/24, are currently licensed for rail shipment of spent fuel in the United States.

IF-300. The IF-300 cask of General Electric Company is a water filled cask designed for rail transport of 7 PWR or 18 BWR fuel assemblies.[3,4] Approximate loaded cask weight is 63 metric tons (140,000 lbs). The gross weight of one cask, its skid and auxiliary components is 80 metric tons (175,000 lb). The cask is normally transported by rail on a 100-metric-ton capacity, four-axle flatcar, but it may be transported for short distances on highways on a special nine-axle truck requiring special overweight permits. This special truck is used to move the cask from reactors without rail facilities to the nearest rail siding. Four IF-300 casks have been built.

The cask has an overall length of 5.33 m (210 in.) and a diameter of 1.62 m (64 in.). The cavity has a length of 4.58 m (180 1/4 in.) and a diameter of 0.95 m (37 1/2 in.). Interchangeable fuel baskets provide it with a capacity of 7 PWR of 18 BWR fuel assemblies.

Gamma shielding is provided by 102 mm (4 in.) of depleted uranium sandwiched between stainless steel inner and outer shells. Neutron shielding is provided by the water in the cask cavity plus 114 mm (4 1/2 in.) of water contained in a stainless steel corrugated jacket. Freezing in the winter months is prevented by using a mixture of water and ethylene glycol. Criticality control is provided by boron carbide filled stainless steel tubes which are welded to the fuel baskets. Impact protection is provided by stainless steel fins mounted radially and on the cask heads. The external water jacket is constructed of thin walled material and does not contribute to the impact protection of the cask.

A single cask lid is provided, made of stainless steel, forged plates. Thirty-two 1-3/4 in. diameter stud bolts provide the lid attachment. The closure head is sealed with a Grayloc metallic ring. The cask cavity is provided with two bellows sealed stainless steel globe valves for fill, drain and sampling purposes. The valve handles are lockwired during transit to prevent loosening.

The cavity maximum normal operating pressure is 200 psig. However, the design working pressure is 400 psig at a material temperature of 615°F (324°C). Cavity overpressure protection is provided by a combination breaking pin and pressure relief valve. Discharge pressure for the pin and valve is 350 psig. The discharge valve is set for a maximum steam or gas blowdown of five percent and a liquid blowdown of ten percent.

Heat is removed from the fuel to the cask cavity walls by natural circulation of the contained water, by conduction through the cask walls to the outer neutron shield, and by convection through the neutron shield to the corrugated outer wall. External cooling of the corrugated wall and steel fins is facilitated by two diesel driven blowers and appropriate air ducts. Maximum heat rejection capacity is 76 kW with blowers operating and 62 kW without the blowers. During normal operation, the maximum fuel temperature is expected to be 326°F. If the forced air impingement system is lost, the temperature will rise to a maximum of about 430°F. If shielding water is lost from the outer compartment, the fuel temperature could reach about 1500°F, but only after all the inner cavity water had boiled off, a time which would conservatively take more than 2 days.

NLI 10/24. The NLI 10/24 of National Lead Industries is a helium filled rail cask capable of holding 10 PWR of 24 BWR fuel elements.[5,6] The approximate loaded cask weight is 88 metric tons (193,000 lbs). The cask and cooling systems are transported on a special 59-ft-long six-axle railroad flat car. Total weight of the system is approximately 152 metric tons (335,000 lbs). The cask was licensed in 1976.

The cask has an overall length of 5.19 m (204.5 in.) and a diameter of 2.24 m (88 in.). The cask cavity has a length of 4.56 m(179.5 in.) and a diameter of 1.14 m (45 in.). Two interchangeable aluminum baskets provide a capability for transporting either PWR or BWR fuel assemblies.

The cask body consists of a 19 mm (3/4 in.) thick inner stainless steel shell and a 51 mm (2 in.) thick outer stainless steel shell which are joined by stainless steel forgings at each end to make a continuous weldment. The annulus between the inner and outer shells contains a 152 mm (6 in.) thick lead gamma shield. Depleted uranium shielding is used on the ends of the cask and at strategic locations in the wall of the cask. Neutron shielding is provided by 229 mm (9 in.) of water contained in a finned stainless steel jacket surrounding the outer shell. Criticality control is provided by the stainless steel clad Ag-In-Cd liners of the aluminum fuel baskets. Balsa impact limiters are provided at each end of the cask in addition to the circumferential cooling fins which also provide impact protection.

Two closure heads are used for the cask. The outer closure head is a 64 mm (2-1/2 in.) thick stainless steel plate held in place by twenty-four 1-1/4 in. high-strength studs. The inner closure head is a stainless steel forging filled with depleted uranium and sealed with a metallic ring. The inner closure head is held in place by twenty 1-1/2 in. high-strength studs. There is one penetration through the head end forging of the cask body which exits into the space between the inner and outer closure heads and is used to drain this space and to pressure test the secondary containment system prior to shipment. There are four penetrations in the inner closure head cask flange which are used for servicing the cask cavity. These penetrations are equipped with globe type angle valves and terminate in the secondary containment volume between the inner and outer heads.

Maximum decay heat load for the NLI 10/24 is 97 kW. The aluminum basket serves as a heat conduction path from each individual fuel assembly to the cavity wall. Decay heat is removed from the cavity wall by means of cooling water circulated through channels welded to the outside surface of this wall. The cooling channels terminate in two separate header arrangements which are connected to separate heat exchanger systems. Without auxiliary cooling and at maximum heat generation rate the average fuel temperature is 348°C (659°F). Without the cooling system in operation, heat dissipation is by conduction through the cask body to the neutron shield, convection to the outer surface, and convection plus radiation from the finned outer surface to the atmosphere. Maximum fuel temperature during fire accident conditions is 533°C (991°F). Normal cavity pressure during transport is expected to be about 23 psig, with a maximum internal pressure of 105 psig occurring in the fire accident. The NLI 10/24 containment vessel has a maximum allowable working pressure several times greater than this value.

Shipment of spent fuel from interim storage to permanent disposal will require the use of rail casks which are designed to accept canistered fuel assemblies. Existing rail casks would have to be about two feet longer in order to accommodate canistered assemblies. Different fuel baskets would also be required because of the larger canister cross section. It is assumed that a suitably modified rail cask based on the NLI 10/24 design could accommodate 7 PWR or 17 BWR canistered assemblies.

6.2.2.1 Truck Casks for Shipment of Spent Fuel

NFS-4 (NAC-1). The NFS-4 cask of Nuclear Fuel Services is a water filled truck cask designed to transport 1 PWR or 2 BWR assemblies.[25,26] Approximate loaded cask weight is 23 metric tons (50,000 lbs). The NAC-1 cask of Nuclear Assurance Corporation is similar to the NFS-4.[27] Two NFS-4 casks and four NAC-1 casks have been built and used for truck transport of spent fuel assemblies.

The cask has an overall length of 5.44 m (214 in.) and a diameter of 0.96 m (38 in.). The cask cavity has a length of 4.52 m (178 in.) and a diameter of 0.34 m (13.5 in.). Interchangeable fuel baskets provide the cask with a capacity of one PWR or two BWR fuel assemblies.

The primary cask cavity consists of a nominal 8 mm (5/16 in.) stainless steel pressure shell surrounded by a 168 mm (6-5/8 in.) thick lead gamma shield and a 32 mm (1-1/4 in.) thick stainless steel penetration barrier. Neutron shielding is provided by a borated water-antifreeze solution contained in a 114 mm (4-1/2 in.) thick compartmentalized tank which surrounds the cask. An expansion chamber for the shield tank is used to accommodate temperature changes of the water-antifreeze solution. Impact protection is provided by stainless steel sheathed balsa wood impact limiters at each end of the cask.

The container has a single lid, attached with high strength bolts and sealed with Teflon O-rings. The closure requires a lifting spider, special tools and O-ring pressure test equipment. Two valve-type drain closures are provided. Reported times to load and unload are approximately 10 hrs each.

Heat rejection is by convection through the water coolant in the cavity to the inner wall, conduction to the neutron shield, convection to the outer wall, and convection plus radiation to the atmosphere. Maximum heat rejection capacity is 11.5 kW. Maximum design conditions for the inner cavity during normal transport (i.e., 130°F direct sunlight, still air, maximum fuel burnup, minimum fuel cooling period) are 345°F and 150 psig. Normal pressure upon receipt is almost always less than 5 psig, however, so the design is quite conservative. The primary cavity is designed to withstand temperature and pressure conditions of 532°F and 984 psig under the fire accident condition (1/2 hour at a temperature of 1475°F).

NFS-5. The NFS-5 cask of Nuclear Fuel Services is a water filled truck cask designed to transport 2 PWR or 3 BWR assemblies.[23] Approximate loaded cask weight is 25 metric tons (55,000 lbs). A Safety Analysis Report for this cask has been submitted to the Nuclear Regulatory Commission.

The cask cavity is 4.52 m (178 in) long with a rectangular cross section of 244 x 462 mm (9.6 x 18.2 in.). Surrounding the cavity is a 6.4 mm (1/4 in.) thick stainless steel pressure shell, a 102 mm (4 in.) thick depleted uranium gamma shield, and a 25 mm (1 in.) thick stainless steel penetration barrier. Neutron shielding is provided by 146 mm (5-3/4 in.) of borated water-antifreeze solution. Copper fins are welded to the exterior of the cask to aid in heat dissipation. Stainless steel enclosed balsa wood impact limiters are provided for the cask body and ends.

The cask lid is held down by heavy-duty bolts and sealed by Teflon O-rings.

Heat rejection is by convection through the coolant to the inner cavity wall, conduction to the neutron shield, convection to the outer wall, and convection plus radiation from the finned surface. Maximum design heat rejection capacity is 24.7 kW. Maximum design conditions for the inner cavity during normal transport with design basis fuel are 370°F at 204 psig. Under fire accident conditions the cask is designed to withstand a temperature and pressure of 504°F and 1131 psig without loss of containment capability.

NLI 1/2. National Lead Industries' NLI 1/2 cask[29] is a helium filled truck cask designed to transport 1 PWR or 2 BWR fuel assemblies. Approximate loaded cask weight is 22 metric tons (48,000 lbs). Two of these casks have been built in the United States.

The cask has an overall length of 4.93 m (194 in.) and a diameter of 1.08 m (42-1/2 in.), including cooling fins. The cask cavity has a length of 4.52 m (178 in.) and a diameter of 340 mm (13-3/8 in.). The cask can be used with an optional 6.4 mm (1/4 in.) thick wall liner which provides an additional level of containment if desired. Use of the optional liner reduces the cavity diameter to 321 mm (12-5/8 in.). Interchangeable fuel baskets provide a capability of transporting 1 PWR or 2 BWR fuel assemblies.

The primary cask cavity consists of a nominal 13 mm (1/2 in.) stainless steel pressure shell surrounded by a gamma shield composed of 70 mm (2-3/4 in.) of depleted uranium and 54 mm (2-1/8 in.) of lead and 25 mm (1 in.) thick stainless steel penetration barrier. Neutron shielding is provided by 127 mm (5 in.) of water. The water jacket which surrounds the cask also carries cooling fins which are welded to the outside of the jacket. An expansion tank is provided for the water jacket. Attached to each end of the cask is a conical structure which serves as impact limiter.

The cask closure head consists of a ring forging whose center section is filled with depleted uranium sandwiched between stainless steel plates. The head is bolted to the cask body and sealed with two elastomer O-ring gaskets.

Heat rejection is by convection through the helium coolant to the inner cavity wall, conduction to the neutron shield, convection to the outer wall, and convection plus radiation from the finned surface. Maximum design heat rejection capacity is 10.6 kW. Maximum fuel temperature during normal transport is conservatively estimated at 1013°F. Normal maximum design pressure is 120 psig when the inner container is used and 22.5 psig when it is absent. Maximum fuel temperature during the fire accident condition is 1102°F. The cask has a pressure rating of 543 psig at 850°F when the inner container is used, and 264 psig at 850°F when it is absent.

TN-8. The TN-8 cask of Transnuclear, Inc. is a truck cask designed to transport 3 PWR assemblies in an air atmosphere.[30, 31] Approximate loaded cask weight is 36 metric tons (80,000 lbs). The TN-8 will normally travel by truck under overweight restrictions, although two casks could be placed together on a single rail car. The cask was licensed by the Atomic Energy Commission (AEC) in 1974. No casks have yet been built in the United States although casks of the same design are presently operated in Europe.

The cask has an overall length of 5.54 m (18-1/6 ft) with impact limiters attached, and an outside diameter of 1.71 m (67.5 in.). The inner cavity is 4.27 m (14 f5) long and consists of three separate compartments 231 x 231 mm (9.1 x 9.1 in) for the individual fuel elements.

The main gamma shield consists of a 185 mm (7.3 in.) thick lead layer which is located between the stainless steel lined inner cavity and the carbon steel outer shell. Together with other materials, the total equivalent lead thickness is 230 mm (9 in.) reducing the maximum gamma dose rate to 35 mr/hr at the cask surface. The neutron shield consists of 152 mm (6 in.) of borated solid resin. Balsa wood is located inside removable covers and fixed end drums to provide impact protection.

Heat rejection is via conduction through the cask body to the outer wall, with convection and radiation from copper cooling fins on the outside. Maximum heat rejection capacity is 35.5 kW. During normal operation the maximum temperature of the inner shell(s) is 239°F. Pressure is stated to be atmospheric during transport. The cavity design pressure is 110 psig.

TN-9. The TN-9 cask of Transnuclear, Inc. is a truck cask designed to transport 7 BWR assemblies in an air atmosphere.[8,9] The TN-9 is similar to the TN-8 except that it has seven compartments, each 4.52 m (14-5/6 ft) long and 150 x 150 mm (5.9 x 5.9 in.) in cross section; for shipment of BWR elements. Heat removal capacity is 24.5 kW.

6.3.1.1 Rail Cask for Shipment of High-Level Waste

Solidified high-level waste is assumed to be contained in disposable stainless steel canisters with welded closures. For vitrified waste a canister would have the dimensions of 0.3 m (12 in.) ID by 3.05 m (10 ft) long and would contain 178 liters of glass (the vitrified waste from processing 3.04 MTHM). For calcined waste a canister would have the dimensions of

(2 in.) ID by 3.05 m (10 ft) long and would contain 70 liters of ... (the calcined waste from processing 2.93 MTHM).

The conceptual high-level waste rail cask[4] is a lead filled, double walled stainless steel cylinder weighing approximately 100 metric tons (220,000 lbs). Nine high-level waste canisters can be accommodated in an aluminum insert which fits into the cask cavity. The cask is transported on an exclusive use, six-axle rail car. The rail car and mounting equipment weigh approximately 68 metric tons (150,000 lbs) bringing the total weight of the transport system to approximately 168 metric tons (370,000 lbs).

Basic structural details of the conceptual high level waste cask are given in Table 6.3.2. The cask is shown in Figure 6.3.2. Leaf springs position the waste canisters in holes in the cavity insert and energy absorbing plugs are attached to the ends of the canisters. In addition to the gamma shielding provided by the lead and steel structural material, neutron shielding is provided by a water jacket which surrounds the cask body. Impact protection is provided by circumferential fins surrounding the cask body and by radial fins on the ends of the cask.

Two covers (an inner and an outer cover) are provided for cask closure. The covers are of stainless steel with depleted uranium for gamma protection. The covers are secured to the cask body by high-strength studs.

The cask will dissipate up to 48 kW of internally generated heat. Heat dissipation is aided by the fins surrounding the cask body. Auxiliary cooling of the cask is not required.

6.4.1 Rail Cask for Chop Leach Fuel Bundle Residues

The dimensions of the conceptual waste canister are dictated by requirements at the Federal repository. The canister is assumed to have a diameter of 760 mm (30 in.) and a length of 3.05 m (10 ft). It would be constructed of stainless steel with a wall thickness of about 6.4 mm (1/4 in.), end thicknesses of 12.7 mm (1/2 in.), and welded closures.

Casks for the transport of cladding wastes would conform to the requirements for Type B packaging and would provide adequate gamma shielding to meet the radiation dose requirements of 49 CFR 173,393. Neutron shielding would not be required. Decay heat loads are low enough that cooling fins would probably also not be required. Impact protection for the cask could be provided by steel clad, balsa impact limiters.

For planning purposes a rail cask has been postulated that would transport three canisters. The conceptual cask is assumed to be a lead filled, double walled stainless steel cylinder weighing approximately 65 MT (143,000 lbs). An insert would serve to position the three canisters inside the cask cavity and would act as a heat conduction path from the waste canisters to the inner surface of the cavity wall. The cask would not be pressurized. Basic structural details are provided in Table 6.4.2.

TABLE C-3

TABLE 6.4.2. Details of the Conceptual Rail Cask for Transport of Chop Leach Fuel Bundle Residues

Length of structural shell	3.9 m (152 in.)
Diameter of structural shell	2.2 m (88 in.)
Length of cask cavity	3.4 m (132 in.)
Diameter of cask cavity	1.8 m (70 in.)
Number of canisters transported	3
Cask weight	
Net weight	65 MT (143,000 lbs)
Loaded weight[a]	74.5 MT (164,000 lbs)
Cavity shell	
Material	Stainless steel
Thickness	19 mm (3/4 in.)
Gamma shield	
Material	Lead
Thickness	152 mm (6 in.)
Outer shell	
Material	Stainless steel
Thickness	51 mm (2 in.)
Impact absorbers	
Internal	Honeycomb
External	Steel clad balsa wood

a. Assumes canisters loaded with 1340 kg of uncompacted hulls and hardware plus 1340 kg of sand to fill void spaces.

6.6.1.1 Containers for Truck Transport of Non-High Level TRU Wastes

Prior to shipment, non-high level TRU wastes are packaged in disposable containers. The waste containers are transported in Type B overpacks which may be unshielded or shielded depending on the radiation level at the surface of a disposable container.

Disposable containers are assumed to include DOT specification 17C 55-gal steel drums[5,6] and DOT specification 7A steel boxes[7] having dimensions of 1.2 m by 1.8 m by 1.8 m (4 ft by 6 ft by 6 ft). The dimensions of the steel boxes have been chosen to conform to the space which is available in the elevator cage postulated for the low level waste shaft at the Federal repository (see Section). This box volume is approximately the same as that occupied by a palletized array of 55-gal drums (two drums by three drums) on two levels for a total of 12 drums per pallet.

Other disposable containers may also be used. For example, because of shielding requirements, some shipments of TRU-contaminated equipment and metal scrap are assumed to be packaged in the canister described for containment of fuel bundle residues. Shipment would be made in a fuel bundle residue cask (see Section 6.4). HEPA filters which are two large to be accommodated in 55-gal drums are assumed to be packaged in 80-gal drums.[8]

To satisfy the retrievability requirement, if shipments are made to interim storage rather than to a permanent disposal facility, it may be necessary to provide either a liner or a disposable overpack for drums and boxes.

on 11/1/77

All TRU waste packaged in disposable containers will be shipped in overpacks which meet Type B package requirements. The mode of shipment will depend on the radiation level at the surface of the disposable container. Regulations permit disposable containers with surface dose rates less than 200 mR/hr to be shipped without shielding. Most 55-gal drums in this category will actually have surface dose rates less than 1 mR/hr. Lead liners can be added to 55-gal drums to reduce surface dose rates to acceptable limits if required for the protection of personnel during the handling of the drums.

For planning purposes, four shipment modes have been defined for TRU wastes packaged in 55-gal drums. These shipment modes are described in Table 6.6.2.

TABLE C-4

TABLE 6.6.2. Shipment Modes for 55-Gallon Drums of Non-High Level TRU Waste

Drum Surface Dose Rate	Shipment Mode[a]
<200 mR/hr	Unshielded sole-use van
200 mR/hr-1 R/hr	Shielded sole-use van
1 R/hr-10 R/hr	Cask with equivalent shield thickness of 2 in. lead + 3/4 in. steel
>10 R/hr	Cask with equivalent shield thickness of 4 in. lead + 1 in. steel

a. All overpacks meet Type B package requirements.

Reusable transport shields constructed to Type B package standards are available both for shipments which do not require shielding and for those which do require shielding. Some commercially available units are listed in Table 6.3.3. Shielded Type B overpacks are typically smaller than unshielded units. The container volume in reusable transport shields must be limited so that shielded weight does not cause overall package weights to exceed truck weight limits.

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TABLE C-5

TABLE 6.6.3. Reusable Type B Transport Shields for 55-Gallon Drums

Cask Identification	Cask Type	Equivalent Shield Thickness	Capacity No. of Drums	Capacity Cubic Feet	Empty Weight (lb)	Company
HN-200	Top Load	3 in. lead + 1 1/4 in. steel	3	75	36,500	Hittman
BS-33-180	Top Load	3 1/2 in. steel	8	180	33,000	ATCOR
LL-50-100	Top Load	4 1/2 in. lead	8	100	50,000	ATCOR
BC-48-220	Top Load	7 in. concrete + 2 1/2 in. steel	14	220	48,000	ATCOR
S3-205	Top Load	3 in. steel	15	320	42,000	NECO
Super Tiger	End Load	1/2 in. steel	42	575	15,000	NECO

Drums and boxes which do not require shielding are assumed to be transported in a Super Tiger.[9] The Super Tiger is a double-walled steel box with a fire resistant polyurethane foam filler for shock and thermal insolation. Interior dimensions are 1.93 m by 1.93 m by 4.36 m (76 in. by 76 in. by 17.2 in.). The empty weight is 6,800 kg (15,000 lb), and the maximum payload is 13,600 kg (30,000 lb). The container is shown in Figure 6.6.1. Three pallets containing twelve 55-gal drums per pallet (total of 36 drums), or three steel boxes could be transported in a Super Tiger. The overpack is loaded from one end in a horizontal position.

Shielded vans licensed for Type B shipments are not available commercially although shielded vans for LSA shipments of drummed waste are in commercial use (for example, the ATCOR and Hittman shielded vans). It is anticipated that a shielded van which meets Type B package standards or a Super Tiger-type overpack which incorporates some shielding could be constructed to transport drummed TRU waste with surface dose rates in the 1 R/hr range.

For planning purposes it is assumed that a Type B transport shield incorporating approximately 2 1/2 in. of lead equivalent shielding would transport 14 drums and that a shield incorporating approximately 4 1/2 in. of lead equivalent shielding would transport six drums of TRU waste.

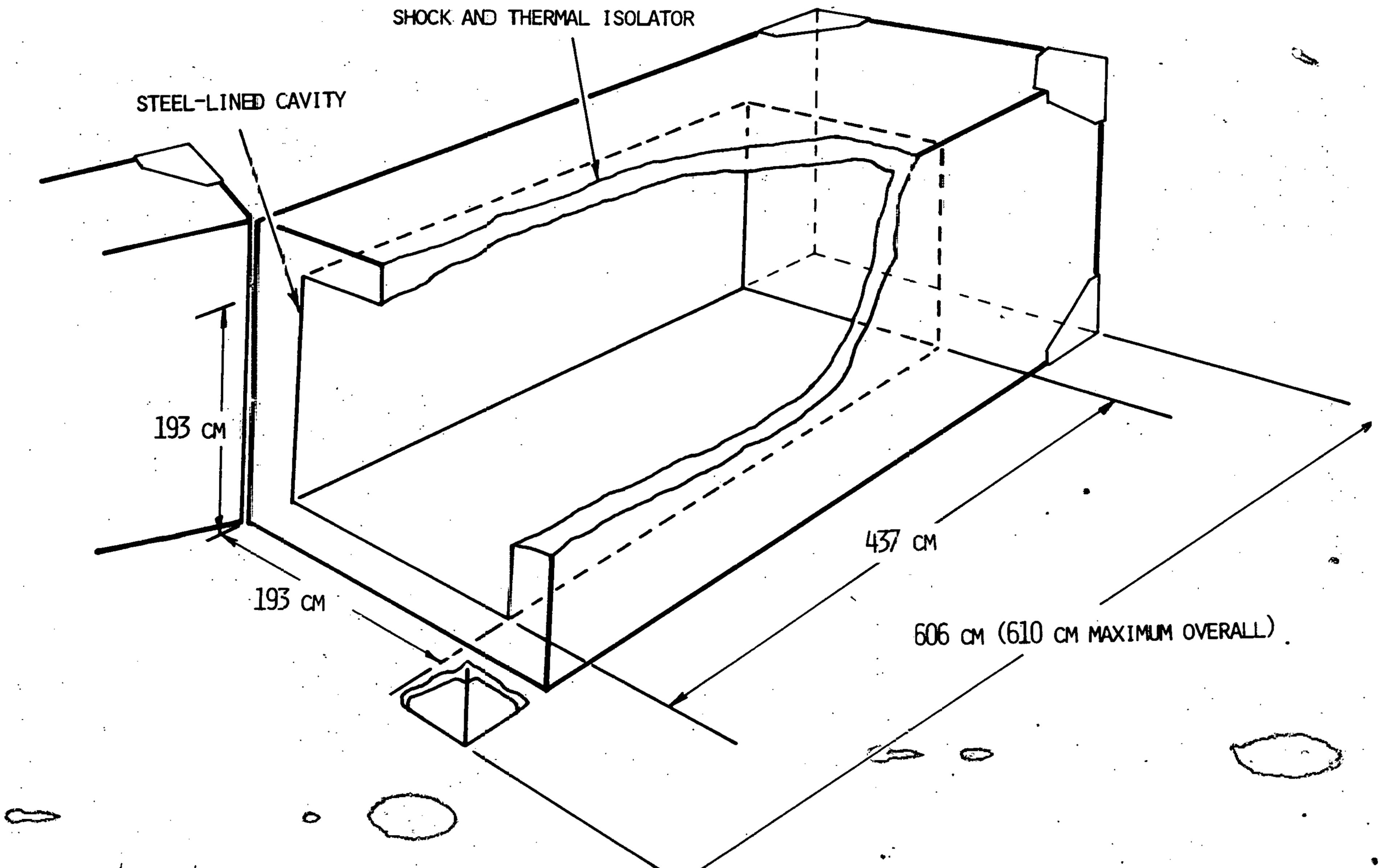


FIGURE C-1. "SUPER TIGER" DRUM CARRIER

As provided by BPNL

APPENDIX D - WASTE PROJECTIONS

The waste projections contained in this appendix were obtained from the May 27 transmittal from R. W. McKee to R. K. Kibbe (for spent fuel tables identified as Table D-1), the November 28 transmittal from R. W. McKee to R. K. Kibbe (for ILW and LLW from U-only Recycle, Table D-2), and the November 11 transmittal from R. W. McKee to R. K. Kibbe (for all Total Recycle projections, Tables D-3 and D-4). High-level and cladding waste projections for Total Recycle were also used for the U-only Recycle case. Where projections began before the year 1985 (beginning of repository operation), the accumulated waste through the year 1984 (backlog) was evenly distributed during the years 1986-1990. In the case of HLW from Total Recycle, when the average yearly canister heat load exceeded the thermal limit (Section 9.3.2.3 of GEIS), the projections were adjusted to reflect less dense and consequently cooler waste.

All projections are tabulated in Tables 9-12 to 9-23 of the GEIS.

TABLE D-1. SPENT FUEL STORAGE (NO RECYCLE)

YEAR	CAPACITY (GWE)	MTHM TO SPENT FUEL STORAGE	MTHM SENT FROM ISFS: PWR ANNUAL	MTHM SENT FROM ISFS: PWR CUMULATIVE	MTHM SENT FROM ISFS: BWR ANNUAL	MTHM SENT FROM ISFS: BWR CUMULATIVE	NO. OF FUEL ASSEMBLIES SENT FROM ISFS: PWR ANNUAL	NO. OF FUEL ASSEMBLIES SENT FROM ISFS: PWR CUMULATIVE	NO. OF FUEL ASSEMBLIES SENT FROM ISFS: BWR ANNUAL	NO. OF FUEL ASSEMBLIES SENT FROM ISFS: BWR CUMULATIVE
1977	47.	705.	0.	0.	0.	0.	0.	0.	0.	0.
1978	51.	903.	0.	0.	0.	0.	0.	0.	0.	0.
1979	56.	974.	0.	0.	0.	0.	0.	0.	0.	0.
1980	60.	1160.	0.	0.	0.	0.	0.	0.	0.	0.
1981	70.	1233.	0.	0.	0.	0.	0.	0.	0.	0.
1982	82.	1314.	0.	0.	0.	0.	0.	0.	0.	0.
1983	93.	1491.	462.	462.	283.	283.	1002.	1002.	1501.	1501.
1984	109.	1718.	560.	1022.	343.	626.	1214.	2216.	1819.	3320.
1985	127.	1920.	604.	1626.	370.	996.	1310.	3526.	1962.	5283.
1986	141.	2395.	719.	2345.	441.	1437.	1560.	5086.	2337.	7620.
1987	153.	2615.	764.	3109.	469.	1906.	1658.	6745.	2484.	10104.
1988	166.	3053.	815.	3924.	499.	2405.	1767.	8512.	2648.	12752.
1989	179.	3394.	924.	4848.	567.	2972.	2005.	10517.	3004.	15756.
1990	193.	3777.	1066.	5914.	653.	3624.	2311.	12828.	3462.	19216.
1991	212.	3942.	1190.	7104.	730.	4354.	2582.	15410.	3859.	23075.
1992	231.	4233.	1479.	8583.	907.	5261.	3209.	18619.	4307.	27392.
1993	250.	4755.	1621.	10205.	994.	6254.	3517.	22136.	5269.	33152.
1994	271.	5053.	1893.	12097.	1160.	7415.	4106.	26242.	6151.	39314.
1995	293.	5454.	2104.	14202.	1290.	8704.	4565.	30806.	6836.	46152.
1996	315.	5993.	2342.	16543.	1435.	10140.	5080.	35886.	7610.	53762.
1997	336.	6546.	2444.	18988.	1498.	11638.	5302.	41188.	7943.	61705.
1998	353.	6384.	2624.	21612.	1609.	13246.	5693.	46881.	8529.	70234.
1999	380.	7569.	2948.	24560.	1807.	15053.	6395.	53276.	9581.	79814.
2000	400.	7950.	3133.	27693.	1920.	16973.	6796.	60071.	10181.	89995.
2001	400.	8553.	3381.	31074.	2073.	19046.	7335.	67407.	10969.	100964.
2002	399.	8979.	3716.	34790.	2277.	21323.	8060.	75467.	12075.	113059.
2003	399.	9432.	4059.	38849.	2487.	23810.	8804.	84270.	13189.	126248.
2004	399.	9229.	4268.	43117.	2616.	26426.	9259.	93529.	13870.	140118.
2005	399.	9181.	4692.	47809.	2876.	29303.	10190.	103708.	15250.	155368.
2006	399.	9190.	4929.	52738.	3021.	32324.	10692.	114400.	16019.	171387.
2007	399.	9094.	5303.	58041.	3250.	35574.	11503.	125903.	17233.	188620.
2008	395.	9120.	5567.	63608.	3412.	38986.	12076.	137979.	18091.	206711.
2009	397.	9024.	5848.	69456.	3584.	42570.	12685.	150664.	19004.	225715.
2010	395.	9189.	5722.	75178.	3507.	46077.	12412.	163076.	18595.	244310.
2011	392.	9154.	5692.	80870.	3489.	49566.	12348.	175424.	18493.	262803.
2012	385.	9079.	5692.	86562.	3468.	53034.	12346.	187770.	18495.	281305.
2013	381.	9075.	5638.	92200.	3476.	56510.	12231.	200000.	18323.	299628.
2014	371.	9281.	5654.	97855.	3466.	59975.	12256.	212256.	18375.	318003.
2015	364.	9168.	5595.	103449.	3429.	63405.	12146.	224402.	18182.	336185.
2016	362.	8882.	5697.	109147.	3492.	66896.	12359.	236761.	18514.	354699.
2017	355.	8226.	5675.	114822.	3479.	70375.	12311.	249072.	18444.	373143.
2018	349.	8497.	5629.	120451.	3450.	73825.	12210.	261282.	18293.	391436.
2019	346.	8087.	5627.	126078.	3449.	77274.	12206.	273489.	18287.	409723.
2020	340.	7973.	5754.	131832.	3527.	80801.	12482.	285971.	18700.	428423.
2021	330.	7769.	5684.	137517.	3464.	84234.	12330.	298301.	18472.	446895.
2022	319.	7622.	5507.	143023.	3375.	87650.	11945.	310246.	17896.	464791.
2023	307.	7593.	5100.	148124.	3126.	90735.	11063.	321309.	16574.	481365.
2024	291.	7687.	5268.	153392.	3279.	94014.	11428.	332737.	17120.	498485.
2025	274.	7519.	5014.	158406.	3073.	97087.	10876.	343613.	16294.	514779.
2026	260.	7318.	4943.	163349.	3030.	100117.	10723.	354336.	16064.	530843.
2027	247.	6972.	4817.	168166.	2952.	103069.	10449.	364785.	15653.	546497.
2028	234.	6363.	4850.	173015.	2972.	106042.	10520.	375304.	15760.	562257.
2029	221.	5863.	4894.	177909.	2999.	109041.	10615.	385920.	15903.	578160.

TABLE D-2. FRP TRU WASTES Case 2a 12A

INCINERATE + CEMENT
NUMBER OF CONTAINERS
(55 GALLON DRUMS)

ST. U PROCESS SCHEDULE		<.20 R/HR		.2-1 R/HR		1.-10 R/HR		>10. R/HR	
EAR	1000MTHM	ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE
977	0.00	0.	0.	0.	0.	0.	0.	0.	0.
978	0.00	0.	0.	0.	0.	0.	0.	0.	0.
979	0.00	0.	0.	0.	0.	0.	0.	0.	0.
980	0.00	0.	0.	0.	0.	0.	0.	0.	0.
981	.50	665.	665.	486.	486.	492.	492.	1066.	1066.
982	1.00	1331.	1996.	973.	1459.	983.	1475.	2133.	3199.
983	1.50	1996.	3992.	1459.	2918.	1475.	2949.	3199.	6398.
984	1.50	1996.	5987.	1459.	4376.	1475.	4424.	3199.	9596.
985	2.17	2883.	8870.	2107.	6484.	2130.	6554.	4621.	14217.
986	2.83	3759.	12640.	2755.	9239.	2785.	9338.	6041.	20259.
987	3.50	4657.	17297.	3404.	12643.	3441.	12779.	7464.	27723.
988	3.50	4657.	21953.	3404.	16046.	3441.	16220.	7464.	35186.
989	3.50	4657.	26610.	3404.	19450.	3441.	19660.	7464.	42650.
990	3.50	4657.	31267.	3404.	22854.	3441.	23101.	7464.	50114.
991	3.50	4657.	35924.	3404.	26258.	3441.	26541.	7464.	57578.
992	3.50	4657.	40580.	3404.	29661.	3441.	29982.	7464.	65041.
993	4.17	5544.	46124.	4052.	33714.	4096.	34078.	8886.	73927.
994	4.83	6430.	52555.	4700.	38414.	4751.	38829.	10306.	84234.
995	5.50	7318.	59873.	5349.	43763.	5407.	44235.	11729.	95962.
996	5.50	7318.	67190.	5349.	49111.	5407.	49642.	11729.	107691.
997	5.50	7318.	74508.	5349.	54460.	5407.	55048.	11729.	119420.
998	6.17	8205.	82713.	5997.	60457.	6062.	61110.	13151.	132571.
999	6.83	9091.	91804.	6645.	67102.	6717.	67827.	14571.	147143.
000	7.50	9979.	101783.	7294.	74396.	7373.	75200.	15994.	163136.
001	7.50	9979.	111762.	7294.	81690.	7373.	82572.	15994.	179130.
002	7.50	9979.	121741.	7294.	88984.	7373.	89945.	15994.	195124.
003	8.17	10866.	132607.	7942.	96926.	8028.	97973.	17416.	212540.
004	8.83	11752.	144359.	8590.	105516.	8683.	106656.	18836.	231376.
005	9.50	12640.	156999.	9239.	114755.	9338.	115994.	20259.	251635.
006	9.50	12640.	169639.	9239.	123994.	9338.	125333.	20259.	271894.
007	9.50	12640.	182279.	9239.	133233.	9338.	134671.	20259.	292153.
008	9.50	12640.	194918.	9239.	142471.	9338.	144010.	20259.	312411.
009	9.50	12640.	207558.	9239.	151710.	9338.	153348.	20259.	332670.
010	9.50	12640.	220198.	9239.	160949.	9338.	162687.	20259.	352929.
011	8.00	10644.	230842.	7780.	168729.	7864.	170551.	17060.	369989.
012	8.67	11531.	242373.	8429.	177157.	8520.	179070.	18482.	388471.
013	9.33	12418.	254791.	9076.	186234.	9174.	188245.	19903.	408374.
014	10.00	13305.	268096.	9725.	195959.	9830.	198075.	21325.	429699.
015	8.00	10644.	278740.	7780.	203739.	7864.	205939.	17060.	446759.
016	8.00	10644.	289384.	7780.	211519.	7864.	213803.	17060.	463819.
017	8.00	10644.	300028.	7780.	219299.	7864.	221667.	17060.	480879.
018	8.00	10644.	310672.	7780.	227079.	7864.	229531.	17060.	497939.
019	8.00	10644.	321316.	7780.	234859.	7864.	237395.	17060.	514999.
020	8.50	11309.	332625.	8266.	243125.	8356.	245750.	18126.	533125.
021	9.00	11975.	344600.	8753.	251878.	8847.	254597.	19193.	552317.
022	10.00	13305.	357905.	9725.	261603.	9830.	264427.	21325.	573642.
023	8.00	10644.	368549.	7780.	269383.	7864.	272291.	17060.	590702.
024	8.00	10644.	379193.	7780.	277163.	7864.	280155.	17060.	607762.
025	8.00	10644.	389837.	7780.	284943.	7864.	288019.	17060.	624822.
026	8.00	10644.	400481.	7780.	292723.	7864.	295883.	17060.	641882.
027	8.00	10644.	411125.	7780.	300503.	7864.	303747.	17060.	658942.

As provided by BPNL on 11/11/77 as Table VII-3

TABLE D-2 (cont'd) FRP TRU WASTES Case 2a

INCINERATE + CEMENT
NUMBER OF CONTAINERS

ST. U PROCESS SCHEDULE		(80 GALLON DRUMS) >10. R/HR		(30 INCH CANNISTERS) .2-1 R/HR		1.-10 R/HR		(BOXES) <.20 R/HR	
EAR	1000MTHM	ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE
977	0.00	0.	0.	0.	0.	0.	0.	0.	0.
978	0.00	0.	0.	0.	0.	0.	0.	0.	0.
979	0.00	0.	0.	0.	0.	0.	0.	0.	0.
980	0.00	0.	0.	0.	0.	0.	0.	0.	0.
981	.50	0.	0.	17.	17.	1.	1.	13.	13.
982	1.00	0.	0.	34.	50.	2.	3.	25.	38.
983	1.50	0.	0.	50.	101.	3.	6.	38.	75.
984	1.50	0.	0.	50.	151.	3.	9.	38.	113.
'85	2.17	0.	0.	73.	223.	4.	13.	54.	167.
'86	2.83	0.	0.	95.	318.	6.	19.	71.	238.
'87	3.50	0.	0.	117.	436.	7.	26.	88.	325.
'88	3.50	0.	0.	117.	553.	7.	33.	88.	413.
'89	3.50	0.	0.	117.	670.	7.	40.	88.	500.
'90	3.50	0.	0.	117.	787.	7.	47.	88.	588.
'91	3.50	0.	0.	117.	905.	7.	54.	88.	675.
'92	3.50	0.	0.	117.	1022.	7.	61.	88.	763.
'93	4.17	0.	0.	140.	1161.	8.	69.	104.	867.
'94	4.83	0.	0.	162.	1323.	10.	79.	121.	987.
'95	5.50	0.	0.	184.	1508.	11.	90.	138.	1125.
'96	5.50	0.	0.	184.	1692.	11.	101.	138.	1263.
'97	5.50	0.	0.	184.	1876.	11.	112.	138.	1400.
'98	6.17	0.	0.	207.	2083.	12.	124.	154.	1554.
'99	6.83	0.	0.	229.	2312.	14.	138.	171.	1725.
00	7.50	0.	0.	251.	2563.	15.	153.	188.	1913.
01	7.50	0.	0.	251.	2814.	15.	168.	188.	2100.
02	7.50	0.	0.	251.	3065.	15.	183.	188.	2288.
03	8.17	0.	0.	274.	3339.	16.	199.	204.	2492.
04	8.83	0.	0.	296.	3635.	18.	217.	221.	2713.
05	9.50	0.	0.	318.	3953.	19.	236.	238.	2950.
06	9.50	0.	0.	318.	4271.	19.	255.	238.	3188.
07	9.50	0.	0.	318.	4590.	19.	274.	238.	3425.
08	9.50	0.	0.	318.	4908.	19.	293.	238.	3663.
09	9.50	0.	0.	318.	5226.	19.	312.	238.	3900.
10	9.50	0.	0.	318.	5544.	19.	331.	238.	4138.
11	8.00	0.	0.	268.	5812.	16.	347.	200.	4338.
12	8.67	0.	0.	290.	6103.	17.	364.	217.	4554.
13	9.33	0.	0.	313.	6415.	19.	383.	233.	4788.
14	10.00	0.	0.	335.	6750.	20.	403.	250.	5038.
15	8.00	0.	0.	268.	7018.	16.	419.	200.	5237.
16	8.00	0.	0.	268.	7286.	16.	435.	200.	5438.
17	8.00	0.	0.	268.	7554.	16.	451.	200.	5638.
18	8.00	0.	0.	268.	7822.	16.	467.	200.	5838.
19	8.00	0.	0.	268.	8090.	16.	483.	200.	6038.
20	8.50	0.	0.	285.	8375.	17.	500.	213.	6250.
21	9.00	0.	0.	302.	8676.	18.	518.	225.	6475.
22	10.00	0.	0.	335.	9011.	20.	538.	250.	6725.
23	8.00	0.	0.	268.	9279.	16.	554.	200.	6925.
24	8.00	0.	0.	268.	9547.	16.	570.	200.	7125.
25	8.00	0.	0.	268.	9815.	16.	586.	200.	7325.
26	8.00	0.	0.	268.	10084.	16.	602.	200.	7525.
27	8.00	0.	0.	268.	10352.	16.	618.	200.	7725.

As provided by BPNL on 11/28/77 as Table VII-3

TABLE D-3. FRP SOLID WASTES *Case 3*

YEAR	EST. U PROCESS SCHEDULE 1000 MT	EST. WASTE EQUIVALENT SHIPPED	NO. OF HL WASTES CONTAINERS — *Reference* 2(GLASS) ANNUAL	2(GLASS) CUMULATIVE	4(CALCINE) ANNUAL	4(CALCINE) CUMULATIVE	NO. OF PPP-1 CONTAINERS PUO2 ANNUAL	PUO2 CUMULATIVE
1977	0.00	0.00	0.	0.	0.	0.	0.	0.
1978	0.00	0.00	0.	0.	0.	0.	0.	0.
1979	0.00	0.00	0.	0.	0.	0.	0.	0.
1980	0.00	0.00	0.	0.	0.	0.	0.	0.
1981	.50	0.00	0.	0.	0.	0.	124.	124.
1982	1.00	0.00	0.	0.	0.	0.	251.	375.
1983	1.50	0.00	0.	0.	0.	0.	393.	769.
1984	1.50	0.00	0.	0.	0.	0.	411.	1179.
1985	2.17	0.00	0.	0.	0.	0.	421.	1601.
1986	2.83	.50	164.	164.	171.	171.	616.	2217.
1987	3.50	1.00	329.	493.	342.	512.	800.	3017.
1988	3.50	1.50	493.	985.	512.	1025.	977.	3995.
1989	3.50	1.50	493.	1478.	512.	1537.	985.	4980.
1990	3.50	2.17	712.	2190.	740.	2277.	985.	5964.
1991	3.50	2.83	931.	3121.	967.	3244.	999.	6963.
1992	3.50	3.50	1150.	4271.	1195.	4440.	1006.	7969.
1993	4.17	3.50	1150.	5420.	1195.	5635.	1006.	8975.
1994	4.83	3.50	1150.	6570.	1195.	6830.	1197.	10172.
1995	5.50	3.50	1150.	7720.	1195.	8025.	1388.	11560.
1996	5.50	3.50	1150.	8870.	1195.	9221.	1580.	13140.
1997	5.50	3.50	1150.	10019.	1195.	10416.	1576.	14716.
1998	6.17	4.17	1369.	11388.	1423.	11839.	1583.	16299.
1999	6.83	4.83	1588.	12976.	1650.	13489.	1771.	18070.
2000	7.50	5.50	1807.	14783.	1878.	15368.	1962.	20032.
2001	7.50	5.50	1807.	16589.	1878.	17246.	2160.	22192.
2002	7.50	5.50	1807.	18395.	1878.	19124.	2167.	24360.
2003	8.17	6.17	2026.	20422.	2106.	21230.	2164.	26523.
2004	8.83	6.83	2245.	22667.	2333.	23564.	2164.	28687.
2005	9.50	7.50	2464.	25130.	2561.	26125.	2171.	30858.
2006	9.50	7.50	2464.	27594.	2561.	28686.	2186.	33044.
2007	9.50	7.50	2464.	30058.	2561.	31247.	2401.	35445.
2008	9.50	8.17	2683.	32741.	2789.	34036.	2603.	38048.
2009	9.50	8.83	2902.	35642.	3016.	37053.	2801.	40849.
2010	9.50	9.50	3121.	38763.	3244.	40297.	2805.	43654.
2011	9.00	9.50	3121.	41884.	3244.	43541.	2805.	46459.
2012	8.67	9.50	3121.	45005.	3244.	46785.	2801.	49261.
2013	9.33	9.50	3121.	48125.	3244.	50030.	2794.	52055.
2014	10.00	9.50	3121.	51246.	3244.	53274.	2788.	54843.
2015	8.00	9.50	3121.	54367.	3244.	56518.	2784.	57626.
2016	8.00	8.00	2628.	56995.	2732.	59250.	2770.	60396.
2017	8.00	8.67	2847.	59842.	2960.	62210.	2780.	63176.
2018	9.00	9.33	3066.	62908.	3187.	65397.	2738.	65914.
2019	8.00	10.00	3285.	66193.	3415.	68812.	2770.	68683.
2020	8.50	8.00	2628.	68821.	2732.	71544.	2791.	71474.
2021	9.00	8.00	2628.	71449.	2732.	74276.	2784.	74258.
2022	10.00	8.00	2628.	74077.	2732.	77008.	2352.	76610.
2023	8.00	8.00	2628.	76705.	2732.	79740.	2345.	78954.
2024	8.00	8.00	2628.	79333.	2732.	82472.	2313.	81267.
2025	8.00	8.50	2792.	82125.	2903.	85375.	2291.	83558.
2026	8.00	9.00	2957.	85081.	3074.	88449.	1721.	85280.
2027	8.00	10.00	3285.	88366.	3415.	91863.	1714.	86994.
2028	6.00	8.00	2628.	90994.	2732.	94595.	1700.	88694.
2029	6.00	8.00	2628.	93622.	2732.	97327.	1675.	90369.

As provided by BPNL on 11/11/77 as Table VII-2

TABLE D-3 (cont'd) FRP SOLID WASTES *Case 3*

YEAR	EST. U PROCESS SCHEDULE 1000 MT	EST. WASTE EQUIVALENT SHIPPED	NO. OF CANNISTERS HULLS + HARDWARE (*Reference*) (B) UNTREATED ANNUAL	(B) UNTREATED CUMULATIVE	(A) COMPACTED ANNUAL	(A) COMPACTED CUMULATIVE
1977	0.00	0.00	0.	0.	0.	0.
1978	0.00	0.00	0.	0.	0.	0.
1979	0.00	0.00	0.	0.	0.	0.
1980	0.00	0.00	0.	0.	0.	0.
1981	.50	0.00	120.	120.	71.	71.
1982	1.00	0.00	240.	360.	141.	212.
1983	1.50	0.00	360.	720.	212.	423.
1984	1.50	0.00	360.	1080.	212.	635.
1985	2.17	0.00	520.	1600.	306.	940.
1986	2.83	.50	680.	2280.	399.	1340.
1987	3.50	1.00	840.	3120.	494.	1833.
1988	3.50	1.50	840.	3960.	494.	2327.
1989	3.50	1.50	840.	4800.	494.	2820.
1990	3.50	2.17	840.	5640.	494.	3314.
1991	3.50	2.83	840.	6480.	494.	3807.
1992	3.50	3.50	840.	7320.	494.	4301.
1993	4.17	3.50	1000.	8320.	588.	4889.
1994	4.83	3.50	1160.	9480.	681.	5569.
1995	5.50	3.50	1320.	10800.	776.	6345.
1996	5.50	3.50	1320.	12120.	776.	7121.
1997	5.50	3.50	1320.	13440.	776.	7896.
1998	6.17	4.17	1480.	14920.	870.	8766.
1999	6.83	4.83	1640.	16560.	963.	9729.
2000	7.50	5.50	1800.	18360.	1058.	10787.
2001	7.50	5.50	1800.	20160.	1058.	11844.
2002	7.50	5.50	1800.	21960.	1058.	12902.
2003	8.17	6.17	1960.	23920.	1152.	14053.
2004	8.83	6.83	2120.	26040.	1245.	15299.
2005	9.50	7.50	2280.	28320.	1340.	16639.
2006	9.50	7.50	2280.	30600.	1340.	17978.
2007	9.50	7.50	2280.	32880.	1340.	19317.
2008	9.50	8.17	2280.	35160.	1340.	20657.
2009	9.50	8.83	2280.	37440.	1340.	21996.
2010	9.50	9.50	2280.	39720.	1340.	23335.
2011	8.00	9.50	1920.	41640.	1128.	24464.
2012	8.67	9.50	2080.	43720.	1222.	25685.
2013	9.33	9.50	2240.	45960.	1316.	27002.
2014	10.00	9.50	2400.	48360.	1410.	28412.
2015	8.00	9.50	1920.	50280.	1128.	29540.
2016	8.00	8.00	1920.	52200.	1128.	30668.
2017	8.00	8.67	1920.	54120.	1128.	31796.
2018	8.00	9.33	1920.	56040.	1128.	32924.
2019	8.00	10.00	1920.	57960.	1128.	34052.
2020	8.50	8.00	2040.	60000.	1199.	35250.
2021	9.00	8.00	2160.	62160.	1269.	36519.
2022	10.00	8.00	2400.	64560.	1410.	37929.
2023	8.00	8.00	1920.	66480.	1128.	39057.
2024	8.00	8.00	1920.	68400.	1128.	40185.
2025	8.00	8.50	1920.	70320.	1128.	41313.
2026	8.00	9.00	1920.	72240.	1128.	42441.
2027	8.00	10.00	1920.	74160.	1128.	43569.
2028	6.00	8.00	1440.	75600.	846.	44415.
2029	6.00	8.00	1440.	77040.	846.	45261.

TABLE D-4. FRP TRU WASTES *Case 3a*

INCINERATE + CEMENT
NUMBER OF CONTAINERS

EST. U PROCESS SCHEDULE		(80 GALLON DRUMS) >10. R/HR		(30 INCH CANNISTERS) .2-1 R/HR		(30 INCH CANNISTERS) 1.-10 R/HR		(BOXES) <.20 R/HR	
YEAR	1000MTHM	ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE	ANNUAL	CUMULATIVE
1977	0.00	0.	0.	0.	0.	0.	0.	0.	0.
1978	0.00	0.	0.	0.	0.	0.	0.	0.	0.
1979	0.00	0.	0.	0.	0.	0.	0.	0.	0.
1980	0.00	0.	0.	0.	0.	0.	0.	0.	0.
1981	.50	0.	0.	17.	17.	1.	1.	15.	15.
1982	1.00	0.	0.	34.	50.	2.	3.	30.	45.
1983	1.50	0.	0.	50.	101.	3.	6.	45.	90.
1984	1.50	0.	0.	50.	151.	3.	9.	45.	135.
1985	2.17	0.	0.	73.	223.	4.	13.	65.	200.
1986	2.83	0.	0.	95.	318.	6.	19.	85.	285.
1987	3.50	0.	0.	117.	435.	7.	26.	105.	390.
1988	3.50	0.	0.	117.	553.	7.	33.	105.	495.
1989	3.50	0.	0.	117.	670.	7.	40.	105.	600.
1990	3.50	0.	0.	117.	787.	7.	47.	105.	705.
1991	3.50	0.	0.	117.	905.	7.	54.	105.	810.
1992	3.50	0.	0.	117.	1022.	7.	61.	105.	915.
1993	4.17	0.	0.	140.	1161.	8.	69.	125.	1040.
1994	4.83	0.	0.	162.	1323.	10.	79.	145.	1185.
1995	5.50	0.	0.	184.	1508.	11.	90.	165.	1350.
1996	5.50	0.	0.	184.	1692.	11.	101.	165.	1515.
1997	5.50	0.	0.	184.	1876.	11.	112.	165.	1680.
1998	6.17	0.	0.	207.	2083.	12.	124.	185.	1865.
1999	6.83	0.	0.	229.	2312.	14.	138.	205.	2070.
2000	7.50	0.	0.	251.	2563.	15.	153.	225.	2295.
2001	7.50	0.	0.	251.	2814.	15.	168.	225.	2520.
2002	7.50	0.	0.	251.	3065.	15.	183.	225.	2745.
2003	8.17	0.	0.	274.	3339.	16.	199.	245.	2990.
2004	8.83	0.	0.	296.	3635.	18.	217.	265.	3255.
2005	9.50	0.	0.	318.	3953.	19.	236.	285.	3540.
2006	9.50	0.	0.	318.	4271.	19.	255.	285.	3825.
2007	9.50	0.	0.	318.	4590.	19.	274.	285.	4110.
2008	9.50	0.	0.	318.	4908.	19.	293.	285.	4395.
2009	9.50	0.	0.	318.	5226.	19.	312.	285.	4680.
2010	9.50	0.	0.	318.	5544.	19.	331.	285.	4965.
2011	8.00	0.	0.	268.	5812.	16.	347.	240.	5205.
2012	8.67	0.	0.	290.	6103.	17.	364.	260.	5465.
2013	9.33	0.	0.	313.	6415.	19.	383.	280.	5745.
2014	10.00	0.	0.	335.	6750.	20.	403.	300.	6045.
2015	8.00	0.	0.	268.	7018.	16.	419.	240.	6285.
2016	8.00	0.	0.	268.	7286.	16.	435.	240.	6525.
2017	8.00	0.	0.	268.	7554.	16.	451.	240.	6765.
2018	8.00	0.	0.	268.	7822.	16.	467.	240.	7005.
2019	8.00	0.	0.	268.	8090.	16.	483.	240.	7245.
2020	8.50	0.	0.	285.	8375.	17.	500.	255.	7500.
2021	9.00	0.	0.	302.	8676.	18.	518.	270.	7770.
2022	10.00	0.	0.	335.	9011.	20.	538.	300.	8070.
2023	8.00	0.	0.	268.	9279.	16.	554.	240.	8310.
2024	8.00	0.	0.	268.	9547.	16.	570.	240.	8550.
2025	8.00	0.	0.	268.	9815.	16.	586.	240.	8790.
2026	8.00	0.	0.	268.	10084.	16.	602.	240.	9030.
2027	8.00	0.	0.	268.	10352.	16.	618.	240.	9270.

As provided by BPNL on 11/28/77 as Table VII-3

TABLE D-4 (cont'd) FRP. TRU WASTES *Case 3a*

INCINERATE + CEMENT
NUMBER OF CONTAINERS
(55 GALLON DRUMS)

EST. J PROCESS SCHEDULE YEAR	1000MTHM	<.20 R/HR ANNUAL	<.20 R/HR CUMULATIVE	.2-1 R/HR ANNUAL	.2-1 R/HR CUMULATIVE	1.-10 R/HR ANNUAL	1.-10 R/HR CUMULATIVE	>10. R/HR ANNUAL	>10. R/HR CUMULATIVE
1977	0.00	0.	0.	0.	0.	0.	0.	0.	0.
1978	0.00	0.	0.	0.	0.	0.	0.	0.	0.
1979	0.00	0.	0.	0.	0.	0.	0.	0.	0.
1980	0.00	0.	0.	0.	0.	0.	0.	0.	0.
1981	.50	678.	678.	488.	488.	492.	492.	1068.	1068.
1982	1.00	1357.	2035.	976.	1463.	983.	1475.	2135.	3203.
1983	1.50	2035.	4070.	1463.	2927.	1475.	2949.	3203.	6405.
1984	1.50	2035.	6104.	1463.	4390.	1475.	4424.	3203.	9608.
1985	2.17	2940.	9044.	2114.	6504.	2130.	6554.	4627.	14234.
1986	2.83	3843.	12887.	2764.	9267.	2785.	9338.	6049.	20283.
1987	3.50	4749.	17635.	3414.	12682.	3441.	12779.	7473.	27755.
1988	3.50	4749.	22382.	3414.	16096.	3441.	16220.	7473.	35228.
1989	3.50	4749.	27130.	3414.	19510.	3441.	19660.	7473.	42700.
1990	3.50	4749.	31879.	3414.	22924.	3441.	23101.	7473.	50173.
1991	3.50	4749.	36625.	3414.	26339.	3441.	26541.	7473.	57645.
1992	3.50	4749.	41373.	3414.	29753.	3441.	29982.	7473.	65118.
1993	4.17	5653.	47025.	4065.	33818.	4095.	34078.	8897.	74014.
1994	4.83	6535.	53582.	4715.	38532.	4751.	38829.	10318.	84332.
1995	5.50	7451.	61032.	5365.	43897.	5407.	44235.	11743.	96075.
1996	5.50	7451.	68503.	5365.	49263.	5407.	49642.	11743.	107818.
1997	5.50	7451.	75964.	5365.	54628.	5407.	55048.	11743.	119560.
1998	6.17	8356.	84320.	6016.	60644.	6062.	61110.	13167.	132727.
1999	6.83	9257.	93593.	6666.	67309.	6717.	67827.	14588.	147315.
2000	7.50	10174.	103772.	7316.	74626.	7373.	75200.	16013.	163328.
2001	7.50	10174.	113945.	7316.	81942.	7373.	82572.	16013.	179340.
2002	7.50	10174.	124120.	7316.	89258.	7373.	89945.	16013.	195353.
2003	8.17	11079.	135198.	7967.	97225.	8025.	97973.	17437.	212789.
2004	8.83	11982.	147180.	8617.	105842.	8693.	106666.	18858.	231648.
2005	9.50	12887.	160067.	9267.	115109.	9339.	115994.	20283.	251930.
2006	9.50	12887.	172954.	9267.	124376.	9339.	125333.	20283.	272213.
2007	9.50	12887.	185841.	9267.	133644.	9339.	134671.	20283.	292495.
2008	9.50	12887.	198727.	9267.	142911.	9339.	144010.	20283.	312778.
2009	9.50	12887.	211614.	9267.	152178.	9339.	153348.	20283.	333060.
2010	9.50	12887.	224501.	9267.	161445.	9339.	162687.	20283.	353343.
2011	8.00	10852.	235353.	7804.	169249.	7864.	170551.	17080.	370423.
2012	8.67	11757.	247110.	8455.	177704.	8520.	179070.	18504.	388927.
2013	9.33	12660.	259770.	9104.	186808.	9170.	188245.	19926.	408853.
2014	10.00	13565.	273335.	9755.	196563.	9830.	198075.	21350.	430203.
2015	8.00	10852.	284187.	7804.	204367.	7864.	205939.	17080.	447283.
2016	8.00	10852.	295039.	7804.	212171.	7864.	213803.	17080.	464363.
2017	8.00	10852.	305891.	7804.	219975.	7864.	221667.	17080.	481442.
2018	8.00	10852.	316743.	7804.	227779.	7864.	229531.	17080.	498523.
2019	8.00	10852.	327595.	7804.	235583.	7864.	237395.	17080.	515602.
2020	8.50	11530.	339125.	8292.	243875.	8355.	245750.	18148.	533750.
2021	9.00	12209.	351334.	8780.	252655.	8847.	254597.	19215.	552965.
2022	10.00	13565.	364899.	9755.	262410.	9830.	264427.	21350.	574315.
2023	8.00	10852.	375751.	7804.	270214.	7864.	272291.	17080.	591395.
2024	8.00	10852.	386603.	7804.	278018.	7864.	280155.	17080.	608475.
2025	8.00	10852.	397455.	7804.	285822.	7864.	288019.	17080.	625555.
2026	8.00	10852.	408307.	7804.	293626.	7864.	295883.	17080.	642635.
2027	8.00	10852.	419159.	7804.	301430.	7864.	303747.	17080.	659715.

As provided by BPNL on 11/11/77 as Table VII-3

APPENDIX E - SOURCE TERMS

The enclosed data package contains tables of BPNL waste source strengths for HLW, cladding waste, ILW and LLW for both recycle cases, and for PWR and BWR spent fuel. Data for individual radionuclides of HLW and spent fuel were obtained from BPNL supplied ORIGEN code runs included in the November 1, 1976 transmittal to A. Quist. Waste descriptions and radioactive content for cladding waste, ILW, and LLW for the recycle cases were obtained from the September 28 transmittal from C. M. Unruh to Dr. C. D. Zerby (for Tables E-7 to E-23). Summary tables for all wastes source term data used in the repository analysis are presented as Tables E-1 through E-6. Low-level waste from the SURF cycle was assumed to have the same source strengths as LLW from the Uranium-Only recycle case. On the HLW and Spent Fuel tables there are specific totals used in the release analyses. The total activity is the sum of all radionucludes on the table. The α-TRU total is the sum of all α-emitting nuclides with half-lives greater than one year (Np-237, Pu-238, Pu-239, Pu-240, Pu-242, Am-241, Am-243, Cm-243, Cm-244). The β-γ total is the difference between total activity and α-TRU.

TABLE E-1

WASTE SOURCE STRENGTHS: HLW FROM TOTAL RECYCLE

	Curies/MTHM		Curies/MTHM
Isotope	6½ Yrs.[a]	Isotope	6½ Yrs.
H-3	2.56E+1	Eu-152	1.17E+1
C-14	0	Eu-154	4.90E+3
Mn-54	3.07E-2	Eu-155	6.10E+2
Fe-55	6.20E0	U-232	1.00E-4
Co-60	1.98E-1	U-233	9.70E-6
Ni-59	1.30E-2	U-234	2.67E-3
Ni-63	1.95E0	U-235	7.97E-5
Kr-85	6.00E-3	U-236	1.32E-3
Sr-90	5.37E+4	U-237	1.73E-2
Y-90	5.37E+4	U-238	1.57E-3
Zr-93	1.60E0	Np-237	4.02E-1
Tc-99	1.28E+1	Np-239	4.73E+1
Ru-106	5.93E+3	Pu-238	7.58E+1
Rh-106	5.93E+3	Pu-239	1.80E0
Ag-110m	5.49E0	Pu-240	6.99E0
Cd-113m	8.09E0	Pu-241	6.92E+2
Sb-125	1.63E+3	Pu-242	1.96E-2
Te-125m	6.75E+2	Am-241	7.10E+2
I-129	3.49E-5	Am-242	4.75E+1
Cs-134	2.20E+4	Am-242m	4.75E+1
Cs-137	8.27E+4	Am-243	4.73E+1
Ba-137m	7.73E+4	Cm-242	4.31E+1
Ce-144	2.83E+3	Cm-243	8.74E0
Pr-144	2.83E+3	Cm-244	5.90E+3
Pm-147	1.85E+4	Total Activity	4.42E+5
Sm-151	1.16E+3	β-γ	4.35E+5
		α-TRU	6.80E+3

a Indicates time since reactor discharge when received at repository.

TABLE E-2

WASTE SOURCE STRENGTHS: Total Recycle

Cladding Waste, ILW and LLW[a]

Waste Type	Container Type	Radioactivity (Curies/container)[b]		Surface Dose Rate (R/hr)
		Actinides[e]	Fission/ Activation Prod.	
Cladding Waste	30" canisters	1.7 E+2	1.8 E+4	>10
Low Level Waste-FRP[c]				
Noncombustible Trash	55 gal. drums	2.9 E-2	7.5 E-2	<0.2
Noncombustible Trash from PuO_2 facility	55 gal. drums	3.2 E+2	0	<0.2
Cemented Incinerator Ash	55 gal. drums	7.2 E-2	5.9 E-4	<0.2
Failed Equipment-General	4'x6'x6' boxes	3.2 E-2	7.4 E-2	<0.2
Failed Equipment-PuO_2 Conversion	4'x6'x6' boxes	1.4 E+2	0	<0.2
Low Level Waste-MOX[d]				
Noncombustible Trash	55 gal. drums	5.0 E+1	0	<0.2
Cemented Wet Waste	55 gal. drums	1.1 E+1	0	<0.2
Filter Media	55 gal. drums	6.8 E+2	0	<0.2
Cemented Incinerator Ash	55 gal. drums	5.7 E+1	0	<0.2
Failed Equipment	4'x6'x6' boxes	1.4 E+1	0	<0.2
Intermediate Level Waste-FRP[c]				
Noncombustible Trash	55 gal. drums	1.7 E-1	4.3 E-1	0.2-1.0
Noncombustible Trash-PuO_2 Conversion	55 gal. drums	1.9 E+3	0	0.2-1.0
Failed Equipment	55 gal. drums	1.0 E-2	2.3 E-2	0.2-1.0
Failed Equipment	30" canisters	6.7 E-2	1.5 E-1	0.2-1.0
Noncombustible Trash	55 gal. drums	1.6 E 0	4.1 E 0	1.0-10.0
Failed Equipment	55 gal. drums	9.3 E-2	2.2 E-1	1.0-10.0
Failed Equipment	30" canisters	5.9 E-1	1.4 E 0	1.0-10.0
Cemented Incinerator Ash	55 gal. drums	3.1 E+2	2.6 E 0	1.0-10.0
Cemented Wet Waste	55 gal. drums	1.1 E+2	3.8 E 0	>10
HEPA Filter Media	55 gal. drums	1.4 E+3	1.7 E+1	>10

a Based on data prepared by BPNL (September 1977).

b Values represent estimates of the radioactive content of waste containers at the time of receipt at the repository (5 years after reprocessing).

c Wastes from "Fuel Reprocessing Plant."

d Wastes from "Mixed Oxide Fuel Fabrication Plant."

e Actinide composition reflects HLW ratio of α-TRU to β-γ of:

α-TRU = 88.5% of actinides

β-γ = 11.5% of actinides

TABLE E-3

WASTE SOURCE STRENGTHS: HLW FROM U-ONLY RECYCLE

Isotopes	Curies/MTHM 6½ Yrs.[a]	Isotope	Curies/MTHM 6½ Yrs.
H-3	2.51E+1	Eu-152	9.00E0
C-14	0	Eu-154	4.40E+3
Mn-54	3.10E-2	Eu-155	5.65E+2
Fe-55	7.08E0	U-232	9.81E-3
Co-60	2.22E-1	U-233	1.12E-5
Ni-59	1.49E-2	U-234	4.36E-2
Ni-63	2.23E0	U-235	8.62E-5
Kr-85	3.52E-1	U-236	1.66E-3
Sr-90	5.81E+4	U-237	2.08E0
Y-90	5.81E+4	U-238	1.58E-3
Zr-93	1.67E0	Np-237	4.68E-1
Te-99	1.28E+1	Np-239	1.35E+1
Ru-106	5.31E+3	Pu-238	3.04E+3
Rh-106	5.31E+3	Pu-239	2.93E+2
Ag-110m	4.36E0	Pu-240	4.52E+2
Cd-113m	6.20E0	Pu-241	8.29E+4
Sb-125	1.45E+3	Pu-242	1.58E0
Te-125m	6.02E+2	Am-241	1.11E+3
I-129	3.32E-5	Am-242	1.04E+1
Cs-134	2.19E+4	Am-242m	1.04E+1
Cs-137	8.22E+4	Am-243	1.35E+1
Ba-137m	7.69E+4	Cm-242	1.00E+1
Ce-144	2.89E+3	Cm-243	3.43E0
Pr-144	2.89E+3	Cm-244	1.00E+3
Pm-147	1.86E+4	Total Activity	4.29E+5
Sm-151	1.10E+3	β-γ	4.23E+5
		α-TRU	5.91E+3

a Indicates time since reactor discharge when received at repository.

TABLE E-4

WASTE SOURCE STRENGTHS: U-only Recycle

Cladding Waste, ILW and LLW[a]

Waste Type	Container Type	Radioactivity (Curies/container)[b] Actinides[d]	Fission/ Activation Prod.	Surface Dose Rate (R/hr)
Cladding Waste	30" canisters	1.8 E+2	1.8 E+4	>10
Low Level Waste-FRP[c]				
Noncombustible Trash	55 gal. drums	3.0 E-2	7.5 E-2	<0.2
Cemented Incinerator Ash	55 gal. drums	1.4 E-2	5.9 E-4	<0.2
Failed Equipment	4'x6'x6' boxes	3.4 E-2	7.4 E-2	<0.2
Intermediate Level Waste-FRP				
Noncombustible Trash	55 gal. drums	1.7 E-1	4.3 E-1	0.2 - 1.0
Failed Equipment	55 gal. drums	1.1 E-2	2.3 E-2	0.2 - 1.0
Failed Equipment	30" canisters	7.0 E-2	1.5 E-1	0.2 - 1.0
Noncombustible Trash	55 gal. drums	1.7 E 0	4.1 E 0	1.0 - 10.0
Failed Equipment	55 gal. drums	9.8 E-2	2.2 E-1	1.0 - 10.0
Failed Equipment	30" canisters	6.2 E-1	1.4 E 0	1.0 - 10.0
Cement and Incinerator Ash	55 gal. drums	5.9 E+1	2.6 E 0	1.0 - 10.0
Cemented Wet Waste	55 gal. drums	1.2 E+2	3.8 E 0	>10
HEPA Filter Media	55 gal. drums	7.8 E 0	1.7 E+1	>10

a Based on data prepared by BPNL (September 1977).

b Values represent estimates of the radioactive content of waste containers at the time of receipt at the repository (5 years after reprocessing).

c Wastes from "Fuel Reprocessing Plant."

d Actinide composition reflects HLW rates of α-TRU to β-γ of:

α-TRU = 6.0% of actinides

β-γ = 94.0% of actinides

TABLE E-5

WASTE SOURCE STRENGTHS: SPENT FUEL - BWR

Isotope	Curies/MTHM 5½ yrs.[a]	Isotope	Curies/MTHM 5½ yrs.
H-3	2.82E+2	Eu-152	9.49E0
C-14	6.11E-1	Eu-154	3.39E+3
Mn-54	3.98E0	Eu-155	6.27E+2
Fe-55	1.96E+3	U-232	8.39E-3
Co-60	3.03E+3	U-233	2.42E-5
Ni-59	1.95E0	U-234	3.54E-2
Ni-63	2.93E+2	U-235	1.45E-2
Kr-85	5.85E+3	U-236	1.92E-1
Sr-90	5.08E+4	U-237	1.78E0
Y-90	5.08E+4	U-238	3.18E-1
Zr-93	1.10E-1	Np-237	2.44E-1
Tc-99	1.11E+1	Np-239	1.01E+1
Ru-106	8.22E+3	Pu-238	1.60E+3
Rh-106	8.22E+3	Pu-239	2.60E+2
Ag-110m	8.16E0	Pu-240	4.23E+2
Cd-113m	4.60E0	Pu-241	7.13E+4
Sb-125	1.42E+1	Pu-242	1.31E0
Te-125m	5.87E0	Am-241	8.19E+2
I-129	2.88E-2	Am-242m	9.51E0
Cs-134	2.17E+4	Am-242	9.51E0
Cs-137	7.21E+4	Am-243	1.01E+1
Ba-137m	6.74E+4	Cm-242	1.36E+1
Ce-144	5.20E+3	Cm-243	3.18E0
Pr-144	5.20E+3	Cm-244	7.04E+2
Pm-147	2.24E+4	Total Activity	4.06E+5
Sm-151	9.64E+2	β-γ	4.02E+5
		α-TRU	3.82E+3

a Indicates time since reactor discharge when received at respository.

TABLE E-6

WASTE SOURCE STRENGTHS: SPENT FUEL - PWR

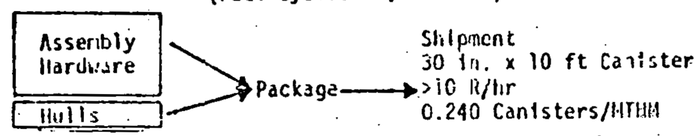
Isotope	Curies/MTHM 5½ Yrs.[a]	Isotope	Curies/MTHM 5½ Yrs.
H-3	3.64E+2	Eu-152	9.44E0
C-14	8.25E-1	Eu-154	5.41E+3
Mn-54	5.99E0	Eu-155	9.65E+2
Fe-55	1.68E+3	U-232	1.42E-2
Co-60	2.34E+3	U-233	3.48E-5
Ni-59	3.84E0	U-234	5.11E-2
Ni-63	5.93E+2	U-235	1.76E-2
Kr-85	7.57E+3	U-236	2.44E-1
Sr-90	6.45E+4	U-237	2.46E0
Y-90	6.45E+4	U-238	3.15E-1
Zr-93	9.34E-2	Np-237	3.55E-1
Tc-99	1.39E+1	Np-239	1.64E+1
Ru-106	1.22E+4	Pu-238	2.38E+3
Rh-106	1.22E+4	Pu-239	3.12E+2
Ag-110m	1.45E+1	Pu-240	4.75E+2
Cd-113m	1.17E+1	Pu-241	9.81E+4
Sb-125	2.12E+3	Pu-242	1.81E0
Te-125m	8.80E+2	Am-241	1.09E+3
I-129	3.60E-2	Am-242	1.13E+1
Cs-134	3.66E+4	Am-242m	1.13E+1
Cs-137	9.17E+4	Am-243	1.64E+1
Ba-137m	8.57E+4	Cm-242	1.72E+1
Ce-144	8.18E+3	Cm-243	3.86E0
Pr-144	8.18E+3	Cm-244	1.32E+3
Pm-147	2.52E+4	Total Activity	5.37E+5
Sm-151	1.20E+3	β-γ	5.31E+5
		α-TRU	5.60E+3

a Indicates time since reactor discharge when received at repository.

TABLE E-7

Hulls and Hardware Wastes

(Fuel Cycles 2a, b and 3)



Source	0	10	50	10^2	10^3	10^4	10^6
	Years After Chemical Separation						
Assembly hardware and hulls							
Activation products/MTHM							
Grams	3.2×10^5	3.2×10^5	3.2×10^5	3.2×10^5	3.2×10^5	3.2×10^5	3.2×10^6
Curies	9.4×10^3	1.8×10^3	3.0×10^2	2.1×10^2	3.2	2.7	1.2×10^{-1}
Watts	7.2×10^1	1.7×10^1	1.4×10^{-1}	3.3×10^{-2}	1.4×10^{-4}	7.4×10^{-5}	2.9×10^{-5}
Hulls, residual fuel							
Fission products/MTHM							
Grams	1.5×10^1	1.5×10^1	1.5×10^1	1.5×10^1	1.5×10^1	1.5×10^1	1.5×10^1
Curies	7.0×10^2	1.3×10^2	4.8×10^1	1.5×10^1	9.4×10^{-3}	9.0×10^{-3}	1.4×10^{-3}
Watts	3.2	4.3×10^{-1}	1.5×10^{-1}	4.5×10^{-2}	1.1×10^{-5}	9.9×10^{-6}	3.8×10^{-7}
Actinides/MTHM							
Grams	4.8×10^2		4.8×10^2	4.8×10^2	4.8×10^2	4.8×10^2	4.8×10^2
Curies	1.0×10^2		1.5×10^1	5.8	1.3	3.0×10^{-1}	1.1×10^{-2}
Watts	4.3×10^{-1}		2.0×10^{-1}	1.6×10^{-1}	4.0×10^{-2}	9.1×10^{-3}	2.6×10^{-4}
Total/MTHM							
Grams	3.2×10^5	3.2×10^5	3.2×10^5	3.2×10^5	3.2×10^5	3.2×10^5	3.2×10^5
Curies	1.0×10^4	1.9×10^3	3.6×10^2	2.3×10^2	4.5	3.0	1.3×10^{-1}
Watts	7.6×10^1	1.8×10^1	4.9×10^{-1}	2.4×10^{-1}	4.0×10^{-2}	9.2×10^{-3}	2.9×10^{-4}
Total contents/container[(a)]							
Noncompacted							
Grams	1.3×10^6	1.3×10^6	1.3×10^6	1.3×10^6	1.3×10^6	1.3×10^6	1.3×10^6
Curies	4.2×10^4	7.9×10^3	1.5×10^3	9.6×10^2	1.9×10^1	1.3×10^1	5.4×10^{-1}
Watts	3.2×10^2	7.5×10^1	2.0	1.0	1.7×10^{-1}	3.8×10^{-2}	1.2×10^{-3}

a. Assumed assembly hardware and cladding (hulls) packaged in same proportion as in original fuel rod assembly.

As provided by BPNL on 9/28/77 as Table A-2

TABLE E-8

FRP Noncombustible Trash

(Fuel Cycle 3)

(Sheet 1)

Noncombustible Noncompactable Trash → Package → Shipment 55 gal Drums <0.2 R/hr, 0.215 Drums/MTHM

Source	Years After Chemical Separation: 0	10	50	10^2	10^3	10^4	10^6
Main plant trash							
Hardware and hulls							
Activation products/ MTHM							
Grams	1.2×10^{-1}	1.2×10^{-1}	1.2×10^{-1}	1.2×10^{-1}	1.2×10^{-1}	1.2×10^{-1}	1.2×10^{-1}
Curies	3.4×10^{-3}	6.5×10^{-4}	1.1×10^{-4}	7.5×10^{-5}	1.2×10^{-6}	9.8×10^{-7}	4.3×10^{-8}
Watts	2.6×10^{-5}	6.2×10^{-6}	5.1×10^{-8}	1.2×10^{-8}	5.1×10^{-11}	2.7×10^{-11}	1.0×10^{-11}
Spent fuel							
Fission products/ MTHM							
Grams	1.2×10^{-3}	1.2×10^{-3}	1.2×10^{-3}	1.2×10^{-3}	1.2×10^{-3}	1.2×10^{-3}	1.2×10^{-3}
Curies	5.5×10^{-2}	1.1×10^{-2}	3.8×10^{-3}	1.2×10^{-3}	7.6×10^{-7}	7.2×10^{-7}	1.2×10^{-7}
Watts	2.6×10^{-4}	3.5×10^{-5}	1.2×10^{-5}	3.6×10^{-6}	8.4×10^{-10}	8.0×10^{-10}	3.1×10^{-11}
Actinides/MTHM							
Grams	3.9×10^{-2}	3.9×10^{-2}	3.9×10^{-2}	3.9×10^{-2}	3.9×10^{-2}	3.9×10^{-2}	3.9×10^{-2}
Curies	8.0×10^{-3}	5.2×10^{-3}	1.2×10^{-3}	4.8×10^{-4}	1.0×10^{-4}	2.4×10^{-5}	9.2×10^{-7}
Watts	3.5×10^{-5}	1.9×10^{-5}	1.6×10^{-5}	1.3×10^{-5}	3.2×10^{-6}	7.2×10^{-7}	2.1×10^{-8}
PuO_2 conversion							
Actinides/MTHM							
Grams	8.8×10^{-7}	8.8×10^{-7}	8.8×10^{-7}	8.8×10^{-7}	8.8×10^{-7}	8.8×10^{-7}	8.8×10^{-7}
Curies	1.3×10^{-5}	8.7×10^{-6}	1.9×10^{-6}	7.2×10^{-7}	1.7×10^{-7}	3.9×10^{-8}	9.3×10^{-10}
Watts	1.6×10^{-8}	2.0×10^{-8}	2.4×10^{-8}	2.1×10^{-8}	5.3×10^{-9}	1.2×10^{-9}	2.2×10^{-11}
Total/MTHM							
Grams	1.6×10^{-1}	1.6×10^{-1}	1.6×10^{-1}	1.6×10^{-1}	1.6×10^{-1}	1.6×10^{-1}	1.6×10^{-1}
Curies	6.6×10^{-2}	1.7×10^{-2}	5.1×10^{-3}	1.8×10^{-3}	1.0×10^{-4}	2.6×10^{-5}	1.1×10^{-6}
Watts	3.2×10^{-4}	6.0×10^{-5}	2.8×10^{-5}	1.7×10^{-5}	3.2×10^{-6}	7.2×10^{-7}	2.1×10^{-8}
Total contents/ 55 gal drum							
Grams	7.4×10^{-1}	7.4×10^{-1}	7.4×10^{-1}	7.4×10^{-1}	7.4×10^{-1}	7.4×10^{-1}	7.4×10^{-1}
Curies	3.2×10^{-1}	7.9×10^{-2}	2.4×10^{-2}	8.4×10^{-3}	4.7×10^{-4}	1.2×10^{-4}	5.1×10^{-6}
Watts	1.5×10^{-3}	2.8×10^{-4}	1.3×10^{-4}	7.9×10^{-5}	1.5×10^{-5}	3.3×10^{-6}	5.1×10^{-6}

As provided by BPNL on 9/28/77 as Table A 3-1

TABLE E-9

FRP Noncombustible Trash

(Fuel Cycle 3)

(Sheet 2)

Noncombustible Noncompactable Trash → Package → Shipment 55 gal Drums 0.2 - 1R/hr, 1.0 Drum/MTHM

Source	0	10	50	10^2	10^3	10^4	10^6
	Years After Chemical Separation						
Main plant trash							
Hardware and hulls							
Activation products/ MTHM							
Grams	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Curies	9.5×10^{-2}	1.3×10^{-2}	3.1×10^{-3}	2.1×10^{-3}	3.2×10^{-5}	2.7×10^{-5}	1.2×10^{-6}
Watts	7.3×10^{-4}	1.8×10^{-4}	1.4×10^{-6}	3.3×10^{-7}	1.4×10^{-9}	7.5×10^{-10}	2.9×10^{-10}
Spent fuel							
Fission products/ MTHM							
Grams	3.4×10^{-2}	3.4×10^{-2}	3.4×10^{-2}	3.4×10^{-2}	3.4×10^{-2}	3.4×10^{-2}	3.4×10^{-2}
Curies	1.6	3.0×10^{-1}	1.1×10^{-1}	3.3×10^{-2}	2.8×10^{-5}	2.0×10^{-5}	3.2×10^{-6}
Watts	7.2×10^{-3}	9.7×10^{-4}	3.3×10^{-4}	1.0×10^{-4}	2.3×10^{-8}	2.2×10^{-8}	8.8×10^{-10}
Actinides/MTHM							
Grams	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Curies	2.2×10^{-1}	1.4×10^{-1}	3.3×10^{-2}	1.3×10^{-2}	2.6×10^{-3}	6.7×10^{-4}	2.6×10^{-6}
Watts	9.7×10^{-4}	5.3×10^{-4}	4.4×10^{-4}	3.6×10^{-4}	9.0×10^{-5}	2.0×10^{-5}	5.8×10^{-7}
PuO_2 conversion							
Actinides/MTHM							
Grams	2.5×10^{-5}	2.5×10^{-5}	2.5×10^{-5}	2.5×10^{-5}	2.5×10^{-5}	2.5×10^{-5}	2.5×10^{-5}
Curies	3.6×10^{-4}	2.4×10^{-4}	5.3×10^{-5}	2.0×10^{-5}	4.5×10^{-6}	1.1×10^{-6}	2.6×10^{-8}
Watts	4.4×10^{-7}	5.6×10^{-7}	6.6×10^{-7}	5.8×10^{-7}	1.5×10^{-7}	3.4×10^{-8}	6.2×10^{-10}
Total/MTHM							
Grams	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Curies	1.9	4.6×10^{-1}	1.4×10^{-1}	4.8×10^{-2}	2.8×10^{-3}	7.2×10^{-4}	3.0×10^{-5}
Watts	8.9×10^{-3}	1.7×10^{-3}	7.7×10^{-4}	4.6×10^{-4}	9.0×10^{-5}	2.0×10^{-5}	5.8×10^{-7}
Total contents/ 55 gal drum							
Grams	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Curies	1.9	4.6×10^{-1}	1.4×10^{-1}	4.8×10^{-2}	2.8×10^{-3}	7.2×10^{-4}	3.0×10^{-5}
Watts	8.9×10^{-3}	1.7×10^{-3}	7.7×10^{-4}	4.6×10^{-4}	9.0×10^{-5}	2.0×10^{-5}	5.8×10^{-7}

As provided by BPNL on 9/28/77 as Table A 3-2

TABLE E-10

FRP Noncombustible Trash
(Fuel Cycle 3)
(Sheet 3)

Noncombustible Noncompactable Trash ——▶ Package ——▶ Shipment 55 gal Drums 1-10 R/hr, 0.970 Drums/MTHM

Source	Years After Chemical Separation						
	0	10	50	10^2	10^3	10^4	10^6
Main plant trash							
Hardware and hulls							
Activatism products/ MTHM							
Grams	2.9×10^1	2.9×10^1	2.9×10^1	2.9×10^1	2.9×10^1	2.9×10^1	2.9×10^1
Curies	8.4×10^{-1}	1.6×10^{-1}	2.7×10^{-2}	1.8×10^{-2}	2.9×10^{-4}	2.4×10^{-4}	1.0×10^{-6}
Watts	6.5×10^{-3}	1.6×10^{-3}	1.2×10^{-5}	2.9×10^{-6}	1.3×10^{-8}	6.7×10^{-9}	2.6×10^{-9}
Spent fuel							
Fission products/ MTHM							
Grams	3.1×10^{-1}	3.1×10^{-1}	3.1×10^{-1}	3.1×10^{-1}	3.1×10^{-1}	3.1×10^{-1}	3.1×10^{-1}
Curies	1.4×10^1	2.7	9.5×10^{-1}	3.0×10^{-1}	1.9×10^{-4}	1.8×10^{-4}	2.9×10^{-5}
Watts	6.5×10^{-2}	8.5×10^{-3}	2.9×10^{-3}	8.9×10^{-4}	2.9×10^{-7}	2.0×10^{-7}	7.8×10^{-9}
Actinides/MTHM							
Grams	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Curies	2.0	1.3	2.9×10^{-1}	1.2×10^{-1}	2.5×10^{-2}	6.0×10^{-3}	2.3×10^{-4}
Watts	8.6×10^{-3}	4.7×10^{-3}	3.9×10^{-3}	3.2×10^{-3}	8.0×10^{-4}	1.8×10^{-4}	5.1×10^{-6}
PuO_2 conversion							
Actinides/MTHM							
Grams	2.2×10^{-4}	2.2×10^{-4}	2.2×10^{-4}	2.2×10^{-4}	2.2×10^{-4}	2.2×10^{-4}	2.2×10^{-4}
Curies	3.2×10^{-3}	2.1×10^{-3}	4.8×10^{-4}	1.8×10^{-4}	4.1×10^{-5}	9.7×10^{-6}	2.3×10^{-7}
Watts	3.9×10^{-6}	5.0×10^{-6}	5.9×10^{-6}	5.2×10^{-6}	1.3×10^{-6}	3.0×10^{-7}	5.5×10^{-9}
Total/MTHM							
Grams	3.9×10^1	3.9×10^1	3.9×10^1	3.9×10^1	3.9×10^1	3.9×10^1	3.9×10^1
Curies	1.7×10^1	4.2	1.3	4.4×10^{-1}	2.6×10^{-2}	6.4×10^{-3}	2.7×10^{-4}
Watts	8.0×10^{-2}	1.5×10^{-2}	6.8×10^{-3}	4.1×10^{-3}	8.0×10^{-4}	1.8×10^{-4}	5.1×10^{-6}
Total contents/ 55 gal drum							
Grams	4.0×10^1	4.0×10^1	4.0×10^1	4.0×10^1	4.0×10^1	4.0×10^1	4.0×10^1
Curies	1.8×10^1	4.3	1.3	4.5×10^{-1}	2.7×10^{-2}	6.6×10^{-3}	2.8×10^{-4}
Watts	8.2×10^{-2}	1.5×10^{-2}	7.0×10^{-3}	4.2×10^{-3}	8.2×10^{-4}	1.9×10^{-4}	5.3×10^{-6}

As provided by BPNL on 9/28/77 as Table A 3-3

TABLE E-11

FRP Failed Equipment Waste
(Fuel Cycles 2b and 3)
(Sheet 1)

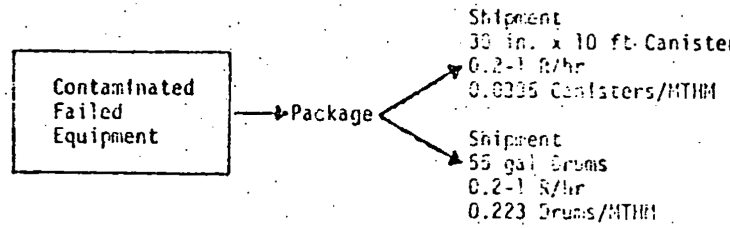
Contaminated Failed Equipment → Package → Shipment
4 x 5 x 6 ft Boxes
<0.2 R/hr
0.025 Boxes/MTHM

Source	Years After Chemical Separation						
	0	10	50	10^2	10^3	10^4	10^6
Contaminated failed equipment							
Fission products/MTHM							
Grams	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}
Curies	8.2×10^{-3}	1.4×10^{-3}	5.1×10^{-4}	1.6×10^{-4}	9.9×10^{-8}	9.5×10^{-8}	1.5×10^{-8}
Watts	3.4×10^{-5}	4.6×10^{-6}	1.6×10^{-6}	4.8×10^{-7}	1.1×10^{-9}	1.0×10^{-10}	4.2×10^{-12}
Actinides/MTHM							
Grams	5.1×10^{-3}	5.1×10^{-3}	5.1×10^{-3}	5.1×10^{-3}	5.1×10^{-3}	5.1×10^{-3}	5.1×10^{-3}
Curies	1.1×10^{-3}	6.8×10^{-4}	1.6×10^{-4}	6.1×10^{-5}	1.3×10^{-5}	3.2×10^{-6}	1.2×10^{-7}
Watts	4.6×10^{-6}	2.6×10^{-6}	2.1×10^{-6}	1.7×10^{-6}	4.3×10^{-7}	9.6×10^{-8}	2.8×10^{-9}
Total/MTHM							
Grams	5.3×10^{-3}	5.3×10^{-3}	5.3×10^{-3}	5.3×10^{-3}	5.3×10^{-3}	5.3×10^{-3}	5.3×10^{-3}
Curies	9.3×10^{-3}	2.1×10^{-3}	6.7×10^{-4}	2.2×10^{-4}	1.3×10^{-5}	3.3×10^{-6}	1.3×10^{-7}
Watts	3.9×10^{-5}	7.2×10^{-6}	3.7×10^{-6}	2.2×10^{-6}	4.3×10^{-7}	9.6×10^{-8}	2.8×10^{-9}
Total contents/container							
Grams	2.1×10^{2}	2.1×10^{2}	2.1×10^{2}	2.1×10^{2}	2.1×10^{2}	2.1×10^{2}	2.1×10^{2}
Curies	3.7×10^{-1}	8.4×10^{-2}	2.7×10^{-2}	8.8×10^{-3}	5.2×10^{-4}	1.3×10^{-4}	5.2×10^{-6}
Watts	1.6×10^{-3}	2.9×10^{-4}	1.5×10^{-4}	8.8×10^{-5}	1.7×10^{-5}	3.8×10^{-5}	1.1×10^{-7}

As provided by BPNL on 9/28/77 as Table A 4-1

TABLE E-12

FRP Failed Equipment Waste
(Fuel Cycles 2b and 3)
(Sheet 2)

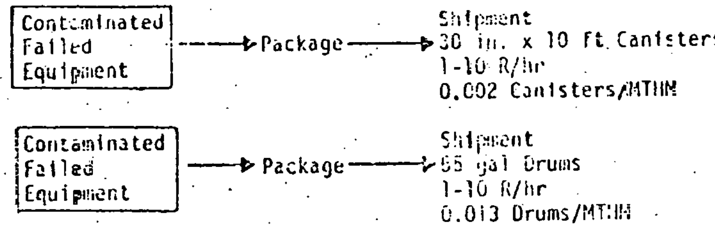


Source	Years After Chemical Separation 0	10	50	10^2	10^3	10^4	10^6
Contaminated failed equipment							
Fission products/MTHM							
Grams	4.5×10^{-4}	4.5×10^{-4}	4.5×10^{-4}	4.5×10^{-4}	4.5×10^{-4}	4.5×10^{-4}	4.5×10^{-4}
Curies	2.0×10^{-2}	3.9×10^{-3}	1.4×10^{-3}	4.3×10^{-4}	2.7×10^{-7}	2.6×10^{-7}	4.2×10^{-8}
Watts	9.4×10^{-5}	1.3×10^{-5}	4.3×10^{-6}	1.3×10^{-6}	3.1×10^{-10}	2.9×10^{-10}	1.1×10^{-11}
Actinides/MTHM							
Grams	1.4×10^{-2}	1.4×10^{-2}	1.4×10^{-2}	1.4×10^{-2}	1.4×10^{-2}	1.4×10^{-2}	1.4×10^{-2}
Curies	2.9×10^{-3}	1.9×10^{-3}	4.3×10^{-4}	1.7×10^{-4}	3.7×10^{-5}	8.7×10^{-6}	3.3×10^{-7}
Watts	1.3×10^{-5}	7.0×10^{-6}	5.7×10^{-6}	4.7×10^{-6}	1.2×10^{-6}	2.6×10^{-7}	7.6×10^{-9}
Total/MTHM							
Grams	1.4×10^{-2}	1.4×10^{-2}	1.4×10^{-2}	1.4×10^{-2}	1.4×10^{-2}	1.4×10^{-2}	1.4×10^{-2}
Curies	2.3×10^{-2}	5.8×10^{-3}	1.8×10^{-3}	6.0×10^{-4}	3.7×10^{-5}	9.0×10^{-6}	3.7×10^{-7}
Watts	1.2×10^{-4}	2.0×10^{-5}	1.0×10^{-5}	6.0×10^{-5}	1.2×10^{-6}	2.6×10^{-7}	7.6×10^{-9}
Total/canister							
Grams	4.2×10^{-1}	4.2×10^{-1}	4.2×10^{-1}	4.2×10^{-1}	4.2×10^{-1}	4.2×10^{-1}	4.2×10^{-1}
Curies	6.9×10^{-1}	1.7×10^{-1}	5.4×10^{-2}	1.8×10^{-2}	1.1×10^{-3}	2.7×10^{-4}	1.1×10^{-5}
Watts	3.6×10^{-3}	6.0×10^{-4}	3.0×10^{-4}	1.8×10^{-4}	3.6×10^{-5}	7.8×10^{-6}	2.3×10^{-7}
Total/55 gal Drum							
Grams	6.2×10^{-2}	6.2×10^{-2}	6.2×10^{-2}	6.2×10^{-2}	6.2×10^{-2}	6.2×10^{-2}	6.2×10^{-2}
Curies	1.0×10^{-1}	7.6×10^{-2}	8.1×10^{-3}	2.7×10^{-3}	1.7×10^{-4}	4.0×10^{-5}	1.7×10^{-6}
Watts	5.4×10^{-4}	9.0×10^{-5}	4.5×10^{-5}	2.7×10^{-5}	5.4×10^{-6}	1.2×10^{-6}	3.4×10^{-8}

As provided by BPNL on 9/28/77 as Table A 4-2

TABLE E-13

FRP Failed Equipment Waste
(Fuel Cycles 2b and 3)
(Sheet 3)



Source	Years After Chemical Separation						
	0	10	50	10^2	10^3	10^4	10^6
Contaminated failed equipment							
Fission products actinides	Input activity levels are 1.5 and 1.47 times greater than those for the FRP failed equipment shown on Sheet 1						
Total contents/canister							
Grams	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Curies	7.0	1.6	5.0×10^{-1}	1.6×10^{-1}	9.7×10^{-3}	2.5×10^{-3}	9.7×10^{-5}
Watts	2.9×10^{-2}	5.4×10^{-3}	2.8×10^{-3}	1.6×10^{-3}	3.2×10^{-4}	7.2×10^{-5}	2.1×10^{-6}
Total contents/55 gal drum							
Grams	6.0×10^{-1}	6.0×10^{-1}	6.0×10^{-1}	6.0×10^{-1}	6.0×10^{-1}	6.0×10^{-1}	6.0×10^{-1}
Curies	1.1	2.4×10^{-1}	7.6×10^{-2}	2.5×10^{-2}	1.5×10^{-3}	3.7×10^{-4}	1.5×10^{-5}
Watts	4.4×10^{-3}	8.1×10^{-4}	4.2×10^{-4}	2.5×10^{-4}	4.9×10^{-5}	1.1×10^{-5}	3.2×10^{-7}

As provided by BPNL on 9/28/77 as Table A 4-3

TABLE E-14

FRP Failed Equipment Waste
(Fuel Cycles 2b and 3)
(Sheet 4)

Failed Equipment from Conversion $Pu(NO_3)_4$ to PuO_2 → Package → Shipment
4 x 6 x 6 ft Boxes
<0.2 R/hr
0.005 Boxes/MTHM

Source	Years After Chemical Separation						
	0	10	50	10^2	10^3	10^4	10^6
Contaminated failed equipment							
Actinides/MTHM							
Grams	6.1×10^{-2}	6.1×10^{-2}	6.1×10^{-2}	6.1×10^{-2}	6.1×10^{-2}	6.1×10^{-2}	6.1×10^{-2}
Curies	9.0×10^{-1}	6.0×10^{-1}	1.3×10^{-1}	5.0×10^{-2}	1.2×10^{-2}	2.7×10^{-3}	6.5×10^{-5}
Watts	1.1×10^{-3}	1.4×10^{-3}	1.6×10^{-3}	1.5×10^{-3}	3.7×10^{-4}	8.5×10^{-5}	1.6×10^{-6}
Total contents/box							
Grams	1.2×10^{1}	1.2×10^{1}	1.2×10^{1}	1.2×10^{1}	1.2×10^{1}	1.2×10^{1}	1.2×10^{1}
Curies	1.8×10^{2}	1.2×10^{2}	2.6×10^{1}	1.0×10^{1}	2.4	5.4×10^{-1}	1.3×10^{-2}
Watts	2.2×10^{-1}	2.8×10^{-1}	3.2×10^{-1}	3.0×10^{-1}	7.4×10^{-2}	1.7×10^{-2}	3.2×10^{-4}

As provided by BPNL on 9/28/77 as Table A 4-4

TABLE E-15

FRP Wet Waste Treatment

(Fuel Cycles 2a, 2b, and 3)

ILW
Silica Gel
Fluorinator Fines
Fluorinator Beds
Secondary Waste
→ Cementation → Shipment
55 gal Drums
>10 R/hr
1.263 Drums/MTHM

Source	Years After Chemical Separation: 0	10	50	10^2	10^3	10^4	10^6
Hardware and hulls							
Activation products/MTHM							
Grams	3.2×10^1	3.2×10^1	3.2×10^1	3.2×10^1	3.2×10^1	3.2×10^1	3.2×10^1
Curies	9.4×10^{-1}	1.8×10^{-1}	3.0×10^{-2}	2.1×10^{-2}	3.2×10^{-4}	2.7×10^{-4}	1.2×10^{-5}
Watts	7.2×10^{-3}	1.7×10^{-3}	1.4×10^{-5}	3.3×10^{-6}	1.4×10^{-8}	7.4×10^{-9}	2.9×10^{-9}
Spent fuel							
Fission products/MTHM							
Grams	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Curies	2.3×10^1	3.3	9.8×10^{-1}	3.0×10^{-1}	3.4×10^{-3}	3.3×10^{-3}	2.0×10^{-3}
Watts	7.0×10^{-2}	8.6×10^{-3}	3.0×10^{-3}	9.0×10^{-4}	7.1×10^{-7}	6.9×10^{-7}	3.2×10^{-7}
Actinides/MTHM							
Grams	2.5×10^3	2.5×10^3	2.5×10^3	2.5×10^3	2.5×10^3	2.5×10^3	2.5×10^3
Curies	1.8×10^2	1.2×10^2	2.3×10^1	5.4	1.1	5.6×10^{-1}	8.5×10^{-4}
Watts	2.3×10^{-1}	2.1×10^{-1}	1.6×10^{-1}	1.2×10^{-1}	3.3×10^{-2}	1.7×10^{-2}	2.1×10^{-4}
Total/MTHM							
Grams	2.5×10^3	2.5×10^3	2.5×10^3	2.5×10^3	2.5×10^3	2.5×10^3	2.5×10^3
Curies	2.0×10^2	1.2×10^2	2.4×10^1	5.7	1.1	5.6×10^{-1}	2.9×10^{-3}
Watts	3.1×10^{-1}	2.2×10^{-1}	1.6×10^{-1}	1.2×10^{-1}	3.3×10^{-2}	1.7×10^{-2}	2.1×10^{-4}
Total/55 gal drum							
Grams	2.0×10^3	2.0×10^3	2.0×10^3	2.0×10^3	2.0×10^3	2.0×10^3	2.0×10^3
Curies	1.6×10^2	9.5×10^1	1.9×10^1	4.5	8.7×10^{-1}	4.4×10^{-1}	2.3×10^{-3}
Watts	2.5×10^{-1}	1.7×10^{-1}	1.3×10^{-1}	9.5×10^{-2}	2.6×10^{-2}	1.3×10^{-2}	1.7×10^{-4}

TABLE E-16

FRP Noncombustible Trash
(Fuel Cycle 3)
(Sheet 4)

Noncombustible Trash from PuO_2 Facility —(1)→ Package → Shipment 55 gal drums <0.2 R/hr, 0.026 Drums/MTHM

Noncombustible Trash from PuO_2 Facility —(2)→ Package → Shipment 55 gal Drums 0.2-1 R/hr, 0.003 Drums/MTHM

Source	Years After Chemical Separation						
	0	10	50	10^2	10^3	10^4	10^6
PuO_2 facility							
Noncombustible trash(1)							
Actinides/MTHM							
Grams	7.2×10^{-1}	7.2×10^{-1}	7.2×10^{-1}	7.2×10^{-1}	7.2×10^{-1}	7.2×10^{-1}	7.2×10^{-1}
Curies	1.1×10^{1}	7.1	1.6	5.9×10^{-1}	1.4×10^{-1}	3.2×10^{-2}	7.6×10^{-4}
Watts	1.3×10^{-2}	1.7×10^{-2}	1.9×10^{-2}	1.7×10^{-2}	4.3×10^{-3}	1.0×10^{-3}	1.8×10^{-5}
Total/55 gal drum							
Grams	2.8×10^{1}	2.8×10^{1}	2.8×10^{1}	2.8×10^{1}	2.8×10^{1}	2.8×10^{1}	2.8×10^{1}
Curies	4.2×10^{2}	2.7×10^{2}	6.2×10^{1}	2.3×10^{1}	5.4	1.2	2.9×10^{-2}
Watts	5.0×10^{-1}	6.5×10^{-1}	7.3×10^{-1}	6.5×10^{-1}	1.7×10^{-1}	3.8×10^{-2}	6.9×10^{-3}
Noncombustible trash(2)							
Actinides/MTHM							
Grams	5.0×10^{-1}	5.0×10^{-1}	5.0×10^{-1}	5.0×10^{-1}	5.0×10^{-1}	5.0×10^{-1}	5.0×10^{-1}
Curies	7.4	4.9	1.1	4.1×10^{-1}	9.4×10^{-2}	2.2×10^{-2}	5.3×10^{-4}
Watts	9.0×10^{-3}	1.1×10^{-2}	1.3×10^{-2}	1.2×10^{-2}	3.0×10^{-3}	7.0×10^{-4}	1.3×10^{-5}
Total/55 gal drum							
Grams	1.7×10^{2}	1.7×10^{2}	1.7×10^{2}	1.7×10^{2}	1.7×10^{2}	1.7×10^{2}	1.7×10^{2}
Curies	2.5×10^{3}	1.6×10^{3}	3.7×10^{2}	1.4×10^{2}	3.1×10^{1}	7.3	1.8×10^{-1}
Watts	3.0	3.7	4.3	4.0	1.0	2.3×10^{-1}	4.3×10^{-3}

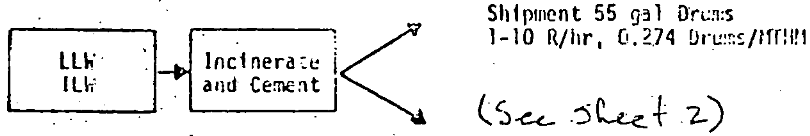
As provided by BPNL on 9/28/77 as Table A6

TABLE E-17

Combustible Trash and Compactable Waste at FRP

(Fuel Cycles 2b and 3)

(Sheet 1)



Source	0	10	50	10^2	10^3	10^4	10^6
	Years After Chemical Separation						
Hardware and hulls							
Activation products/MTHM							
Grams	3.2×10^{-1}	3.2×10^{-1}	3.2×10^{-1}	3.2×10^{-1}	3.2×10^{-1}	3.2×10^{-1}	3.2×10^{-1}
Curies	9.4×10^{-3}	1.8×10^{-3}	3.0×10^{-4}	2.0×10^{-4}	3.2×10^{-5}	2.7×10^{-6}	1.2×10^{-7}
Watts	7.2×10^{-5}	1.7×10^{-5}	1.3×10^{-7}	3.3×10^{-3}	1.4×10^{-10}	7.4×10^{-11}	2.9×10^{-11}
Spent fuel							
Fission products/MTHM							
Grams	6.9×10^{-1}	6.9×10^{-1}	6.9×10^{-1}	6.9×10^{-1}	6.9×10^{-1}	6.9×10^{-1}	6.9×10^{-1}
Curies	4.3	5.3×10^{-1}	1.9×10^{-1}	6.0×10^{-2}	1.4×10^{-4}	1.3×10^{-4}	9.0×10^{-5}
Watts	1.3×10^{-2}	1.7×10^{-3}	5.9×10^{-4}	1.8×10^{-4}	9.2×10^{-8}	8.9×10^{-8}	4.4×10^{-8}
Actinides/MTHM							
Gram	1.1×10^{1}	1.1×10^{1}	1.1×10^{1}	1.1×10^{1}	1.1×10^{1}	1.1×10^{1}	1.1×10^{1}
Curies	2.0×10^{1}	1.3×10^{1}	2.5	6.1×10^{-1}	1.2×10^{-1}	6.1×10^{-2}	1.1×10^{-4}
Watts	2.6×10^{-2}	2.4×10^{-2}	1.8×10^{-2}	1.4×10^{-2}	3.5×10^{-3}	1.9×10^{-3}	3.0×10^{-6}
PuO_2 conversion							
Actinides/MTHM							
Grams	6.1	6.1	6.1	6.1	6.1	6.1	6.1
Curies	9.0×10^{1}	6.0×10^{1}	1.3×10^{1}	5.0	1.2	2.7×10^{-1}	6.5×10^{-3}
Watts	1.1×10^{-1}	1.4×10^{-1}	1.6×10^{-1}	1.5×10^{-1}	3.7×10^{-2}	8.5×10^{-3}	1.6×10^{-4}
Total/MTHM							
Grams	1.8×10^{1}	1.8×10^{1}	1.8×10^{1}	1.8×10^{1}	1.8×10^{1}	1.8×10^{1}	1.8×10^{1}
Curies	1.2×10^{2}	7.4×10^{1}	1.6×10^{1}	5.7	1.3	3.3×10^{-3}	6.7×10^{-3}
Watts	1.5×10^{-1}	1.7×10^{-1}	1.8×10^{-1}	1.6×10^{-1}	4.1×10^{-2}	1.0×10^{-2}	1.6×10^{-4}
Total/55 gal drum							
Grams	6.6×10^{1}	6.6×10^{1}	6.6×10^{1}	6.6×10^{1}	6.6×10^{1}	6.6×10^{1}	6.6×10^{1}
Curies	4.4×10^{2}	2.7×10^{2}	5.8×10^{1}	2.1×10^{1}	4.7	1.2	2.4×10^{-2}
Watts	5.5×10^{-1}	6.2×10^{-1}	6.6×10^{-1}	5.8×10^{-1}	1.5×10^{-1}	3.6×10^{-2}	5.8×10^{-4}

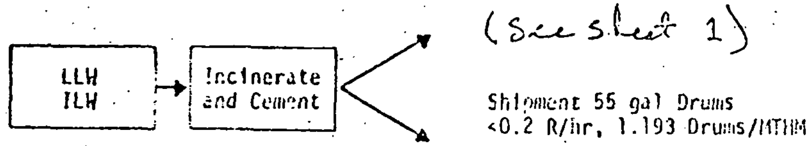
As provided by BPNL o
9/28/77 as Table A-6

TABLE E-18

Combustible Trash and Compactable Waste at FRP

(Fuel Cycles 2b and 3)

(Sheet 2)



Source	Years After Chemical Separation: 0	10	50	10^2	10^3	10^4	10^6
Hardware and hulls							
Activation products/MTHM							
Grams	3.2×10^{-4}	3.2×10^{-4}	3.2×10^{-4}	3.2×10^{-4}	3.2×10^{-4}	3.2×10^{-4}	3.2×10^{-4}
Curies	9.4×10^{-6}	1.6×10^{-6}	3.0×10^{-7}	2.1×10^{-7}	3.2×10^{-9}	2.7×10^{-9}	1.2×10^{-10}
Watts	7.2×10^{-8}	1.7×10^{-8}	1.4×10^{-10}	3.3×10^{-11}	1.4×10^{-13}	7.4×10^{-14}	2.9×10^{-14}
Spent fuel							
Fission products/MTHM							
Grams	6.2×10^{-4}	6.2×10^{-4}	6.2×10^{-4}	6.2×10^{-4}	6.2×10^{-4}	6.2×10^{-4}	6.2×10^{-4}
Curies	4.3×10^{-3}	5.3×10^{-4}	2.0×10^{-4}	5.9×10^{-5}	1.3×10^{-7}	1.2×10^{-7}	9.2×10^{-8}
Watts	1.4×10^{-5}	1.7×10^{-6}	5.9×10^{-7}	1.8×10^{-7}	9.5×10^{-11}	9.0×10^{-11}	5.0×10^{-11}
Actinides/MTHM							
Grams	9.6×10^{-3}	9.6×10^{-3}	9.6×10^{-3}	9.6×10^{-3}	9.6×10^{-3}	9.6×10^{-3}	9.6×10^{-3}
Curies	2.0×10^{-2}	1.3×10^{-2}	2.5×10^{-3}	6.1×10^{-4}	1.2×10^{-4}	6.1×10^{-5}	1.3×10^{-7}
Watts	2.6×10^{-5}	2.4×10^{-5}	1.8×10^{-5}	1.4×10^{-5}	3.6×10^{-6}	1.9×10^{-6}	3.6×10^{-9}
PuO_2 conversion							
Actinides/MTHM							
Grams	6.1×10^{-3}	6.1×10^{-3}	6.1×10^{-3}	6.1×10^{-3}	6.1×10^{-3}	6.1×10^{-3}	6.1×10^{-3}
Curies	9.0×10^{-2}	6.0×10^{-2}	1.3×10^{-2}	5.0×10^{-3}	1.2×10^{-3}	2.7×10^{-4}	6.5×10^{-6}
Watts	1.1×10^{-4}	1.4×10^{-4}	1.6×10^{-4}	1.5×10^{-4}	3.6×10^{-5}	8.5×10^{-6}	1.6×10^{-7}
Total/MTHM							
Grams	1.7×10^{-2}	1.7×10^{-2}	1.7×10^{-2}	1.7×10^{-2}	1.7×10^{-2}	1.7×10^{-2}	1.7×10^{-2}
Curies	1.1×10^{-1}	7.3×10^{-2}	1.6×10^{-2}	5.7×10^{-3}	1.3×10^{-3}	3.3×10^{-4}	6.7×10^{-6}
Watts	1.5×10^{-4}	1.6×10^{-4}	1.8×10^{-4}	1.6×10^{-4}	4.0×10^{-5}	1.0×10^{-6}	1.6×10^{-7}
Total/55 gal drum							
Grams	1.4×10^{-2}	1.4×10^{-2}	1.4×10^{-2}	1.4×10^{-2}	1.4×10^{-2}	1.4×10^{-2}	1.4×10^{-2}
Curies	9.2×10^{-2}	6.1×10^{-2}	1.3×10^{-2}	4.8×10^{-3}	1.1×10^{-3}	2.8×10^{-4}	5.6×10^{-6}
Watts	1.3×10^{-4}	1.3×10^{-4}	1.5×10^{-4}	1.3×10^{-4}	3.4×10^{-5}	8.4×10^{-7}	1.3×10^{-7}

As provided by BPNL 9/28/77 as Table A

TABLE E-19

Combustible Trash and Compactable Waste at FRP

(Fuel Cycles 2 b and 3)

(Sheet 3)

Filters → Package → Shipment 55 gal Drums
>10 R/hr, 0.208 Drums/MTHM

Source	Years After Chemical Separation						
	0	10	50	10^2	10^3	10^4	10^6
FRP filters							
Spent fuel							
Fission products/MTHM							
Grams	3.1×10^{-1}	3.1×10^{-1}	3.1×10^{-1}	3.1×10^{-1}	3.1×10^{-1}	3.1×10^{-1}	3.1×10^{-1}
Curies	1.4×10^{1}	2.7	9.6×10^{-1}	3.0×10^{-1}	1.9×10^{-4}	1.8×10^{-4}	2.9×10^{-5}
Watts	6.5×10^{-2}	8.7×10^{-3}	3.0×10^{-3}	9.0×10^{-4}	2.1×10^{-7}	2.0×10^{-7}	7.9×10^{-9}
Actinides/MTHM							
Grams	9.7	9.7	9.7	9.7	9.7	9.7	9.7
Curies	2.0	1.3	3.0×10^{-1}	1.2×10^{-1}	2.5×10^{-2}	6.0×10^{-3}	2.3×10^{-4}
Watts	8.7×10^{-3}	4.8×10^{-3}	4.0×10^{-3}	3.2×10^{-3}	8.1×10^{-4}	1.6×10^{-4}	5.2×10^{-6}
PuO_2 conversion							
Actinides/MTHM							
Grams	2.4×10^{1}	2.4×10^{1}	2.4×10^{1}	2.4×10^{1}	2.4×10^{1}	2.4×10^{1}	2.4×10^{1}
Curies	3.6×10^{2}	2.4×10^{2}	5.3×10^{1}	2.0×10^{1}	4.6	1.1	2.6×10^{-2}
Watts	4.4×10^{-1}	5.6×10^{-1}	6.6×10^{-1}	5.8×10^{-1}	1.4×10^{-1}	3.4×10^{-2}	6.2×10^{-4}
Total/MTHM							
Grams	3.4×10^{1}	3.4×10^{1}	3.4×10^{1}	3.4×10^{1}	3.4×10^{1}	3.4×10^{1}	3.4×10^{1}
Curies	3.6×10^{2}	2.4×10^{2}	5.4×10^{1}	2.0×10^{1}	4.6	1.1	2.6×10^{-2}
Watts	5.1×10^{-1}	5.7×10^{-1}	6.7×10^{-1}	5.8×10^{-1}	1.4×10^{-1}	5.2×10^{-2}	6.3×10^{-4}
Total/55 gal drum							
Grams	1.6×10^{2}	1.6×10^{2}	1.6×10^{2}	1.6×10^{2}	1.6×10^{2}	1.6×10^{2}	1.6×10^{2}
Curies	1.7×10^{3}	1.2×10^{3}	2.6×10^{2}	9.6×10^{1}	2.2×10^{1}	5.3	1.3×10^{-1}
Watts	2.5	2.7	3.2	2.8	6.7×10^{-1}	2.5×10^{-1}	3.0×10^{-3}

As provided by BPNL
9/28/77 as Table A (

TABLE E-20

MOX Failed Equipment and Noncombustible Trash
(Fuel Cycle 3)

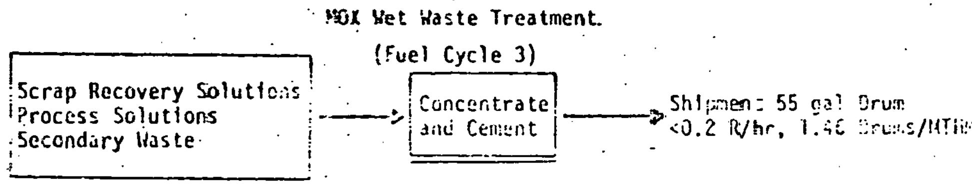
Noncombustible Trash → Package → Shipment
55 gal Drums
<0.2 R/hr
0.985 Drums/MTHM

Failed Equipment → Package → 4 x 6 x 6 ft Boxes
<0.2 R/hr
0.05 Boxes/MTHM

Source	Years After Chemical Separation						
	0	10	50	10^2	10^3	10^4	10^6
Noncombustible trash							
Actinides/MTHM							
Grams	1.0×10^2	1.0×10^2	1.0×10^2	1.0×10^2	1.0×10^2	1.0×10^2	1.0×10^2
Curies	6.4×10^1	4.1×10^1	9.4	3.7	8.0×10^{-1}	1.9×10^{-1}	5.0×10^{-3}
Watts	7.9×10^{-2}	9.9×10^{-2}	1.2×10^{-1}	1.0×10^{-1}	2.6×10^{-2}	5.9×10^{-3}	1.2×10^{-4}
Total/55 gal drum							
Grams	1.0×10^2	1.0×10^2	1.0×10^2	1.0×10^2	1.0×10^2	1.0×10^2	1.0×10^2
Curies	6.4×10^1	4.2×10^1	9.5	3.8	8.1×10^{-1}	1.9×10^{-1}	5.1×10^{-3}
Watts	8.0×10^{-2}	1.0×10^{-1}	1.2×10^{-1}	1.0×10^{-1}	2.6×10^{-2}	6.0×10^{-3}	1.2×10^{-4}
Failed Equipment							
Actinides/MTHM							
Grams	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Curies	9.6×10^{-1}	6.2×10^{-1}	1.4×10^{-1}	5.6×10^{-2}	1.2×10^{-2}	2.9×10^{-3}	7.5×10^{-6}
Watts	1.2×10^{-3}	1.5×10^{-3}	1.7×10^{-3}	1.5×10^{-3}	3.9×10^{-4}	8.9×10^{-5}	1.8×10^{-6}
Total/box							
Grams	3.0×10^1	3.0×10^1	3.0×10^1	3.0×10^1	3.0×10^1	3.0×10^1	3.0×10^1
Curies	1.9×10^1	1.2×10^1	2.8	1.1	2.4×10^{-1}	5.8×10^{-2}	1.5×10^{-4}
Watts	2.4×10^{-2}	3.0×10^{-2}	3.4×10^{-2}	3.0×10^{-2}	7.8×10^{-3}	1.8×10^{-3}	3.6×10^{-5}

As provided by BPNL on 9/28/77 as Table A 7

TABLE E-21



Source	Years After Chemical Separation						
	0	10	50	10^2	10^3	10^4	10^6
MOX plant wet wastes							
Actinides/MTHM							
Grams	3.5×10^1	3.5×10^1	3.5×10^1	3.5×10^1	3.5×10^1	3.5×10^1	3.5×10^1
Curies	2.3×10^1	1.4×10^1	3.6×10^2	3.6×10^2	8.8×10^1	5.7×10^{-2}	1.8×10^{-3}
Watts	2.8×10^{-2}	5.2	1.2×10^1	1.2×10^1	2.9	2.1×10^{-3}	4.2×10^{-5}
Total/55 gal drum							
(with cement)							
Grams	2.4×10^1	2.4×10^1	2.4×10^1	2.4×10^1	2.4×10^1	2.4×10^1	2.4×10^1
Curies	1.6×10^1	9.6	2.5×10^2	2.5×10^2	6.0×10^1	4.2×10^{-2}	1.2×10^{-3}
Watts	1.9×10^{-2}	3.6	8.2	8.2	2.0	1.4×10^{-3}	2.9×10^{-5}

TABLE E-22

Combustible Trash and Compactable Waste at MOX
(Fuel Cycle 3)
(Sheet 1)

Combustible Trash → Incinerate and Cement → 55 gal Drums <0.2 R/hr 2.51 Drums/MTHM

Source	Years After Chemical Separation						
	0	10	50	10^2	10^3	10^4	10^6
Combustible trash							
Actinides/MTHM							
Grams	3.0×10^2	3.0×10^2	3.0×10^2	3.0×10^2	3.0×10^2	3.0×10^2	3.0×10^2
Curies	1.9×10^2	1.2×10^2	2.8×10^1	1.1×10^1	2.4	5.7×10^1	1.5×10^{-2}
Watts	2.4×10^{-1}	3.0×10^{-1}	3.5×10^{-1}	3.1×10^{-1}	7.7×10^{-2}	1.8×10^{-2}	3.5×10^{-4}
Total/container							
Incinerate and cement							
Grams	1.2×10^2	1.2×10^2	1.2×10^2	1.2×10^2	1.2×10^2	1.2×10^2	1.2×10^2
Curies	7.6×10^1	4.8×10^1	1.1×10^1	4.4	9.6×10^{-1}	2.2×10^{-1}	6.0×10^{-3}
Watts	9.6×10^{-2}	1.2×10^{-1}	1.3×10^{-1}	1.2×10^{-1}	3.1×10^{-2}	712×10^{-3}	1.4×10^{-4}

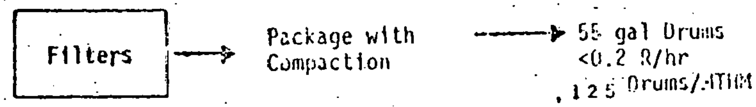
As provided by BPNL on 9/28/77 as Table A 9-1

TABLE E-23

Combustible Trash and Compatable Waste at MOX

(Fuel Cycle 3)

(Sheet 2)



Source	Years After Chemical Separation 0	10	50	10^2	10^3	10^4	10^6
MOX plant filters							
Actinides/MTHM							
Grams	7.0×10^2	7.0×10^2	7.0×10^2	7.0×10^2	7.0×10^2	7.0×10^2	7.0×10^2
Curies	4.5×10^2	2.9×10^2	6.6×10^1	2.6×10^1	5.6	1.3	3.5×10^{-2}
Watts	5.5×10^{-1}	6.9×10^{-1}	8.1×10^{-1}	7.1×10^{-1}	1.8×10^{-1}	4.1×10^{-2}	8.3×10^{-4}
Total/55 gal drum							
Grams	1.4×10^3	1.4×10^3	1.4×10^3	1.4×10^3	1.4×10^3	1.4×10^3	1.4×10^3
Curies	9.0×10^2	5.8×10^2	1.3×10^2	5.2×10^1	1.1×10^1	2.6	7.0×10^{-2}
Watts	1.1	1.4	1.6	1.4	3.6×10^{-1}	8.2×10^{-2}	1.6×10^{-3}

APPENDIX F - HEAT GENERATION RATES

This appendix includes the original heat generation data supplied by BPNL in the November 17 transmittal from R. W. McKee to R. K. Kibbe (Table F-1), plus an additional table of annual heat generation rates derived from this data (Table F-2). The yearly data were obtained from linear interpolation of the given five-year interval data received from BPNL. Because of the lack of data prior to 1990, the heat generation rates presented for the years 1986-1990 reflect the given 1990 value. As noted on Table F-2, the annual heat generation rate for an HLW canister from total recycle exceeds 3.6 kW (Section 9.3.2.3.1 of GEIS) from the year 2010 on. After that year, the HLW projections were adjusted by a factor equal to 3.6 divided by the original watts/canister for that year. Similar adjustments were required for U-only recycle HLW from the year 2013 on.

As provided by BPNL
on 11/17/77

TABLE F-1

HEAT GENERATION RATE IN HLW CONTAINERS

(watts)

	Case 2a - U Only Recycle Pu to HLLW		Case 3 - U & Pu Recycle	
	Solid High-Level Canisters		Solid High-Level Canisters	
	FP	Actinides	FP	Actinides
1985	0	0	0	0
1990	2.14 E + 03	4.74 E + 02	2.14 E + 03	1.70 E + 02
1995	2.65 E + 03	4.95 E + 02	2.63 E + 03	3.30 E + 02
2000	2.76 E + 03	5.75 E + 02	2.72 E + 03	5.83 E + 02
2005	2.79 E + 03	5.75 E + 02	2.75 E + 03	6.26 E + 02
2010	2.86 E + 03	6.36 E + 02	2.80 E + 03	7.33 E + 02
2015	3.03 E + 03	7.06 E + 02	2.95 E + 03	1.00 E + 03
2020	2.96 E + 03	7.44 E + 02	2.86 E + 03	1.24 E + 03
2025	2.85 E + 03	7.59 E + 02	2.75 E + 03	1.39 E + 03
2030	2.86 E + 03	7.70 E + 02	2.76 E + 03	1.39 E + 03
2035	2.78 E + 03	8.97 E + 02	2.64 E + 03	1.87 E + 03
2040	2.54 E + 03	9.08 E + 02	2.41 E + 03	1.83 E + 03
2045	2.25 E + 03	9.64 E + 02	2.15 E + 03	1.34 E + 03
2050	1.79 E + 03	8.87 E + 02	1.75 E + 03	4.07 E + 02

TABLE F-2

Average Annual Heat Generation Rates in HLW Canisters[a]

Year	Total Recycle Watts/Canister	U-Only Recycle Watts/Canister
1985	0	0
1986	2310	2614
1987	2310	2614
1988	2310	2614
1989	2310	2614
1990	2310	2614
1991	2440	2720
1992	2570	2826
1993	2700	2933
1994	2830	3039
1995	2960	3145
1996	3029	3183
1997	3097	3221
1998	3166	3259
1999	3234	3297
2000	3303	3335
2001	3318	3341
2002	3332	3347
2003	3347	3353
2004	3361	3359
2005	3376	3365
2006	3407	3391
2007	3439	3417
2008	3470	3444
2009	3502	3470
2010	3533	3496
2011	3616	3544
2012	3700	3592
2013	3783	3640
2014	3867	3688
2015	3950	3736
2016	3980	3730
2017	4010	3723
2018	4040	3717
2019	4070	3710
2020	4100	3704
2021	4108	3684
2022	4116	3664
2023	4124	3644
2024	4132	3624
2025	4140	3604

a Based on data supplied by BPNL (November 1977). Yearly values were obtained from linear interpolation of 5 year data.

APPENDIX G - WASTE THERMAL HISTORY

The BPNL waste thermal history described in this appendix (Table G-1) was derived from ORIGEN runs contained in the November, 1976 transmittal from BPNL to A. Quist. From the table it is obvious that HLW at 10 years after reprocessing will generate about 3.2 kW/canister. At 6.5 years after reprocessing, the canisters will be somewhat hotter (about 4.0 kW/canister); however, the maximum acceptable heat load remains at 3.2 kW/canister. Therefore, according to these data, HLW must be aged 10 years after reprocessing prior to burial, or the waste must be diluted with inert material prior to packaging.

TABLE G-1

BPNL Waste - Thermal History

	Time - years[a,b,f]								
	5	10	50	100	500	1000	5000	10000	100000
HLW: Total Recycle									
Watts/MTHM	1450	1020	355	119	14.1	7.55	1.90	1.35	0.121
Watts/canister[c]	4410	3100	1080	362	42.9	23.0	5.78	4.10	0.368
U-only Recycle									
Watts/MTHM	1420	1050	514	278	86.5	49.7	16.9	12.3	0.879
Watts/canister[c]	4320	3190	1560	846	263	151	51.4	37.4	2.67
SURF: PWR									
Watts/MTHM	1850	1200	559	295	95.2	54.6	18.0	13.1	0.921
Watts/canister[d]	853	551	258	136	43.9	25.2	8.31	6.05	0.425
BWR									
Watts/MTHM	1350	911	420	222	72.8	43.0	15.4	11.2	0.729
Watts/canister[e]	247	167	76.9	40.6	13.3	7.87	2.82	2.05	0.133

a For HLW, time is given as time after reprocessing. This is assumed to occur 1 1/2 years after discharge from the reactor.

b For SURF, time is given as time after an initial holding period (6 months). Hence, time since reactor discharge is 0.5 year greater than these headings. (ie. 5 yrs.=5.5yrs. since discharge).

c HLW canister is assumed to hold 3.04 MT of reprocessed fuel with an active volume of 6.28ft^3.

d PWR canister is assumed to hold one assembly of PWR spent fuel (.461MT) with an active volume of 2.8ft^3.

e BWR canister is assumed to hold one assembly of BWR spent fuel (.183MT) with an active volume of 1.1ft^3.

f Data obtained from BPNL supplied ORIGEN run.