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Characterization of the Low-Level Radioactive Wastes and Waste Packages of General Electric Vallecitos Nuclear Center

Final Report

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**Prepared for
U.S. Nuclear Regulatory
Commission**

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ABSTRACT

An evaluation of the low-level wastes and waste packages generated by General Electric Vallecitos Nuclear Center (GEVNC) was made on the basis of 10 CFR Part 61 criteria and on the Technical Position on Waste Form (TP). In addition, a review has been performed of the handling and storage methods used by GEVNC for their transuranic wastes. Several options have been discussed for management of these materials. This evaluation was the result of a study initiated by the U.S. Nuclear Regulatory Commission (NRC), in which GEVNC participated.

GEVNC generates radioactive wastes in hot cell processes which include examination of reactor fuel and components, and production of sources and radiopharmaceuticals. These wastes are usually Class B or greater. Class A wastes result from support activities which include maintenance of the hot cells. The dominant contaminating radioisotopes are Cs-137 and Co-60. In addition, transuranic wastes result from examination and burnup analyses of fuel. The latter wastes are all currently stored on-site at GEVNC. The low activity Class A, Cs-137 and Co-60 dominated wastes are generally packaged in 55-gallon drums and wooden boxes, while those of higher activity (Class B and greater) are packaged in 84-gallon extended 17H drums that are grouted with cement. The Class A packages meet the requirements in 10 CFR Part 61. The Class B and greater grouted drum packages have been evaluated with respect to meeting the stability requirements in 10 CFR Part 61 and with respect to the guidance in the TP. Based on the evaluation, overall, the waste forms of these packages are expected to maintain their stability, but a few concerns are identified and testing should be performed by GEVNC to demonstrate waste form stability.

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CHARACTERIZATION OF THE LOW-LEVEL RADIOACTIVE WASTES AND WASTE PACKAGES OF GENERAL ELECTRIC VALLECITOS NUCLEAR CENTER

1. INTRODUCTION

The low-level radioactive waste generated by many non-fuel cycle industries and institutions is not as well characterized as that produced by nuclear power plants. As a part of a program to characterize non-fuel cycle waste shipped to commercial shallow land burial, Brookhaven National Laboratory (BNL) has identified, contacted and visited a number of non-fuel cycle waste generators. For selected generators, BNL has performed detailed evaluations of their low-level radioactive waste. These evaluations were performed with respect to 10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste" and included (1) an assessment of the chemical, physical, radiological and biological degradation mechanisms of the waste form and waste container which may affect the ability of the waste package to meet the acceptance criteria for disposal, and (2) the identification of chemical hazards in the waste packages which by themselves or in conjunction with the radiological hazards may affect the behavior of the waste packages and the ability of the site to perform adequately. To date, three such evaluations have been performed. They are evaluations of the Class B waste packages of the New England Nuclear Corporation[1], of the large quantity waste packages of the Union Carbide Corporation[2], and of the wastes and containers of the 3M Corporation[3]. A fourth generator, the General Electric Vallecitos Nuclear Center (GEVNC), is the subject of this study. This study has been conducted in cooperation with GEVNC in order to provide the Nuclear Regulatory Commission with an evaluation of GEVNC low-level wastes with respect to 10 CFR Part 61 criteria as well as the guidelines for Class B and C wastes specified in the Technical Position on Waste Form [Revision 0, May 1983] (TP). The relevant sections of 10 CFR Part 61 used in this study are those on waste classification and waste characteristics. These sections, 61.55 and 61.56, respectively, have been included in Appendix A. The relevant sections of the TP are included as Appendix B. The characterization of transuranic (TRU) wastes generated at GEVNC has been performed and the evaluation of potential waste management strategies for the TRU waste stored at GEVNC was also incorporated into this study.

Radioactive waste is generated at GEVNC during examination of reactor components and fuel and during the production of radiopharmaceuticals and radioactive sources. In an effort to categorize the low-level wastes according to the waste classification scheme set forth in 10 CFR Part 61, a review of the wastes shipped from GEVNC has been performed by surveying selected radioactive shipment records (RSRs) from 1982 and 1983. The results of this survey are summarized in Section 2. In addition, information has been included from a GEVNC report,[4] a letter from GEVNC including a tabular summary of the waste shipments,[5] and telephone conversations with GEVNC personnel. Descriptions of the processes in which the low-level and TRU wastes are

generated and of the containers in which these wastes are packaged for either burial or storage have been written based on information provided by GEVNC. These descriptions are given in Section 3.

There are three parts to the evaluations of the GEVNC low-level waste. First, waste packages are evaluated to determine if they meet the minimum requirements for all wastes to be disposed of by commercial shallow land burial as well as the stability requirements for Class B and C wastes, as appropriate. This evaluation includes a consideration of pertinent degradation mechanisms, consideration of the requirements given in 10 CFR Part 61, as well as of the guidance given in the TP for the demonstration of waste form/package stability. The requirements for each class of waste and the evaluation of the GEVNC wastes in the context of these requirements are given in Section 4. The second part of the low-level waste evaluation was an identification of those components of the GEVNC wastes which are either hazardous or which could affect the performance of the site in which these wastes are buried. As can be seen from the package descriptions and evaluations contained herein, it was felt that no such concerns existed with the GEVNC wastes themselves. The third part of this study involved the evaluation of potential strategies for managing the TRU wastes currently being stored by GEVNC. This assessment was performed to provide the NRC with background information on the types and forms of TRU wastes that are generated in processes at this type of facility. This evaluation is given in Section 5.

The evaluation of the low-level waste packages and the consideration of the TRU wastes have resulted in some concerns and recommendations. These are provided in Section 6.

2. QUANTITIES OF LOW-LEVEL AND TRU WASTES GENERATED AT GEVNC

In order to consider the impact of the then-proposed 10 CFR Part 61 on GEVNC's non-fuel-cycle waste, representatives from GEVNC, NRC, and BNL met in September 1982.[6] It was learned that GEVNC generates waste from three main sources: hot cell activities, liquid waste evaporator operations, and a research reactor (presently shut down). The hot cell activities consisted mainly of examination work on reactor components and fuel, the fabrication of Co-60 and Cf-252 sources, and the manufacture of Xe-133, Cl-36, and C-14 radiopharmaceuticals. The bulk of the waste was from these hot cell activities and the primary waste radioisotopes were Co-60 and Cs-137. In the past, GEVNC has shipped their waste to Beatty, Nevada, but they now ship to Richland, Washington. In addition, GEVNC generates TRU-contaminated waste which is stored on site.

As a result of more recent contacts,[7] GEVNC supplied BNL with the Radioactive Shipment Records (RSRs) for six waste shipments during the period from April through August of 1983 as well as an RSR for a shipment in March 1982. Some of the information from these RSRs is summarized in Table 2.1. There were a total of 62 packages shipped, a total shipping volume of 3629 cubic feet, and a total activity of about 617 Ci. One of the RSRs is reproduced in Appendix C. Most of GEVNC's annual waste activity was attributable to two isotopes, Cs-137 and Co-60, although C-14, Sb-124, and U-235 were also shipped. It was found in review of these RSRs that three packages contained waste for which the specific activity exceeded the Class B limit (according to the classification scheme of 10 CFR Part 61). These packages were all 84-gallon drums shipped in casks. All other packages listed in the RSRs are Class A under current regulations. It should be noted that the selected GEVNC RSRs supplied to BNL did not include all radioactive wastes shipped from GEVNC for the period covered. The RSR review indicates that GEVNC has shipped mainly Class A and Class C (and one greater than Class C) waste packages. In telephone conversations with GEVNC staff, it has been stated that GEVNC does ship some Class B wastes. In any event, all GEVNC Class B or greater wastes have been shipped in one type of container, the 84-gallon 17H drum grouted with cement. The waste streams at GEVNC and the detailed RSR information are discussed more fully in Section 3. A summary of GEVNC radioactive waste shipments from 1980 through 1983 is given in Table 2.2.

GEVNC also supplied BNL with a tabular summary of waste shipment information and with a copy of a report[4] published by GEVNC which included the results of tests performed on higher activity GEVNC waste packages to demonstrate the fulfillment of requirements necessary to apply for a certificate of compliance for these packages. The tabular summary indicated that GEVNC ships wastes in 55-gallon drums, in wooden boxes, and in cement-grouted 84-gallon (11.5-cu. ft.) drums. The 55-gallon drums may be shipped in overpacks while the cement-grouted drums are shipped in the GE Model 1600 shielded shipping container. (A copy of the U.S. NRC Certificate of Compliance No. 9044, Revision 6 is Appendix D.) In general, the tabular summary and the RSRs both indicate that most of the waste volume shipped from GEVNC is Class A (55-gallon drums, wooden boxes, and occasionally, a cement-grouted drum). As

would be expected, the Class B or greater wastes comprise a much smaller fraction of the total volume shipped.

Several maximum activity values for specific grouted drum packages were found. The RSR survey yielded 103 Ci and 16.65 Ci for Co-60 and Cs-137, respectively. The tabular summary indicated values of 189 Ci and 81 Ci for these two isotopes, respectively, while the report published by GEVNC gave activity limit totals of 5000 Ci for aged mixed fission products (assumed to be ~50/50 Cs-137 and Sr-90), and 3000 Ci for Co-60. For the purposes of the waste package evaluations, it is desirable that the activities used for calculations on radiolysis, dose, etc., be conservatively high. The totals from the GEVNC report would be used were they not, for Cs-137 and Sr-90, in excess of the Class C limit for this size container. Hence, for the evaluation in this report, the activity values for the GEVNC grouted drum packages were taken as the upper Class C limit for both Cs-137 and Sr-90 or 1500 and 2300 Ci, respectively, while 3000 Ci was retained as the activity limit for Co-60.

Table 2.1

Summary of the GEVNC Low Level Radioactive Waste Shipments
Information From RSRs Supplied by GEVNC

RSR	Date	No. Packages	Total Volume (cu. ft.)	Total Activity (Ci)	Isotopes	Package Descriptions
0314[a]	3/09/82	10	1144.5	216.05	Cs-137 Co-60 U-235	LSA wood boxes
1097	4/18/83	18	135	2.025	Cs-137 Co-60	55-gallon drums
21618	7/06/83	8	795.5	51.895	Cs-137 Co-60	7 LSA wood boxes 1 cask (Class C)
21615	7/25/83	11	175.5	1.7538	Cs-137 Co-60	2 LSA wood boxes 9 55-gallon drums
21614	7/27/83	7	683.5	186.801	Cs-137 Co-60 Cs-137 Sb-124 C-14	6 LSA wood boxes 1 cask (>Class C)
21608	8/24/83	5	459.5	55.544	Cs-137 Co-60	4 LSA wood boxes 1 cask (Class C)
21619	8/31/83	3	235.5	103.019	Cs-137 Co-60	2 LSA wood boxes 1 cask
		67	3629.0	617.09		

[a]Shipped to Beatty, Nevada, disposal site. All others shipped to Richland, Washington.

Table 2.2[a]

GEVNC Radioactive Waste Shipment Summary for 1980-1983

	1980	1981	1982	1983
Total Volume Shipped (ft^3)	10,400	12,900	6,500	5,900
Total Number of Shipments	12	32	15	19
Activity Total (Ci)	651	1216.4	639.0	1643.2
Co-60	521	1146	515.8	1095.2
Cs-137	130.5	70.2	123.2	405.4
other			3.5 mCi (U-235)	100 Ci (Sb-124) 42.46 Ci (C-14) 127 mCi (U-235)
Total Packages[b]				
Drums (55-gallon)	56	96	108	134
Boxes	90	106	54	44
Casks (11.5 ft^3)	11	11	4	9

[a]Information provided by J. Tenorio of GEVNC in conference call with BNL staff on February 27, 1984.

[b]The vast majority of the waste activity is concentrated in the cask packages. The 55-gallon drums and boxes contain essentially trace amounts.

The Class A waste packages are subject only to the minimum waste characteristic requirements of 10 CFR Part 61 and their evaluation is given in Section 4.1. As stated earlier, those waste packages which are Class B or greater are, for GEVNC wastes, all 84-gallon cement-grouted drums. These are subject to requirements for structural stability in addition to the minimum waste characteristic requirements of 10 CFR Part 61 and they are evaluated in Section 4.2.

An overview of the TRU waste stored at GEVNC has also been provided.* The TRU waste with activity much greater than 100 nCi/g consists of 9 one-gallon "paint cans" containing cement-solidified liquid from burnup analyses of nuclear fuel. The upper bound for the activity in these cans is 3 mCi/g or about 30 Ci per can. The remaining TRU waste, consisting mostly of cellulosics and miscellaneous debris with activities in the range of 80 to 100 nCi/g, is stored in 91 liners with approximate volumes of 1.5 cubic feet (about 2/3 of the liners) or 5.5 cubic feet (about 1/3).

*Information provided by J. Tenorio of GEVNC in conference call with BNL staff on February 27, 1984.

Summary

Most of the volume of wastes shipped by GEVNC is Class A and is packaged in 55-gallon drums, wooden boxes, and occasionally, in a cement-grouted 84-gallon drum. Higher activity wastes, Class B or greater, are shipped only in the cement-grouted 84-gallon drums. Principal contaminating radioisotopes in Class B and greater wastes are Cs-137 and Co-60. For the purposes of the higher activity grouted-drum waste package evaluation in this report, Cs-137 and Sr-90 have been taken as waste contaminants at the Class C activity limit (1500 and 2300 Ci, respectively, for this size container), and Co-60 has been included at 3000 Ci per package. These values are all based on the GEVNC report,[4] which was the most conservative activity estimate available. Prior to the establishment of the regulation waste classification scheme of 10 CFR Part 61, GEVNC shipped at least one package of activity greater than what is now the Class C limit. Such wastes would not generally be acceptable for disposal in a commercial shallow land burial site unless approved by the NRC or by the appropriate licensing authority.

Other radioisotopes in GEVNC wastes, e.g., Xe-133, Cl-36, etc., have been stated to be at quite low activity levels compared to the Cs-137 and Co-60, i.e., these isotopes generally occur in GEVNC Class A waste packages. The C-14 and Sb-124 packages that were found in the RSR survey were one-time shipments and have therefore not been considered as a regular component in the GEVNC waste streams.

TRU wastes which GEVNC has divided into categories of 80-100 nCi/g and >100 nCi/g are all presently stored on site.

3. DESCRIPTION OF RADIOACTIVE WASTE STREAMS AT GEVNC

GEVNC is involved in three main activities from which their radioactive wastes are generated:

(1) hot cell activities which involve examination work on reactor fuel and components, fabrication of Co-60 and Cf-252 sources and manufacture of Xe-133, Cl-36, and C-14 radiopharmaceuticals. The primary waste radioisotopes from these hot cell activities are Co-60 and Cs-137.

(2) operation of a liquid waste evaporator. Liquid wastes from all non-TRU GEVNC radwaste generating operations and outside sources as well are evaporated.

(3) non-TRU operations generating solid wastes at other locations on the GEVNC site, and research reactor work, none of which is being done presently since the reactor is not in operation.

Radwastes from these activities are divided into three waste streams: (i) hot cell wastes, (ii) support activity wastes and (iii) TRU wastes. Hot cell and support activity wastes and their treatment prior to disposal are described in Section 3.1. A detailed discussion of information from GEVNC RSRs for shipments of hot cell and support activity wastes is given in Section 3.2. TRU wastes and treatment are presented in Section 3.3.

3.1 Hot Cell and Support Activity Wastes

3.1.1 General Description of Hot Cell Wastes and Waste Packages

Hot cell processes involve examination work on reactor fuel and components, fabrication of Co-60 and Cf-252 sources and the production of radiopharmeceuticals. Wastes from these operations consist of irradiated metals, glass, and general cell trash. Radioisotopes identified in these wastes include Co-60, Cs-134, and Cs-137. Other radioisotopes are present in trace amounts that are not expected to exceed 1% of the values in Table 1, Column 1 of 10 CFR Part 61, Section 55. These wastes are mainly in solid form. Compactible solid hot cell wastes are placed in one gallon cans and compacted prior to disposal. The liquid waste volume from hot cell activities was estimated to be approximately 30 gal per year. Liquid hot cell wastes are solidified with cement in a 2:1 cement to liquid ratio by volume in one-gallon cans. GEVNC has indicated that, according to the NRC waste classification scheme in 10 CFR Part 61, these hot cell wastes are expected to be Class B or Class C.

The container used for disposal of hot cell wastes consists of 11-1/2-cu. ft. 17H-drum with two inner perforated carbon steel baskets (84-gallon). These baskets have steel angle iron spacers attached to the outer sides and bottom which hold the basket approximately 3/4 inches away from the drum itself. The waste is prevented, by this basket arrangement, from having any direct contact with the drum. Figure 3.1 shows two baskets

filled with simulated (non-radioactive) waste typical of hot cell wastes.[4] There is an open space 1-1/2-in. wide at the top of each drum after the baskets have been inserted. A series of dose rate measurements is made on the waste-filled container. The highest in the series of readings is used in application of a conversion factor to obtain activities. GEVNC has stated this factor is generated by a computer code based on average dose rates and waste configurations (solidified, compacted, etc.). This procedure is discussed in Section 3.1.2.

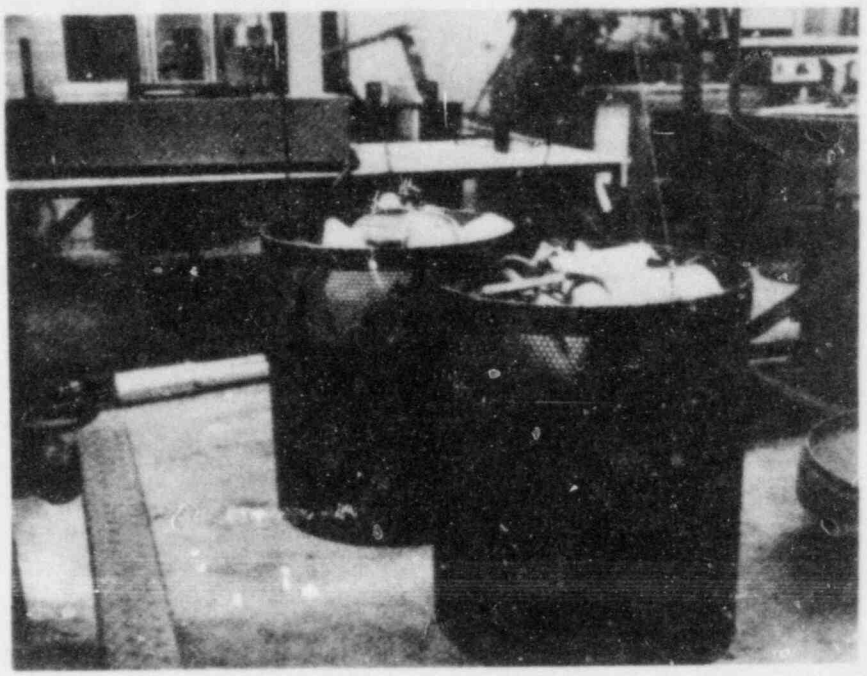

Figure 3.1 Two perforated steel basket liners filled with simulated hot cell wastes.[4]

The hot cell wastes in the basket and drum assembly are then stabilized by a cement grouting treatment. The grout consists of 600-lb Portland cement, 600-lb sand and 30-gal water. Cement is poured from the top into the annulus between the inner basket and the inner drum side. The flow characteristics of the cement are such that it penetrates the openings of the baskets and fills nearly all the void space in and around the waste materials. The drum is vibrated during this cement pouring process to ensure effective grouting. Figure 3.2 shows an 11-1/2 ft^3 drum in a test stand ready for grouting. The vibrator is also shown attached to the drum. The cement is usually allowed to set up for two days. Drums are then checked for free liquid and concrete hardness and each drum is photographed prior to shipment. Figure 3.3 shows the top of a grouted drum of simulated hot cell waste.[4] Following the

grouting process, the drums are closed with a ring-bolt-sealed lid. Another series of dose rate measurements is made subsequent to the grouting for purposes of limiting the radiation exposure of transportation personnel.

Drums containing simulated waste have been given this cement-grouting treatment and then sectioned horizontally and vertically to allow inspection of the concrete-waste matrix.[4] The concrete in these drums could be seen to have thoroughly filled the voids in the container.

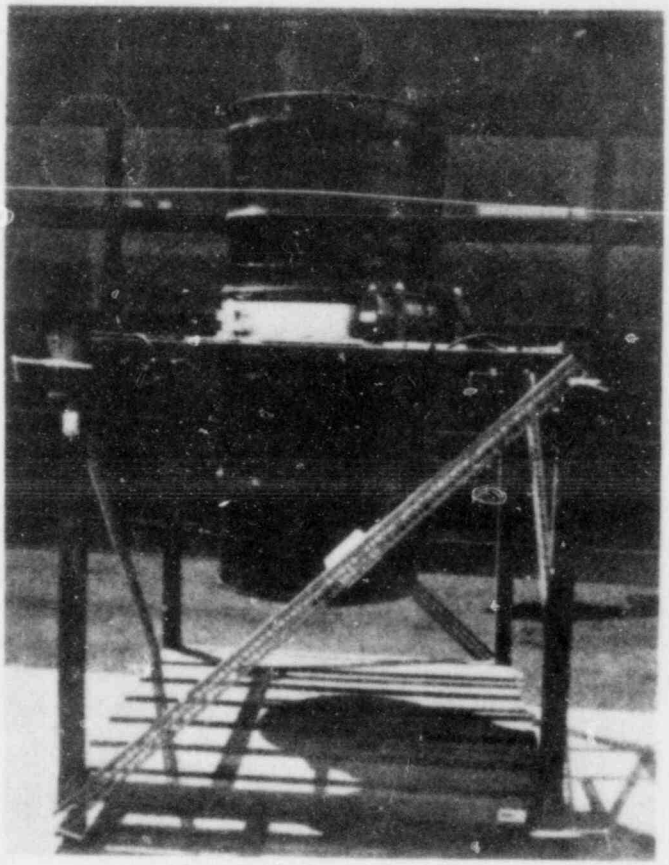

Figure 3.2 Test stand used for test drum grouting. A vibrator, located near the middle of the drum, is used to promote grout penetration.[4]

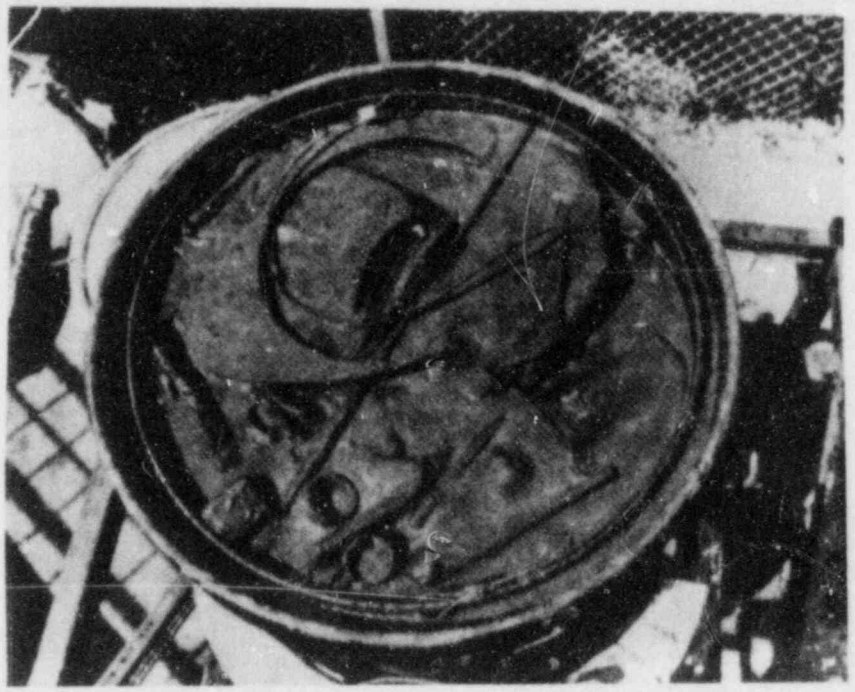

Figure 3.3 Top view of a grouted drum of simulated hot cell waste.

GEVNC provided an estimate of the average composition of one of their higher activity cement-grouted drums. Typical total weights range from 1600 to 2300 lbs of which ~300 lbs is waste. This waste is approximately 40% metal (ferrous, some aluminum, <10% lead), 10% glass and 50% paper and plastic. The plastic is mainly polyethylene, but the tubing is polyvinyl chloride.

3.1.2 Activity Determination for Radioactive Wastes at GEVNC

The activity contained in GEVNC higher activity radioactive waste packages is estimated using dose rate to activity conversion factors generated with the computer code, ISOSHLD[8], combined with actual dose rate measurements for waste packages, and smear measurements from the hot cells. The code was written to perform gamma ray shielding calculations. The input to the code consists of an activity loading and an assumed distribution of this activity in a matrix (e.g., concrete) and in a specified geometric shape (e.g., a cylinder in the case of a drum). The output of the code is a dose rate.

The procedures used by GEVNC to estimate the activity in a waste package may be separated into four steps.

Step 1: The dose rate is measured at various places around a waste package and the highest dose rate is recorded.

Step 2: Smears are taken in the hot cells to determine the fractional contribution of Cs-137 and Co-60 in the activity.

Step 3: The ISOSHLD code was used to generate a dose rate per curie value for a unit Co-60 activity level for each of the waste containers used at GEVNC. The activity content of the waste is estimated by multiplying the measured waste package dose rate by this conversion factor. For ungrouted drums, GEVNC assumes a homogeneous distribution of activity in a matrix with the density of 0.5 g/cm^3. For the grouted drums, GEVNC assumes a homo-geneous distribution of activity in the drum in a concrete matrix of density 2.35 g/cm^3.

Step 4: The smear data is used to partition the activity into Cs-137 and Co-60 fractions. No other isotopes are assumed to be present.

The accuracy of this procedure of determining the activity in a given waste package depends upon the representativeness of dose rate measurement, the accuracy of the ISOSHLD code for the conditions in which it is being used, and the correctness of the Cs-137/Co-60 fractional distribution from the smear measurement. It should be noted that if the Cs is a result of fuel examination, other fission products, particularly Sr-90, may be present in the waste. Depending on the concentration of these other radionuclides, the waste classification may change and some waste could potentially exceed the Class C limit. It is, therefore, recommended that a more detailed characterization of the radionuclide inventory in the waste be performed by GEVNC.

The technical correctness of the ISOSHLD code has been experimentally verified.[8] This was done by testing of the ISOSHLD code output against the measured dose rates for known radionuclide sources. The code yields consistently correct values. The mechanical correctness of the code can not be questioned from the point of view of distinguishing between heterogeneous and homogeneous activity distributions, since the code itself simply converts activities to dose rates for an assumed homogeneous source. In practice, GEVNC uses the highest dose rate measurement from each waste package as the input to the code. This should result in a conservative overestimation of the activity contained in the package. The degree of overestimation cannot be quantitatively stated on the basis of the information available. However, it might be advantageous for GEVNC to determine this since they have shipped wastes of activities calculated to be in excess of the Class C limit. Depending on the magnitude of the overestimation, these wastes may not have been greater than Class C.

The correctness of the partitioning of activity into Cs-137 and Co-60 fractional contributions depends completely upon the correctness of the smear data. GEVNC conducts periodic smear tests of hot cell waste contamination and analyzes the data for the Cs-137/Co-60 ratio. The smear samples are taken from various (essentially random) locations in the non-compartmentalized hot cell area where fuel examination work is done. GEVNC has indicated that

materials in the hot cell make up a general mixture and that, since the work is not partitioned according to different steps in processing, there is no reason to believe that the contamination distributed throughout this hot cell work area is different from that which occurs in waste materials. The ISOSHLD ouput is partitioned according to this smear test ratio such that respective Cs-137 and Co-60 activities can be assigned to the waste drums. On occasion, GEVNC has some wastes that are only Co-60-contaminated, but these batches are said to be well tracked. In general, GEVNC feels that their smear test analyses result in a Cs-137/Co-60 ratio that is indeed representative of that in the waste. GEVNC has not specifically performed an analysis to determine if the ratios obtained from hot cell smears tests are representative of the radioisotope ratios in their waste packages. As mentioned earlier, it is recommended that a more detailed characterization of the radionuclide inventory in the waste be prepared by GEVNC. This could include tests to determine the correlation between the hot cell smears and radionuclide distribution in the waste.

3.1.3 Support Activity Wastes

The second main waste stream at GEVNC includes wastes from what GEVNC terms "support" activities, i.e., waste from maintenance of all GEVNC facilities in which radioactivity is handled. These wastes comprise the largest fraction by volume of GEVNC radioactive wastes. GEVNC estimated that 70% of the ~12,000 cu. ft. radioactive waste annually shipped for burial is low-level waste resulting from these "support" efforts. GEVNC has indicated that all packages of these wastes are Class A. Wastes from "support" activities are divided into two groups: solidified/treated and not solidified. These are discussed in the following sections.

3.1.3.1 Solidified/Treated Support Activity Wastes

These wastes consist of three types: dewatered resins, solidified liquids, and non-compactible items. Resin dewatering is accomplished by passing hot air through a mesh-like bucket containing the resins. This treatment requires about one day. The activity on the resins is occasionally counted, and a representative radioactivity loading is approximately 0.3 µCi of Co-60 per cubic centimeter. Only rarely are resins solidified with cement. Liquids originate from cleanup activities, fuel rod "de-crudding", hot water "leach-outs" from fuel elements, and evaporator bottoms. Generation of liquid wastes outside the hot cells is approximately 100,000 gals per year. Much of this is sent to the waste evaporator from which approximately 100-125, 55-gal drums of waste are generated in a year. All of these wastes are solidified with cement in a 2:1 (by volume) cement-to-liquid ratio. Many of the fuel rod "de-crudding" solutions are acidic and are neutralized prior to solidification. Non-compactible items include equipment components, glass, etc. These items are manually placed in the waste container. All of this category of waste is packaged in 55-gal, 17H drums. There are no mixes of materials in these packages, i.e., one drum would not contain both dewatered resins and solidified liquids or non-compactible items. A typical package of this type weighs between 600 and 700 pounds. All of these drums are lined with 50-mil plastic

liners in which the wastes are placed, RTV* is applied and then the drums are ring-bolt sealed.

Non-aqueous chemicals (such as acetone) are present in GEVNC wastes only in trace amounts since the vast majority of solution processes are performed in aqueous systems. The comment was made that most of the work at GEVNC is non-destructive so there is actually very little "analysis-type" liquid waste.

Low-level liquid waste processing is offered as a service by GEVNC to contracted waste generators in the area. The example was given that liquid wastes have been received from Rancho Seco Nuclear Generating Station. Specific contaminating radionuclides and activities were not given, but it was stated that typical wastes registered a few thousand counts per minute. These wastes are sent to the GEVNC waste evaporator and the evaporator bottoms are then solidified with cement and packaged as are the solidified liquids discussed earlier.

3.1.3.2 Non-Solidified Support Activity Waste

These compactible general lab wastes are Class A, contaminated with Co-60, Cs-134, and Cs-137, and are generally compacted into 112 cu. ft. plywood boxes that meet low specific activity (LSA) packaging requirements. These packages are loaded to minimize void spaces and, on the average, weigh 2000 pounds.

Two other comparatively minor waste types from GEVNC contain Xe-133 and liquid scintillation vials (LSV). The Xe-133 waste arises from repackaging bulk Xe-133 into glass ampules to be used for nuclear medicine. The Xe-133 contaminates vacuum pump oil and this waste is generated at the rate of approximately 25 gal per year. The contaminated oil is solidified with "Envirostone" (U.S. Gypsum Company). This waste is then considered solidified liquid and is packaged in a 50-mil plastic liner in a 55-gal, 17H drum in a manner similar to the solidified liquids discussed earlier. Waste from liquid scintillation vials (LSV) is generated at a very low rate. In two years, enough LSV waste will accumulate to fill a 55-gal drum in an arrangement in which the liquid scintillation vials are placed in layers alternating with diatomaceous earth. The absorbent is, again, present in a volume twice that necessary to absorb the LSV volume.

3.2 Summary of Waste Shipments From GEVNC

The material in this section is based on information contained in a tabular summary and a review of seven RSRs provided by GEVNC. One of the RSRs was dated 3/9/82 while the rest were selected from the period 4/18/83 to 8/31/83. The first is discussed below, while the latter are discussed in the following sections.

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*RTV is a tradename for a sealant that is marketed by the General Electric Company.

The RSR from 1982 listed waste which was shipped to the shallow land burial site (SLB) at Beatty, Nevada. It included LSA wastes consisting of compacted trash shipped in ten boxes of various sizes ranging from 265 ft^3 to 6 ft^3. The two smallest boxes (6 ft^3 and 9.5 ft^3) contained special nuclear material, i.e., U-235. The remainder of the boxes (112 ft^3 minimum size) contained only Cs-137 and Co-60 and were all Class A. The boxes containing U-235 are also Class A. The 9.5-ft^3 box was listed as containing 10 g with a total activity of 3×10^{-4} Ci. The 6-ft^3 box contained 17 g of material; however, the activity level listed on the form was illegible. Since no limit is specified in 10 CFR Section 61.55 for U-235 these two packages may also be considered Class A.

The following discussion summarizes the information gleaned from RSRs selected from a five-month period in 1983 and dealing with shipments to the SLB at Richland, Washington, which is where GEVNC currently ships its wastes.

The majority of waste (by volume) is shipped in 112 ft^3 wooden boxes and consists of compacted trash. There were two instances of 54 ft^3 boxes being used.

The remaining waste is shipped in drums. There are two sizes of drums currently in use; a standard 55-gallon drum, and an extended 17H (x17H) (~84-gallon) drum. In general, the 55-gallon drums are shipped without the addition of a solidification agent; however, in the RSRs examined, there were 2 examples of 55-gallon drums in which cement binder was used. One contained "crud in cement", and the other had liquid solidified in cement. Otherwise, the 55-gallon drums (each 7.5 ft^3 according to the RSRs) contained trash, dewatered resins, or liquids absorbed on diatomaceous earth.

Tables 3.1, 3.2, and 3.3 summarize the information contained in the RSRs. From Table 3.1, it can be seen that 90% (by volume) of the waste is shipped in boxes, 8% in 55-gallon drums, and 2% in the extended 17H drums. With one exception, the only radionuclides listed in the RSRs were Co-60 and Cs-137. (This appears to be a result of the manner in which GEVNC estimates the activity distribution in their waste. See Section 3.1.2.) Table 3.1 lists the numbers, contents, and total activites of boxes and 55-gallon drums.

Higher activity wastes are shipped in x17H drums which, following emplacement of the wastes, are filled with a cement grout. The grouted waste in general consists of metal oxides for the most part, but according to the RSRs, miscellaneous trash, i.e., plastics and paper, as well as resins were also shipped in this manner. Four x17H drums were shipped during the period surveyed. Table 3.3 details the waste characteristics and activity loadings of these higher activity packages. Included is the only package which was listed as containing radionuclides other than Co-60 and Cs-137. The other nuclides were Sb-124 (100 Ci) and C-14 (42.46 Ci) and, as mentioned in Section 2, this shipment was later clarified by GEVNC to be a one-time event.

Table 3.1

Summary of RSRs

	Totals for 1983 (April--August)					
	Boxes		Drums			
			55-gallon		80-gallon	
Total Shipped	Number	Volume (ft^3)	Number	Volume (ft^3)	Number	Volume (ft^3)
2484.5 ft^3	21	2236.0	27	202.5	4	46.0

Table 3.2

Breakdown of Class A Radioactivity Loadings and Waste Contents

Package (No.)	Waste	Radioactivity (Ci)		
		Co-60	Cs-137	Total
Boxes (21)	compacted trash	1.029	0.446	1.475
Drums (15) (55-gallon)	compacted trash	1.183	0.426	1.609
Drums (2) (55-gallon)	dewatered resins	0.036	0.015	0.051
Drums (8) (55-gallon)	liquid/ diatomaceous earth	0.443	0.245	0.688
Drums (2)	crud/liquids (in cement)	0.044	0.018	0.062
Totals		2.735	1.150	3.885

Table 3.3

Summary of the Four Grouted Drums Shipped
(From RSRs Covering 4/83 Throughout 8/83)

Shipment Date	Contents[a]	Co-60 (Ci)	Cs-137 (Ci)	Other (Ci)	Total	Class[b]
7/27/83	metal oxides/ irradiated hardware	31.0	13.3	142.46 (Sb-124, C-14)	186.76	>C
7/6/83	metal/plastic/ resin	36.26	15.54	--	51.8	C
8/31/83	metal oxide	103.0	--	--	103.0	A
8/24/83	metal oxide	38.85	16.65	--	55.5	C

[a]The contents are as listed on the RSRs. There is not complete agreement between the description on the RSRs and that provided by GEVNC as summarized in Section 3.1.
[b]Based on comparison with 10 CFR Part 61 requirements.

3.3 Characterization of GEVNC TRU-Contaminated Waste

3.3.1 Description of the Waste and Amounts

Essentially all the TRU-contaminated waste generated by GEVNC arises from analysis or examination of fuel. Fuel elements are sectioned in a hot cell, using a diamond wheel cutter. Sections through a UO_2 fuel pellet are taken for metallographic examination and a sample roughly 1/2 inch in length is taken for burnup analysis. The Zircaloy cladding is removed mechanically. The sections for metallographic examination are transferred to a metallurgy cell for polishing. The sample for burnup analysis is dissolved in the hot cell to a final volume of 100 mL. A small aliquot of this solution, such as 0.1 mL, is diluted by a factor of 10^4 to make up the solution which is used for the analytical work.

The "hot" liquid solutions produced by dissolving the samples of fuel are estimated to comprise roughly 2/3 of the TRU activity in the waste and this is contained in 5-6% of the volume. The dilute solutions on which the burnup analyses are performed contain only ~0.1% of the activity in the hot liquid waste stream, but make up roughly 2/3 of the total volume. Both types of liquid waste solution (acidic when prepared) are neutralized and then solidified with cement in a volume ratio of 2:1 cement to liquid, in either pint or gallon cans.

The remainder of the waste, approximately one-third of the activity and 1/4 of the volume, consists of solid waste, which is placed in both pint and gallon cans, without encapsulation in cement. The waste contains the cuttings from the fuel sectioning (picked up on wipe papers), the cutting wheels, pieces of Zircaloy cladding, the metallographic polished sections in their plastic mounts, contaminated glassware and other contaminated equipment. Another contribution to this waste comes from the polishing operations. It is made up of particles of fuel and polishing compound which collect in a sump. The sump is cleaned out occasionally and the sludge is solidified in cement. The total volume of this waste is quite small, and the TRU level was estimated by GEVNC to be considerably lower than that in the solidified hot liquid waste.

All TRU wastes are currently stored at GEVNC in their Hillside Storage Facility.

3.3.2 TRU Concentrations

According to GEVNC personnel, the TRU concentration in the solidified waste from the dilute liquid waste stream is in the range of 80-100 nCi/g. This estimate should have been made quite accurately, since TRU concentrations in the solution would be determined during the burnup analysis, and known weights of cement and solution could be mixed to achieve the concentration range stated. If accurately known weights were not always used, of course, TRU concentrations in some cases may exceed 100 nCi/g.

GEVNC personnel gave a figure of 3 mCi/g as an upper bound for the level of TRU activity in any of their waste. This value was for solidified waste from the hot liquid waste stream. The fuel from which the waste originated was stated to be mostly ~3% enriched UO_2, BWR fuel in the burnup range of 5,000-50,000 megawatt days per ton (MWD/Ton), with most of it in the range of 15,000-30,000 MWD/Ton. Since GEVNC had a standard procedure for solidifying its hot solutions, it is assumed that the TRU isotope concentrations in the final cement product were proportional to their concentrations in the corresponding fuel sections, which in turn would be approximately proportional to the burnup. Thus, the TRU concentrations in this waste stream are estimated to be in the range 0.2-3 mCi/g, with most in the range of 1-2 mCi/g, and to average approximately 1.5 mCi/g. The exact values of the "average" or of the individual packages of this waste are not particularly important since they are so much greater (a factor of some 10^4) than the Class C limit.

The solid waste would have considerable variation in its TRU content from container to container, depending on the particular components placed in each container. For example, waste from the metallurgy cell would be very hot if it contained any of the polished fuel pellet sections. Otherwise, it would be much "cooler". GEVNC did not provide information on the TRU content of this waste stream except to state that it was >100 nCi/g. Assuming three sections were taken for metallographic examination when a burnup analysis sample was taken (GEVNC estimate), that the sections were 1/16-in. thick while the analytical sample was 1/2-in. long, and that all three sections went in a

single pint paint can, the TRU concentration of such a can would approach that of the hot solidified burnup analysis solution from the same pellet.

It is probably not useful to try to estimate a range for the TRU content of the solid waste since the variation would be significant and the amounts connected with the lower end of the range would contribute very little to the total TRU content of the waste. However, an average TRU content can be estimated on the basis of the hot liquid waste stream and the relative amounts of fuel going into each stream. Assuming sample and section sizes as given in the last paragraph (1/2 in. and 1/16 in., respectively), three sections for each sample, and 1/64-in. saw cuts, the solid waste would have approximately half the TRU content of the solidified hot liquid waste. This is contained in four times the volume of the latter waste and is associated with a weight estimated by GEVNC (5-6 lb/gal) as 1-1/4 times that of the hot liquid waste stream. Thus, the average concentration of the solid waste stream is estimated to be a factor of 2.5 less than that estimated for the hot liquid waste. These concentrations and other information about the waste streams are given in Table 3.4.

Table 3.4

GEVNC TRU Waste Inventory Information

Waste Stream	Approximate Volume		Liner Volume Fraction	Estimated Annual Production, gal/yr	Estimated TRU Activity, Ci	Activity Fraction	Average TRU Content, nCi/g
	In Paint Cans, Gallons	Storage Liner Volume, ft^3					
Solidified Hot Liquid From Dissolving Fuel Samples	9	1.9	0.06	3	135	0.65	1.5×10^6
Solidified Dilute Solutions From Burnup Analysis	90	22	0.65	30	0.01	$<10^{-4}$	80-100
Solid Waste	38	10	0.29	13	72	0.35	6×10^5

3.3.3 Classification of Waste

Since GEVNC performs no chemical separations on either their hot or dilute solutions, the isotopic ratios in the solidified liquid and in the solid waste are the same for any particular fuel. The enrichment and the usual burnup range quoted for their samples are very similar to those for commercial LWR fuel, so, to a first approximation, isotopic ratios in the GEVNC waste can be considered the same as those for LWR fuel on average. Thus, Sr-90 and Cs-137 activities would be about 40 times TRU α-activity,[9] and far lower than the concentration required to put waste which is Class C by virtue of its TRU content over the Class C limits. However, Pu-241 activities would be about 30 times the TRU α-activity,[9] and this would undoubtedly

put at least some of the GEVNC waste in the 80-100 nCi/g category (in terms of TRU activity) over the Class C limit on the basis of other radionuclides present in the waste given application of the sum of fractions rule in 10 CFR Section 61.55. If the Pu-241:TRU α-activty ratio were, in fact, 30, waste with a TRU content as low as 60 nCi/g would exceed the Class C limit. How much of the GEVNC solidified dilute liquid waste would exceed the limit would depend on specific values of the TRU concentration and the Pu-241:TRU ratio. (The latter apparently has not been determined.) In any event, none of this dilute solidified waste would greatly exceed the Class C limit.

The average TRU concentrations of the solid waste and of the solidified hot liquid waste, as given in Table 3.4, are a factor of about 10^4 higher than the Class C limit. All this waste is thus actual TRU waste, and not TRU-contaminated waste. It should be pointed out that the waste contains non-TRU isotopes in concentrations which are also orders of magnitude greater than the Class C limit. Plutonium-241 concentrations, about 30 times those of the TRU isotopes, are a factor of about 10^4 over the Class C limit. Cesium-137 and Sr-90, whose concentrations are 40 times higher than the TRU concentrations,[9] are present in amounts which exceed the Class C limits by 1 to 2 orders of magnitude.

3.4 Summary

GEVNC wastes consist of three main types:

(1) hot cell process wastes - generally Cs-137 and Co-60 at higher activities and packaged in 84-gallon cement-grouted drums, typically Class B or greater.

(2) support activity wastes - relatively lower activity wastes containing a variety of isotopes, may be packaged in wooden boxes, 55-gallon drums or, on occasion, 84-gallon cement-grouted drums, typically Class A.

(3) TRU-contaminated wastes - two main concentration ranges: 80-100 nCi/gm and >>100 nCi/gm, currently stored at GEVNC. Wastes in the first category are Class C on the basis of TRU content but may exceed the Class C limit on the basis of other isotopes present. Wastes in the second category exceed the Class C limit by orders of magnitude on the basis of TRU, Pu-241, Cs-137, and Sr-90 concentrations.

4. EVALUATION OF GEVNC WASTE PACKAGES WITH RESPECT TO NRC REQUIREMENTS

Low-level radioactive waste must meet the requirements specified in 10 CFR Part 61 if it is to be considered acceptable for shallow land burial. The waste must be classified according to the scheme presented in Section 61.55 of the regulation, and also it must conform to the specifications regarding waste characteristics given in Section 61.56. In this evaluation section, a comparison is made between the requirements for low level waste and characteristics of the waste being shipped from GEVNC to shallow-land burial sites. Information about the GEVNC wastes was obtained from GEVNC during the course of this work, and may not represent radioactive waste which will be shipped from GEVNC in the future.

4.1 Class A Wastes

4.1.1 10 CFR Part 61 Requirements for Class A Wastes

Section 55 of 10 CFR Part 61 gives guidelines for classifying low-level radioactive wastes (LLW) according to the concentration and type of radioactive species present in the LLW. There are three classes: A, B, and C, and these are determined for a particular waste package using the criteria listed in Section 55. The first consideration is whether the package contains any of the long-lived radionuclides listed in Table 1 of Section 61.55. Table 1 also gives limiting concentrations for these radionuclides, and these are reproduced here in Table 4.1, in which the concentration limits for Class A wastes are explicitly presented in units of curies per cubic meter, as well as in units more amenable to comparison with values reported by GEVNC in their radioactive shipment records (RSRs). If more than one of the radionuclides listed in Table 1 is present, then the sum of fractions rule is applied. This rule can be represented as follows:

$$SF = \sum_i \frac{RN_i}{RNL_i}$$

where RN_i = radionuclide concentration in the waste package and, RNL_i = concentration limit for that particular radionuclide from Table 4.1. As long as SF, the sum of the fractions calculated for the different radionuclides, is less than 1.0, the waste is Class A.

If the waste does not contain any of the long-lived radionuclides listed in Table 4.1, then the presence of short-lived radionuclides is considered next. In 10 CFR Part 61, the concentration limits for Classes A, B and C of several radionuclides are listed in Table 2 of Section 61.55. The limits for Class A wastes are reproduced here in Table 4.2. If none of the radionuclides listed in Table 4.2 is present in the waste, it is Class A. If a combination of the short-lived radionuclides is present, the sum of fractions rule must be applied, and the calculated value of SF must not exceed 1.0.

Table 4.1

Concentration Limits of Long-Lived Radionuclides for Class A Wastes[a]

Radionuclide	Concentration Limit			
	Ci/m^3	Ci/ft^3	Ci/55 gal drum[b]	Ci/x17H drum[c]
C-14	0.8	0.023	0.17	0.26
C-14 (IAM)[d]	8.0	0.23	1.7	2.6
Ni-59 (IAM)[d]	22.0	0.62	4.58	7.16
Nb-94 (IAM)[d]	0.02	0.00057	0.0042	0.0065
Tc-99	0.3	0.0085	0.062	0.098
I-129	0.008	0.00023	0.0017	0.0026
TRU ($t_{1/2}$>5 yr)[e]	10[f]	--	--	--
Pu-241	350[f]	--	--	--
Cm-242	2000[f]	--	--	--

[a]Calculated from values given in Table 1, 10 CFR Part 61.
[b]55-gallon = ~7.5 ft^3.
[c]x17H drum = 11.5 ft^3.
[d]IAM = in activated metal.
[e]TRU = α-emitting transuranic nuclides (half-life greater than 5 years).
[f]Units are nanocuries per gram.

Table 4.2

Concentration Limits of Short-Lived Radionuclides for Class A Wastes[a]

Radionuclide	Concentration Limit			
	Ci/m^3	Ci/ft^3	Ci/55 gal drum[b]	Ci/x17H drum[c]
All with $t^{1/2}$ < 5y[d]	700	19.8	145.6	227.9
H-3	40	1.13	8.32	13.0
Co-60	700	19.8	145.6	227.9
Ni-63	3.5	0.099	0.728	1.139
Ni-63 (IAM)[e]	35	0.99	7.28	11.39
Sr-90	0.04	0.0011	0.008	0.013
Cs-137	1	0.028	0.208	0.32

[a]From Table 2 in 10 CFR Section 61.55.
[b]55-gallon = ~7.5 ft^3.
[c]x17H drum = 11.5 ft^3.
[d]i.e., all radionuclides with half-life less than 5 years.
[e]IAM = in activated metal.

If a combination of both long-lived and short-lived radionuclides is present in a waste package, the waste can be labeled Class A provided the limits listed in both Table 1 and Table 2 are not exceeded.

The waste characteristics requirements for Class A wastes are given in 10 CFR Section 61.56. These requirements deal with the chemical and physical nature of the waste package. Section 61.56 specifies that cardboard and fiberboard boxes cannot be used for packaging wastes. Liquids are required to be solidified or packaged in an amount of absorbent sufficient to absorb twice the volume of liquid. In solid wastes containing liquid, the liquid may not exceed one percent of the volume.

Chemical stability with respect to detonation, explosive decomposition, and explosive reaction with water is also required of the wastes. Generation or containment of toxic gases, vapors or fumes which could be harmful to people is disallowed, as well as pyrophoric materials. If pyrophoric materials are present in the waste, these must be processed so as to be nonflammable. Hazardous, biological, pathogenic and infectious materials in wastes must be treated so that the potential hazards from these materials are reduced as much as possible.

Requirements for gaseous radioactive wastes are also prescribed. These must be packaged so that the internal pressure does not exceed 1.5 atmospheres (~7.4 psig) at 20°C, and the total activity is limited to 100 Ci per container.

4.1.2 Evaluation of Class A Waste Shipments From GEVNC

4.1.2.1 Support Activity Waste

As discussed in Section 3, waste from support activities is packaged in 55-gallon drums or wooden boxes while hot-cell waste is packaged in an 84-gallon extended 17H drum which is grouted with cement. GEVNC further subdivides support activity waste into two groups: "stabilized" and "not stabilized." The "stabilized" wastes are solidified with cement and packaged in a 55-gal drum or x17H drum. These wastes can include dewatered resins, noncompactible items, and solidified liquids. "Not stabilized" waste is compacted into 112 ft^3 plywood boxes.

The major radioactive contaminants in support activity and hot-cell waste streams are Co-60 and Cs-137. As mentioned in Section 3, small amounts of Xe-133 in pump oil are generated, and this is packaged in accordance with 10 CFR Part 61 requirements. Other radionuclides may be present in low-level liquid waste processed as a contract service to waste generators in the area. However, specific information is not available regarding which radionuclides and activity levels are present in this portion of the waste streams. Based on information supplied from GEVNC, these wastes are not greater than Class A and, given the absence of more specific information, they are not considered in this evaluation.

The presence of hazardous chemicals, e.g. acetone, appears to be a minor concern, since these are only present in trace amounts.

From the description of the waste streams given in Section 3 and a review of the RSRs provided by GEVNC, it appears that all wastes shipped in wooden boxes or 55-gallon drums meet the minimum Class A requirements with respect to radionuclide levels and waste characteristics. Liquids are either solidified in cement or absorbed on diatomaceous earth, in both cases in a 2:1 ratio to the liquid volume.

4.1.2.2 Hot Cell Wastes

Hot cell wastes in general are packaged in 84-gallon extended 17H grouted drums and shipped in GE model 1600 shipping casks. These wastes contain higher activity levels than support activity wastes and are considered for the most part to be Class B or Class C wastes. However, as mentioned in Section 3, it appears that at least one of this type of package met the radionuclide concentration limits for Class A waste (see Table 3.3). In such a case, this package appears to meet 10 CFR Part 61 minimum waste requirements.

4.2 Class B and Class C Wastes

4.2.1 10 CFR Part 61 Requirements for Class B and Class C Wastes

The method for determining whether waste is Class B or Class C is detailed in Section 61.55 of 10 CFR Part 61. As with Class A wastes, the presence of long-lived radionuclides is the first consideration. Class B wastes may not contain any long-lived radionuclides. If long-lived radionuclides are present in excess of the Class A concentration limits given in Table 4.1, the waste may be considered Class C provided the limits given for this class are not exceeded. These limits are ten times the values given in Table 4.1.

If short-lived radionuclides are present in a waste package, the guidelines based on Table 2 of 10 CFR Part 61 must be followed. The radionuclide limits for Class B and Class C wastes are reproduced here in Table 4.3. If more than one radionuclide of either type, i.e., short- or long-lived, is present, then the sum of fractions rule must be applied as with the Class A wastes.

If the Class C limits of either long-lived or short-lived radionuclides are exceeded, the waste is generally considered not acceptable for shallow land burial.

The general characteristics for Class A wastes discussed earlier also apply to Class B and Class C wastes, i.e., the waste may not contain free liquids (in excess of 1%), pyrophoric or explosive materials, or materials which will generate significant quantities of gas.

Table 4.3

Concentration Limits of Short-Lived Radionuclides for Class B and Class C Wastes[a]

Radionuclide	Concentration Limit							
	Class B				Class C			
	Ci/m^3	Ci/ft^3	Ci/55-gal[b]	Ci/x17H[c]	Ci/m^3	Ci/ft^3	Ci/55-gal[b]	Ci/x17H drum[c]
All with $t_{1/2}$ < 5y[d]	e	--	--	--	e	--	--	--
H-3	e	--	--	--	e	--	--	--
Co-60	e	--	--	--	e	--	--	--
Ni-63	70	1.98	14.5	22.7	700	19.8	145.6	227.8
Ni-63 (IAM)[f]	700	19.8	145.6	227.9	7000	198	1456	2279
Sr-90	150	4.24	31.2	48.8	7000	198	1456	2279
Cs-137	44	1.24	9.15	14.3	4600	130	957	1497

[a]Calculated from Table 2 in 10 CFR Section 61.55.
[b]55-gal = ~7.5 ft^3.
[c]x17H drum = 11.5 ft^3.
[d]i.e., all radionuclides with half lives less than 5 years.
[e]No limits.
[f]IAM = in activated metal.

In addition to the minimum requirements on waste characteristics given in 10 CFR Section 61.56(a), minimum stability requirements are specified in 10 CFR Section 61.56(b). These relate to structural stability, minimization of free liquid content and void spaces in the waste.

Structural stability means that the waste will maintain its form and physical dimensions for a minimum of 300 years under expected disposal conditions, which may include weight of overburden, moisture, microbial activity, radiation effects and chemical changes. Stability can be provided by the waste form itself by processing to a stable form (e.g., by solidification in a binder) or by placing the waste in a container which can provide structural stability. The limits on free liquid are 1% of the volume if a container is used, and 0.5% of the volume if the waste is processed to a stable form. Void spaces in waste packages must be minimized to the greatest extent possible.

4.2.2 Evaluation of Class B and Class C Wastes from GEVNC With Respect to 10 CFR Part 61 Requirements

4.2.2.1 Minimum Requirements

From the description of the support and hot cell activity waste streams and based on the review of the RSRs from GEVNC given in Section 3, it appears that only waste generated in hot cell activities contains sufficient levels of radionuclides to be considered Class B or Class C. Some of these may even meet Class A radionuclide concentration limits (see Section 4.1.2.2).

Table 3.3 lists the packages of this type shipped during the period 4/83 through 8/83. The right-hand column of Table 3.3 indicates the waste

class for each of these according to the specifications given in 10 CFR Part 61. It is apparent that the wastes from hot cell activities may go from Class A to unacceptable (greater than Class C).

It should be noted that the one package which fails to meet the Class C limit does so because it exceeds the concentration limit for C-14. Further information regarding this particular package was obtained from GEVNC, and it was reported that the C-14 contaminated waste consisted of aluminum nitride pellets which had been encapsulated. According to the RSR, the waste was grouted hot cell waste. However, the aluminum nitride pellets were used for the production of C-14, which requires a high neutron flux, such as that in a reactor. Thus, the possibility exists that some waste generated at the GEVNC research reactor prior to its shutdown is still being shipped. At present, C-14 is not a major concern in wastes from hot-cell activities (see Section 3).

All hot-cell wastes are packaged according to the description given in Section 3, i.e., the wastes are placed in metal baskets, the baskets are placed in 84-gallon extended 17H drums, and the drums are filled with a cement grout. Simulated waste packages processed in this manner have been prepared by GEVNC[4]. Sectioning of these simulated packages has made it possible to observe the absence of free liquids and void spaces in the cement matrix. As noted in Section 3, liquid wastes are solidified in paint cans before the cans are placed in the inner metal baskets. Assuming the radioactive waste packages correspond to the simulated ones, it appears that the solidification of hot cell wastes in cement as practiced at GEVNC meets the free-liquid and void-space requirements given in 10 CFR Section 61.56(b) for Class B and Class C wastes. In addition, based on the information provided by GEVNC that any and all hazardous chemicals in these wastes are present in trace amounts, it is concluded that the general requirements in 10 CFR Section 61.56(a) which cover non-radiological hazards are fulfilled also.

The structural stability requirements for Class B and Class C wastes may not be so readily fulfilled, however. In 10 CFR Section 61.56(b) the statement is given that "a structurally stable waste form will generally maintain its physical dimensions and form...." More specific guidelines are listed in the Branch Technical Position on Waste Form (TP), and these are discussed in more detail in Section 4.2.3. Some general considerations of the waste package and its structural stability with respect to 10 CFR Part 61 will be given here. In particular, the issue of maintenance of monolithic form and physical dimensions will be discussed from the viewpoint of potential degradative effects of spalling and cracking of the concrete as a consequence of corrosion of the internal steel components.

4.2.2.2 Structural Stability

The grouted drum package can be treated as having three components. The outermost is the carbon steel drum itself, the second is comprised of the internal perforated mild steel baskets embedded in concrete, and the third is

the waste itself solidified in cement. A discussion of the potential failure modes in which structural stability may be compromised is given in the following sections.

4.2.2.2.1 Carbon Steel Outer Container

The outer container is an 84-gallon 17H carbon steel drum with a ring-bolt seal. Gause, et al.[1] have considered the stability of carbon steel drums in a trench enviroment. As they point out, it is not possible to accurately estimate the drum lifetime at a disposal site from existing data on carbon steel corrosion in soil. They have, however, estimated a time to pitting of from 2.5 to 9.6 years and a container lifetime of from 10 to 120 years depending on soil conditions. Thus, the carbon steel drum is expected to provide stability for only a relatively short time compared to the period over which structural stability is required.

4.2.2.2.2 Perforated Mild Steel Baskets Embedded in Concrete

The perforated mild steel baskets embedded in concrete may be considered analogous to reinforced concrete with an overpack of 0.75 inches. A possible degradative process that could take place in this section of the waste package involves corrosion of the metal followed by spalling of the concrete. The spalling is a result of the pressure generated by the greater volume occupied by metal oxide versus that occupied by the non-corroded metal. It has been found that formation of rust on steel members embedded in concrete is accompanied by a volume increase which can give rise to pressures up to 300 kg/cm^2.[10] This corresponds to ~4300 psi which is in excess of the typical range of compressive strengths for concrete at 28 days curing time.[11] The issues of (1) whether or not such corrosion can be expected to occur and (2) the rate at which it occurs, are discussed in the following sections.

Factors Affecting Corrosion of Steel Embedded in Concrete

Reinforcing steel in concrete is covered by a passivating film which must be penetrated before corrosion of the steel can take place. Chemical factors which strongly influence the depassivation of the film and, consequently, the onset of corrosion include:

(1) chloride ion

(a) the apparent threshold level of chloride at the steel surface in concrete that will cause breakdown of the passive film is between 0.025 and 0.035% chloride by weight of concrete[12,13] for a concrete with a cement factor of 700 lb/yd. GEVNC's cement is ~1500 lb/yd and it has been assumed that this level of chloride is necessary in this case as well.

(b) for corrosion of reinforcing steel to occur in a saturated, aerated $Ca(OH)_2$ solution, the threshold concentration of chloride ranged from 0.02 to 0.03 M.[14,15].

(2) pH

(a) the high pH of concrete is generally the major factor in determining the behavior of steel embedded therein; typical Portland cement concrete pHs are 12 or above. This high pH may be a corrosion-inhibiting factor.

(b) the possibility exists for pH cells to be set up between regions in the concrete, e.g., between the outer surface where contact with water may have lowered the pH and nearer the metal surface where the pH may still be high. This may or may not be a mitigating factor in any given reinforced concrete structure.

It has also been shown that the interaction of pH and chloride influences the threshold chloride levels necessary for the initiation of corrosion, and once such initiation has occurred, the presence of oxygen is critical in supporting corrosion. Of course, the presence of chloride and oxygen at the metal surface depends in part on the permeabiltiy of the concrete. In other words, it is necessary that both initiators and supporters of corrosion diffuse through the concrete before reaching the reinforcing steel.

Conditions Expected in the GEVNC Grouted Drums and at the Hanford Burial Site

The concrete overpack on the metal perforated baskets is 0.75-inches thick, which, were the chemical components necessary for initiation and propagation of corrosion (chloride and oxygen) present in sufficient quantities, would probably not present a significant barrier to these chemicals. Diffusion of chloride ion to a reinforced concrete rebar has been documented to occur in less than one year for concrete 4-in. thick.

The question of whether chloride is present in sufficient quantities to bring about initiation of the steel corrosion has been considered from two points of view:

(1) the viewpoint of outside the package--once breach of the outer carbon steel drum has occurred, the grouted drum will be subjected to exposure to the trench soil environment which includes chloride. and

(2) the viewpoint of inside the package--chlorides in the GEVNC wastes, or chloride present in the grout mixture itself may both be potential sources of corrosion-initiating ion.

The chloride concentrations given earlier as the threshold for corrosion initiation in a $Ca(OH)_2$ solution (0.025 to 0.035 M) have been used for comparison here because it is believed these values are conservatively low. It has been suggested that the amount of chloride needed to cause corrosion in concrete is significantly in excess of that needed in $Ca(OH)_2$ solutions of similar pH due to the presence of a lime-rich layer on the surface of the steel in concrete, which effectively acts as a source of "reserve alkalinity" and thereby increases the chloride ion concentration necessary for passive film breakdown.[16,17]

Hanford soil (as mentioned in Section 2, GEVNC ships their wastes to the Hanford, Washington site) has been found to have chloride present at 1.6×10^{-1} mg-eq per 100 grams of soil.[18] An idea of a possible chloride ion concentration that might contact these wastes at the burial site can be arrived at by assuming 100 mL of water were to contact 100 grams of soil, deplete the soil completely of its chloride content, and then enter the grouted drum concrete monolith. The effective chloride concentration in this 100 mL would be ~0.002 M, or over than an order of magnitude lower than the threshold value of 0.025 M. In addition, even were the chloride present in sufficient quantities in Hanford soils, there is evidence that annual evaporation potential at that site exceeds total precipitation[19] so that water transport of chloride to the waste form should be precluded.

GEVNC believes that chloride concentrations in their wastes are insignificant. Chloride concentrations in the grouting mixture would arise from the chloride present in tap water used to prepare the mixture. A table of results from GEVNC tap water analyses is given (Section 4.2.2.1 and Table 4.4) and shows a maximum chloride value of ~60 mg/L (January 1983). This converts to ~0.002 M chloride concentration in the tap water which, of course, is subsequently diluted further as the water is mixed into the grouting material. It can be seen that this also is below the threshold chloride concentration and, thus, concern about the tap water concentrations exceeding the chloride threshold for corrosion initiation can be eliminated.

Additionally, constituents of concrete, specifically tricalcium aluminate (C_3A), can react with diffusing chloride, thereby reducing "free chloride" available to implement the depassivation step.[20] The amount of C_3A in concrete is dependent on the type of cement and, for normal Portland cement, C_3A constitutes 45% of the cement mix.[21]

In summary, it appears that the initiation of corrosion of the perforated steel basket in the grouted drum package may not occur due to insufficient chloride ion concentration. Were depassiviation of the embedded metal to occur, the possibility of continuation of the corrosion to the extent

necessary to bring about spalling is dependent on the presence of sufficient oxygen and water. Oxygen should be present in sufficient amounts unless conditions of the burial trench were to become anoxic (this is expected to be unlikely at Hanford), but water is expected to be extremely scarce at the Hanford site.

Rates of Corrosion of Steel in Concrete

General information available on the rates of corrosion of steel in concrete is given here for completeness. Growth of Fe_3O_4 on steel as a function of time and of the permeability of the concrete is given in work by Tuuti.[22] Corrosion of reinforced steel to the extent that failure of the concrete cover occurred has been studied in salt water solutions for natural[23] and impressed voltage situations.[24] The times to failure were ~345 and 7-8 days, respectively. Steel, embedded in concrete and stored on the ocean floor for fifteen years as part of a low level radioactive waste package, was found to have corroded, but not to a sufficient extent that spalling of the concrete occurred.[25] This may have been due to the fact that in seawater environments, a reaction can occur at outer surfaces of the concrete, and in the pores, whereby $Mg(OH)_2$ is precipitated within the pores due to its decreased solubility product over $Ca(OH)_2$. This evidently leads to a decreased permeability, and thus diffusion rate, in concrete immersed in seawater.[26] Additionally, the level of oxygen on the ocean floor is significantly lower than at the surface and this lack of oxygen also may lower the steel corrosion rate.

Summary

The structural stability of the grouted drum monolith is subject to compromise should spalling of the concrete occur as a consequence of corrosion of the embedded steel perforated baskets. This corrosion must be initiated and propagated. Conditions for this to occur depend on several chemical constituents; particularly chloride ion, oxygen, and water. It is anticipated that insufficient chloride is present both at the waste package burial site (Hanford) and in the package itself for initiation of the corrosion of the steel to occur. Spalling of the concrete overpack due to corrosion of the perforated baskets is thus not expected at the Hanford site.

4.2.2.2.3 Wastes in Concrete

The third component of the waste package is comprised of the waste itself solidified in cement. The waste can consist of paint cans containing solidified liquids, compacted paint cans containing compactible solid items, and miscellaneous solid items such as plastic and rubber tubing, metal pieces, paper, other plastics, etc. This inner level of the waste package may be considered analogous to reinforced concrete due to the presence of metallic items, or it might also be treated as an analogue to a concrete mix containing a rather unique aggregate. This latter consideration may be the more significant with regard to the long-term structural stability of the inner component waste form.

In general, the properties of concretes are dependent on a number of variables. Among these are relative proportions of cement, aggregate, and water, the type of cement, type of aggregate, gradation of aggregate particles, and distribution of aggregate particles within the cement matrix.[27,28] Aggregates used in concretes are generally of a mineral type, with a gradation of sizes from fine to coarse (usually no greater than 3 inches in the largest dimension).[28] Chemical characteristics of the aggregate, particularly at the surface, influence the strength and durability of the concrete mix as a result of cement-aggregate surface interactions.

The GEVNC wastes which are packaged in the extended 17H drum obviously constitute an inhomogeneous mixture of items. Extremely limited information is available on the properties, i.e., strength and durability, of cement forms containing cellulosics, plastics, and metals other than steels and aluminum. Some concerns that should be addressed are:

(1) the influence of size, geometry, and distribution of the waste items on the waste form properties;

(2) whether, given the inhomogeneity of the waste stream, there is a limiting waste/cement binder ratio as has been found with other waste streams, e.g., ion-exchange resins;[29]

(3) whether chemical reactions between cement and the different waste materials can occur, and whether these could compromise the overall integrity of the waste form.

These points have been raised to indicate that an evaluation of the stability of the waste is not possible given the information currently available. Stability and monolithic form are provided initially by the outer carbon steel drum and perforated metal basket. After the cement grout has set, the outer drum need not be considered since stability can be provided by the waste form itself. A major question then appears to be whether the basket embedded in cement can provide the required stability as discussed earlier, since it is not clear that the different types of waste encapsulated in cement matrix provide stability in the absence of the metal basket.

The requirement for structural stability has been addressed in terms of the different components of this package.

(1) The carbon steel outer drum is expected to corrode totally within 120 years after burial. It cannot be relied upon to supply structural stability for the required period.

(2) The perforated metal baskets embedded in concrete can be considered analogous to reinforced concrete and, as such, are expected to be able to

supply structural stability for a significant time. A principal failure mode, spalling of the concrete due to pressures generated through the rusting of the embedded steel, has been considered and determined to be unlikely given the absence of sufficient chloride to initiate the corrosion process. If some other chemical(s) capable of initiating the corrosion of the baskets were present, the probability of causing spalling is quite low due to the scarcity of water, which is needed in the corrosion process.

(3) The component made up of the waste items themselves embedded in concrete is difficult to evaluate with respect to structural stability. Since many of the waste items are steel, this component could also be considered similar to reinforced concrete and, hence, also subject to spalling but, it is believed that this can be ruled out on the same basis as in (2). However, the heterogeneity of the concrete/waste item matrix may be the limiting factor in its ability to provide structural stability. Normal monolithic concrete forms with conventional size aggregate are expected to provide stability, but the behavior of concrete in which there are randomly-distributed, heterogeneous objects of sizes quite in excess of the concrete aggregate particle size cannot, at this time, be predicted.

4.2.3 Evaluation of GEVNC Class B and C Wastes With Respect to the Guidance in the Technical Position on Waste Form

The evaluation of the GEVNC extended 17H cement-grouted drum waste packages with respect to the guidelines of the Technical Position on Waste Form follows. Each of the guidelines has been considered individually, and where it has occurred that there is overlap of factors being considered, reference to the pertinent section(s) has been made. It should be noted that, for the purposes of evaluation of the GEVNC waste packages themselves, two guidelines from the TP do not directly apply (process control program and sample testing size). These are, however, included for completeness.

Given the expectation that the carbon steel outer drum used for the GEVNC Class B and C grouted drum packages will not last beyond 120 years after burial, the waste form has been taken as the concrete-waste monolith that fills the carbon steel drum, including the perforated baskets and the wastes themselves. For the purposes of several calculations involved in the evaluation, the isotopes present in the package have been considered sequentially at conservatively high (Class C limit) values of Cs-137, Sr-90, and Co-60. The values used have been based on statements made in a GEVNC report[4] to the effect that a grouted drum package may contain 5000 Ci of aged mixed

fission products or 3000 Ci of Co-60 (See Section 2). Given that a reasonable activity distribution for aged mixed fission products is 50/50 Cs-137 and Sr-90, the 5000 Ci was halved to derive the individual isotope activities, but this proved to be in excess of the Class C limits. Therefore, Class C limits were taken for Cs-137 (1500 Ci) and Sr-90 (2300 Ci) for this size package, and for Co-60, GEVNC's estimate of 3000 Ci was used.

4.2.3.1 Process Control Program

The TP states that radioactive waste generators should implement and maintain a process control program to demonstrate periodically that the solidification system is functioning properly and waste products continue to meet the 10 CFR Part 61 stability requirements. Waste specimens should be prepared such that they are representative of the waste streams to be solidified.

The GEVNC waste streams that result in those wastes that are packaged in tne cement-grouted extended 17H drum are the hot cell process wastes and the "support" (principally, clean-up and maintenance) wastes. In general, the hot cell process would be classified as Class B or greater (and hence, are required to have stability) while the "support" wastes usually are disposed of in packages with activities in the Class A range. As was discussed earlier, no GEVNC wastes of activity high enough to exceed Class A limits are disposed of in regular 55-gallon drums or wooden crates.

The handling of radioactive wastes at GEVNC is subject to quite specific guidelines in the form of written instructions. However, it is not clear that these instructions constitute a full process control program including explicitly stated directions and weight/volume ranges for the materials used in the cement grout mixture. It is known that GEVNC uses a set grout mixture which consists of 600 lbs of Portland cement, 600 lbs of sand and 30 gallons of water (tap water - sample analysis is given in Table 4.4) per batch.[5] The amount of variation that can be tolerated in these values has been detailed in the GEVNC Radioactive Products and Services Operating Procedure, but it is not clear that the mix itself has been thoroughly characterized with regard to its use in a Class B or greater waste package.

The process for packaging of GEVNC Class B and greater wastes involves (1) placement of waste items in the two steel perforated baskets, (2) placement of the baskets in the extended 17H drum, (3) introduction of the cement grout mixture, (4) vibration of the drum during (3) to ensure effective dispersal of the grouting material throughout the waste package, (5) setting and hardening of the grout, (6) inspection of the waste for free water, (7) testing of the grout for hardness, (8) photographing of the waste package, and (9) placement and ring bolting (clamp ring) of the drum lid. A simulated grouted drum package has been tested for its ability to inhibit dispersal of the waste materials. During this testing, a sample package was subjected to a 30-ft. drop which resulted in crumbling of one corner and a "single fracture across the diameter."[4] (It is presumed that this crack represented the plane between the two perforated steel baskets.) Additionally, the grouted

cylinder containing simulated wastes was cut into four sections for examination of the degree of grout penetration. The grout was found to have penetrated practically every space in the matrix.[4]

Table 4.4

GEVNC Tap Water Analysis (1983)

	Influent Nonradioactive Constituents (mg/L)						
	Chlorides	Chromium	Copper	Lead	Mercury	Zinc	pH
January	59.4	0.002	<0.0001a	0.005	0.0001	0.005	7.2
February	<0.5	0.003	0.0029	0.01	0.0006	0.008	8.25
March	b	0.008	0.0035	0.0006	0.0002	0.038	b
April	2.0	0.005	0.0031	0.003	0.0002	0.010	7.9
May	3.0	0.001	0.0026	0.013	<0.0001	0.035	8.15
June	3.2	0.0038	0.0046	0.0004	0.0004	0.0117	7.85
July	4.0	0.001	0.0029	0.002	0.0002	0.006	8.75
August	5.4	0.008	<0.0001	0.01	0.0004	0.046	7.4
September	2.35	0.01	0.0012	0.012	0.0003	0.011	7.3
October	2.0	0.013	<0.0001	0.034	0.00015	0.016	9.6
November	2.0	0.001	0.0001	0.01	0.0007	0.05	9.3
December	3.5	<0.005	<0.0017	<0.001	<0.0001	<0.01	8.9

[a] < indicates less than the detection limit for the measurement method.
[b] Lost sample.

Summary

At GEVNC there are explicitly written handling instructions, but it is not clear that there is a full process control program. GEVNC has established procedures to ensure a uniform cement grout is obtained. It has not been demonstrated that these procedures will ensure compliance with the recommendations given in the TP. Ideally, the process control program implemented by the generator would be one such that the end-process waste packages were consistently structured according to a design that produced a package/waste form with the required stability.

4.2.3.2 Compressive Strength

The TP states that solidified waste specimens should have compressive strengths of at least 50 psi when tested in accordance with ASTM C39. Concretes of varying compositions[11] are expected to have compressive strengths of 2650 to 4000 psi at 28 days. Typically, the GEVNC grouted drum concrete is allowed to set for two days prior to hardness testing and it is

not known whether 28 days elapse prior to shipping of these packages to the burial site. It is expected, however, that concrete alone would have a compressive strength of at least 50 psi. The GEVNC grouted drum package has one potentially significant influencing factor, namely, the presence of "non-concrete" waste materials in the concrete monolith. The waste materials themselves (as outlined in Section 3) may be metal, paper, glass, or plastics which have been placed in metal paint cans and compacted prior to grouting. These items may or may not represent locations of potential cracking or non-adhesion of the grout such that there may be failure upon compression. Such questions can only be answered by actual testing of representative waste forms and, as mentioned earlier, performance of such testing is planned by GEVNC.

4.2.3.3 Radiation Stability

The TP states that waste form specimens should remain stable after being exposed in a radiation field equivalent to the maximum level of exposure expected from the proposed wastes to be solidified. Specimens should be exposed to a minimum of 10^8 rad and specimens should have a minimum compressive strength of 50 psi following irradiation.

GEVNC has indicated that "aging" tests have been performed on cement cylinders in which the grout mixture has been duplicated. Apparently, no metal, glass or plastic waste items were present in the test samples. The cylinders were exposed to a dose of 10^8 rad and no breakdown was observed. Thus, it may be expected that the grouting mixture is stable to this radiation dose. However, two important factors must be considered before it can be concluded that the GEVNC grouted drum waste packages are expected to have radiation stability:

(1) The maximum accumulated doses which GEVNC wastes may experience are on the order of 10^9 rad and thus, the effects of this dose on a representative waste form must be tested, and

(2) the presence of waste items, particularly of paper and plastics, may influence the behavior of the grouted waste cylinder in a radiation field because the radiolysis products of these materials have the potential to be degradative.

Activity loadings and expected accumulated doses at 300 years based on these loadings which may occur in the GEVNC grouted drum packages are given in Table 4.5. The procedure and assumptions made for the dose calculations are discussed below.

Table 4.5

Radionuclide Activities and Accumulated Doses for GEVNC Grouted Drum Waste Packages

Radionuclide	Upper[a] Activity Limit (Ci)	Waste[b] Shipment Summary Limit (Ci)	Upper[c] Class C Activity Limit (Ci)	β^d $D_{(300\ yr)}$ (rad)	γ^d $D_{(300\ yr)}$ (rad)	total[d] $D_{(300\ yr)}$ (rad)	β^e $D_{(300\ yr)}$ (rad)	γ^e $D_{(300\ yr)}$ (rad)	total[e] $D_{(300\ yr)}$ (rad)
Aged HFP taken as 50/50	5000	none given	----						
Cs-137	2500	81	1500	1.2×10^9	1.54×10^9	2.7×10^9	7.2×10^8	9.2×10^8	1.6×10^9
Sr-90	2500	none given	2300	1.1×10^9	none	1.1×10^9	1.0×10^9	none	1.0×10^9
Co-60	3000	189	not specifically set	1.2×10^8	1.25×10^9	1.4×10^9	1.2×10^8	1.25×10^9	1.4×10^9

[a]Values from GEVNC Report Reference 4.
[b]Values from Waste Shipment Summary, Attachment to Reference 5.
[c]10 CFR Part 61 Values extended to 84-gallon container.
[d]Calculated for activity values from (a).
[e]Calculated for activity values from (c).

Radiation Dose Calculations(30)

The equation used for the beta dose calculation is

$$D_i^{\beta}(300\ yr) = \left[\frac{A\ C_i\ \bar{E}_i \times 8.76 \times 10^3\ h\cdot yr^{-1}}{\lambda_i}\right](1 - e^{-\lambda_i t})$$

where

A is a proportionality constant equal to 2.1×10^3 rad·cm^3 MeV-mCi·cm^{-3}.

C_i is the activity density of the ith radionuclide in the waste form in mCi·cm^{-3}.

$\bar{E}_i$ is average beta energy of the ith radionuclide in MeV.

λ_i is the decay constant for the ith radionuclide in yr^{-1}.

t is the time period of interest (for these calculations, 300 yrs).

Pertinent values for all of these parameters for the radionuclides concerned are given in Table 4.6. Substitution of the parameters given in Table 4.6 and of appropriate values of C_i (given in Table 4.7) for the corresponding activity limits, yields the total accumulated beta dose for 300 years. The waste activity has been assumed to be homogeneously distributed throughout the container.

Table 4.6

Dose Calculation Parameter Values for
Principal GEVNC Waste Radionuclides

Radionuclide	λ (yr^{-1})	$t_{1/2}$ (yr)	E_i (MeV)	Γ_i ($rad \cdot cm^2 h^{-1} mCi^{-1}$)
Co-60	0.132	5.25	0.094	12.8
Sr-90	0.025	28	0.200	no γ
Cs-137	0.023	30	0.195	3.3

Table 4.7

Activity Densities for the
GEVNC Waste Radionuclides

Radionuclide	C_i[a] (mCi/cm^3)	C_i[b] (mCi/cm^3)
Cs-137	7.7	4.6
Sr-90	7.7	7.1
Co-60	9.2	9.2

[a]Based on values in Reference 1.
[b]Based on values in 10 CFR Part 61.

The equation used for the gamma dose calculation is

$$D_i^{\gamma}(300\ yr) = \frac{C_i \Gamma_i g \times 8.76 \times 10^3\ h \cdot yr^{-1}}{\lambda_i} (1 - e^{-\lambda_i t})$$

where

C_i has the same meaning as before (see Table 4.7)

Γ_i is the gamma dose constant for the ith radionuclide (see Table 4.6)

g is the geometry factor for the particular three-dimensional structure under consideration, conservatively taken as 160 cm[31] for the 84-gallon extended 17H drum used at GEVNC.

λ_i is the decay constant for the ith radionuclide.

Tissue equivalency has been assumed. Substitution of the appropriate values from Tables 4.6 and 4.7 yields the 300-year accumulated gamma dose for the particular radionuclides considered (given in Table 4.5).

Radiation Exposure Tests

As can be seen in Table 4.5, the total accumulated dose for each of the radionuclides individually exceeds 10^9 rad. In general, if the Class C limit activities of these radionuclides are expected to be present, the minimum radiation testing accumulated dose should be at least 10^9 rad.

Radiolysis Effects

The radiation exposure experienced by the waste materials in the GEVNC grouted drum package may lead to several gaseous and liquid radiolysis products. The effect of the radiation dose on the metal and glass waste components is expected to be minimal, but the effects on paper (cellulosic) and plastic materials may be significant and is discussed in the following sections.

Radiolysis of Cellulosic Components of GEVNC Grouted Drum Packages

As mentioned in Section 3, the average composition of a GEVNC grouted drum package includes ~50% by weight paper and plastic. Given ~300 lbs of waste per grouted drum, this represents ~150 lbs or 68 kg of paper and plastic. For the purposes of the radiolysis calculations to be performed here, it is assumed that the paper and plastic component of the waste is divided 50/50 into paper (cellulosics) and plastics. Additionally, this material has been taken to have a density of 1 g/cm^3 and the accumulated doses corresponding to radionuclide loadings at the Class C limit have been used.

Gaseous Radiolysis Products

Radiolysis of the cellulosic component of these wastes is expected to result in hydrogen, carbon dioxide and carbon monoxide gas production. The amounts expected have been calculated based on the G value (total gas) of 0.63 molecule/100 eV,[32] and on the total accumulated radiation dose (γ and β) for a package containing only Cs-137 at the Class C limit (~2 x 10^9 rad). The total doses expected for packages with Sr-90 or Co-60 alone or, in combination with Cs-137 such that unity is not exceeded on application of the sum of fractions rule for Class C wastes, are all on the order of 1-3 x 10^9 rad.

Given the total accumulated γ and β dose of 2 x 10^9 rad, it is expected that ~9 moles or ~200 L(STP) of gas would be generated by radiolysis over the 300-year period. Given the porosity of concrete, and the lack of a gas-tight seal on this package, this gas production is expected to be of little consequence. There is, however, one conern as discussed below.

Should any water be present in the vicinity of CO_2 production by radiolysis, a solution of carbonic acid in a localized region could result. Carbonic acid has been shown to enhance the corrosion of rebars in reinforced concrete.[33] Thus, it may be expected that the corrosion of ferrous metal waste items in the vicinity of cellulosic waste items all placed in the grouted drum package could be aggravated as a consequence of penetration of the concrete by water. However, the extremely high pH of concrete makes this unlikely.

Liquid Radiolysis Products

It has been found[34] that radiolysis of cellulosics may also lead to the production of carboxylic acid group-containing molecules. The G-value for this is 3.6 molecules/100 eV and the major acids produced are: formic (G = 2.3, 64%), glucuronic, 2-ketohexanoic, and 3 unspecified "5-ketohexanoic or uronic acids."[34] There is a potential for acceleration of metal waste component corrosion by these components.

It has been assumed that the G-value of 3.6 applies to both γ and β radiation exposure. The accumulated dose of 2×10^9 rad should yield a total of ~50 moles of organic acids, of which ~30 moles would be formic acid. This organic acid production may be of significance in regard to acceleration of the corrosion of metal waste components and, consequently, potential acceleration of cracking/spalling of the concrete waste form. Formic acid (anhydrous or 10-85% solution) in contact with carbon steel leads to corrosion >50 mils penetration/year.[35] Since it is possible that cellulosic wastes may be in direct contact with metal wastes (i.e., not physically in contact with concrete and, hence not necessarily neutralized by the high pH-producing hydroxide in the concrete) in the grouted drum package, this corrosion effect of the organic acids produced by radiolysis, and particularly of the formic acid, has the potential to be degradative. The quantitative effect of low-molecular-weight organic acids on concrete does not seem to have been documented. Acids such as acetic, citric, malic, and lactic, but not oxalic, have been found to attack concrete, often having "a marked action" within a few months to a year.[27] When compared to acetic acid in its effect on concrete, formic acid has been described as corroding concrete more slowly.[36] On the other hand, it has also been described as being more destructive.[27] There is thus no consensus on the possibility of significant damage to the concrete grout as a result of attack by organic acids produced in the radiolysis of the cellulosics in these wastes. The presence of water is not clearly indicated as a necessity for these destructive interactions to occur.

Radiolysis of Plastics Component of GEVNC Grouted Drum Packages

The plastics fraction of these wastes (taken as 50% of the paper and plastic component, ~68 kg average per drum) would be expected to generate gas, predominantly hydrogen, in a radiation field.[2] The gaseous products expected to be produced at the total γ and β accumulated dose (2×10^9 rad) based on the G-value for polyethylene [3.7 molecules per 100 eV absorbed[37]] should amount to approximately 10^3 L of gas (STP).

As mentioned earlier, the porosity of the concrete in this package and the lack of a gas-tight seal on the outer drum should allow escape of this radiolytically-produced gas.

Summary

The radiation stability of the GEVNC grouted waste packages is predicated on the stability in a radiation field of each of the waste package components: concrete, metal and glass, and paper and plastics. The grouting mix concrete has been tested by GEVNC in a radiation field to 10^8 rad with no signs of degradation evident. The higher activity loadings that these packages may contain, however make testing at higher ($\sim 10^9$ rad) doses necessary. In addition, the effects of the radiation field on the waste components themselves must be considered. The cellulosics component of these wastes may result in production of up to 200 L (STP) of gas (H_2, CO_2, and CO) and ~50 moles of organic acids. The plastics component may result in production of up to 10^3 L(STP) of gas (predominantly hydrogen). The gases are expected to escape the waste package. The presence of CO_2 gas and water (should it be present) may lead to carbonation and, if neutralization by the hydroxide in the concrete is incomplete, consequently, to accelerated corrosion of the ferrous metal components of the package (and, subsequent to this corrosion to cracking/spalling of the concrete). The organic acids produced through radiolysis of the cellulosics may be destructive in contact with either the concrete or carbon steel waste components or both.

4.2.3.4 Biodegradation Effects

The TP states that specimens for each proposed waste stream formulation should be tested for resistance to biodegradation. GEVNC has indicated that biodegradation testing is planned for the grouted drum waste form, but at this time, no information on this testing is available.

Biodegradation of the GEVNC concrete-grouted package materials has been considered from two points of view (1) outside the container, i.e., in the trench soil environment, and (2) inside the container, i.e., in the wastes themselves. In neither case is biodegradation expected to be a primary problem, i.e., direct biodegradation of the concrete and carbon steel is not expected since neither material supplies a carbon source. In addition, the high pH of concrete precludes most microbe growth. From both viewpoints, however, biodegradation by-products may be of concern with respect to corrosion of the container. A discussion of the complexity of the composition and behavior of a system of microorganisms which may exist either in the soil or in the wastes and also of the different chemicals they may consume or produce has been given in Gause et al.[2] For the case at hand, it should be noted that:

(1) from the point of view of the soil environment, the consideration of corrosion of the container from outside (see Section 4.1) has been based on published measured corrosion rates for

metals in soils which contained microorganisms (i.e., not sterilized) and thus the effect of microbial activity on corrosion is reflected in this soil corrosion data.

and

(2) from the point of view of biodegradation of the wastes, there is the potential for self-sterilization within the first year for wastes at contamination levels at the upper Class C limit.

The consideration of sterilization of the wastes by radiation from waste radioisotopes must include several factors as summarized below.

(1) Sterilization has been shown to occur at accumulated doses up to 5×10^6 rad (that necessary for sterilization of sporulating bacteria);[38] the dose rate effect has not yet been totally established.

(2) At dose rates greater than 10^4 rad/h, it appears that the sterilization effect is independent of the dose rate,[38] and the exact lower bound on dose rate has not been determined.

(3) For the Class C limit Cs-137 activity considered for the GEVNC grouted drum packages the initial dose rates (β^- and γ) are in excess of 10^3 rad/h. These dose rates will decrease exponentially at a rate dependent on the radionuclide decay constant.

Since the lower limit for sterilization to have dose rate independence is not known, it is possible that those packages which produce a dose rate within an order of magnitude of the known 10^4 rad/h upper threshold may also effectively sterilize the wastes once the necessary accumulated dose has been reached.

For the upper Class C activity limit GEVNC grouted drum waste packages, biodegradation may not occur until

(1) The radiation dose rate has fallen below the "threshold" of 10^3 rad/h and

(2) the waste package has been re-inoculated with microbes from outside the package.

The intervals over which the waste package may experience the 10^3 rad/h or greater dose rates are given for the particular waste isotopes in Table 4.8.

Both the γ and β^- dose contributions have been included in these calculations. Inclusion of the β^- dose implies the assumption that the β^- emitting activity and the microbes are homogeneously distributed throughout the wastes. For each of these radionuclides (Co-60, Cs-137, and Sr-90) at the activities given in the table, the necessary accumulated doses for self-sterilization are reached within the first year. To be specific, at a dose

rate of 10^3 rad/h, 5000 hours or 210 days are needed to reach the necessary accumulated dose[38] of 5×10^6 rad (self-sterilization). Thus, as long as the dose rate remains at 10^3 rad/h or greater, a self-sterilization may require 210 days. This is important in reference to the potential inoculation of the waste form from outside following breach of the outer carbon steel drum used in the GEVNC grouted drum package. As was mentioned earlier, the estimated period to first pitting of carbon steel drums in a trench environment has been given as 2.5 to 9.6 years and drum lifetime estimates range from 10 to 120 years depending on the soil conditions.[1] Once the package is buried, there is expected pitting and eventual total corrosion of the outer drum within the time period from 2.5 to 120 years. Essentially, the drums with activities given earlier will initially be self-sterilized until first pitting and then, even given the possibility of influx of water and the introduction of any microbes that may be present therein, the packages should remain sterilizing (this is assuming, of course, virtually total containment of the activity in the waste form, which for Cs-137 contaminated packages, may be questionable given the high diffusivity of this isotope in many concretes) until 23, 44, and 64 years have elapsed for Co-60, Sr-90, and Cs-137 packages, respectively.

Table 4.8

GEVNC Grouted Drum Upper Class C Activity Dose Rate

Radionuclide/Activity Loading (Ci)	Interval With Dose Rate $>10^3$ rad/h (yr)
Co-60/3000[a]	23
Sr-90/2300[b]	44
Cs-137/1500[b]	64

[a]Activity given in Reference 3.
[b]Upper Class C limit values.

In general, self-sterilized packages should experience minimal effects from biodegradation. Following the interval during which the waste radionuclide activities are high enough to render the packages sterile, however, the wastes may be subject to inoculation from outside. There could thus be a replenishment of the microogranism population responsible for biodegradation. For the GEVNC grouted drum packages, the microorganisms may metabolize the cellulosics and, possibly, the plastic portions of the wastes. The by-products of this metabolism could potentially degrade the concrete and/or the metal components of the waste form and thereby lead to failure.

Several uncertainties exist which preclude the assignment of quantitative degradative effects of biodegradation. These include:

(1) when inoculation from outside the package will occur,

(2) likelihood that microorganisms, even should they enter the package once it is no longer capable of self-sterilization, will find, in addition to a location immune from the extremely alkaline pH of the concrete grout, a sufficient carbon source and other necessary growth-sustaining conditions.

(3) the degree to which the rates of biodegradation are dependent on the particular types of microorganisms, the ambient gas conditions (anaerobic vs aerobic), the amount of water present, the type and amounts of nutrients present, etc.

Summary

GEVNC grouted packages may be capable of self-sterilization at least initially, depending on the radionuclides and activities. It is expected that the high pH of the concrete will inhibit microbial growth, but a description of the effects of biodegradation cannot be quantitatively given.

4.2.2.5 Leach Testing

The TP states that leach testing should be performed for a minimum of 90 days in accordance with the procedure in ANS 16.1.[39] Specimen sizes should be consistent with the samples prepared for the compressive tests (Section 4.2.2.2). Leaching tests should be carried out in a variety of leachants besides demineralized water; specifically, it is preferred that synthesized seawater leachant be used. The leachability index[39] should be greater than 6.

GEVNC has indicated that leach testing on the grouted drum waste forms is planned but no data is yet available.

The establishment of the leach testing procedure to be used on the GEVNC grouted drum waste form should include consideration of three factors:

(1) The heterogeneity of both the waste compositions and sizes in the GEVNC wastes will probably make it difficult to ensure that the leach test samples (and all test samples, for that matter) are indeed representative of typical hot cell process waste forms.

(2) Each particular grout mixture has characteristic radionuclide retention characteristics which makes testing necessary unless the grout mixture exactly duplicates that of a previously tested solidification medium. Example published Cs-137 leach rates for various cement mixtures are:

(a) 2×10^{-2} - 12×10^{-2} g/cm^2·day for Cs-137 contaminated liquid wastes in a cement waste form with a 3:4 solution: cement ratio and 7.5% bentonite clay added.(40)

(b) 10^{-2} - 10^{-3} g/cm^2 day for Cs-137 in wastes cemented with ordinary Portland cement.(41)

(c) 10^{-7} g/cm^2·day for Cs-137 in hydrofracture grout* made of cement: fly ash: Attapulgite-150: Grundite in a 2.5: 2.5: 1.0: 0.5 ratio.(42)

A process control program could address this issue. Length of curing time has also been found to affect the leach rates, particularly at initial stages.

(3) The presence of waste items that are relatively large with respect to the components of the solidification medium may change the aggregate character of the concrete, for example, the adhesion interface between waste item and concrete may be affected such that crevices or channels develop between the two phases. Such inhomogeneities may signficantly influence leach test results.

Aside from these issues, the physical distribution of the waste radionuclide activity in the grouted form may be expected to influence the amounts of material released in the leaching tests. For the GEVNC hot cell process wastes, the radionuclide contamination is in and on the solid waste components themselves and not homogeneously distributed throughout the cement grout mixture during its preparation. The guidance in the Technical Position that waste forms should have a leachability index greater than 6 is presumably directed toward monoliths containing uniformly distributed activity. The application of this guidance to a non-homogeneous waste form may be based on the assumption that the regulatory purpose is limitation of radionuclide releases from wastes. It should be determinable which waste form has better radionuclide retention characteristics through comparison of the leach test results for two different waste forms, one with a homogeneous activity distribution and a leachability index greater than 6, and the other heterogenous (or, containing concentrated point sources) and not having a known or even specifically-defined leachability index.

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*Portland cement Type I. Fly ash (a pozzolanic material) obtained from the coal-fired Kingston Steam Plant, Kingston, TN. Attapulgite-150 is the trade name of a clay product from the polygorskite group of clay minerals (with the general formula $5\ MgO \cdot 8SiO_2 \cdot 9H_2O$). Grundite is the trade name of a clay product from the illite group of clay minerals [with the general formula $(OH)_4\ K_x(Al_4 \cdot Fe_4 \cdot Mg_4 \cdot Mg_6)\ (Si_{8-x} \cdot Al_x)\ O_{20}$] from Grundy County, Illinois.

An idea of the expected form of the leach test results for the two types of waste forms just mentioned may be obtained through consideration of the following discussion.

The assumptions pertaining to the leaching conditions are:

(1) the leaching is diffusion-limited and hence, the transport of material is driven by the concentration gradient,

(2) there is essentially infinite leaching solution available and/or the concentration of the diffusing substance in the leaching solution is zero, and

(3) the radionuclide activity initially exists as point sources in the heterogeneous package.

The heterogeneous waste form, with its point sources of activity, will tend toward homogeneity. Each of the sources of activity will be initially surrounded by a region in which the radionuclide concentration is much less. Thus, due to this concentration gradient, activity will diffuse radially away from the source. Given sufficient time the activity will distribute itself throughout the form. In time, release can occur from portions of the forms that did not initially contain the radioisotopes of interest. Modeling the release from such a form is dependent upon the particular activity distribution in a given package and may not be possible in a generic sense. Hence, leach testing of this form is required.

It should be noted that there is a potential for the release observed from such a leach test to be initially low due to the initial depletion of activity in the surface of the form. It is important that leach test results which may, at first glance, appear more favorable for the heterogeneous waste form not be misinterpreted such that the waste stabilization medium is credited with the better radionuclide retention abilities. The leach test results may be simply reflecting the "induction" period for this type of activity distribution.

A more pragmatic approach to the question of the leaching behavior of the GEVNC grouted drum package leads to the two statements:

(1) The fluidity of the GEVNC grouting mixture and the existence of smearable contamination on the waste items will lead to spread (homogenization) of the radionuclide activity throughout the package during the grouting procedure, and

(2) that activity which is not dispersed by the grout (i.e., not smearable) will likely remain as a fairly intact point source (e.g., activated metal) and, in any case, probably be rather slow to leach.

Summary

Leach testing should be performed on representative samples of the GEVNC grouted drum packages. The tests must be thoroughly and rigorously designed and the results of such tests must be carefully interpreted to ensure that the true behavior of the wastes and grouting material is understood. It is not clear that the heterogeneity of the GEVNC grouted drum monolith will lead to increased cumulative radionuclide release through leaching as compared with a homogeneously distributed waste form.

4.2.3.6 Immersion Testing

The TP recommends that waste specimens should maintain a minimum compressive strength of 50 psi as tested using ASTM C39 or ASTM 1074, following immersion for a minimum period of 90 days.

The immersion testing of the GEVNC grouted waste forms is planned but has not yet been completed. The actual behavior of these forms under such conditions cannot be predicted but the observations may be made that:

(1) the presence of water may influence the corrosion of the metallic waste items (either directly or in conjunction with corrosive products of radiolysis discussed in Section 4.2.2.3) and, consequently enhance the spalling/cracking of the concrete (reinforced concrete samples immersed in aqueous chloride solutions have been found, depending on conditions, to spall or crack after periods of from 7-8 days[24] to 345 days[23]), and

(2) water may cause swelling of the waste cellulosics and some of the waste plastics as well. This may lead to cracking and crumbling of the waste form. Incorporation of waste items of sizes much different from the cement components may affect the strength/integrity of the concrete.

4.2.3.7 Thermal Degradation

Degradation of concrete with changes in temperature is caused by several factors.[27,43] These include the breakdown of the concrete structure due to the different thermal expansion coefficients of various constituents embedded in the concrete, from stresses caused by temperature differences between the surface and interior parts of concrete structures during temperature changes and from freeze-thaw cycling when water is present in concrete. By far, the most damaging conditions occur when concrete saturated with water undergoes repeated freezing and thawing. Dry concrete per se is not affected by frost. Procedures used by GEVNC to grout their radwaste drums are designed to ensure that no free water remains in the grouted drums.[4]

In general, temperature changes cause stresses to develop in concrete due to differences in thermal expansion coefficients between the binder and bound solids. The binder in the GEVNC grouted waste is cement mortar composed of a 1:1 mix (by weight) of Portland cement and sand. The bound solids include metal articles, compacted 1-gallon cans, glass and other hot cell trash (cellulosics, etc.) placed in the perforated steel baskets. The thermal expansion coefficient of mortar is typically 8-10 x 10^{-6} per ^{o}F[27,43] (i.e., 14-18 x 10^{-6} per ^{o}C). While for carbon steel it is approximately 11 x 10^{-6} per ^{o}C, for glass about 8-10 x 10^{-6} per ^{o}C, for rubber about 80-110 x 10^{-6} per ^{o}C, for lead about 27 x 10^{-6} per ^{o}C, and for stainless steel it is approximately 17-20 x 10^{-6} per ^{o}C.[44] Steel reinforcement of concrete is a common practice and materials with thermal expansion coefficients similar to that of steel would presumably cause no problems due to thermal cycling. Thus, glass and stainless steel should not be affected by thermal cycling, but lead might cause some problems for "large" temperature expansions. (It is not known how large a temperature change would be required before expansion of a piece of lead would significantly damage the surrounding mortar.) No quantitative estimates of tolerable temperature variations as thermal expansion coefficients for concretes have been found. Generally, differential thermal expansion of aggregate in concrete is not considered to be a major concern.[43] Solid rubber objects might cause some degradation of the surrounding mortar upon thermal cycling due to rubber's relatively large thermal expansion coefficient. However, it seems doubtful that tubing or hollow rubber objects would cause a problem.

Thermal stresses may also arise from temperature differences between the interior and the surface of concrete structures. The largest stresses occur for large, rapid temperature changes. Stresses are intially incorporated into concrete from the heat generated by the setting of the wet cement. For normal Portland cement structures not over a few feet in thickness, the heat generated by setting is dissipated rapidly enough that excessive temperature differences between the inner and outer portions of the structure do not occur. Therefore, it is not expected that large stresses will be incorporated into the GEVNC grouted drum, which is a relatively small structure and whose internal volume is largely occupied by waste, from the heat generated by the setting mortar. External temperature changes, which cause differential temperature effects through a concrete structure have been said to be important in some climates.[28] Differential temperature effects were considered to be of concern in concrete paving slabs.[28,45] Curbing stresses caused by temperature differences between the upper and lower surfaces of a concrete slab result in cracking when slabs are made too long between expansion joints. The separation between expansion joints tolerable for reinforced concrete slabs was found to be 35-80 ft compared to 15-20 for plain concrete.[28] It may follow that the reinforced structure of the GEVNC grouted waste, which is primarily attributable to the concrete/steel basket layer, should help protect the waste form from cracking and degradation due to temperature gradients from environmental temperatures changes.

Summary

It is not expected that thermal effects would compromise the stability of the grouted drum waste. In particular, the reinforcement of the grouted drum provided by the steel baskets, which contain the waste, should help stabilize the waste form against degradation due to thermal cycling. However, thermal cycling testing of representative waste forms should be performed.

4.2.3.8 Free Liquid

The TP states that waste specimens should have less than 0.5 percent by volume of the waste specimen as free liquid as measured using the method described in ANS 55.1. Free liquid should have a pH between 4 and 11.

GEVNC has indicated that grouted drum packages are checked for free liquid prior to closure of the ring-bolt lid. The method used by GEVNC is believed to be a visual inspection such as that in Section 4.2 of ANS 55.1. The check described in Section 4.3 of ANS 55.1 that involves breach of the container by drilling and then observation of the opening for flowing or dripping of free liquid from the breach has not been carried out. The test described in Section 4.4 of ANS 55.1 involving sectioning of the waste container contents has been completed by GEVNC for a simulated waste package and has indicated total penetration of the grout and no free liquid. In general, GEVNC solidifies waste solutions prior to emplacement in the grouted drum package. Thus, free liquids, should they exist in this package, would be expected to result from excess water used in the grout mixture.

Summary

The GEVNC simulated grouted drum waste form has been found to contain no free liquids by visual inspection and observation following sectioning of the waste form (Sections 4.2 and 4.4 of ANS 55.1). The test involving breach of the container by drilling and subsequent checking for draining of fluids (Section 4.3 of ANS 55.1) has not yet been performed.

4.2.3.9 Testing Sample Size

The TP indicates that if small, simulated laboratory size specimens are used for the testing recommended in the Technical Position, test data from sections or cores of the anticipated full-scale products should be obtained to correlate the characteristics of full-size products with those of simulated laboratory size specimens.

As was discussed in the section on leach testing (Section 4.2.2.5), the production of representative samples other than full-scale may be difficult for the case of GEVNC grouted drum packages. The presence of the various waste items in their different sizes, degrees, locations of contamination (smearable, integral to the material, e.g., activated metals, etc.), and compositions (glass, metal, paper) leads one to believe that the local behavior

of different areas in the form may strongly depend on the type of waste items present. A consequence of this observation is that it may become difficult to justify the representativeness of small-scale sample size waste form specimens.

Summary

Testing of the GEVNC grouted drum waste form must be carefully planned to include assurance that samples are indeed representative. It is likely that full-scale sample testing may be required since sampling of a heterogeneous waste form is naturally subject to question with respect to representation of "typical" waste forms.

4.2.3.10 Homogeneity of Compressive Strength

The TP states that waste samples from full-scale specimens should be destructively analyzed to ensure that the product produced is homogeneous to the extent that all regions in the product can be expected to have compressive strengths of at least 50 psi.

Testing of this type has not yet been performed by GEVNC. As was mentioned in earlier sections (4.2.2.2, -5 and -6) the cement grout itself would be expected to have a uniform compressive strength of at least 50 psi but the grout/waste item combination may have properties that differ significantly from those of the grout alone. Glass and metal waste components would probably have sufficient compressive strengths, but the compressive strengths of plastic and cellulosic wastes in the concrete matrix cannot easily be predicted.

Summary

The testing to determine whether the grouted drum waste form has sufficient homogeneous compressive strength should be performed by GEVNC. Aside from the difficulties of setting a representative test specimen size, there may be problems in determining the necessary scale on which the destructive testing recommended here should be performed (i.e., should waste items themselves be destructively analyzed?) Testing to show that sufficient aggregation and adhesion of the concrete grout occurs in the vicinity of the different types of waste items may make possible assurance that the waste form has the necessary uniform compressive strength (given that individual waste items such as paper and plastic do not compromise this property).

Section Summary

The guidance given in the TP has been considered as it pertains to the GEVNC grouted drum waste package, and concerns and information gaps have been identified. In most instances, concerns can be addressed through testing and this is recommended in several cases. GEVNC has very detailed waste handling procedures, but it is not clear that they have a process control program in which specific instructions, complete with limits of error and value

ranges, etc. are given. Compressive strength testing should be performed on representative waste forms. The radiation stability of these waste forms needs to be tested at 10^9 rad for wastes with the highest Class C activities of contaminating radioisotopes. Radiolytic production of gases is not expected to be a problem since gases should escape the package. There is a concern about the effect of carbonic and organic acids which may result from radiolysis of the wastes. Biodegradation by-products may be able to affect the waste form stability but quantitative discussion of effects is not possible since several information gaps exist. Self-sterilization may occur in some of the higher activity packages; this could extend the time during which the package is not subject to biodegradation. Biodegradation testing should be performed. Leach testing should be performed on represenatative samples of these waste forms. It is not clear that the heterogeneity of the GEVNC waste form activity will lead to increased cumulative radionuclide releases compared to those from a homogeneously distributed waste form. Thermal degradation of the waste form is not anticipated but thermal cycling testing should be performed. Free liquid testing should be completed. The establishment of representative testing samples may require significant justification but this needs to be done before recommended testing can be performed. Homogeneity of compressive strength throughout the waste form should be tested as well.

5. TRU WASTE

At present, GEVNC stores all TRU-contaminated waste with a level of TRU isotopes >10 nCi/g. According to 10 CFR Part 61, wastes with a level between 10 and 100 nCi/g could be disposed of as Class C low-level waste, provided that any other nuclides listed in Tables 1 and 2 of 10 CFR 61 which might be present were not in concentrations such that Class C limits were exceeded. Those wastes containing such other radionuclides in excess of the Class C limits or having TRU isotopes present at levels >100 nCi/g, would be considered "not generally acceptable" for shallow land burial, under Section 61.55 of 10 CFR Part 61.

Section 61.58 allows for authorization by NRC of other provisions for waste exceeding the Class C limits, providing the Commission finds reasonable assurance of compliance with the performance objectives given in Subpart C of 10 CFR Part 61 (Sections 61.40 through 61.44). Section 61.7 (b) (5), recognizing that there may be instances where waste with concentrations greater than permittted for Class C would be acceptable for near-surface disposal "with special processing or design," provides for evaluation of such waste on a case-by-case basis. It is under these sections, then, that the GEVNC waste containing >100 nCi/g of TRU isotopes would have to be considered by NRC for near-surface disposal.

DOE has recently begun programs[45-49] to develop a concept for treating wastes with radioactivity levels greater than the Class C limit. The concept is known as greater confinement disposal (GCD), and includes such alternatives as improved waste form, deeper burial, and underground engineered barriers. These alternatives address the need expressed in Section 61.7 for special processing or design to enable waste to be considered by NRC on a case-by-case basis. So far as is known, however, there is as yet no move to provide GCD facilities at any of the commercial LLW burial sites, and no proposed rules regarding GCD have been issued by NRC.

This section of the report, then, reviews methods proposed in the literature for treating TRU wastes, and discusses their applicability to GEVNC's stored waste. In Section 5.1, alternatives relevant to near-surface disposal are considered. Specifically, waste forms potentially suitable for TRU waste are discussed in Section 5.1.1, and decontamination methods useful for treating TRU waste are described in Section 5.1.2. Section 5.1.3 discusses the options for dealing with combustible organic waste. GCD options are considered in Section 5.2. In Section 5.3, possible alternatives for handling GEVNC's specific waste streams are discussed.

5.1 Near-Surface Disposal

For standard shallow land burial of waste exceeding Class C limits, NRC may allow other provisions for the waste classification, but it is clear from Section 61.7 (b) (5) that the waste should be accepted for near-surface disposal only after special treatment -- "with special processing or design." Alternatively, wastes could be treated to reduce the TRU levels to either Class C or Class A, and be disposed of as standard LLW. However in the

process, a secondary TRU waste stream of potentially higher concentrations would be produced and would have to be disposed of. Possible alternative waste forms and special treatments are discussed below in Section 5.1.1 and 5.1.2.

It should be pointed out that the container is relatively unimportant for TRU waste, since no container can be expected to last more than a small fraction of the hazardous lifetime of the long-lived TRU activity. This applies not only to regular containers, but also to HICs, both those presently licensed and any that are likely to be. Thus, HICs probably should not be considered as an option for near-surface disposal of TRU waste in forms which are thought to be unsuitable for use in regular containers, since they will probably not provide adequate long-term containment of TRU activity.

5.1.1 Waste Form Considerations

DOE work on waste form development for immobilization of TRU waste was discontinued in 1981. Waste forms developed up to that time were evaluated for NRC in a BNL report on alternative technologies for geologic disposal of TRU wastes.[46] The waste form evaluation included comparisons of ease of preparation, ability to incorporate reasonable loadings of a wide variety of TRU wastes, physical and chemical durability, radiation stability, and leachability. This last was treated as the single most important property, and the report assessed the different waste forms on the basis of their ability to pass the 10^{-5}/yr release rate criterion required of the waste in a high-level waste (HLW) geologic repository. This was a conservative approach, since it was the repository as a whole which had to meet that criterion. Thus if a waste form could meet it, whatever the other engineered barriers and the geology could add would be a bonus. The emphasis on waste form rather than engineered barriers and geology is particularly apt for near-surface disposal since the container is not a factor in the case of TRU waste, there is very little in the way of engineered barriers, and the geological pathway to the surface is short.

5.1.1.1 Forms Involving Conventional and Relatively Simple Processing

Much of the earlier work on waste forms specifically applied to TRU waste was based on rather simple concepts. These generally involved mixing solid TRU waste, such as incinerator ash, dried sludge, scrap metal or used filters, in a steel drum with a liquid or slurry and letting the mixture set. The principal binder or encapsulants were bitumen, urea formaldehyde resin, and ordinary hydraulic cement.

In the NUREG/CR-2333 evaluation,[50] waste forms prepared with bitumen and urea formaldehyde were considered unacceptable for use in a geologic repository because of gas production from radiolysis and biodegradation. The same would apply to vinyl ester-styrene polymer, which was not considered in NUREG/CR-2333 because it had not been used as a TRU waste form. Gas generation may not be a problem for shallow land burial, and these organic forms may be considered capable of providing sufficient stability for Class C

wastes. However, in view of the adverse effects of radiolysis and biodegradation over the long term (i.e., periods >> 300 years), it is doubtful if any organic waste form could be relied on to provide the very long-term performance required for waste with concentrations of the long-lived TRU isotopes exceeding Class C limits. Use of urea formaldehyde, in any case, has been discontinued as a waste form because of production of excessive amounts of free standing liquid, expressly forbidden by Section 61.56 of 10 CFR Part 61.

In NUREG/CR-2333, ordinary cast concretes or hydraulic cements were considered to have excellent leachability with respect to Pu loss, but generation of gas (particularly hydrogen) due to radiolysis of pore water was considered a weakness. For this reason, it was recommended that further work on cement as a TRU waste form for repository emplacement be restricted to specially prepared concretes with essentially no unbound water. Experimental work with some of these special concretes had shown acceptably low levels of gas generation in a number of tests before the programs were discontinued.

In fact, gas generation from concrete appears not to be a serious problem for shallow land burial, at least under circumstances which can be readily envisaged. In that case ordinary cast concrete might be a suitable TRU waste form if TRU leach rates were deemed low enough to meet the performance objectives of Section 61.41. This would, of course, have to be demonstrated with the particular formulation of concrete to be used, but is is worth noting that one formulation containing actual TRU waste has demonstrated a release rate of $<10^{-5}$ yr.[51] Aside from SYNROC, which was primarily a HLW form, it was the only waste form reviewed in NUREG/CR-2333 which was judged to have met that release rate criterion.

5.1.1.2 More Advanced Ceramic and Mineral Phase Waste Forms

Several waste forms were reviewed in NUREG/CR-2333, which required considerably more advanced technology than simply mixing waste and binder at or near ambient temperature. These included iron-enriched synthetic basalt (at one time the reference form for immobilization of DOE's stored TRU waste at INEL), borosilicate glasses, specially prepared concretes and cementitious forms, synthetic monazite, and SYNROC. This last form had been developed for use with HLW, but testing (including leach testing) had been done with samples containing TRU isotopes in concentrations comparable to those found in actual TRU waste. Borosilicate glass was, of course, being considered for the reference HLW form, however certain formulations were developed specifically for application to TRU waste streams.

It was concluded in NUREG/CR-2333 that the more advanced forms generally had not undergone sufficient testing, particularly leach testing, to demonstrate suitability as forms for immobilizing TRU waste in geologic repositories. However, certain SYNROC formulations apparently met the release rate and other criteria applied in NUREG/CR-2333, even though it had been developed as a high level waste form.

While the more advanced forms developed specifically for TRU waste were judged as not completely demonstrated for geologic disposal, it is possible they could be considered suitable for shallow land burial of reasonable amounts of TRU waste. Certainly SYNROC is in that category since it appears to be acceptable for geologic disposal. They are all generally quite stable with respect to thermal degradation, biodegradation and to expected amounts of radiation, and can assuredly be described as having received "special processing or design," as required by Section 61.7 (b) (5) for case-by-case evaluation by NRC. In fact, the fault of most of them may be that they require too much "special processing" in their preparation, and might, therefore, be considered too expensive.

5.1.2 Decontamination Processes

One possible alternative has been mentioned (Section 5.1) of treating a TRU waste stream exceeding Class C limits by reducing or removing surface contamination so that the waste can be treated as Class A, or at least Class C. At the same time, the removed TRU contaminant gives rise to a secondary waste stream. Although this requires disposal, it will be in a much more compact form than the original and one which should be easier to treat.

Decontamination processes are generally designed for use with metals. Some can be applied to ceramics, and even to rubber and plastics, but such applications are limited. Methods developed up to 1981 were reviewed in NUREG/CR-2333. Since that time, the only DOE-sponsored work connected with TRU isotope contaminants has been carried out under the Civilian Nuclear Waste Treatment Program. Relevant processes from these sources are described in the following sections.

5.1.2.1 Electrolytic Methods

These are applicable only to contaminated metals. The general method of operation in electrolytic decontamination is to remove the contamination along with a surface layer of metal. This layer is removed by passing an electric current through a suitable electrolyte in a cell in which the piece to be decontaminated is the anode. Depending on the choice of electrolyte and the current-voltage conditions, the metal can be relatively uniformly dissolved and the surface left in either a highly polished state or in a somewhat roughened condition. Strong acids, usually H_3PO_4, alone or in combination, are used to achieve a highly polished surface, and the process is called electropolishing. In terms of contamination removal, it can be considered as one type of electrodecontamination. Another type, producing a roughened surface, uses mildly basic strong salt solution as the electrolyte.

A great deal of research and development work has been done on these electrolytic methods, both in the U. S. and in other countries, and the technology is in a well-developed state. Decontamination to well below the 10 nCi/g level is routinely achievable, so that the decontaminated metals is Class A low-level waste. However, at the time of the NUREG/CR-2333 review, satisfactory treatment of the secondary TRU waste stream from electropolishing

had not been demonstrated. TRU isotopes in basic electrolyte precipitate as hydroxides along with the dissolved metal being decontaminated, and can be easily filtered to provide a small volume of secondary TRU waste. Since there has been no DOE effort in electrolytic methods since that time, the basic electrolyte must be considered the more attractive from the strictly waste management point of view.

An electrolytic method developed in the U.K., which does not involve removal of metal from the contaminated surface was described in NUREG/CR-2333. This was called electro-cleaning, and involved removal of surface contamination by microbubbles of electrolytically generated gas, with no metal dissolution. To the extent this method was applicable to a given waste stream, it would be preferred over use of either of the dissolution processes, since it would give an even smaller secondary TRU waste stream. The current status of development of the electro-cleaning method is not known.

5.1.2.2 Vibratory Finishing

Vibratory finishing is an industrial process used for surface finishing of both small and large metal pieces. Its first waste management application was to pretreat metal surfaces for subsequent electropolishing. It was shown to have general applicability, removing scale, rust, grease, paint, and organic films of all kinds. In the process it was found to remove most of the TRU contamination, and was therefore developed as a decontamination method in its own right. Early work used ceramic cutting media, but this contributed relatively large proportions of both ceramic and metal particles to the secondary waste stream. By the time of the review carried out in NUREG/CR-2333, metal media were used almost exclusively, particularly case-hardened carbon steel and stainless steel ball cones, which have the substantial advantage of producing no secondary waste due to media wear.

The process is carried out in a liquid, commonly 10% NaOH solution, from which the secondary waste can be easily filtered. The method is applicable to rubber and plastic as well as metal (unlike electrolytic methods), and experience has been that the presence of rubber and plastic pieces facilitates processing of metal pieces. Decontamination to <10 nCi/g has usually been obtained. Recently in the Civilian Nuclear Waste Treatment Program, the vibratory finishing process has been applied to decontamination of Zircaloy cladding hulls with similar good results.(52)

5.1.2.3 Chemical Decontamination

Removal of radioactive contamination from solid surfaces by treating with various chemical solutions is standard practice at U.S. and foreign nuclear installations, particularly as applied to decommissioning operations and cleaning contaminated equipment. Some procedures have been developed for use with TRU-contaminated equipment, but the principles are the same regardless of the nature of the radioactive contaminant. In general, the aim is to remove only the oxide layer from a contaminated metal surface, with the expectation that any contamination would have been held in the oxide layer and would be removed along with it.

In some instances, contamination might penetrate deeper than the oxide layer and a layer of metal might have to be removed in order to remove the contamination. Electrolytic methods could remove a surface layer of metal, but removal is not uniform with irregular shaped pieces. A method developed by HEDL[53] for treating Pu-contaminated stainless steel used strong nitric acid solutions containing 0.1 M Ce(IV) at somewhat elevated temperatures (approximately 90°C). While the process was very effective in removing Pu contamination, it employed rather aggressive conditions and produced a secondary waste stream requiring considerable treatment prior to disposal.

The milder treatments which do not remove metal have the advantage that they are simple to use, since application of the cleaning solutions and collection of the contaminants do not require highly specialized equipment. The method can be applied to "washing" of large structures and pieces of equipment, or to immersion of smaller pieces. Good results with cleaning Pu glove boxes and cell liners after 12 years of service were demonstrated at SRL[54], and their process could presumably be adapted to small metal pieces. Chemical treatment consisted of washing with alkaline permanganate and oxalic acid solutions, with intervening water flushes, all at ambient temperature. Two cycles reduced the contamination level to <10 nCi/g.

It can be concluded that relatively simple treatment may be capable of reducing TRU contamination levels on metal surfaces to the point where the metal is Class A waste. The SRL procedures, for example, achieved this with the use of relatively small amounts of innocuous chemicals. Use of various complexing and chelating agents which are included in standard procedures for certain other types of contamination and contaminated equipment is not recommended; in fact, their use could presumably only be permitted if the secondary waste were treated to ensure their complete destruction before disposal.

5.1.3 Cellulosics and Other Combustible Waste

Properties of TRU waste in temporary storage at INEL and still being generated by DOE were reviewed in NUREG/CR-2333 with particular attention to leachability and gas generation. Leach data for this existing stored waste was minimal and covered a range of many orders of magnitude. More work had been planned by DOE, but was not done. In any case, it would be difficult, if not impossible, to obtain data quantitatively relating leachability to some standard waste due to the very wide range of materials, especially organics, making up the waste. On the basis of the available information, it was concluded that "no credit can be given to as-generated TRU waste as a major barrier in the controlled release of actinides."[50] Thus, while containment of activity from this type of waste in a geologic repository might be possible because of the major barrier imposed by the geology, it could not be expected in a shallow land burial situation, where the pathway to the surface is short and the possibility exists for relatively rapid migration due to chelates.

Production of gas from radiolysis of pore water in concrete has been mentioned (Section 5.1.1.1). In general, gas generation from contaminated

cellulosics and other organics constitutes more of a problem, for a given TRU activity level, since they are subjected to production of gas from biodegradation as well as from radiolysis. Gas production from radiolysis is in direct proportion to the amount of radioactivity present, whereas that from biodegradation is not connected with the level of contamination. Thus biodegradation can be, and has indeed often been found to be, the cause of the greater production of gas. This will, of course, depend on the exact nature of the organic waste, and the conditions (temperature, moisture, etc.) to which the waste is subjected. The particular mixture of gases, as well as the amounts formed, will also vary considerably in biodegradation.

Because of the problems associated with contaminated organic TRU-contaminated waste as a waste form, particlularly those connected with leachability and gas generation, it was recommended in NUREG/CR-2333 that combustible TRU waste not be accepted in geologic repositories. Such waste is not excluded from shallow land burial as Class A Waste, provided it is not capable of generating quantities of toxic gases harmful to persons transporting, handling, or disposing of it. For any combustible TRU-contaminated waste (other than Class A), it would undoubtedly be advisable to process the waste (by incineration or acid digestion) to an inorganic form, as recommended in NUREG/CR-2333 for geologic disposal. For actual TRU waste (TRU content >100 nCi/g) avoidance of combustible organics would be even more important due to the more stringent long-term stability requirements for waste exceeding Class C limits. As discussed in Section 5.1, use of HICs for disposal of any TRU waste, including combustibles, is considered unacceptable.

5.2 Greater Confinement Disposal (GCD)

This term refers to disposal in such a manner that confinement of the disposed radionuclides will be greater than that provided by standard shallow land burial. It is meant to be applied to non-high-level wastes considered unacceptable for shallow land burial, i.e., those that contain such high concentrations of radionuclides and/or quantities of long-lived radionuclides that standard shallow land burial would result in a dose to a member of the general public exceeding the performance objectives given in 10 CFR Section 61.41.[47] Emplacement in a deep geologic repository is ruled out by its high cost. Thus GCD has been proposed as a safe alternative to shallow land burial, and an economic alternative to deep geologic disposal.[46]

DOE for several years has been involved in work with GCD concepts, and criteria were published in 1981.[45] More recently, a generic study has been completed[47] which analyzes the costs and risks of a number of GCD alternatives, comparing them with those for standard shallow land burial and HLW burial in a geologic repository. The results are summarized in Table 5.1. They indicate that risks for all the GCD options analyzed are likely to be several orders of magnitude less than those for regular shallow land burial, while costs should be within a factor of 2 or 3 greater.

Table 5.1

Generic Cost Plus Risk Comparison Alternatives[a]
(Taken From Table 7 of Reference 47)

Facility Type	Cost ($10^6)	Health Risk ($10^6)[b]	Total ($10^6)[c]
SLB reference facility	8	5000	5000
Deep trench	14	1	15
Improved waste form	27	0.06	27
Engineered structure:			
concrete-walled trench	22	0.009	22
intruder barrier	15	1	16
Augered shaft:			
southeast region	19	0.4	19
southwest region	19	0.004	19
Hydrofracture[d]	24	<0.01	24
HLW repository	>>50	<0.01	>>50

[a]Based on disposal of 10,000 m^3 of warm GCD waste and 62.5 m^3 of hot GCD waste at a facility co-located with a SLB facility for LLW that meets 10 CFR Part 61 or equivalent criteria for near-surface disposal.
[b]All health risk estimates have been rounded to one significant digit.
[c]The total is the ranking parameter which is the sum of cost plus health risk. Costs and ranking parameter values have been rounded to two significant digits.
[d]For liquid waste.

It is emphasized that this study was generic, and that the particular alternative to be chosen for a given site would have to be based on a site-specific analysis. One factor which is of great importance is the depth of the water table,[47] and alternatives requiring greater depths will not necessarily be better at any given site. A point about the study which should also be kept in mind is that the two reference waste streams whose compositions were used for analysis of most of the options (all except hydrofracture) contained insignificant amounts of α-activity (<1 nCi/g). There is thus some doubt as to the relevance of the analyses of these options for TRU wastes containing relatively high TRU concentrations. The third reference waste stream had a TRU concentration well above the Class C limit. Its composition was used for analysis of the hydrofracture option, so that anlaysis, at least, should be relevant for TRU waste.

A study has been reported by Pacific Northwest Laboratories (PNL)[55] on possible "TRU advanced disposal systems" for burial at Hanford of some of the TRU waste for which there will not be room in the Waste Isolation Pilot

Plant (WIPP). It identifies several techniques, including grouting and in situ vitrification, which were considered to provide "greater confinement" against intrusion than that provided by shallow land burial. An example systems analysis was performed with assumed performance objectives and Hanford-specific disposal systems, waste forms, site characteristics, and engineered barriers. Preliminary waste disposal criteria for Pu-239 were determined by applying the Allowable Residual Contamination Level (ARCL) method. The dependence of exposure on depth for Pu-239-contaminated soil derived from this analysis was such that allowable soil concentrations of Pu-239 were 0.5 nCi/g between the surface and a depth of 1 m, 2200 nCi/g at a depth of 5 m, and 10,000 nCi at a depth of 10 m.

The two general options for GCD are exemplified by the 2nd and 3rd alternatives in Table 5.1, namely deeper burial and improved waste form. The other alternatives in that table involve special combinations of deeper burial with engineered barriers. Field work has been commenced by DOE on several GCD concepts at two sites, one in Nevada (arid),[48] and one at Savannah River Laboratory (SRL) (humid).[49] Work at the Nevada Test Site[48] is designed to demonstrate the use of large diameter bore holes (3 m diameter, 37 m depth), and is in the nature of a relatively long-term test, with instruments in the shaft and in monitoring holes to monitor migration of tracers and radionuclides. At SRL, the emphasis is more on actual disposal of waste being generated.[49] It has been found that 95% of the activity of this waste is contained in 5% of the volume, and this high activity fraction will be disposed of by GCD in boreholes and concrete-lined trenches.

5.3 Specific Applications to GEVNC TRU-Contaminated Waste

Three different waste streams containing TRU isotopes were identified and described in Section 3.3. Each is characterized by a particular form and a range of TRU isotope concentrations. Possible methods of dealing with each type of waste to allow for its disposal are discussed below. This discussion does not constitute a set of recommendations to GEVNC for disposal of their waste, but describes some possible options.

5.3.1 Waste Containing 80-100 nCi/g of TRU Isotopes

This waste stream accounts for about 2/3 of the total waste volume and an insignificant fraction of the total activity in the current inventory (see Table 3.4). All the cement-solidified dilute burnup analysis solutions belong in this category, and essentially no other waste. As discussed in Section 3.3.3, it is likely that a good deal of this waste exceeds the Class C limit significantly, but not to a great extent, because of its Pu-241 content. Specifically, applying the sum of fractions rule (10 CFR Section 61.55) would probably yield a value significantly >1, but <1.8, for a good deal of the waste. That part of it would thus be officially TRU waste, rather than simply TRU-contaminated LLW, but it is close enough to Class C LLW that it could be expected to be considered by NRC as a special case for near-surface disposal (see Section 5).

At least some formulations of ordinary hydraulic cement[51] have been shown to have excellent Pu leach resistance, as discussed in Section 5.1.1.1. If the GEVNC formulation can be shown to behave similarly, there is reason to expect that NRC would consider the form acceptable for near-surface disposal of this low concentration TRU waste. An even stronger case could be made if the small waste form, preferably without paint cans, were placed in a larger container, such as a 30-gal or 55-gal drum, and made into a solid monolithic form by encapsulation in concrete. Documentatation of the waste form's good leach performance would presumably be required. In addition, in order that this waste be accepted as Class C stabilized waste, data would have to be presented by GE to show that the properties of the waste form were consistent with 10 CFR Part 61 and the TP for Class C stabilized waste.

As far is known, no work is being done at commerical LLW burial sites on development of GCD methods and no facility for GCD is in the active planning stage at these sites (or elsewhere). This situation will presumably continue until NRC indicates a need for such a facility, and provides guidelines and criteria for its construction and operation. Some non-DOE waste (e.g., the GEVNC waste under discussion) exceeds Class C limits, and more will undoubtedly be produced. It is probable that some fraction of it will be considered unsuitable for regular shallow land burial but acceptable for GCD. The volume of this fraction may not be large enough to warrant building a special GCD site, but one or more facilities at existing LLW burial sites may be required. This need, in term, implies a need for criteria for GCD disposal.

5.3.2 Solidified Hot Liquid Waste Stream

Inventory information for this waste stream is given in Table 3.4. The waste represents 6% of the total volume and about 2/3 of the TRU activity in the current inventory. The only waste in this waste stream is that obtained by cement solidification of the hot liquid waste arising from dissolution of samples of irradiated fuel used for burnup analysis. As discussed in Section 3.3.2, the TRU content is estimated to be in the range of 0.2 to 3 mCi/g, with most of it in the range 1 to 2 mCi/g (1 to 2 x 10^6 nCi/g). Plutonium-241 concentrations are probably some 30 times these levels, so both TRU and Pu-241 activities are of the order of 10^4 times the respective Class C limits. Also Cs-137 and Sr-90 concentrations are 1 to 2 orders of magnitude higher than the Class C limits. It seems clear that this waste, while not equivalent to HLW, is so much more radioactive than the hottest low-level waste generally acceptable by NRC for land disposal that it is not expected to be considered acceptable for disposal at a commercial LLW site, even as a special case.

One possible option for dealing with the waste would be to arrange for its transfer to DOE. DOE has several possible alternatives for handling it, which are not available to non-DOE generators. These include emplacement in the Waste Isolation Pilot Plant (WIPP) and storage at a facility such as that at INEL until a suitable GCD facility operated by DOE became available.

The present inventory of 9 gallons could presumably be repackaged, without paint cans, in one or two 55-gallon drums lined with 6 in. or more of cement, which could then be filled with cement. Dilution of the activity to this extent would probably be acceptable, but would still leave it about 10^3 times the Class C limit. However, the procedure would provide a significant barrier of nonradioactive cement for the waste, and might be acceptable for one of the GCD options. It will, of course, be some years before any suitable GCD option is likely to be available at a commercial burial site and criteria are not yet available to judge the adequacy of this waste form.

The current inventory of this waste stream is already solidified, but for hot liquid waste produced in the future the option exists of treatment to prepare one of the special waste forms discussed in Section 5.1.1.2. A suitable SYNROC formulation or iron-enriched synthetic basalt should provide good long-term stability, and SYNROC in particular has been shown to have very low leach rates for Pu. These qualities address the concern for "special processing or design" expressed in 10 CFR Part 61. Thus such waste forms might qualify for regular land burial at somewhat greater depth than normally used at commercial LLW burial sites. At least a good case could be made for their disposal with some form of GCD. However, the applicable criteria do not exist at present to determine the acceptability of processed wastes for GCD.

From the preceding discussion, it can be concluded that no acceptable method of disposing of waste containing very high levels of TRU activity appears to exist in the private sector. When the concepts for a high level waste repository were described in the original version of 10 CFR Part 60[55], it was considered that TRU waste would be emplaced in a licensed HLW respository, along with the HLW. Although the present version of 10 CFR Part 60[52] deals only with HLW, it does not explicitly rule out emplacement of TRU waste in an HLW repository. In fact, waste with levels of TRU activity such as those in the GEVNC waste may still be required to be emplaced in a geologic repository. However, if not, it seems clear that if such waste is to be disposed of at commercial sites, development of suitable GCD alternatives at one or more of these sites will be necessary.

5.3.3 Solid Waste

The principal components of this waste stream are described in Section 3.3. In terms of activity it represents about 1/3 of the total inventory while contributing about 1/4 of the volume. The bulk of the activity is concentrated in the sections of fuel pellets used for metallographic examination, and in the cuttings formed when they are removed from the fuel elements by a diamond cutting wheel. The cuttings are cleaned up with paper wipes. The remainder of the activity is associated with pieces of Zircaloy cladding, pieces of discarded equipment, including the diamond-encrusted brass cutting wheels, used glassware, and the small amount of solidified sludge resulting from polishing operations.

The solid waste varies widely in its TRU content, but on average is a factor of only 2.5 lower than that of the solidified hot liquid waste (see Table 3.4). Thus much of it will be at a high enough level that the same situation exists for it as for the solidified hot liquid waste discussed in Section 5.3.2, i.e., there appears to be no way of disposing of it at a commercial site. In its present form (loose scrap in paint cans), it would be even less acceptable than the solidified hot wastes. However, since it is loose, it should be possible to sort it into its components and to devise methods of treating it to obtain some acceptable waste forms for shallow land burial. Some of these possible methods as they apply to the mixed waste and to different components of the solid waste stream are discussed below. On the basis of the information on this waste stream at our disposal, there seems to be no reason why the methods could not be applied to the present inventory. They could obviously be applied to future waste generated, and it might be advantageous to do so. At least the waste could be segregated into its separate components as it was generated, in case the option to treat components separately was chosen at a later time.

5.3.3.1 Encapsulated Mixed Solid Waste

The solid waste could be encapsulated in cement as is (without the paint cans, or at least without the lids) in cement-lined 55-gallon drums as described in Section 5.3.2 for blocks of solidified hot liquid waste. Although there is a larger volume of solid waste, the dilution factor upon encapsulation would be similar, so the TRU concentration would still be some 10^2 to 10^3 times higher than the Class C limit. As is the case with the solidified hot liquid waste encapusluated in this way, it might be acceptable for one of the GCD options.

5.3.3.2 Fuel Pellet Sections

This component of the solid waste stream contains the largest fraction of the activity and would be easy to separate from the rest of the waste. An apparently simple method of treating the polished sections would be to remove them from their plastic (presumably Lucite) mounts and dissolve them as the larger samples for burnup analysis are dissolved. The resulting acidic solution could be neutralized and cement solidified in the same way as the burnup analysis solutions have been handled. Alternatively, this solution could be treated to convert the radioactive isotopes into a chemical form from which one of the special waste forms discussed in Section 5.1.1.2 could be prepared. The discussion of special waste forms included in Section 5.3.2 applies here also.

5.3.3.3 Paper Wipes with Fuel Cuttings

The second largest fraction of activity in the solid waste is that arising from cutting the fuel pellets. The small particles of fuel end up mostly on paper wipes, which could easily be separated or kept separate, from the rest of the waste. As discussed in Section 5.1.3, it is advisable to exclude organic combustible waste from Class C LLW. When encapsulated in a

solid waste form, it would almost certainly detract from the form's long-term stability due to its decomposition by radiolysis and biodegradation. There is even more reason to exclude it from waste forms containing highly active TRU waste, where long-term stability is crucial.

In any case, organics can easily be destroyed by such methods as incineration and acid digestion, so it seems reasonable to require this treatment for the paper wipes. Considering their small volume, incineration might be impractical, but ashing in a crucible could presumably be substituted, and the ash could be incorporated in cement or in one of the special waste forms discussed in Section 5.1.1.2. Acid digestion would also be easy to apply on a small scale, particularly to cellulosics, but would leave the TRU isotopes dissolved in sulfuric acid solution. Treatment to prepare special waste forms would still be feasible, and preparation of ordinary hydraulic cement would be straightforward. In fact, for the latter form, the acid solutions from this stream, from the dissolving of the fuel pellet sections and from the hot liquid waste stream could all be combined if desired.

5.3.3.4 Miscellaneous Solids

Surface-contaminated solids (other than wipe papers) account for most of the volume in the solid waste stream but only a small fraction of the TRU activity, perhaps 10%. It is possible that a great deal of this waste could be decontaminated to levels where it would be Class A or Class C LLW, and thus could be sent to shallow land burial. In the process, a secondary TRU waste stream would be produced, but with TRU concentrations much less than those in the solutions resulting from processing burnup analysis samples, metallographic examination sections, or wipe papers. This secondary waste stream, when converted to a solid waste form, would still have TRU levels much lower than waste forms prepared from the hot liquid wastes, quite possibly in a range where the waste could be considered on a case-by-case basis by NRC for near-surface disposal.

Specific components of the GEVNC solid waste and possible treatments are listed below and presented in tabular form in Table 5.2. Although results obtained with decontamination procedures will vary with the exact nature of the waste, the methods considered have all been shown to be capable of reducing TRU levels to <10 nCi/g on actual (rather than simulated) waste. To be applicable to the GEVNC waste, they would have to be capable of operating on a small scale, since the amounts of waste involved are relatively quite small.

1. Contaminated Equipment Made of Steel

   a. This could be decontaminated electrolytically by one of the methods described in Section 5.1.2.1. Electrolytic methods can readily be applied on a small scale. Use of basic electrolyte would be preferable from the point of view of disposing of the secondary waste.

   b. Chemical decontamination methods, such as those discussed in Section 5.1.2.3, can also be applied on a small scale.

c. Vibratory finishing (Section 5.1.2.2) works well with metals and also plastics, but might not be feasible for the GEVNC waste, depending on the shapes and sizes of the waste to be decontaminated and its amount. Adapting to the small scale required might be impractical.

2. Zircaloy Cladding

a. Chemical decontamination is applicable on the small scale called for here. A simple treatment with HNO_3 in a beaker might be suitable to dissolve any fuel still adhering to the cladding.

b. The volume of waste is so small that vibratory finishing would almost certainly be impractical for this waste by itself.

3. Diamond Cutting Wheels

a. These are made of brass and could probably be decontaminated readily by simple treatment with HNO_3.

b. Since the number of wheels entering the waste stream is expected to be small, the remarks under 2b apply here also.

4. Plastic Metallographic Section Holders

a. It is quite likely that chemical decontamination would work for this waste. If it were not satisfactory, the plastic could be ashed, or decomposed by acid digestion. All of these treatments are suitable for small-scale work.

b. The plastic pieces could also be treated by vibratory finishing, but again the small volume of waste might make this method unsuitable.

5. Contaminated Glassware

a. The only obvious and simple way of decontaminating glass waste is probably by chemical treatment, which can readily be applied to whatever volumes are generated.

b. An alternative method of handling glass waste might be to pulverize it and incorporate the powder in cement or another suitable waste form.

6. Overall Waste Stream

a. Although chemical decontamination is applicable to all known components of the solid waste, several different agents would

almost certainly be required for efficient treatment of the different materials. This effectively necessitates that each component be handled separately. As pointed out in Section 5.1.2.3, chelating agents should not be used unless they are completely removed from the secondary waste stream.

b. All the components except glass can be decontaminated by vibratory finishing. The method would probably be impractical for any one component, but if they were combined, it is possible the waste volume might be large enough to make the method feasible.

Table 5.2

Possible Alternative for Treatment of Sorted GEVNC Solid Waste
(Applicable technology indicated by x)

Component	Treatment Method			Decontamination Method		
	Standard Dissolution	Acid Digestion	Ashing	Electrolytic	Chemical	Vibratory Finishing[a]
Metallographic Sections	x					
Paper Wipes		x	x			
Steel Equipment				x	x	x
Zircaloy Cladding					x	x
Cutting Wheels					x	x
Plastic Holders		x	x		x	x
Glassware					x	

[a]Method works well for types of waste indicated. Might be impractical for small amounts of any one type produced, but might be feasible if all combined.

5.3.4 Summary of Options

The GEVNC solidified dilute burnup analysis solutions can probably be handled at a commercial LLW burial site. The remainder of the waste, both current inventory and that produced in the future will require some other treatment. Most of its radioactivity will probably not be able to be handled by shallow land burial, even on a special case-by-case basis. On the other hand, most of its volume could be decontaminated and disposed of as LLW at a commerical disposal site.

- The solid waste in both the current inventory and that resulting from future operation could be sorted into components. Sections of fuel and wipes of fuel cuttings contain the bulk of the activity in a small volume, and could be treated as discussed in Sections 5.3.3.2 and 5.3.3.3. Possible methods for treating the contaminated solids, which account for only about 5% or less of GEVNC's total TRU activity, have been described in Section 5.3.3.4. The object of all these methods is to convert the solid waste volume to Class A waste, with production of a secondary waste stream which can readily be incorporated into a solid waste form exhibiting long-term stability and low TRU leachability. The levels of TRU activity in such secondary waste might be low enough that it could also be considered for near-surface disposal on a special case basis.

- It was pointed out in Section 5.3.3.3 that all the hot waste solutions resulting from dissolving fuel sections (for burnup analysis and metallographic examination), and from acid digestion of paper wipes, could be combined. This would allow treatment of 95% or more of GEVNC's total TRU activity in one waste stream. The TRU concentrations of a waste form prepared from such solutions would be several orders of magnitude higher than the Class C limit, but no greater than those in the current solidified hot liquid waste.

- As discussed in Section 5.3.2, there appears presently to be no acceptable method in the private sector for disposing of wastes containing such high levels of TRU activity. One possible option would be to arrange to transfer them to DOE. If this option is not available, they would either have to be emplaced in a future licensed geologic repository, or in a suitable GCD facility at a LLW burial site once such a facility has been developed. Both of these alternatives appear to be some distance in the future.

- The potential need for GCD facilities for non-DOE wste was pointed out in Section 5.2. Guidelines and criteria would have to be developed by NRC for construction and operation of such facilities. Criteria would also have to be developed for the types of waste and waste forms to be handled by GCD.

6. CONCLUSIONS

The waste generated by GEVNC during the examination of reactor components and fuel and in the production of sources and radiopharmaceuticals has been characterized. It was found that GEVNC produces wastes which can be classified as Class A, Class B, and Class C according to the waste classification system of 10 CFR Part 61. GEVNC also has shipped wastes with radionuclide concentration in excess of the Class C limit.

A review of RSRs for waste shipped by GEVNC to Hanford indicates that GEVNC shipped its wastes in three main types of packages. These are wooden crates, carbon steel drums (55 gallon) and 84-gallon extended 17H drums grouted with cement. Class A wastes have been packaged in each of the container types. Based on the review of the RSRs, Class B and greater wastes are packaged in concrete-grouted drums. A total of five isotopes were specifically identified in the RSRs reviewed although it is known that much of the waste is actually composed of mixed fission products. GEVNC has indicated that its wastes are dominated by Cs-137 and Co-60. Class A, B, or C wastes may contain both of these isotopes, or occasionally only Co-60.

GEVNC determines the concentrations of radionuclides in its waste from dose rate measurements, the distribution of isotopes in smears and a computer code which converts the dose rate measurements to activities. This procedure was reviewed. It was recommended that GEVNC perform a more detailed characterization of the radionuclide inventory in its grouted drum waste as the waste classification could be affected by this inventory.

Each of the waste packages used by GEVNC was evaluated with respect to the appropriate sections of 10 CFR Part 61 on waste characteristics, as well as the Technical Position on Waste Form. In addition, the components of the GEVNC waste packages were reviewed to determine if materials were present which were hazardous or which could compromise burial site performance. The results of these evaluations, as well as concerns and needs for additional information, are summarized below.

6.1 Class A Waste Packages

The largest volume (~70%) of waste shipped by GEVNC is Class A waste. These wastes appear to meet the minimum requirements for Class A wastes.

6.2 Class B and Class C Waste Packages

GEVNC currently ships its Class B and C wastes in cement-grouted 84-gallon extended 17H drums. The waste itself consists of miscellaneous components from hot cell operations. These include metal, glass, paper and plastics. These wastes are placed in perforated carbon steel baskets which are then put in the outer drum and the entire basket/waste array is grouted with cement. The outer carbon steel drum is not expected to provide stability and be recognizible for 300 years in the trench environment. The inner concrete/perforated basket/waste monolith, however, may have these characteristics and it is this monolithic waste form that has been evaluated with

respect to the guidelines given in the TP for waste forms. In addition, this waste package was evaluated to see if it met the minimum requirements for wastes given in 10 CFR Part 61.

6.2.1 Minimum Requirements

The Class B and C waste packages evaluated appear, in general, to meet the minimum requirements for waste given in 10 CFR Part 61 Section 56.

6.2.2 Stability Requirements

Spalling and cracking of the concrete/basket/waste monolith in the GEVNC high activity waste package as a consequence of the pressures generated in corrosion of embedded steel was considered for the GEVNC package as generated and in its trench environment. This spalling/cracking process is a potential failure mode that is not directly addressed in the Technical Position. Such spalling and cracking could lead to loss of monolithic form of the waste. It was determined that insufficient chloride was present in the wastes, grout, or trench environment to allow initiation of the metal corrosion process. If other agents capable of initiating the corrosion of the baskets were present, the probability of these causing spalling is quite low due to the scarcity of water at the Hanford site. If these packages were disposed of in a humid site, an assessment of the expected corrosion rates in the presence of these agents would be necessary before conclusions about lifetime stability could be drawn.

6.2.3 Guidelines in the Technical Position

The GEVNC grouted drum concrete/basket/waste monolith has been evaluated with respect to the guidance on processed waste provided in the TP. A major factor that enters into this evaluation is that very little actual testing in accordance with the TP has yet been performed by GEVNC and, the determination of proper representative test sample sizes is not straightforward because GEVNC has heterogeneous waste.

The TP guidelines have been considered individually as they apply to the GEVNC high activity Class B and C waste form and the evaluation summaries are given as follows:

- GEVNC high activity wastes are packaged according to a well-defined procedure which cannot strictly be called a process control program since it lacks specific information on weights/volumes. It does, however, provide tolerances for the grout mixtures. It has not been demonstrated that this procedure will ensure compliance with the recommendations given in the TP. The variability in the waste stream is considered a limiting factor in production of consistently uniform processed waste packages.

- The compressive strengths of the concrete grout and of the waste metal and glass are all expected, individually, to exceed 50 psi.

The compressive strength of compacted paper and plastics present in the wastes is not known. However, the compressive strength of a monolith produced by combination of these materials cannot be simply determined by means other than actual testing.

- The radiation stability of the GEVNC grouted waste monolith is dependent on the radiation stability of the individual components. The concrete, metal and glass waste items are expected to be stable in a radiation field. GEVNC has run tests on the grout mixture concrete to 10^8 rad exposure in which no signs of degradation were evident, but testing of representative waste samples should be performed at 10^9 rad since this is the dose that occurs with the Class C waste activity limits.

  The waste plastics and cellulosics are expected to undergo radiolysis. The radiolysis products are expected to include both gases (H_2, CO, and CO_2) and liquids (organic acids). Gaseous radiolysis products should, under normal conditions, escape the package. The liquid organic acids may attack the concrete and/or metal waste items depending on the distance between these materials. The large amount of acid-neutralizing hydroxide present in concrete is expected to reduce the capacity of radiolysis-produced acids to compromise the waste form stability.

- The high pH of the concrete will tend to inhibit microbial growth. The potential exists for radiation self-sterilization of the high activity grouted waste forms. Acids are the principal biodegradation by-products expected to be waste form-degradative but acid neutralization will occur in the concrete (until its capacity is exceeded) and, thereby the potential effects of these acids may be lessened.

- Leach testing should be performed on representative GEVNC waste samples. Leach tests of these forms must be carefully designed and their results carefully interpreted to ensure appropriate assignment of leaching properties. The leachability index of the grouting material and/or the form itself should be determined by GEVNC through testing.

- Immersion testing should be performed on these waste forms.

- The presence of free liquid in the waste package has been ruled out on the basis of observations during tests performed by GEVNC. However, the check by breach-drilling of the container for drainable free liquid has not yet been done and it should be performed.

- The establishment of test sample size for the GEVNC heterogeneous high activity grouted waste monolith must ensure that samples are indeed representative. It may be found that only full-size testing is appropriate and justifiable.

- The homogeneity of compressive strength throughout the waste form monolith is questioned on the basis of the heterogeneity of waste items. Testing must be done to show that this monolith has the necessary strength throughout.

Conclusions and Recommendations

- Regarding GEVNC's TRU-contaminated waste, the solidified dilute burnup analysis solutions can probably be handled at a commercial LLW burial site. The remainder of the waste, both current inventory and that produced in the future, will require some other treatment. Most of its radioactivity will probably not be able to be handled by shallow land burial, even on a special case-by-case basis. On the other hand, most of its volume could be decontaminated and disposed of as LLW at a commercial disposal site. In order to accomplish this, sorting of the solid waste into its components would be necessary.

- Combining all the hot waste solutions resulting from dissolving fuel sections and from acid digestion of paper wipes would allow treatment of 95% or more of GEVNC's total TRU activity in one waste stream. The TRU concentrations of a waste form prepared from such solutions would be several orders of magnitude higher than the Class C limit, but no greater than those in current solidified hot liquid waste.

- There appears presently to be no acceptable method in the private sector for disposing of waste containing such high levels of TRU activity. One possible option would be to arrange to transfer them to DOE. If this option is not available, they would either have to be emplaced in a future licensed geologic repository, or in a suitable GCD facility at a LLW buiral site once such a facility has been developed.

- It is recommended that guidelines and criteria be developed by NRC for construction and operation of GCD facilities. Criteria should also be developed for the types of waste and waste forms to be handled by GCD.

6.3 Evaluation of Additional Hazards in the GEVNC Wastes

Based upon the information obtained from GEVNC regarding the contents of their wastes, as well as the evaluations performed by BNL, there do not appear to be any materials present in the Class B and C wastes which pose a significant non-radiological hazard. Further, there appear to be no materials present in these wastes in sufficient quantity to compromise long-term performance of the burial site.

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APPENDIX A

10 CFR PART 61 SECTIONS 55 and 56

disposal site before they leave the site boundary.

§ 61.54 Alternative requirements for design and operations.

The Commission may, upon request or on its own initiative, authorize provisions other than those set forth in §§ 61.51 through 61.53 for the segregation and disposal of waste and for the design and operation of a land disposal facility on a specific basis, if it finds reasonable assurance of compliance with the performance objectives of Subpart C of this part.

§ 61.55 Waste classification.

(a) Classification of waste for near surface disposal.

(1) *Considerations.* Determination of the classification of radioactive waste involves two considerations. First, consideration must be given to the concentration of long-lived radionuclides (and their shorter-lived precursors) whose potential hazard will persist long after such precautions as institutional controls, improved waste form, and deeper disposal have ceased to be effective. These precautions delay the time when long-lived radionuclides could cause exposures. In addition, the magnitude of the potential dose is limited by the concentration and availability of the radionuclide at the time of exposure. Second, consideration must be given to the concentration of shorter-lived radionuclides for which requirements on institutional controls, waste form, and disposal methods are effective.

(2) *Classes of waste.* (i) Class A waste is waste that is usually segregated from other waste classes at the disposal site. The physical form and characteristics of Class A waste must meet the minimum requirements set forth in § 61.56(a). If Class A waste also meets the stability requirements set forth in § 61.56(b), it is not necessary to segregate the waste for disposal.

(ii) Class B waste is waste that must meet more rigorous requirements on waste form to ensure stability after disposal. The physical form and characteristics of Class B waste must meet both the minimum and stability requirements set forth in § 61.56.

(iii) Class C waste is waste that not only must meet more rigorous requirements on waste form to ensure stability but also requires additional measures at the disposal facility to protect against inadvertent intrusion. The physical form and characteristics of Class C waste must meet both the minimum and stability requirements set forth in § 61.56.

(iv) Waste that is not generally acceptable for near-surface disposal is waste for which waste form and disposal methods must be different, and in general more stringent, than those specified for Class C waste. In the absence of specific requirements in this part, proposals for disposal of this waste may be submitted to the Commission for approval, pursuant to § 61.58 of this part.

(3) Classification determined by long-lived radionuclides. If radioactive waste contains only radionuclides listed in Table 1, classification shall be determined as follows:

(i) If the concentration does not exceed 0.1 times the value in Table 1, the waste is Class A.

(ii) If the concentration exceeds 0.1 times the value in Table 1 but does not exceed the value in Table 1, the waste is Class C.

(iii) If the concentration exceeds the value in Table 1, the waste is not generally acceptable for near-surface disposal.

(iv) For wastes containing mixtures of radionuclides listed in Table 1, the total concentration shall be determined by the sum of fractions rule described in paragraph (a)(7) of this section.

TABLE 1

Radionuclide	Concentration, curies per cubic meter
C-14	8
C-14 in activated metal	80
Ni-59 in activated metal	220
Nb-94 in activated metal	0.2
Tc-99	3
I-129	0.08
Alpha emitting transuranic nuclides with half-life greater than five years	[1]100
Pu-241	[1]3,500
Cm-242	[1]20,000

[1] Units are nanocuries per gram.

(4) Classification determined by short-lived radionuclides. If radioactive waste does not contain any of the radionuclides listed in Table 1, classification shall be determined based on the concentrations shown in Table 2. However, as specified in paragraph (a)(6) of this section, if radioactive waste does not contain any nuclides listed in either Table 1 or 2, it is Class A.

(i) If the concentration does not exceed the value in Column 1, the waste is Class A.

(ii) If the concentration exceeds the value in Column 1, but does not exceed the value in Column 2, the waste is Class B.

(iii) If the concentration exceeds the value in Column 2, but does not exceed the value in Column 3, the waste is Class C.

(iv) If the concentration exceeds the value in Column 3, the waste is not generally acceptable for near-surface disposal.

(v) For wastes containing mixtures of the nuclides listed in Table 2, the total concentration shall be determined by the sum of fractions rule described in paragraph (a)(7) of this section.

TABLE 2

Radionuclide	Concentration, curies per cubic meter		
	Col. 1	Col. 2	Col. 3
Total of all nuclides with less than 5 year half life	700	[1]	[1]
H-3	40	[1]	[1]
Co-60	700	[1]	[1]
Ni-63	3.5	70	700
Ni-63 in activated metal	35	700	7000
Sr-90	0.04	150	7000
Cs-137	1	44	1500

[1] There are no limits established for these radionuclides in Class B or C wastes. Practical considerations such as the effects of external radiation and internal heat generation on transportation, handling, and disposal will limit the concentrations for these wastes. These wastes shall be Class B unless the concentrations of other nuclides in Table 2 determine the waste to the Class C independent of these nuclides.

(5) Classification determined by both long- and short-lived radionuclides. If radioactive waste contains a mixture of radionuclides, some of which are listed in Table 1, and some of which are listed in Table 2, classification shall be determined as follows:

(i) If the concentration of a nuclide listed in Table 1 does not exceed 0.1 times the value listed in Table 1, the class shall be that determined by the concentration of nuclides listed in Table 2.

(ii) If the concentration of a nuclide listed in Table 1 exceeds 0.1 times the value listed in Table 1 but does not exceed the value in Table 1, the waste shall be Class C, provided the concentration of nuclides listed in Table 2 does not exceed the value shown in Column 3 of Table 2.

(6) Classification of wastes with radionuclides other than those listed in Tables 1 and 2. If radioactive waste does not contain any nuclides listed in either Table 1 or 2, it is Class A.

(7) The sum of the fractions rule for mixtures of radionuclides. For determining classification for waste that contains a mixture of radionuclides, it is necessary to determine the sum of fractions by dividing each nuclide's concentration by the appropriate limit and adding the resulting values. The appropriate limits must all be taken from the same column of the same table. The sum of the fractions for the column must be less than 1.0 if the waste class is to be determined by that column. Example: A waste contains Sr-90 in a

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concentration of 50 Ci/m³ and Cs-137 in a concentration of 22 Ci/m³. Since the concentrations both exceed the values in Column 1, Table 2, they must be compared to Column 2 values. For Sr-90 fraction 50/150 = 0.33; for Cs-137 fraction, 22/44 = 0.5; the sum of the fractions = 0.83. Since the sum is less than 1.0, the waste is Class B.

(8) *Determination of concentrations in wastes.* The concentration of a radionuclide may be determined by indirect methods such as use of scaling factors which relate the inferred concentration of one radionuclide to another that is measured, or radionuclide material accountability, if there is reasonable assurance that the indirect methods can be correlated with actual measurements. The concentration of a radionuclide may be averaged over the volume of the waste, or weight of the waste if the units are expressed as nanocuries per gram.

§ 61.56 Waste characteristics.

(a) The following requirements are minimum requirements for all classes of waste and are intended to facilitate handling at the disposal site and provide protection of health and safety of personnel at the disposal site.

(1) Waste must not be packaged for disposal in cardboard or fiberboard boxes.

(2) Liquid waste must be solidified or packaged in sufficient absorbent material to absorb twice the volume of the liquid.

(3) Solid waste containing liquid shall contain as little free standing and noncorrosive liquid as is reasonably achievable, but in no case shall the liquid exceed 1% of the volume.

(4) Waste must not be readily capable of detonation or of explosive decomposition or reaction at normal pressures and temperatures, or of explosive reaction with water.

(5) Waste must not contain, or be capable of generating, quantities of toxic gases, vapors, or fumes harmful to persons transporting, handling, or disposing of the waste. This does not apply to radioactive gaseous waste packaged in accordance with paragraph (a)(7) of this section.

(6) Waste must not be pyrophoric. Pyrophoric materials contained in waste shall be treated, prepared, and packaged to be nonflammable.

(7) Waste in a gaseous form must be packaged at a pressure that does not exceed 1.5 atmospheres at 20°C. Total activity must not exceed 100 curies per container.

(8) Waste containing hazardous, biological, pathogenic, or infectious material must be treated to reduce to the maximum extent practicable the potential hazard from the non-radiological materials.

(b) The requirements in this section are intended to provide stability of the waste. Stability is intended to ensure that the waste does not structurally degrade and affect overall stability of the site through slumping, collapse, or other failure of the disposal unit and thereby lead to water infiltration. Stability is also a factor in limiting exposure to an inadvertent intruder, since it provides a recognizable and nondispersible waste.

(1) Waste must have structural stability. A structurally stable waste form will generally maintain its physical dimensions and its form, under the expected disposal conditions such as weight of overburden and compaction equipment, the presence of moisture, and microbial activity, and internal factors such as radiation effects and chemical changes. Structural stability can be provided by the waste form itself, processing the waste to a stable form, or placing the waste in a disposal container or structure that provides stability after disposal.

(2) Notwithstanding the provisions in §§ 61.56(a) (2) and (3), liquid wastes, or wastes containing liquid, must be converted into a form that contains as little free standing and noncorrosive liquid as is reasonably achievable, but in no case shall the liquid exceed 1% of the volume of the waste when the waste is in a disposal container designed to ensure stability, or 0.5% of the volume of the waste for wastes processed to a stable form.

(3) Void spaces within the waste and between the waste and its package must be reduced to the extent practicable.

§ 61.57 Labeling.

Each package of waste must be clearly labeled to identify whether it is Class A waste, Class B waste, or Class C waste in accordance with § 61.55.

§ 61.58 Alternative requirements for waste classification and characteristics.

The Commission may, upon request or on its own initiative, authorize other provisions for the classification and characteristics of waste on a specific basis, if, after evaluation of the specific characteristics of the waste, disposal site, and method of disposal, it finds reasonable assurance of compliance with the performance objectives in Subpart C of this part.

§ 61.59 Institutional requirements.

(a) *Land ownership.* Disposal of radioactive waste received from other persons may be permitted only on land owned in fee by the Federal or a State government.

(b) *Institutional control.* The land owner or custodial agency shall carry out an institutional control program to physically control access to the disposal site following transfer of control of the disposal site from the disposal site operator. The institutional control program must also include, but not be limited to, carrying out an environmental monitoring program at the disposal site, periodic surveillance, minor custodial care, and other requirements as determined by the Commission; and administration of funds to cover the costs for these activities. The period of institutional controls will be determined by the Commission, but institutional controls may not be relied upon for more than 100 years following transfer of control of the disposal site to the owner.

Subpart E—Financial Assurances

§ 61.61 Applicant qualifications and assurances.

Each applicant shall show that it either possesses the necessary funds or has reasonable assurance of obtaining the necessary funds, or by a combination of the two, to cover the estimated costs of conducting all licensed activities over the planned operating life of the project, including costs of construction and disposal.

§ 61.62 Funding for disposal site closure and stabilization.

(a) The applicant shall provide assurance that sufficient funds will be available to carry out disposal site closure and stabilization, including: (1) Decontamination or dismantlement of land disposal facility structures; and (2) closure and stabilization of the disposal site so that following transfer of the disposal site to the site owner, the need for ongoing active maintenance is eliminated to the extent practicable and only minor custodial care, surveillance, and monitoring are required. These assurances shall be based on Commission-approved cost estimates reflecting the Commission-approved plan for disposal site closure and stabilization. The applicant's cost estimates must take into account total capital costs that would be incurred if an independent contractor were hired to perform the closure and stabilization work.

(b) In order to avoid unnecessary duplication and expense, the Commission will accept financial sureties that have been consolidated with earmarked financial or surety arrangements established to meet

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APPENDIX B

TECHNICAL POSITION ON WASTE FORM

2. Stability Guidance for Processed (i.e., Solidified) Class B and C Wastes

a. The stability guidance in this technical position for processed wastes should be implemented through the qualification of the individual licensee's process control program. Generic test data may be used for qualifying process control programs. Through the use of a well designed and implemented process control program, frequent requalification to demonstrate stability is expected to be unnecessary. However, process control programs should include provisions to periodically demonstrate that the solidification system is functioning properly and waste products continue to meet the 10 CFR Part 61 stability requirements. Waste specimens should be prepared based on the proposed waste streams to be solidified and based on the range of waste stream chemistries expected. The tests identified may be performed on radioactive or non-radioactive samples.

b. Solidified waste specimens should have compressive strengths of at least 50 psi when tested in accordance with ASTM C39[3]. Compressive strength tests for bituminous products should be performed in accordance with ASTM D1074[4].

Many solidification agents will be easily capable of meeting the 50 psi limit for properly solidified wastes. For these cases, process control parameters should be developed to achieve the maximum practical compressive strengths, not simply to achieve the minimum acceptable compressive strength.

c. The specimens for each proposed waste stream formulation should remain stable after being exposed in a radiation field equivalent to the maximum level of exposure expected from the proposed wastes to be solidified. Specimens for each proposed waste stream formulation should be exposed to a minimum of 10^8 Rads in a gamma irradiator or equivalent. If the maximum level of exposure is expected to exceed 10^8 Rads, testing should be performed at the expected maximum accumulated dose. The irradiated specimens should have a minimum compressive strength of 50 psi following irradiation as tested in accordance with ASTM C39 or ASTM D1074.

d. Specimens for each proposed waste stream formulation should be tested for resistance to biodegradation in accordance with both ASTM G21[5] and ASTM G22[6]. No indication of culture growth should be visible. Specimens should be suitable for compression testing in accordance with ASTM C39 or ASTM D1074. Following the biodegradation testing, specimens should have compressive strengths greater than 50 psi as tested using ASTM C39 or ASTM D1074.

For polymeric or bitumen products, some visible culture growth from contamination, additives or biodegradable components on the specimen surface which do not relate to overall substrate integrity may be present. For these cases, additional testing should be performed. If culture growth is observed upon completion of the biodegradation test for polymeric or bitumen products, remove the test specimens from the culture, wash them free of all culture and growth with water and only light scrubbing. An organic solvent compatible with the substrate may be used to extract surface contaminants. Air dry the specimen at room temperature and repeat the test. Specimens should have observed culture growths rated no greater than 1 in the repeated ASTM G21 test, and compressive strengths greater than 50 psi. The specimens should have no observed growth in the repeated ASTM G22 test, and a compressive strength greater than 50 psi. Compression testing should be performed in accordance with ASTM C39 or ASTM D1074.

If growth is observed following the extraction procedure, longer term testing of at least six months should be performed to determine biodegradation rates. The Bartha-Pramer Method[7] is acceptable for this testing. Soils used should be representative of those at burial grounds. Biodegradation extrapolated for full-size waste forms to 300 years should produce less than a 10 percent loss of the total carbon in the waste form.

e. Leach testing should be performed for a minimum of 90 days in accordance with the procedure in ANS 16.1[8]. Specimen sizes should be consistent with the samples prepared for the ASTM C39 or ASTM D1074 compressive strength tests. In addition to the demineralized water test specified in ANS 16.1, additional testing using other leachants specified in ANS 16.1 should also be performed to confirm the solidification agents leach resistance in other leachant media. It is preferred that the

synthesized sea water leachant also be tested. In addition, it is preferable that radioactive tracers be utilized in performing the leach tests. The leachability index, as calculated in accordance with ANS 16.1, should be greater than 6.

f. Waste specimens should maintain a minimum compressive strength of 50 psi as tested using ASTM C39 or ASTM D1074, following immersion for a minimum period of 90 days. Immersion testing may be performed in conjunction with the leach testing.

g. Waste specimens should be resistant to thermal degradation. The heating and cooling chambers used for the thermal degradation testing should conform to the description given in ASTM B553, Section 3. Samples suitable for performing compressive strength tests in accordance with ASTM C39 or ASTM D1074 should be used. Samples should be placed in the test chamber and a series of 30 thermal cycles carried out in accordance with Section 5.4.1 through 5.4.4 of ASTM B553. The high temperature limit should be 60C and the low temperature limit -40C. Following testing the waste specimens should have compressive strengths greater than 50 psi as tested using ASTM C39 or ASTM D1074.

h. Waste specimens should have less than 0.5 percent by volume of the waste specimen as free liquids as measured using the method described in ANS 55.1. Free liquids should have a pH between 4 and 11.

i. If small, simulated laboratory size specimens are used for the above testing, test data from sections or cores of the anticipated full-scale products should be obtained to correlate the characteristics of actual size products with those of simulated laboratory size specimens. This testing may be performed on non-radioactive specimens. The full-scale specimens should be fabricated using actual or comparable solidification equipment.

j. Waste samples from full-scale specimens should be destructively analyzed to ensure that the product produced is homogeneous to the extent that all regions in the product can expect to have compressive strengths of at least 50 psi. Full-scale specimens may be fabricated using simulated non-radioactive products, but should be fabricated using actual solidification equipment.

APPENDIX C

SAMPLE RADIOACTIVE SHIPMENT RECORD FOR WASTES FROM GEVNC

GENERATOR NUMBER C A D 0 5 3 9 1 4 2 0 6

(1) GENERATOR NAME: G.E.-Vallecitos Nuclear Center
ADDRESS: P. O. Box 460
Vallecitos Road
CITY: Pleasanton STATE: California 94566
CONTACT: J. I. Tenorio
PHONE: (415) 862-2211
USER PERMIT NO.: 3140 SHIPMENT NO.: 83-30-02

RADIOACTIVE WASTE SHIPMENT & DISPOSAL FORM

US ECOLOGY, INC.
EXECUTIVE OFFICE: (502) 426-7160
P.O. BOX 7246 • LOUISVILLE, KENTUCKY 40207
Illinois Office: (815) 454-2376

(2) Consigned To:
XX P.O. Box 638, Richland, WA 99352, (509) 377-2411
☐ P.O. Box 578, Beatty, NV 89003, (702) 553-2203

USE THIS NO. ON ALL CONTINUATION PAGES No. 21614 PAGE 1 OF 1

(3) AGENT/BROKER: NO BROKER USED
ADDRESS: N/A
CITY: N/A STATE: N/A
CONTACT: N/A
PHONE: N/A USER PERMIT NO.: N/A

(4) CARRIER: TSMT SHIPPING DATE: 7/27/83
TYPE OF CASK: 1601 RADIATION READING: 120 m.R./hr @ C

(5) Item No.	(6) Container Type	(7) Contained Volume (Cu. Ft.)	(8) Container Weight (pounds)	(9) Physical Form	(10) Waste Description	(11) Solidification or Absorbent Media	(12) Chemical Form	(13) Radionuclide	(14) Activity ☒ Curies ☐ Millicuries	(15) Special Nuclear Material (Grams)	(16) Source Material (Kilograms)	Radiation Levels mR/HR (17) Container Surface	Radiation Levels mR/HR (18) 3 Ft. (TI)	(19) Spray Shield	(20) Fissile Class	(21) Label
38113	BOX	112	1,200	SOLID	COMPACTED METAL, WOOD, PAPER, PLASTIC	N/A	SOLID	Co60	0.007	N/A	N/A	16	3	A_2	N/A	Radioactive - LSA
								Cs137	0.003							Radioactive -
38114	BOX	112	2,000	SOLID		N/A	SOLID	Co60	0.002	N/A	N/A	30	1		N/A	Radioactive - LSA
								Cs137	0.001							Radioactive -
38115	BOX	112	2,600	SOLID		N/A	SOLID	Co60	0.002	N/A	N/A	1	0.5		N/A	Radioactive - LSA
								Cs137	0.001							Radioactive -
38117	BOX	112	2,800	SOLID	COMPACTED WOOD, METAL, PLASTIC, BROKEN GLASS	N/A	SOLID	Co60	0.002	N/A	N/A	5	0.5		N/A	Radioactive - LSA
								Cs137	0.001							Radioactive -
38118	BOX	112	2,700	SOLID	COMPACTED METAL, WOOD, PAPER, PLASTIC	N/A	SOLID	Co60	0.013	N/A	N/A	65	6		N/A	Radioactive - LSA
								Cs137	0.006							Radioactive
38116	BOX	112	1,800	SOLID	COMPACTED METAL, WOOD, PLASTIC	N/A	SOLID	Co60	0.002	N/A	N/A	1	0.5		N/A	Radioactive - LSA
								Cs137	0.001							Radioactive
1601	CASK	~~XXX~~ 11.5	28,000	SOLID	METAL OXIDES, IRRAD. HARDWARE IN CEMENT GROUT	~~N/A~~ CEMENT	CEMENT	Co60	31.000	N/A	N/A	≤600 *(W/O FIRESHIELD)	≤60 **120	Type B	N/A	Radioactive YELLOW III
								Cs137	13.300				**18			Radioactive
								Sb124	100.000				**(WITH FIRESHIELD)			Radioactive
								C-14	42.460							Radioactive
		~~XXX~~ 683.5	41,100	(22) TOTALS					186.801	N/A	N/A					Radioactive

THE ENTIRE AGREEMENT BETWEEN U. S. ECOLOGY AND GENERAL ELECTRIC COMPANY REGARDING SHIPMENT AND DISPOSAL FROM VNC IS CONTAINED IN PURCHASE ORDER NO. 529-VN706X. ANY TERM OR CONDITION NOT INCORPORATED IN THAT AGREEMENT SHALL NOT BE BINDING ON EITHER PARTY.

(23)

TOTAL QUANTITY	PROPER SHIPPING NAME & HAZARD CLASS (PER 49 CFR 172.101)	IDENTIFICATION NUMBER	TOTAL WEIGHT IN POUNDS
	Radioactive Device, N.O.S. — Radioactive Material	UN2911	
	Radioactive Material, Fissile, N.O.S. — Radioactive Material	UN2918	
6 BOXES	Radioactive Material, Low Specific Activity, N.O.S. — Radioactive Material	UN2912	13,100
1601 CASK	Radioactive Material, N.O.S. — Radioactive Material UN2982	XXXX	~~28,000~~
	Radioactive Material, Limited Quantity, N.O.S. — Radioactive Material	UN2910	
	Radioactive Material, Special Form, N.O.S. — Radioactive Material UN2994	XXXX	

INNER CONTAINER DOSE RATE IS 200 R/HOUR @ CONTACT.

Total # of Pkgs. This Shipment	Total Activity This Shipment	Total Volume This Shipment
7	186.801 ☒ Ci ☐ mCi	~~683.5~~ ~~679.5~~ cu ft

(25) THIS IS TO CERTIFY THAT THE ABOVE NAMED MATERIALS ARE PROPERLY CLASSIFIED, DESCRIBED, PACKAGED, MARKED AND LABELED AND ARE IN PROPER CONDITION FOR TRANSPORTATION ACCORDING TO APPLICABLE REGULATIONS OF THE DEPARTMENT OF TRANSPORTATION AND ARE IN COMPLIANCE WITH ALL REGULATIONS APPLICABLE TO THE DESIGNATED DISPOSAL SITE.

J. I. Tenorio Mgr., Remote Handling Operation
Authorized Signature Title

CUSTOMER COPY

APPENDIX D

CERTIFICATE OF COMPLIANCE FOR RADIOACTIVE MATERIALS PACKAGES

Form NRC-618
(12-73)
10 CFR 71

U.S. NUCLEAR REGULATORY COMMISSION
CERTIFICATE OF COMPLIANCE
For Radioactive Materials Packages

1.(a) Certificate Number	1.(b) Revision No.	1.(c) Package Identification No.	1.(d) Pages No.	1.(e) Total No. Pages
9044	6	USA/9044/B( )F	1	4

2. PREAMBLE

2.(a) This certificate is issued to satisfy Sections 173.393a, 173.394, 173.395, and 173.396 of the Department of Transportation Hazardous Materials Regulations (49 CFR 170-189 and 14 CFR 103) and Sections 146-19-10a and 146-19-100 of the Department of Transportation Dangerous Cargoes Regulations (46 CFR 146-149), as amended.

2.(b) The packaging and contents described in item 5 below, meets the safety standards set forth in Subpart C of Title 10, Code of Federal Regulations, Part 71, "Packaging of Radioactive Materials for Transport and Transportation of Radioactive Material Under Certain Conditions."

2.(c) This certificate does not relieve the consignor from compliance with any requirement of the regulations of the U.S. Department of Transportation or other applicable regulatory agencies, including the government of any country through or into which the package will be transported.

3. This certificate is issued on the basis of a safety analysis report of the package design or application-

3.(a) Prepared by (*Name and address*):

General Electric Company
P. O. Box 460
Pleasanton, CA 94566

3.(b) Title and identification of report or application:

General Electric Company application dated January 8, 1969, as supplemented.

3.(c) Docket No. 71-9044

CONDITIONS

This certificate is conditional upon the fulfilling of the requirements of Subpart D of 10 CFR 71, as applicable, and the conditions specified in item 5 below.

5. Description of Packaging and Authorized Contents, Model Number, Fissile Class, Other Conditions, and References:

(a) Packaging

(1) Model No.: GE-1600

(2) Description

Steel encased lead shielded shipping cask. A double-walled steel cylinder protective jacket encloses the cask during transport. It is bolted to a steel pallet. The cask is closed by a lead-filled flanged plug fitted with a silicone rubber gasket and bolted closure. The cavity is equipped with a drain line and the physical description is as follows:

Cask height, in	67.5
Cask diameter, in	38.5
Cavity height, in	54.0
Cavity diameter, in	26.5
Lead shielding, in	5.0
Protective jacket height, in	81.4
Protective jacket width, in	68.0
Packaging weight, lbs	23,050

5. (b) (1) Contents (continued)

(vi) Solid nonfissile irradiated metal hardware, reactor control rods (blades), and reactor start-up sources.

(c) Fissile Class III

Maximum number of packages per shipment

(i) Contents 5.(b)(1)(i), 5.(b)(1)(ii), or 5.(b)(1)(iii):

Two (2): or

(ii) Contents 5.(b)(1)(iv):

One (1)

6. The U-235 equivalent mass is determined by U-235 mass plus 1.66 times U-233 mass plus 1.66 times Pu mass.

7. For packaging of neutron sources, the cavity drain line shall be closed with a plug with a melting temperature of 200°F and the cask cavity shall be filled with water with a 5-inch air space within the cask cavity. When needed, sufficient antifreeze in the cask shall be used to prevent damage to any component of the package due to freezing.

8. For packaging of other than neutron sources, the cask shall be delivered to a carrier dry and the cavity drain line shall be closed with a plug which will maintain its seal at temperatures up to at least 620°F.

9. Shoring shall be provided to minimize movement of contents during accident conditions of transport.

10. Prior to each shipment the silicone rubber lid gasket(s) shall be inspected. This gasket(s) shall be replaced if inspection shows any defects or every twelve (12) months, whichever occurs firts. Cavity drain line shall be sealed with appropriate sealant applied to threads of pipe plug.

11. For packaging of neutron sources, measurements shall be made to determine that the dose rate does not exceed 1,000 mrem/hr at 3 feet from the surface of a dry cask with no additional shielding within the cask.

12. The contents described in 5.(b)(1)(v) shall be transported on a motor vehicle, railroad car, aircraft, inland water crafts, or hold or deck of a seagoing vessel assigned for sole use of the licensee.

13. The package authorized by this certificate is hereby approved for use under the general license provisions of 10 CFR §71.12(b).

14. Expiration date: December 31, 1980.

5. (a) Packaging (continued)

(3) Drawings

The packaging is constructed in accordance with the following General Electric Company Drawing Nos.:

212E255, Rev. 3	135C5598, Rev. 1
106D3986, Rev. 1	106D3973, Rev. 1
174F237, Rev. 1	

(b) Contents

(1) Type, form and maximum quantity of material per package

Plutonium in excess of twenty (20) curies per package must be in the form of metal, metal alloy or reactor fuel elements; and

(i) Byproduct material and special nuclear material as solid metal or oxides. Decay heat not to exceed 600 watts. The radioactive material shall be in the form of fuel rods, or plates, fuel assemblies, or meeting special form requirements of 10 CFR §71.4(o).

500 gm U-235 equivalent mass; or

(ii) Neutron sources in special form.

500 gm U-235 equivalent mass. Decay heat not to exceed 50 watts; or

(iii) Irradiated PuO_2 and UO_2 fuel rods clad in zircaloy or stainless steel. Decay heat not to exceed 600 watts. All fuel rods shall be contained within a closed 5-inch Schedule 40 pipe with a maximum useable length of 39-5/8 inches.

1,200 gm fissile material with no more than 300 gm fissile material per 5-inch Schedule 40 pipe.

(iv) Irradiated UC and ThC fuel particles clad in graphite and contained within a standard HTGR hexagonal cross-section graphite block. Decay heat not to exceed 600 watts. Each graphite block shall be contained within a sealed cylindrical inner container constructed in accordance with General Atomic Company Drawing No. 021583, Issue A, with three, 1/2-inch by 4-1/2-inch radial fins to provide centering within the cavity.

1,400 grams U-235 equivalent mass in each inner container with no more than one inner container per package.

(v) Process solids, either dewatered, solid, or solidified in a secondary sealed container meeting the requirements for low specific activity radioactive material.

CERTIFICATE OF COMPLIANCE FOR RADIOACTIVE MATERIALS PACKAGES

REFERENCES

General Electric application dated January 8, 1969.

Supplements dated: February 12, 20, and 27, and March 10 and 24, 1969; November 20, 1970; January 29 and March 12, 1971; July 3 and November 15, 1973; and August 26, 1980.

Nuclear Plant Services supplement dated: July 7, 1975.

FOR THE U.S. NUCLEAR REGULATORY COMMISSION

Charles E. MacDonald, Chief
Transportation Certification Branch
Division of Fuel Cycle and
Materials Safety

Date: OCT 03 1980

NRC FORM 335 (11 81)

U.S. NUCLEAR REGULATORY COMMISSION

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3. RECIPIENT'S ACCESSION NO.

7. AUTHOR(S)
C. R. Kempf, D. R. MacKenzie, B. S. Bowerman, D. R. Dougherty, and B. Siskind

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9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
Brookhaven National Laboratory
Department of Nuclear Energy
Upton, New York 11973

DATE REPORT ISSUED
MONTH: November YEAR: 1984

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8. (Leave blank)

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Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

10. PROJECT/TASK/WORK UNIT NO.

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15. SUPPLEMENTARY NOTES

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16. ABSTRACT (200 words or less)

An evaluation of the low-level wastes and waste packages generated by General Electric Vallecitos Nuclear Center (GEVNC) was made on the basis of 10 CFR Part 61 criteria and on the Technical Position on Waste Form (TP). In addition, a review has been performed of the handling and storage methods used by GEVNC for their transuranic wastes. Several options have been discussed for management of these materials. This evaluation was the result of a study initiated by the U.S. Nuclear Regulatory Commission (NRC), in which GEVNC participated. GEVNC generates Class B or greater radioactive wastes in hot cell processes which include examination of reactor fuel and components, and production of sources and radiopharmaceuticals. The dominant contaminating radioisotopes are Cs-137 and Co-60. In addition, transuranic wastes which result from examination and burnup analyses of fuel are all currently stored on-site at GEVNC. Class B and greater wastes are packaged in 84-gallon extended 17H drums that are grouted with cement. Based on the evaluation, overall, the waste forms of these packages are expected to maintain their stability, but a few concerns are identified and testing should be performed by GEVNC to demonstrate waste form stability.

17. KEY WORDS AND DOCUMENT ANALYSIS

17a. DESCRIPTORS

low-level, Cs-137, Co-60, grouted concrete waste forms, package evaluation with respect to Technical Position on Waste Form, low-level TRU waste management options

17b. IDENTIFIERS/OPEN-ENDED TERMS

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NRC FORM 335 (11 81)

NUREG/CR-3864

CHARACTERIZATION OF THE LOW-LEVEL RADIOACTIVE WASTES AND WASTE PACKAGES OF GENERAL ELECTRIC VALLECITOS NUCLEAR CENTER

NOVEMBER 1984