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Preliminary Reference Waste Descriptions for a Repository at Yucca Mountain, Nevada

Paul D. O'Brien

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PRELIMINARY REFERENCE WASTE DESCRIPTIONS FOR A REPOSITORY AT YUCCA MOUNTAIN, NEVADA

Paul D. O'Brien
Nuclear Waste Engineering
Projects Division 6311
Sandia National Laboratories
Albuquerque, New Mexico 87185

Abstract

This report describes the reference waste forms and containers for the early stages of conceptual design of a radioactive waste repository being considered for location in the tuff formations at Yucca Mountain, Nye County, Nevada. An assessment of the effects of nonreference waste characteristics on repository design is included. The report is based on the premise that repository would receive 50% spent fuel and 50% commerical high-level waste. Future information will be developed based on the current guidance that the repostiory would receive 100% spent fuel.

Preface

The data in this report were compiled based on the repository receiving 50% spent fuel and 50% commercial high-level waste. The current plan is that the repository would receive 100% spent fuel. New data will be developed based on the current plan.

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1. INTRODUCTION

The Nevada Nuclear Waste Storage Investigations (NNWSI) Project, managed by the Nevada Operations Office of the U. S. Department of Energy (DOE), is studying the feasibility of locating a radioactive waste repository in the tuff formations at Yucca Mountain, in Nye County, Nevada. As a participant in this program, Sandia National Laboratories is responsible for the conceptual design of the surface and underground facilities of the repository. This report describes the waste forms and containers that were used as a basis for early conceptual design activities. The waste descriptions and quantities cited here represented the best estimates of the author at the time the report was prepared, and are subject to change as new data are developed and when the generic requirements for a Mined Geologic Disposal System are promulgated.

Most of the information reported here was taken from various drafts of an unpublished DOE guidance document, "Planning Base for Wastes to be Received at an MGDS*." Spent fuel rod canister dimensions were taken from a Lawrence Livermore National Laboratory (LLNL) report, "Initial Specifications for Nuclear Waste Package External Dimensions and Materials."[1] Defense high-level waste (DHLW) characteristics apply specifically to the vitrified waste that will be produced at the Savannah River Defense Waste Processing Facility (DWPF).[2] TRU waste characterization was based on data in a recent Allied-General Nuclear Services (AGNS) report, "Waste Model Characterization Study: Evaluation of Reprocessing Waste Estimates."[3] Every effort was made to compile the most authoritative information available for each of the waste forms considered; nevertheless, there may be differences between the waste descriptions presented here and those which may ultimately be incorporated into the DOE planning base.

The Nuclear Waste Policy Act of 1982 specifies that the first commercial waste repository will be designed to accommodate the radioactive wastes derived from 70,000 metric tons of uranium (MTU) initially charged to civilian power reactors. In addition, the repository may be designated as a

* Mined Geologic Disposal System.

disposal site for solidified high-level waste resulting from the defense activities of the United States government. In this report, the reference case for commercial waste quantities, receival rates, and thermal and radiation characteristics was based on three fundamental assumptions:

- The 70,000 MTU of commercial waste is divided evenly between spent fuel and vitrified high-level waste (plus the associated cladding and TRU waste) from reprocessing.

- Waste is received and emplaced at the rate of 3,000 MTU/year -- again, evenly divided between spent fuel and reprocessing waste.

- The waste is 10 years out-of-reactor at the time of emplacement.

2. WASTE CHARACTERISTICS, QUANTITIES, AND CONTAINER DESCRIPTIONS

The waste characteristics used as the basis in early stages of conceptual design of the Yucca Mountain repository are summarized in Table 1. Brief discussions of the various waste types are presented in Sections 2A through 2G.

A. Spent Fuel

Spent fuel would be shipped to the repository as intact fuel assemblies. Although the economic feasibility of fuel rod consolidation has not yet been demonstrated, it is assumed here that individual fuel rods would be removed from the assemblies and packaged in stainless steel canisters designed especially for the Yucca Mountain repository. In this scenario, spent fuel is the only waste type that would arrive at the repository in a configuration different from that of the actual disposal package.

It is assumed that spent fuel would be received at the rate of 1,500 MTU/year, divided 62/38 percent, respectively, between pressurized water reactor (PWR) and boiling water reactor (BWR) fuel. Thus, PWR fuel would be received at the rate of 930 MTU/year (2,016 fuel assemblies annually), and BWR fuel would be received at the rate of 570 MTU/year (3,100 fuel assemblies annually).

On the basis of a preliminary economic analysis, LLNL has proposed that different canister diameters be used for the two fuel types. The present plan is to use a 50-cm-diameter canister for the fuel rods from 6 PWR assemblies, and a 57-cm-diameter canister for the fuel rods from 18 BWR assemblies. For these canister capacities, and for the spent fuel receival rates cited above, the number of PWR and BWR waste packages to be emplaced are, respectively, 336 and 173/year. The nominal canister length for both fuel types is 450 cm, but consideration is being given to choosing one or two other standard lengths for more efficient packaging of shorter fuel rods. Loaded with 10-year-old spent fuel, the PWR canister has a thermal power of 3,050 W, and the BWR canister has a thermal power of 3,000 W.

TABLE 1

CHARACTERIZATION OF WASTE FOR THE YUCCA MOUNTAIN REPOSITORY

Waste Type	Disposal Package Type	Disposal Package Dimensions ($\frac{cm}{in}$)	Disposal Package Weight ($\frac{kg}{lb}$)	Total Packages	Packages/Yr	Thermal Power (W)	Surface Dose Rate (mrem/hr) Gamma	Surface Dose Rate (mrem/hr) Neutron	Remarks
Spent Fuel PWR	Canister	50 OD × 450 19.7 OD × 177.2	4,500 9,900	7,839	336	3,050	1.7×10^7	3.9×10^3	Canister contains fuel rods from 6 PWR assemblies.
Spent Fuel BWR	Canister	57 OD × 450 22.4 OD × 177.2	5,600 12,300	4,031	173	3,000	$\sim 1.3 \times 10^7$	$\sim 2.8 \times 10^3$	Canister contains fuel rods from 18 BWR assemblies.
CHLW	Canister	32 OD × 300 12.75 OD × 118.1	825 1,900	15,350	660	1,844 (BWR) to 2,244 (PWR)	1.1×10^8	2.7×10^4	Waste from 2.28 MTU fuel charged to reactors. Waste will usually be a blend from BWRs and PWRs.
DHLW (DWPF)	Canister	61 OD × 300 24 OD × 118.1	1,935 4,260	6,720	500	470	5.5×10^6	~0	Equilibrium product with 28 weight percent waste loading.
WVHLW	Canister	61 OD × 300 24 OD × 118.1	1,935 4,260	300	TBD	~300	$\sim 4.0 \times 10^6$	~0	Solidification process not defined.
Cladding Waste	Canister	61 OD × 300 24 OD × 118.1	1,460 3,210	12,290	484	~68	$>5.0 \times 10^5$	~0	Hulls compacted with 2:1 volume reduction ratio.
TRU Waste (Reprocessing)	6-packed 55-gal drums	188 × 125 × 90 74 × 49 × 36.0	Variable (<2,000 kg)	1,143	49	~0	≤200	~0	Compacted with 3:1 overall volume reduction.
TRU Waste (Reprocessing)	SAND box	173 × 137 × 98 68 × 54 × 38.5	Variable (<2,000 kg)	677	29	~0	≤200	~0	Compacted with 3:1 overall volume reduction.
TRU Waste (Reprocessing)	Canister	61 OD × 300 24 OD × 118.1	Variable (<2,000 kg)	10,734	460	TBD	>200	~0	Compacted with 3:1 overall volume reduction.
TRU Waste (MOX Fuel Fabrication)	6-packed 55-gal drums	188 × 125 × 90 74 × 49 × 36.0	Variable (<2,000 kg)	4,527	194	~0	<10	~0	Compacted with 3:1 overall volume reduction.
TRU Waste (MOX Fuel Fabrication)	SAND box	173 × 137 × 98 68 × 54 × 38.5	Variable (<2,000 kg)	2,707	116	~0	<10	~0	Compacted with 3:1 overall volume reduction.
Spent Fuel Hardware Waste	Canister	61 OD × 300 24 OD × 118.1	1,975 4,350	1,932	83	~0	>200	~0	Nozzles, spacers, etc., from fuel rod packaging operations.

BWR - Boiling water reactor.
CHLW - Commercial high-level waste.
DHLW - Defense high-level waste.
DWPF - Defense Waste Processing Facility (Savannah River).
MOX - Mixed uranium and plutonium oxide.
OD - Outside diameter.
PWR - Pressurized Water Reactor
TBD - To be determined.
TRU - Transuranic waste.
WVHLW - West Valley high-level waste.

Since the fuel rods would be packaged at the repository, the incidence of canister damage is likely to be lower than for waste packages shipped from other locations. For that reason, there is no provision for overpacking spent fuel canisters; if a canister is damaged, it would be returned to the receiving facility where the fuel rods would be repackaged. For all other waste types, damaged containers would be overpacked prior to disposal; handling equipment and transfer casks, therefore, would have to be designed for oversized waste packages.

A significant amount of hardware waste, such as nozzles and spacers, would be generated in the fuel rod consolidation operation. This is discussed in Section G below.

B. Commercial High-Level Waste

The waste form for commerical high-level waste (CHLW) consists of actinide and fission product oxides (about 30 weight percent) immobilized in borosilicate glass (about 70 weight percent). Canister diameter is determined by the thermal properties of the waste package and its geologic surroundings, and by the devitrification temperature of the glass (about 500°C). The reference canister is nominally 32 cm in outside diameter (actually 12.75 inches--the outside diameter of standard 12-inch pipe), and is 300 cm long; it contains the waste produced in reprocessing 2.28 MTU of spent fuel. Loaded with 10-year-old waste, it has a thermal power of between 1,844 and 2,244 W depending on the relative amounts of PWR and BWR fuel in the feed stock.

CHLW would be received at the repository at the rate of 1,500 MTU/year (660 canisters annually); this corresponds to the yearly output from a single reprocessing plant the size of the Barnwell Nuclear Fuel Plant (BNFP).

The repository would also accommodate some of the secondary wastes--specifically, cladding hulls and TRU waste--produced during the operation of the reprocessing plant. These are discussed in Sections E and F below.

C. Defense High-Level Waste

The reference defense high-level waste (DHLW) is that which will be produced in the proposed Savannah River Defense Waste Processing Facility (DWPF). It is anticipated that both Hanford and Idaho National Engineering Laboratory (INEL) will produce a colder (in the sense of having a lower thermal power density) high-level waste product whose physical and chemical characteristics may be different from those of the DWPF waste.

As in the case of commercial high-level waste, the reference waste form is actinide and fission product oxides immobilized in borosilicate glass; the waste loading is 28 weight percent. The thermal power density of the Savannah River waste is substantially lower than that of the reference commercial high-level waste, and the DWPF canister diameter is correspondingly larger--nominally 61 cm in outside diameter (actually 24 inches--the outside diameter of standard 24-in pipe). The canister length is 300 cm, and the thermal power of the reference canister is 470 W. A total of about 6,720 reference canisters of DWPF DHLW will be produced; these would be delivered to the repository at the rate of 500/year.

Consideration is being given to increasing the waste loading in the DWPF glass before the scheduled plant startup in 1989. This would result in a proportionate decrease in the total number of canisters. It is assumed, however, that the receival rate would remain constant at 500 canisters/year. Whatever the total number of canisters, the entire Savannah River inventory of DHLW would be exhausted midway through the operational lifetime of the repository.

D. West Valley High-Level Waste

Final decisions or commitments have not yet been made regarding the processing and packaging of West Valley high-level waste (WVHLW), but it is assumed that both the waste form and canister will be similar to those proposed for DWPF DHLW. The West Valley waste will be somewhat colder than Savannah River waste; a reasonable estimate is that the thermal power of a reference canister of WVHLW will not exceed 300 W. About 300 canisters will accommodate all the West Valley waste. No delivery schedule has been formulated, but shipments would probably be coordinated with shipments of Savannah River DHLW so as not to exceed the throughput capacity of the repository receiving facility.

E. Cladding Waste

The reference cladding waste package is different in two significant ways from one being considered by the Office of Nuclear Waste Isolation (ONWI) for the salt repository program: (1) for the Yucca Mountain repository, a 61-cm-diameter-by-300-cm-long canister (similar to the DWPF DHLW canister) replaces the AGNS 600-gallon drum, and (2) it is assumed that the cladding hulls would be compacted (with a 2:1 volume reduction ratio), whereas the ONWI characterization assumes no compaction.

The change in canister size was made because the AGNS 600-gallon drum is probably not transportable in a legal-weight truck cask, it was not designed to survive an accidental drop that could occur during repository handling operations, and its unique size is incompatible with other repository handling equipment. Hull compaction is easily accomplished and is likely to be cost-effective because of the smaller number of canisters to be shipped to and emplaced in the repository. AGNS confirms that the assumed 2:1 volume reduction ratio is achievable in practice and, in fact, the assumption may be overly conservative.

Rockwell Hanford Operations has under development a canister for defense remote-handled TRU waste; its dimensions were chosen for compatibility with the shipping cask and handling equipment for DWPF DHLW. It is assumed here that the same canister is usable for cladding waste and for the more highly radioactive commercial TRU waste. Calculations based on AGNS data indicate that this canister will accommodate the cladding waste from 3.1 MTU of reprocessed fuel and that it will have a thermal power of about 68 W. With a reprocessing waste receival rate of 1,500 MTU/year, the canisters would be received at the rate of 484/year.

F. Transuranic (TRU) Waste

Transuranic (TRU) waste is derived from two sources--spent fuel reprocessing and mixed-oxide (MOX) fuel fabrication. The following characterization of TRU waste from reprocessing is based on AGNS data;[3] the June 1983 draft of the DOE MGDS planning base document provides the basis for characterizing TRU waste from MOX fuel fabrication.

AGNS estimates TRU waste volumes and surface dose rate distributions for six scenarios covering fuel burnup values from 25,200 to 32,000 MWd/MTU and cooling times from 180 days to 50 years. Case IV, based on an average burnup of 28,500 MWd/MTU and a cooling time of 9 years, most accurately describes the TRU waste from reprocessing that would be received at a Yucca Mountain repository.

In accordance with an AGNS recommendation, it is assumed that all compactible TRU waste would be compacted at the waste generating site with a volume reduction ratio of 4:1. For TRU waste from reprocessing, this results in an overall volume reduction ratio of about 3:1; it is assumed, arbitrarily, that the same overall volume reduction is attainable for TRU waste from MOX fuel fabrication. Incineration is not considered because of relative cost and because it produces almost no overall volume reduction (because of the anticipated need to immobilize incinerator ash, and because of the secondary wastes produced in off-gas treatment).

AGNS data show that commercial TRU waste from reprocessing is relatively more radioactive than defense TRU waste. Regardless of the treatment option, only about 30 volume percent of the waste exhibits a surface dose rate less than 200 mrem/hour. One-half to two-thirds of the waste, depending on the treatment option, has a dose rate greater than 10,000 mrem/hour. By contrast, TRU waste from MOX fuel fabrication is relatively "cold," having a surface dose rate less than 10 mrem/hour when uncompacted. Even with an assumed volume reduction ratio of 3:1, however, the volume of MOX TRU waste is four times as great as the volume of under-200-mrem/hour TRU waste from reprocessing. This suggests that the terms "contact-handled" and "remote-handled" have no meaning for commercial TRU waste: in the interest of minimizing radiation dose to workers, and because of the very large volume of waste involved, virtually all TRU waste would be handled by remote or semiremote methods.

The practical distinction between low-activity and high-acitvity TRU waste is in the packaging. It is assumed here that the under-200-mrem/hour waste would be packaged in metal boxes and drums and shipped in TRUPACT-like carriers, and that the over-200-mrem/hour waste would be packaged in metal canisters and shipped in shielded casks. Specifically, it is assumed that the under-200-mrem/ hour waste would be divided evenly between 6-packed 55-gallon drums and 173-cm × 137-cm × 98-cm SAND boxes (chosen for efficient loading in a truck TRUPACT). Over-200-mrem/hour TRU waste would be packaged in the 61-cm-diameter, 300-cm-long canister used for cladding waste.

Calculations based on AGNS data indicate that under-200-mrem/hour TRU waste from reprocessing would be received at the repository at the rate of 114 m^3/year, and that over-200-mrem/hour TRU waste would be received at the rate of 301 m^3/year. With the above assumptions for packaging, annual receipts would total 49 6-packs, 29 SAND boxes, and 460 canisters.

About 457 m^3--194 6-packs and 116 SAND boxes--of low-activity compacted TRU waste would be received each year from the reference MOX fuel fabrication plant. Such a plant has a throughput of 400 MTHM/year; this is the amount of uranium and plutonium recovered in a 1,500-MTU/year reprocessing plant like BNFP.

G. Spent Fuel Hardware Waste

A surprisingly large amount of hardware waste would be produced in the repository's spent fuel rod consolidation operation. It is estimated that about 37 kg of scrap metal (nozzles, spacers, etc.,) would be collected for each PWR fuel assembly processed, and that about 16 kg would be collected for each BWR assembly processed. The scrap is unlikely to contain as much as 100 nCi of transuranic radionuclides per gram of waste; it is, therefore, not really TRU waste as defined by the Environmental Protection Agency (EPA) standards.* It would, nevertheless, be disposed of in the underground TRU waste facility because the repository complex would not include a surface burial area. Metal activation and crud accumulation would undoubtedly necessitate handling by remote methods; it is assumed, therefore, that the scrap would be packaged in the 61-cm-diameter, 300-cm-long canisters used for cladding waste and high-activity TRU waste.

In estimating hardware waste volumes, it was assumed that the thin Zircaloy scrap can be compacted and packaged at 50 percent of theoretical density, and that the nozzles and spacers can be packaged at 25 percent of theoretical density. Based on these assumptions, a PWR fuel assembly produces about 0.016 m^3 of hardware waste, and a BWR assembly produces about 0.007 m^3. For the spent fuel receival rates cited in Section II A, 51 canisters of PWR scrap and 32 canisters of BWR scrap would be generated during each year of repository operation.

* Federal Register, "Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Waste," (draft) 47 CFR 25, December 29, 1982.

3. DEPARTURES FROM REFERENCE WASTE CHARACTERISTICS

The waste characteristics shown in Table 1 are for reference waste forms that may or may not ever be produced. Some of the effects of departure from reference conditions are discussed in the following sections.

A. Spent Fuel/CHLW Ratio

In the early stages of conceptual design, it was assumed that the Yucca Mountain repository would accommodate 3,000 MTU/year of waste--1,500 MTU/year, each, of spent fuel and CHLW. At present, there are no firm plans to build or operate commercial spent fuel reprocessing plants in the U.S. This raises the question of the availability of CHLW and, therefore, the appropriateness of the assumed 50/50 ratio of spent fuel to CHLW.

Because the receiving facilities for spent fuel are much more complex than those for CHLW, there would be no flexibility for receiving more than 1,500 MTU/year of spent fuel. On the other hand, spent fuel receiving facilities could, with difficulty, be adapted to CHLW canisters. The current plan is that the repository will receive 100% spent fuel and future data will be developed based on that assumption.

If two reprocessing plants were to become operational, the repository could be modified to permit receival of 100 percent CHLW. It is noted, however, that the cladding and TRU waste associated with the extra CHLW (i.e., the amount above 1,500 MTU/year assumed in the preliminary studies) would pose both handling rate and repository capacity problems.

B. Waste Age

Informal DOE guidelines, as contained in drafts of the MGDS planning base, specify that all commercial waste is assumed to be 10 years out-of-reactor at the time of emplacement. This assumption is not always valid; spent power reactor fuel has been accumulating since 1969 and would be as old as 29 years out-of-reactor in 1998, when the first commercial waste repository in the U.S. is scheduled to begin operation. Furthermore, the age of incoming waste would vary throughout the operational lifetime of the repository and will be affected by such unknowns as the rate of growth of nuclear power generation and the timing of additional repositories.

Preliminary analysis of far-field rock movement indicates that 10-year-old spent fuel, for example, can be emplaced with an initial areal power density (IAPD) up to about 14 W/m^2. For fuel that is not 10 years out-of-reactor, the question arises as to whether it should be emplaced at this design value of IAPD or with the canister spacing determined for 10-year-old spent fuel. Emplaced at a constant IAPD, old waste deposits more energy per unit area than young waste because there are more canisters of old waste per area, and because old waste decays more slowly than young waste. Emplaced at a constant canister spacing, on the other hand, old waste deposits less energy per unit area than young waste because the IAPD is lower for old waste, although the effect is partially offset by the slower decay of the older fuel.

To provide a quantitative perspective of the problem, calculations[4] were carried out in which spent PWR fuel was assumed to represent high-level waste in general. First, using historical records and DOE projections of power reactor fuel discharges[5,6], the actual age of the spent fuel at the time of emplacement* was calculated for each year of repository operation beginning in 1998. Results of the calculations are summarized in Figure 1. It is seen that weighted-average waste age is lower for shorter delays between startup of the first and second repositories and for the lower value, 128.6 GW(e), of nuclear generating capacity in the year 2000. Thus, in this example, the youngest spent fuel emplaced has a weighted-average age of 5 years out-of-reactor; this occurs in the period from 2018 to 2022, and corresponds to the case of zero delay between the first and second repositories, and a nuclear generating capacity of 128.6 GW(e) in the year 2000. The oldest waste is 32 years out-of-reactor; this occurs in the year 2046, and

* In this study, it was assumed that there is no delay between the receipt of waste at the repository and emplacement in the underground disposal area.

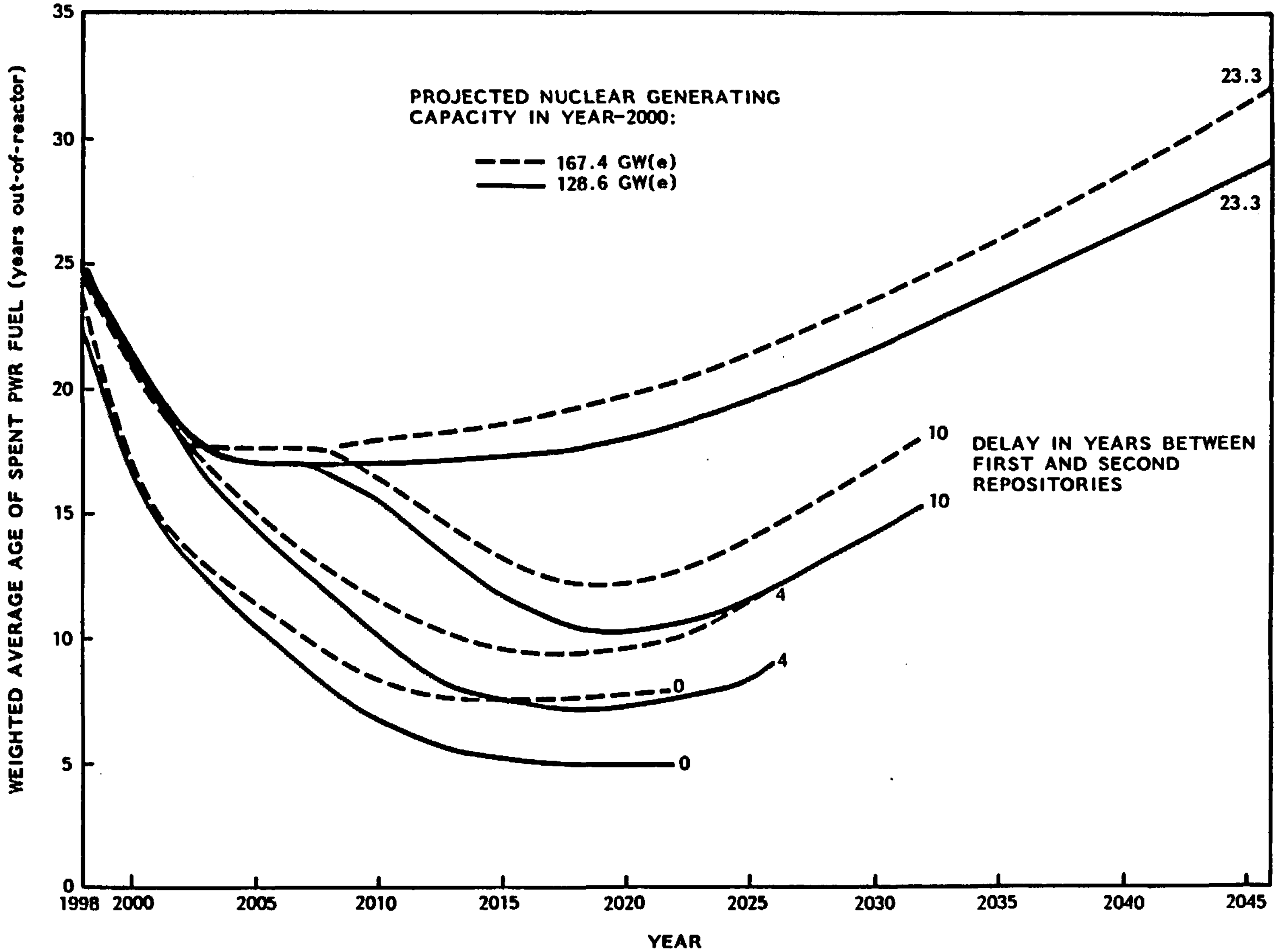

Figure 1. Effect of Second Repository Timing on the Age of Spent Pressurized Water Reactor (PWR) Fuel

corresponds to the case of 23.3 years delay between the first and second repositories (i.e., first repository filled before loading of second repository begins), with a nuclear generating capacity of 167.4 GW(e) in the year 2000.

Realistically, it is likely that the rate of growth of nuclear generating capacity will be even lower than the rates considered in these calculations. In Appendix C of Reference 6, DOE discusses a limiting case in which the nuclear generating capacity is only 109.7 GW(e) in the year 2000.* The effect of lower growth rate is, of course, to decrease the age of the waste received at the repository because a smaller inventory of spent fuel is depleted at the constant rate of 3,000 MTU/year (for a single repository).

The effect of waste age on thermal power is illustrated in Table 2, which is based on ORIGEN2[7] calculations** by Charles Alexander of ORNL. Data for CHLW less than 10 years out-of-reactor are not shown because Alexander assumed that the spent fuel was 10 years old at the time of reprocessing.

TABLE 2

EFFECT OF WASTE AGE ON THE THERMAL
POWER OF HEAT-PRODUCING WASTES

Years Out-of-Reactor	Relative Thermal Power			
	PWR Spent Fuel	BWR Spent Fuel	PWR CHLW	BWR CHLW
1	8.78	7.76	--	--
2	4.52	4.06	--	--
5	1.57	1.51	--	--
10	1.00	1.00	1.00	1.00
20	0.78	0.78	0.73	0.74

In the second phase of the study described in Reference 4, areal energy deposition was calculated for a range of waste ages (at emplacement) of 5 to

* For this projection, it was assumed that spent fuel will come from reactors already in operation or now under construction and more than 35 percent complete.

** These calculations were intended for inclusion in the MGDS planning base document, which has not yet been published.

40 years and for emplacement periods--times over which areal power density is integrated--up to 50,000 years. These calculations were carried out both for a constant IAPD of 14 W/m^2 and for a uniform canister spacing determined for 10-year-old spent PWR fuel. Results of the calculations are shown in Figure 2. As expected, for a fixed IAPD, areal energy deposition is substantially higher for older waste (and lower for younger waste) than it is for the reference 10-year-old waste. For a fixed emplacement array, areal energy deposition is somewhat lower for older waste (and higher for younger waste); in this case, however, the effect is relatively small--particularly for long periods after emplacement. After 50,000 years, for example, 5-year-old waste deposits 1 percent more energy than 10-year-old waste; 20-year-old waste deposits 2 percent less energy; and 40-year-old waste deposits 4 percent less energy.

An optimum emplacement array will have to be determined for each type of heat-producing waste. This determination will be based on the decay properties of the individual waste forms, the time after emplacement at which certain thermally induced phenomena become important, and the distance from the disposal array at which these phenomena occur. It is clear from this analysis, however, that optimum canister spacings can be approximated quite adequately by choosing an appropriate reference waste age for each type of waste.

C. Uranium Loading and Burnup

Time-dependent characteristics of the various waste forms are forecast on the basis of Oak Ridge decay calculations* using the isotope generation code, ORIGEN2[7]. These calculations are based on fuel loadings (kg U/fuel assembly) and fuel burnup values (MWd/MTU) that have not yet been attained in routine operation. Lower fuel loadings and burnups will result in actual values of thermal power that are lower than the reference values shown in Table 1. On the other hand, there is an economic incentive for increasing uranium loading and burnup above the reference values; if and when this

* These calculations were intended for inclusion in the MGDS planning base document, which has not yet been published.

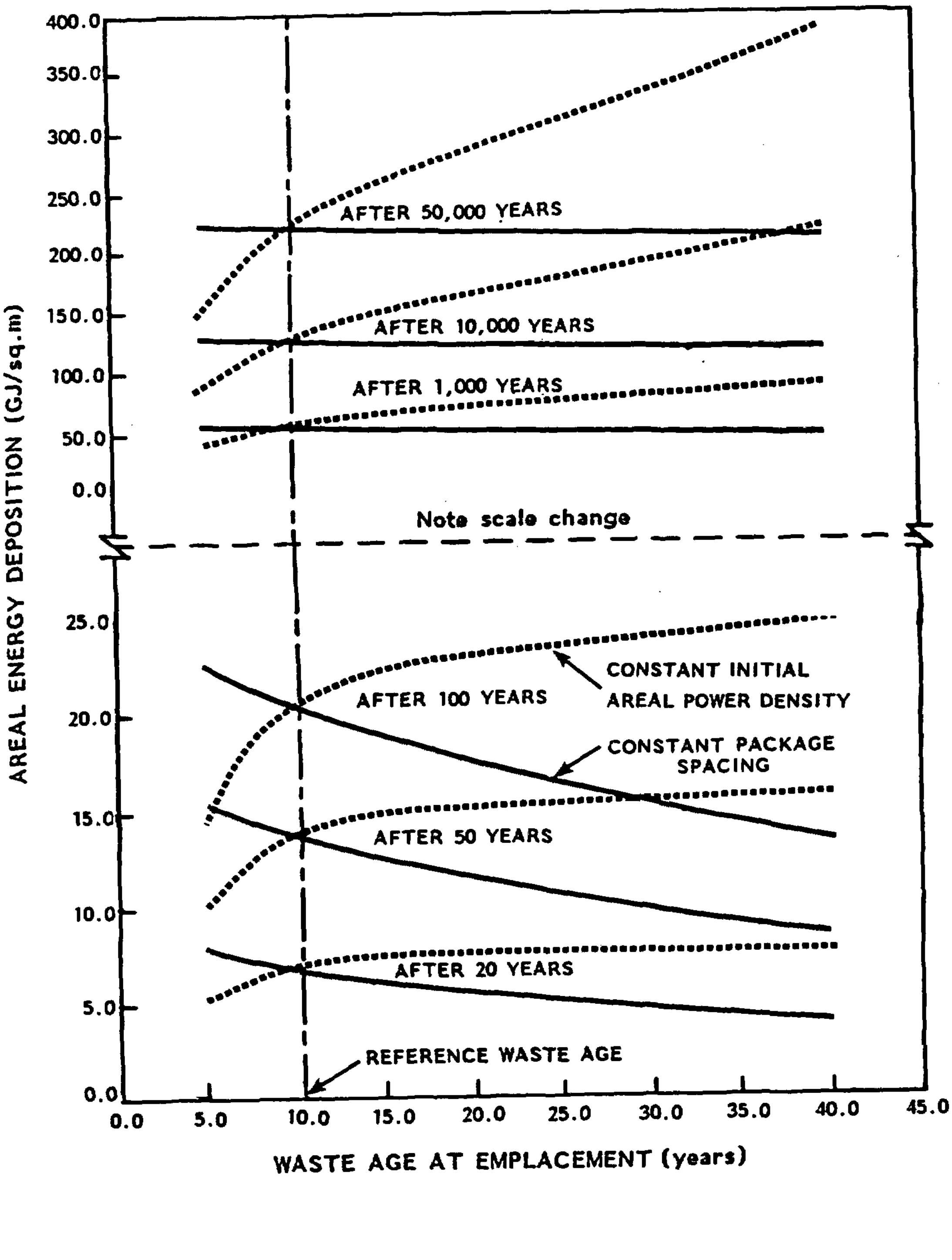

Figure 2. Areal Energy Deposition as a Function of Waste Age at the Time of Emplacement

occurs, thermal power will be correspondingly higher than the reference values. In either case, actual values of thermal power must be considered in developing the final mine layout and waste emplacement schedule; this, of course, will be possible only when actual waste shipments are scheduled--presumably at least two years prior to shipment.

Lower-than-reference fuel loadings pose a subtle problem with regard to spent fuel disposal: there will be more fuel assemblies per MTU received than is predicted for reference fuel. The average uranium loading in PWR fuel discharged through 1981 was 0.4156 MTU/fuel assembly (compared to a reference loading of 0.4614 MTU/fuel assembly). The average uranium loading in BWR fuel discharged through 1981 was 0.1785 MTU/fuel assembly (compared to a reference loading of 0.1833 MTU/fuel assembly). To provide a qualitative assessment of the importance of these differences, a 1982 projection[5] of spent fuel discharges was used as the basis for comparing the actual and reference cumulative numbers of fuel assemblies that would be received at the first (and, in this example, the only) repository. The reference ratio, 62/38 percent, between PWR and BWR fuel was assumed; thus, the repository would receive 21,700 MTU of spent PWR fuel and 13,300 MTU of spent BWR fuel.

Table 3 summarizes the results of this analysis; during the operational lifetime of the repository the difference between reference and actual spent fuel receipts would be 713 disposal packages -- the equivalent of 1.4 years of operation at the nominal emplacement rate.

TABLE 3

ACTUAL VS REFERENCE NUMBERS OF SPENT FUEL ASSEMBLIES

				Difference	
Fuel Type	Cumulative MTU	Reference Assemblies	Actual Assemblies	Assemblies	Disposal Packages
PWR	21,700	47,031	50,834	3,803	634
BWR	13,300	72,559	73,969	1,410	79
	35,000	119,590	124,803	5,213	713

D. DWPF DHLW Thermal Power

The reference characteristics for DWPF DHLW are for a waste form that will be produced only late in the operating history of the DWPF. The first of DWPF waste will produce only about 50 or 60 W of thermal power, as compared to the a reference value of 470 W. The gradual increase in thermal power must be considered in developing the repository layout for DHLW, but at present there is no basis for predicting the rate of increase. Fortunately, the scheduled startup of the DWPF precedes that of the first repository by some 9 years; thus, there should be no problem in designing the repository for the actual values of thermal power for each canister.

E. Cladding Waste Treatment

The number of cladding waste canisters will vary depending on the volume reduction factor actually achieved in the compaction operation. It is also possible that cladding hulls, compacted or not, will be found to be unsuitable as a waste form because of poor radionuclide retention. In this case, a different treatment option, such as smelting, will have to be selected, and an appropriate waste package and transportation system will have to be developed.

F. TRU Waste Treatment

The assumption that TRU waste would be compacted but not incinerated was based solely on cost considerations. There is some risk in this assumption: (1) it may be determined later that it is unsafe to dispose of cellulosic materials in a tuff repository with a large inventory of heat-producing waste, and (2) even if the disposal of cellulosic waste poses no serious safety problems, the Nuclear Regulatory Commission may refuse to license a repository in which a highly variable waste form would be emplaced. On the first point, there is some reassurance in the fact that after careful study it was decided that unprocessed cellulosic materials can be disposed of safely in a bedded salt repository[8] [Waste Isolation Pilot Project (WIPP)]--which, admittedly, will contain only experimental quantities of heat-producing waste. On the second point, a very unfavorable cost/benefit ratio may well dictate against incineration.

G. MOX Fuel Fabrication

Plans for a mixed-oxide (MOX) fuel fabrication plant are even more nebulous than those for a spent fuel reprocessing plant. Without such a plant, the receival rate of low-activity TRU waste boxes and drums would be reduced by 80 percent.

4. SUMMARY

This report has described the reference waste forms and containers used as a basis for the early stages of conceptual design of a radioactive waste repository at Yucca Mountain, Nevada. These waste descriptions should be regarded only as a departure point; changes will be required as generic requirements for a radioactive waste disposal system and the technology of waste management evolve.

The effects of non-reference waste properties on repository design have been discussed qualitatively. Analysis of waste age distribution suggests that hot cells and transfer casks should be designed for waste that is less than 10 years out-of-reactor. An early concern for the effect of waste age variability on the design of disposal arrays has been resolved; for each type of heat-producing waste, a practical emplacement array can be chosen to ensure efficient use of repository space and to limit areal energy deposition to an acceptable value.

Important questions remaining to be answered in the area of TRU waste management. Is it necessary to eliminate organic materials--by incineration, for example? If processing is necessary, where would it be done--at the waste generating sites, or at the repository? Will there be an operational MOX fuel fabrication plant during the lifetime of the repository?

Answers to these and other questions will be forthcoming as the NNWSI Project and the programs directed by the Office of Civilian Radioactive Waste Management progress. For the present, the waste forms and containers described in this report provide a starting point for the repository design.

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DISTRIBUTION LIST

J. W. Bennett (RW-20)
Acting Associate Director
Geologic Repository Deployment
U. S. Department of Energy
Washington, D. C. 20545

Ralph Stein (RW-21)
Acting Deputy Associate Director
Geologic Repository Deployment
U. S. Department of Energy
Washington, D. C. 20545

M. J. Lawrence (RW-1)
Acting Director
Office of the Director
U. S. Department of Energy
Washington, DC 20545
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Program Management Division
Geologic Repository Deployment
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Geosciences and Technology Division
Geologic Repository Deployment
U. S. Department of Energy
Washington, D. C. 20545

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Institutional Relations Staff
Geologic Repository Deployment
U. S. Department of Energy
Forrestal Building

Chief, High-Level Waste Technical
Development Branch
Division of Waste Management
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

NTS Project Manager
High-Level Waste Technical
Development Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Document Control Center
Division of Waste Management
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

J. O. Neff
Salt Repository Project Office
U.S. Department of Energy
505 King Avenue
Columbus, OH 43201

Ralph Stein (RW-21)
Acting Deputy Associate Director
Geologic Repository Deployment
U. S. Department of Energy
Washington, DC 20545

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P.O. Box 550
Richland, WA 99352

E. B. Ash
Rockwell International Atomics
Rockwell Hanford Operations
Richland, WA 99352

A. A. Metry, Program Manager
Roy F. Weston, Inc.
2301 Research Blvd., 3rd Floor
Rockville, MD 20850

D. C. Newton (RW-23)
Engineering and Licensing Division
Geologic Repository Deployment
U. S. Department of Energy
Washington, DC 20545

R. R. Loux, Jr., Manager
Nuclear Waste Project Office
State of Nevada
Capitol Complex
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Office of Nuclear Waste Isolation
505 King Avenue
Columbus, OH 43201

S. A. Mann, Manager
Crystalline Rock Project Office
U.S. Department of Energy
9800 S. Cass Avenue
Argonne, IL 60439

L. D. Ramspott (3)
Technical Project Officer for NNWSI
Lawrence Livermore National Laboratory
P.O. Box 808
Mail Stop L-204
Livermore, CA 94550

D. C. Hoffman
Los Alamos National Laboratory
P.O. Box 1663
Mail Stop E-515
Los Alamos, NM 87545

D. T. Oakley (3)
Technical Project Officer for NNWSI
Los Alamos National Laboratory
P.O. Box 1663
Mail Stop F-671
Los Alamos, NM 87545

R. W. Lynch
Sandia National Laboratories
P. O. Box 5800
Organization 6300
Albuquerque, NM 87185

Barry Gale (RW-25)
Siting Division
Geologic Repository Deployment
U.S. Department of Energy
Forrestal Building
Washington, DC 20585

K. Street, Jr.
Lawrence Livermore National Laboratory
P.O. Box 808
Mail Stop L-209
Livermore, CA 94550

A. R. Hakl
Technical Project Officer for NNWSI
Westinghouse Electric Corporation
Waste Technology Services Division
Nevada Operations
P.O. Box 708
Mail Stop 703
Mercury, NV 89203

W. W. Dudley, Jr. (3)
Technical Project Officer for NNWSI
U.S. Geological Survey
P.O. Box 25046
418 Federal Center
Denver, CO 80225

J. A. Cross, Manager
Las Vegas Branch
Fenix & Scission, Inc.
P.O. Box 15408
Las Vegas, NV 89114

M. E. Spaeth (2)
Technical Project Officer for NNWSI
Science Applications, Inc.
2769 South Highland Drive
Las Vegas, NV 89109

W. S. Twenhofel
820 Estes Street
Lakewood, CO 80215

D. L. Vieth, Director (6)
Waste Management Project Office
U.S. Department of Energy
P.O. Box 14100
Las Vegas, NV 89114

D. F. Miller, Director
Office of Public Affairs
U.S. Department of Energy
P.O. Box 14100
Las Vegas, NV 89114

D. A. Nowack (14)
Office of Public Affairs
U.S. Department of Energy
P.O. Box 14100
Las Vegas, NV 89114

B. W. Church, Director
Health Physics Division
U.S. Department of Energy
P.O. Box 14100
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Mail Stop 555
Las Vegas, NV 89114

William W.-L. Lee
Roy F. Weston, Inc.
2301 Research Boulevard
Third Floor
Rockville, Maryland 20850

R. J. Blaney (RW-22)
Program Management Division
Geologic Repository Deployment
U. S. Department of Energy
Washington, DC 20545

P. T. Prestholt
NRC Site Representative
1050 East Flamingo Road
Suite 319
Las Vegas, NV 89109

T. Hay, Executive Assistant
Office of the Governor
State of Nevada
Capitol Complex
Carson City, NV 89710

C. H. Johnson
Nuclear Waste Project Office
State of Nevada
Capitol Complex
Carson City, NV 89710

Abby Johnson
414 West Ninth Street
Carson City, NV 89701

John Fordham
Desert Research Institute
Water Resources Center
P.O. Box 60220
Reno, NV 89506

Dr. Martin Mifflin
Desert Research Institute
Water Resources Center
Suite 201
1500 East Tropicana Avenue
Las Vegas, NV 89109

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