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Greater-Than-Class C Low-Level Radioactive Waste Characterization

Appendix E-5: Impact of the 1993 NRC Draft Branch Technical Position on Concentration Averaging of Greater-Than-Class C Low-Level Radioactive Waste

***Greater-Than-Class C Low-Level Waste
Management Program***

September 1994

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Appendix E-5: Impact of the 1993 NRC Draft Branch Technical Position on Concentration Averaging of Greater-Than-Class C Low-Level Radioactive Waste

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ABSTRACT

This report evaluates the effects of concentration averaging practices on the disposal of greater-than-Class C low-level radioactive waste (GTCC LLW) generated by the nuclear utility industry and sealed sources. Using estimates of the number of waste components that individually exceed Class C limits, this report calculates the proportion that would be classified as GTCC LLW after applying concentration averaging; this proportion is called the concentration averaging factor. The report uses the guidance outlined in the 1993 Nuclear Regulatory Commission (NRC) draft Branch Technical Position on concentration averaging, as well as waste disposal experience at nuclear utilities, to calculate the concentration averaging factors for nuclear utility wastes. The report uses the 1993 NRC draft Branch Technical Position and the criteria from the Barnwell, South Carolina, LLW disposal site to calculate concentration averaging factors for sealed sources.

The report addresses three waste groups: activated metals from light water reactors, process wastes from light-water reactors, and sealed sources. For each waste group, three concentration averaging cases are considered: high, base, and low. The base case, which is the most likely case to occur, assumes using the specific guidance given in the 1993 NRC draft Branch Technical Position on concentration averaging. To project future GTCC LLW generation, each waste category is assigned a concentration averaging factor for the high, base, and low cases.

SUMMARY

The U.S. Department of Energy (DOE) is responsible for the disposal of all greater-than-Class C low-level radioactive waste (GTCC LLW) generated by radioactive waste generators licensed through the U.S. Nuclear Regulatory Commission (NRC) or Agreement States. Therefore, DOE must be able to accurately project anticipated volumes of GTCC LLW to effectively plan for disposal.

The final volume of GTCC LLW that will require disposal may be affected by several factors, such as the practice of concentration averaging. This practice can be used by waste generators to dispose of some LLW components that individually exceed Class C limits in low-level radioactive waste disposal facilities. The waste generator mixes such components with components of a lesser classification, such as Class A, B, or C. This results in a waste package with allowable concentrations of restricted radionuclides, calculated over the volume of all the waste in the package; this package can then be disposed of in a disposal facility for Class A, B, or C waste. This practice is widely used by generators of LLW and is accepted by LLW disposal facilities.

This 1994 report updates an earlier report that evaluated the impact of the 1991 concentration averaging guidelines on estimated amounts of GTCC LLW. This study uses the guidance outlined in the 1993 NRC draft Branch Technical Position, as well as waste disposal experience at nuclear utilities, to update estimates of GTCC LLW from nuclear utility wastes. The report uses the 1993 NRC draft Branch Technical Position and criteria from the Barnwell, South Carolina, LLW disposal site to calculate projections for sealed sources.

This report quantifies the effects of concentration averaging disposal practices on GTCC LLW. Using estimates of the number of waste components that individually exceed Class C limits, this report calculates the proportion that would be classified as GTCC LLW after applying concentration averaging. This proportion is called the concentration averaging factor.

The radioactive waste generated by the private sector is divided into three main categories for reporting purposes: activated metals from light water reactors (LWRs), process wastes from LWRs, and sealed sources. The first two waste groups are generated by the nuclear utility industry. The third group, sealed sources, results from a wide range of sealed sources used in private industry and medical fields.

The volume of GTCC LLW projected for each of the three waste groups is analyzed under three credible concentration averaging cases: high, base, and low. Each concentration averaging case is defined using a different set of assumptions. The low case assumptions result in the smallest waste volume that would be classified as GTCC LLW after applying concentration averaging. In contrast, the high case assumptions yield the largest waste volume that would be classified as GTCC LLW after applying concentration averaging. The base case presents the most likely case to occur. The base case uses the specific guidance given in the 1993 NRC draft Branch Technical Position on concentration averaging.

To perform future projections of GTCC LLW generation, each waste type is assigned a concentration averaging factor for the high, base, and low cases. These concentration averaging factors are used in two different databases to calculate projected volumes of GTCC LLW requiring disposal, as reported in the body of the DOE/LLW-114 Revision 1 report.

This report indicates that using the 1993 NRC draft Branch Technical Position for concentration averaging will allow a substantial amount of waste components that individually exceed Class C limits to be concentration averaged for disposal in a Class A, B or C waste disposal site. The base case for activated metals and process wastes estimates that more than half of all waste components that individually exceed Class C limits can be concentration averaged for disposal as Class A, B, or C waste. The base case for sealed sources estimates that two-thirds of all potentially GTCC sealed sources can be concentration averaged for disposal as Class A, B or C waste.

FOREWORD

In 1990, EG&G Idaho contracted with WMG Inc. to integrate their extensive experience with nuclear power plant waste characterization and shipping into the Department of Energy Greater-Than-Class C Low-Level Waste (GTCC LLW) Management Program. Those efforts led to two reports in support of the GTCC LLW Program, which were issued in 1991: DOE/LLW-114F, *Greater-Than-Class C Low-Level Radioactive Waste Light Water Reactor Projections*, and DOE/LLW-114I, *Impact of Concentration Averaging Low-Level Radioactive Waste Volume Projections*. To a large extent, both reports relied on data representative of LLW that was characterized, packaged, and shipped for disposal prior to 1991.

This report describes further work performed in 1993 by WMG under EG&G Idaho contract C93-170362 to update DOE/LLW-114I, WMG's earlier report on the impact of concentration averaging on projected volumes of GTCC LLW.

This report also includes a section on concentration averaging of sealed sources that was researched and written by Gerry Harris, EG&G Idaho, Inc.

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Appendix E-5: Impact of the 1993 NRC Draft Branch Technical Position on Concentration Averaging of Greater-Than-Class C Low-Level Radioactive Waste

1. INTRODUCTION

The Code of Federal Regulations, 10 CFR 61.55, defines the requirements for low-level radioactive waste (LLW) classification. This regulation separates low-level radioactive waste into three classes—A, B, or C. LLW must meet the requirements of one of these classes to be suitable for shallow-land disposal. To determine the waste class, the radionuclide concentrations within the waste are compared to concentration limits for particular radionuclides. The Class C designation is the most restrictive. If radionuclide concentrations in the LLW exceed Class C limits, then the waste is not suitable for shallow-land disposal. LLW that exceeds these limits is referred to as "greater-than-Class C" (GTCC) LLW.

According to Public Law 99-240, the Low-Level Radioactive Waste Policy Amendments Act of 1985, the U.S. Department of Energy (DOE) is responsible for the disposal of all GTCC LLW generated by radioactive waste generators that have been licensed through the U.S. Nuclear Regulatory Commission (NRC) or Agreement States. Therefore, DOE must be able to project anticipated volumes of GTCC LLW to effectively plan for disposal. This report is part of a series of studies undertaken to determine disposal requirements and options for management of GTCC LLW. This report evaluates how LLW packaging choices, specifically concentration averaging, may affect the amount of GTCC LLW that DOE must plan to dispose of.

The reader should note that, even though this report estimates volumes of low-level radioactive waste that might require disposal as GTCC LLW, many other factors can influence the actual disposal practices eventually employed. Thus, the estimates in this report are based on the authors' experience and knowledge and represent the best estimate of projected GTCC LLW volumes based on current information.

This report addresses three waste groups that produce GTCC LLW: activated metals from light water reactors (LWRs), process wastes from LWRs, and sealed sources. For each waste group, three concentration averaging cases are considered: high, base, and low. Each concentration averaging case is defined using a different set of assumptions, based primarily upon the 1993 NRC draft Branch Technical Position.

The purpose of this report is threefold: (a) describe how the 1993 NRC draft Branch Technical Position on concentration averaging may be applied to the three waste groups, (b) define concentration averaging cases for each waste group based primarily on the NRC 1993 draft Branch Technical Position, and (c) estimate GTCC LLW concentration averaging factors that reflect these cases. To determine the concentration averaging factors, the study begins with estimates of the number of waste components that individually exceed Class C limits (see Appendix A-3)^a and then factors in concentration averaging practices. The concentration

a. References to appendices in this report are to the appendices in *Greater-Than-Class C Low-Level Radioactive Waste Characterization: Estimated Volumes, Radionuclide Activities, and Other Characteristics* (DOE/LLW-114, Revision 1).

averaging factors represent the proportion that would be classified as GTCC LLW after concentration averaging. These factors were used in DOE computer models to project volumes of GTCC LLW in future years (from 1993 to 2055).

Section 2 of this report describes the 1993 NRC draft Branch Technical Position on concentration averaging. Section 3 documents the processes used to determine volumes of GTCC LLW from light water reactor components and sealed sources after concentration averaging, as well as the assumptions used to define the high, base, and low concentration averaging cases for the three waste groups examined in this report. Section 4 summarizes the report and presents conclusions. Section 5 lists the references used in this report.

Attachment 1 of this report summarizes concentration averaging data gathered in 1991 for an earlier version of this report.¹ Attachment 2 describes the methodology used to derive the concentration averaging factors for LWR components for each of the cases examined. Attachment 3 discusses the concentration averaging criteria used at the Barnwell, South Carolina, low-level waste disposal facility. The report uses the Barnwell criteria to help calculate concentration averaging factors for sealed sources. The 1993 NRC Branch Technical Position on concentration averaging is included in Attachment 4.

1.1 Definition of Concentration Averaging

How waste is packaged for disposal can influence its classification. To determine the concentrations of radionuclides within a package, the estimated radioactivity is divided by the volume, or mass in some cases, of the waste material in the package. Such a calculation assumes that the waste material within the package is homogeneous. In some cases, relatively high-concentration waste materials are combined with low-concentration waste materials in the same container; within defined bounds, the overall radionuclide concentration in that container is used as the basis for the waste classification. This practice, referred to as "concentration averaging," is widely used by generators of LLW and is accepted by LLW disposal facilities.

How concentration averaging is applied to different types of waste affects how the waste is classified under 10 CFR 61. For example, if a LLW generator packages waste components that individually exceed Class C limits together with lower-concentration waste components, this concentration averaging practice sometimes allows the waste to be disposed of as Class C. Such packaging practices have made it difficult to accurately predict the amounts of GTCC LLW for which DOE would be responsible. As illustrated in Figure 1, in most cases concentration averaging would substantially reduce the amount of LLW that would be classified as GTCC LLW.

Figure 1. Concentration averaging determines the amount of GTCC LLW.

1.2 Waste Groups

This report addresses three waste groups that produce GTCC LLW: activated metals from LWRs, process wastes from LWRs, and sealed sources. These groups are described below.

Activated Metals from LWRs—Activated metals are components, usually stainless steel, that are activated by neutrons within a reactor core. These wastes primarily contain activation product radionuclides. Whether activated metals exceed 10 CFR 61 Class C limits generally depends on their radionuclide concentrations of the beta emitters Ni-59 and Ni-63 and the gamma emitter Nb-94.

Process Wastes from LWRs—During cleanup of radioactive liquids, process wastes are produced in the form of ion-exchange resins and filter cartridges. These wastes contain activation and fission product radionuclides as well as transuranics. Whether process wastes exceed 10 CFR 61 Class C limits usually depends on concentrations of transuranics, the beta emitters Sr-90, Ni-63, and C-14, and the gamma emitter Cs-137.

Sealed Sources—Sealed sources consist of small capsules, usually stainless steel, that contain relatively high concentrations of a single radionuclide. Sources are used for a wide range of industrial and medical applications and become waste when they are no longer usable. For disposal planning, sealed sources can be divided into two distinct groups: (a) those containing transuranics, and (b) those containing other radionuclides. Whether sealed sources exceed Class C limits depends on their radionuclide concentrations relative to 10 CFR 61 Table 1 and 2 limits.

1.3 Concentration Averaging Cases

For each waste group, three concentration averaging cases are considered: high, base, and low. Each concentration averaging case is defined using a different set of assumptions. The low case assumptions result in the smallest waste volume that would be classified as GTCC LLW after applying concentration averaging. In contrast, the high case assumptions yield the largest waste

volume that would be classified as GTCC LLW after applying concentration averaging. The base case reflects the case most likely to occur.

Many of the assumptions used to define the high, base, and low cases are derived from the 1993 NRC draft Branch Technical Position on concentration averaging (see Attachment 4), which the NRC released for comment in September 1993. It was provided as guidance on concentration averaging practices to encourage states and LLW compacts to develop consistent regulations in this area. Criteria from the Barnwell, South Carolina, LLW disposal site are also used to define the high and low cases for sealed sources.

Table 1 summarizes the assumptions used in the high, base, and low cases for each of the three waste groups.

Table 1. GTCC LLW volume projection cases—concentration averaging assumptions.

Waste group		High volume case	Base volume case	Low volume case
1.	Activated metals	No concentration averaging	1993 NRC draft Branch Technical Position on concentration averaging	1993 NRC draft Branch Technical Position plus alternative provisions variances on Nb-94
2.	Process waste	No concentration averaging	1993 NRC draft Branch Technical Position on concentration averaging	1993 NRC draft Branch Technical Position on concentration averaging; no alternative provisions apply
3.	Sealed sources			
	Transuranics:	1993 NRC draft Branch Technical Position using 1.3 g/cm ³ encapsulating mass density	1993 NRC draft Branch Technical Position and averaged encapsulating mass density (between 1.3 and 2.5 g/cm ³)	1993 NRC draft Branch Technical Position using 2.5 g/cm ³ encapsulating mass density - corresponds to current Barnwell criteria
	Nontransuranics:	Lowest activity limit from either 10 CFR 61 Tables 1 and 2, corresponding to 0.2 m ³ (55-gal drum), or from current Barnwell criteria (see Attachment 3)	Activity limit from 10 CFR 61 Tables 1 and 2, corresponding to 0.2 m ³ (55-gal drum)	Highest activity limit from either 10 CFR 61 Tables 1 and 2, corresponding to 0.2 m ³ (55-gal drum), or from current Barnwell disposal criteria (see Attachment 3)

2. 1993 NRC DRAFT BRANCH TECHNICAL POSITION

This section of the report discusses the three main approaches to concentration averaging identified in the 1993 NRC draft Branch Technical Position (Attachment 4). The 1993 NRC draft Branch Technical Position defines standards for concentration averaging (or blending) of most waste types. It provides guidance for applying the waste classification requirements of 10 CFR 61.55.

Three main approaches to concentration averaging are identified in the 1993 NRC draft Branch Technical Position: (a) a simple, conservative method, (b) an approach that uses specific standards for various types of waste, and (c) an alternative provisions guidance that provides variances to the specific standards guidance. The second and third of these three approaches to concentration averaging provide the assumptions for many of the high, base, and low cases used in this report. Each approach is described as it relates to the different waste groups.

2.1 Conservative Method

Under this proposed guidance, a simple, conservative compliance strategy would be to classify the container with commingled waste according to the highest class of any discrete item or waste type in the container. Applying the conservative approach would cause more waste forms to fall into a higher class than would otherwise be determined if the specific concentration averaging guidance were employed. For example, if a container holds 50 cartridge filters that are Class A and one cartridge filter that is Class C, the entire disposal container becomes Class C under the conservative approach.

This conservative approach may be applied by some LLW generators if the packaged waste would be classified as A, B, or C low-level waste. However, it is highly unlikely that the conservative approach would be applied if using the highest classification of any item in a container would result in the container becoming GTCC LLW.

2.2 Specific Concentration Averaging Guidance

The concentrations of radionuclides within a container are determined by dividing the estimated radioactivity by the volume or mass of the waste material within the container. This calculation assumes that the waste material within the container is homogeneous, and the calculated concentrations are averaged over the packaged waste volume or mass (excluding the disposal container). In some cases, relatively high-concentration wastes are combined with low-concentration wastes in the same container; thus, the concentration calculations are based on the combined radioactivity divided by the combined waste volume and mass. This practice is referred to as concentration averaging or blending. The application of this practice to different types of waste affects the 10 CFR 61 waste classification. Therefore, the extent to which concentration averaging is permitted significantly affects what wastes will be classified as GTCC LLW.

Since it is highly unlikely that the conservative method will be used when dealing with GTCC LLW, this study makes a base case assumption that the specific guidance in the 1993 NRC draft Branch Technical Position will be employed for all LLW components that individually exceed Class C limits.

The specific concentration averaging guidance varies with the type(s) of waste being commingled. In all cases, the sums of the fractions of 10 CFR 61 radionuclide concentrations (relative to Table 1 and Table 2 Class C limit concentrations) for all waste contained in the same package must be less than 1 after blending. Some rules apply to using this sum-of-fractions guidance to determine if waste is GTCC. These rules are waste-group dependent and are summarized below.

The 1993 NRC draft Branch Technical Position defines homogeneous waste as a type in which radionuclide concentrations are likely to approach uniformity in the context of 500-year intruder scenarios. Thus, for a 500-year framework, a waste type's homogeneity is not affected by short-lived radionuclides like Co-60, but by longer lived radionuclides such as those included in the Class C limits. Many different waste types, such as spent resins, can be considered homogeneous for classification under this guidance. The 1993 NRC draft Branch Technical Position also defines several waste types as nonhomogeneous, such as activated and contaminated metals, and cartridge filters.

2.2.1 Guidance for Spent Resins

Spent resin is one example of a homogeneous waste under the 1993 NRC draft Branch Technical Position.

- **Rule of 10**

A homogeneous waste type can be blended and classified based on average container concentrations of 10 CFR 61 radionuclides, provided the highest and lowest concentrations for any batch/item in the container are within a factor of 10 of the average concentrations for the container. This factor of 10 applies to both alpha/beta emitter and gamma emitter concentrations relative to limits set in 10 CFR 61 Tables 1 and 2.

- **Resin Stabilization**

Where spent resins are solidified with a medium that meets the 10 CFR 61 stabilization criteria, the volume of the stabilized mass can be included in the total volume to determine radionuclide concentrations.

The spent resins considered in this study would be blended under this guidance.

2.2.2 Guidance for Activated and Contaminated Metals

Activated and contaminated metals are considered nonhomogeneous wastes. To classify a mixture of these wastes, the guidance distinguishes between 10 CFR 61 radionuclides that are beta emitters (Ni-63 and Ni-59) and those that are gamma emitters (Nb-94). Specific guidance applicable to metals includes the following:

- **Alpha/Beta Rule of 10**

Different metal wastes containing alpha/beta emitters can be blended and classified based on average container concentrations of the 10 CFR 61 radionuclides Ni-59, Ni-63, C-14, and transuranics, *provided* the highest and lowest concentrations for any discrete item in the container are within a factor of 10 of the average alpha/beta concentrations for the container.

- **Nb-94 Rule of 1.5**

Different metal wastes containing Nb-94 can be blended and classified based on average container concentrations of Nb-94, *provided* the highest and lowest Nb-94 concentrations for discrete items in the container are within a factor of 1.5 of the average Nb-94 concentration for the container.

- **1 mCi Nb-94 Exemption**

If a component contains less than 1 mCi of Nb-94, the component is exempt from the restrictions of blending under the Nb-94 Rule of 1.5.

The activated metals considered in this study would be blended under this guidance.

2.2.3 Guidance for Cartridge Filters

Cartridge filters are considered nonhomogeneous wastes. To classify a mixture of these wastes, the guidance distinguishes between 10 CFR 61 radionuclides that are alpha/beta emitters (Ni-63, Ni-59), gamma emitters (Cs-137), and transuranics. Specific guidance applicable to filters includes the following:

- **Alpha/Beta Rule of 10**

Different filters containing alpha/beta emitters can be blended and classified based on average container concentrations of 10 CFR 61 radionuclides, *provided* the highest and lowest concentrations for any filter in the container are within a factor of 10 of the average alpha/beta concentrations for the container.

- **Cs-137 Rule of 1.5**

Different filters containing Cs-137 can be blended and classified based on average container concentrations of Cs-137, *provided* the highest and lowest Cs-137 concentrations for any waste in the container are within a factor of 1.5 of the average Cs-137 concentration for the container.

The cartridge filters considered in this study would be blended under this guidance.

2.2.4 Guidance for Encapsulation

Filter cartridges and sealed sources can be encapsulated. The volume and mass of the encapsulation media can be used to calculate the 10 CFR 61 classification. Specific guidance for encapsulation includes the following:

- **Maximum Encapsulated Mass or Volume**

The total mass shall not exceed 500 kg (1,100 lb) or 0.2 m³ (55-gal drum).

- **Maximum Gamma Emitting Activity**

This is expressed with two different criteria:

- **Dose Rate Limit**—The maximum allowable activity must yield a 500-year container surface dose below 0.02 mrem/hr, provided that the shielding attenuation factor does not exceed that inherent in 15 in. of concrete.
- **Cs-137 Limit**—No encapsulated source shall contain more than 30 Ci of Cs-137 at the time of encapsulation.

For Cs-137 sources, the 30 Ci limit governs. For the other Class C gamma emitter, Nb-94, the dose rate criteria will govern.

- **Maximum Alpha/Beta Emitting Activity**

For transuranics, these limits are expressed as a function of the density of the encapsulation medium, which is defined in the NRC guidance as 1.3 to 2.5 g/cm³. Use of the 2.5 g/cm³ maximum results in a 50-Ci limit, which is calculated from the 100 nCi/g limit from 10 CFR 61, multiplied by the 500-kg mass limit from the NRC guidance, as explained above.

For beta emitters like Sr-90 and Ni-63, the 0.2 m³ volume limit above governs. Therefore, at a Class C limit of 7,000 µCi/cm³, up to 1,400 Ci of Sr-90 can be encapsulated. At a Class C limit of 700 µCi/cm³ (nonmetal), up to 140 Ci of Ni-63 can be encapsulated.

The sealed sources considered in this study would be blended under this guidance.

2.3 Alternative Provisions Guidance

The 1993 NRC draft Branch Technical Position includes an alternative provisions section that provides for variances to the above guidance. This section is particularly relevant to concentration averaging of the relatively large activated metal components or pieces generated during LWR decommissioning. The low case for this study assumes that the alternative provisions guidance will be used to request variances from the Nb-94 rule of 1.5 for shipments of these activated metals.

3. CONCENTRATION AVERAGING FACTORS FOR GTCC LLW

The effects of the 1993 NRC draft Branch Technical Position are quantified in this section through concentration averaging factors (CAFs). Each component is evaluated for three different concentration averaging cases (high, base, and low). The methodology used to calculate the CAFs is presented in Attachment 2 of this report. A comparison of Attachment 1 with Attachment 2 will yield some insight into the differences between new NRC guidance and how the concentration averaging practices were previously interpreted. For example, experience from decommissioning the Yankee Rowe reactor² indicates that portions of some reactor vessel internals components that could be blended under previous concentration averaging interpretation are no longer eligible for blending under the more detailed interpretation given in the 1993 NRC draft Branch Technical Position. This does not preclude blending such components; instead, individual shipments containing these components or pieces could be considered under the alternative provisions guidance in the 1993 NRC draft Branch Technical Position. Such variances will be addressed on a case-by-case basis.

To present GTCC LLW projections, this section divides the three waste groups discussed in this report into two subsections: (a) activated metals and process wastes from light water reactors, and (b) sealed sources, which is subdivided into transuranic waste and nontransuranic waste. Table 1 summarizes the assumptions used in the high, base, and low cases for each of the three waste groups.

3.1 GTCC LLW from LWRs

The methodology used to evaluate GTCC LLW from light water reactors is to first determine which LWR components could possibly include some GTCC LLW (see Appendix A-3 for this determination). Then the 1993 NRC draft Branch Technical Position guidance is applied, using the concentration averaging assumptions of the various cases. The resulting CAFs represent, of those LLW components that individually exceed Class C limits, the proportion that would be classified as GTCC LLW after applying the NRC guidance on concentration averaging.

Take, for example, dry tubes. The high case assumes that no concentration averaging is applied; thus, the CAF for dry tubes under the high case will be 1, or all dry tubes that individually exceed Class C limits would be classified as GTCC LLW. Under the base case assumptions, dry tubes qualify for the 1 mCi Nb-94 exemption. As a result, the CAF for the base case would be 0.25, indicating that one-quarter of all dry tubes that individually exceed Class C limits would be classified as GTCC LLW. Under the low case, which assumes alternative provisions are applied, the CAF for dry tubes would be 0.1, indicating that approximately one-tenth of all dry tubes that individually exceed Class C limits would be classified as GTCC LLW.

See Attachment 2 of this report for further information concerning the methodology used to calculate concentration averaging factors for LWR components.

3.1.1 Concentration Averaging Cases for LWR Components

The assumptions used to define the high, base, and low concentration averaging cases for LWR components are as follows:

- **High case**

For all LWR waste groups considered under the high case, no concentration averaging is assumed for components and pieces that individually exceed Class C limits. This very restrictive reading of 10 CFR 61 requirements reflects the prospective criteria of a few compact regions,^b which have no provisions for concentration averaging, use of stabilization media volumes for concentration calculations, or encapsulation.

- **Base case**

The specific guidance criteria defined in the 1993 NRC draft Branch Technical Position is used for the base case concentration averaging of LWR components.

- **Low case**

Although the criteria in the 1993 NRC draft Branch Technical Position will represent prospective concentration averaging practices, the alternative provisions guidance defines a process for obtaining variances on a case-by-case basis. A waste group affected by the 1993 NRC draft Branch Technical Position is activated metals generated during LWR decommissioning; this group is cited as an example in the Technical Position. It is likely that the alternative provisions guidance will be used to request variances from the Nb-94 rule of 1.5 for shipments of activated metals. The low case for this study assumes that the Nb-94 criteria can be increased from 1.5 to a factor of 3 for activated metals.^a

For each LWR waste type, Appendix A-3 determines the amount of LLW components that individually exceed Class C limits. The following sections evaluate those LWR waste types to estimate how much of such LLW would be classified as GTCC LLW after concentration averaging is performed under the various cases. The reason for selecting each component's CAF is explained under the corresponding heading, and the Results section for each component lists the CAFs for that component.

b. This assumption is based on the authors' knowledge and experience.

3.1.2 Activated Metals From LWRs

Activated metals consist of the nonfuel-bearing components that become radioactive through exposure to neutron flux within light water reactors. Two sources are considered: (a) components that are periodically replaced during normal operations, and (b) structural components in the reactor vessel that are removed at decommissioning. See Appendix A-3 for a description of estimated volumes, activities, and generation rates for the activated metal components.^c

The concentration averaging assumptions used for both operations activated metals and decommissioning activated metals are the same. These include

- **High case**—No concentration averaging
- **Base case**—Concentration averaging according to the specific guidance provided in the 1993 NRC draft Branch Technical Position
- **Low case**—Concentration averaging according to the 1993 NRC draft Bench Technical Position with an assumed variance under the alternative provisions guidance, which increases the Nb-94 Rule of 1.5 to a factor of 3.0.

For the base and low cases, the Nb-94 exemption in the NRC guidance will dictate what metals can be classified as Class C after concentration averaging practices. Most activated metals are type 304 stainless steel and various grades of inconel. For type 304 stainless steel, the relationship between Nb-94 and Ni-59 and C-14 (the other two critical nuclides from 10 CFR 61 Table 1) is relatively constant. That is, Nb-94 typically represents 40–60% of the sum of the Table 1 fractions. Thus, when the sum of the Table 1 fractions is unity (just at the Class C limit), Nb-94 is 0.4 to 0.6 of the Class C limit. Under the 1993 NRC draft Branch Technical Position, individual components and discrete items can be blended if the 10 CFR 61 Table 1 fraction of Nb-94 of any component is within a factor of 1.5 of the average Nb-94 concentration for all the metals in the container. This restriction does *not* apply if the component or discrete item contains less than 1 mCi Nb-94.

For larger components where the Nb-94 activity is usually greater than 1 mCi, the Nb-94 Rule of 1.5 determines the limits for concentration averaging under the base case. For the typical stainless steel component in which Nb-94 represents about 50% of the 10 CFR 61 Table 1 sum of fractions, components with a Table 1 sum of fractions greater than about 1.5 cannot be blended under the 1993 NRC draft Branch Technical Position. This also means that the difference in concentrations between discrete items with the highest and lowest activity in a disposal container is about a factor of 2.

Many of the smaller components qualify for the 1 mCi exemption. Since metals rely on displaced volumes to determine radionuclide concentrations, and since most components are of stainless steel with the same density, mass can be substituted for volumes when considering the

c. Appendix A-3 assumes that a 40-year operating lifetime is used as a fixed parameter for all plants to predict activation levels of decommissioning waste metals.

Nb-94 exemption. At the 10 CFR 61 Class C limit of $0.2 \mu\text{Ci}/\text{cm}^3$ for Nb-94, 1 mCi equates to about 90 lb of metal. Since Nb-94 contributes approximately 50% to the Table 1 Class sum of fractions, a 90-lb component could have a Table 1 sum of fractions of up to 2 and still be exempt from the Nb-94 blending requirements. As metal component mass (volume) decreases, there is a corresponding increase in the allowable Table 1 sum of fractions for waste components that are still exempt from the Nb-94 blending restriction.

For purposes of this study, the 1 mCi Nb-94 exemption is used to define GTCC LLW for smaller components up to 50 lb, which is the maximum weight of any component that qualifies for the Nb-94 exemption. For the larger components under the base case, this means that any component with an estimated 10 CFR 61 Table 1 sum of fractions above 1.5 cannot be blended. For the low case, a similar restriction based on a Nb-94 factor of 3 is defined; any larger component with an estimated 10 CFR 61 Table 1 sum of fractions above 3 cannot be blended. For the high case, no concentration averaging is assumed.

It is worth noting several points concerning blending materials used for concentration averaging at boiling water reactors (BWRs) and pressurized water reactors (PWRs):

- Blending material with relatively high radionuclide concentrations (but still Class C or less) is needed to allow concentration averaging under the Nb-94 guidance in the 1993 NRC draft Branch Technical Position.
- To maintain a 10 CFR 61 Table 1 sum of fractions of less than 1 for a disposal container and to meet the Nb-94 rule of 1.5, the pieces with the highest and lowest concentrations in a container must have concentrations within about a factor of 2 of each other, so that they are each within 1.5 of the average.
- When the high-concentration pieces are at 1.5 times Class C Table 1 limits, the pieces used for blending at equal volumes must be 0.5 times Table 1 Class C limits so that the average is about 1, or just slightly below, to be classified as Class C instead of GTCC.

Table 2 summarizes CAFs for GTCC activated metals components. Each of the components is discussed in the following sections.

Table 2. GTCC LLW concentration averaging factors—activated metals.

		High case CAF	Base case CAF	Low case CAF
1.	BWR operations			
	a. Control rod blades	1	0.1	0
	b. LPRM strings	1	0.13	0.01
	c. Dry tubes	1	0.25	0.1
2.	PWR operations			
	a. Thimble plug assemblies	1	0	0
	b. Instrument strings			
	c. Primary sources	1	0.23	0.01
		1	1	1
3.	BWR decommissioning			
	a. Core shroud	1	0.75	0.5
	b. Orificed fuel supports	1	0	0
	c. Top fuel guide	1	0.67	0.33
4.	PWR decommissioning			
	a. Core baffle (shroud)	1	1	1
	b. Lower core barrel	1	0.67	0.33
	d. Lower core support plate	1	0.67	0.33
	c. Upper core support plate	1	0.67	0.13

3.1.2.1 BWR Operations Components. It is common practice at boiling water reactors to combine different types of components in the same container for disposal as LLW. The routine operations components identified in Appendix A-3 as potentially including some GTCC LLW are discussed below in the context of the concentration averaging cases considered for this study.

1. Control Rod Blades

Control rod blades (CRBs) account for the largest-volume of routinely generated LLW components that individually exceed Class C limits. See Appendix A-3 for a description of estimated CRB volumes, activities, and generation rates.

When the radionuclide concentration of an individual CRB exceeds Class C limits, the Nb-94 content exceeds 1 mCi, so the Nb-94 exemption does not apply. Thus, for the base case, any blending must be considered in the context of the Nb-94 rule of 1.5. Under this rule, an individual CRB with a 10 CFR 61 Table 1 sum of fractions above about 1.5 cannot be blended. For the low case, a CRB cannot be blended if it has a Table 1 sum of fractions of 3 or more.

However, as described in Appendix A-3, CRBs run in the conventional mode were estimated to have a 10 CFR 61 Table 1 sum of fractions of about 1.4. For plants run in the controlled cell mode, a 10 CFR 61 Table 1 sum of fraction of about 1.3 was estimated. This implies that most CRBs can be blended.

Results. Under the high case, which assumes no concentration averaging, all CRBs that individually exceed Class C limits would be classified as GTCC LLW; the CAF equals 1. Under the base case, a few such CRBs would be classified as GTCC LLW, with a CAF of 0.1. It is highly unlikely that a CRB will exceed a 10 CFR 61 Table 1 sum of fractions of 3, so no such CRBs will be classified as GTCC LLW under the low case; the CAF equals 0.

2. Local Power Range Monitor Strings

Each core contains 31 local power range monitor (LPRM) strings. See Appendix A-3 for a description of estimated LPRM string volumes, activities, and generation rates. The normal operating life for an LPRM string is about three cycles.

Under the 1993 NRC draft Branch Technical Position, most LPRM strings will qualify for the 1 mCi Nb-94 exemption. At the 1 mCi maximum, the allowable Nb-94 concentrations in these components is $0.35 \mu\text{Ci}/\text{cm}^3$. This concentration, and a typical Nb-94 contribution of 50% to the 10 CFR 61 Table 1 sum of fractions, indicates that an LPRM string can be blended if it has a Table 1 sum of fractions of up to about 3.5.

In Appendix A-3, it was estimated that LPRM strings would have a 10 CFR 61 Table 1 sum of fractions of about 1.6. This assumes that hot ends and cold ends are shipped in the same container.

Results. Under the high case, which assumes no concentration averaging, all LPRM strings that individually exceed Class C limits would be classified as GTCC LLW; the CAF equals 1. However, with the 1 mCi Nb-94 exemption under the 1993 NRC draft Branch Technical Position, most such LPRMs could be blended. Therefore, under the base case, the CAF equals 0.13. Under the low case, essentially none of these LPRMs would be classified as GTCC LLW; the CAF equals 0.01.

3. IRM/SRM Dry Tubes

Each core contains eight intermediate range monitors (IRM) and four source range monitors (SRM). These monitors are fission chambers that are inserted into the core region through stainless steel tubes referred to as dry tubes. Dry tubes are not routinely discharged; they are replaced only when damaged or embrittled. See Appendix A-3 for a description of estimated IRM/SRM dry tube volumes, activities, and generation rates.

Under the 1993 NRC draft Branch Technical Position, dry tubes qualify for the 1 mCi Nb-94 exemption. At the 1 mCi maximum, the allowable Nb-94 concentration in these components is $0.44 \mu\text{Ci}/\text{cm}^3$. This concentration, and a typical Nb-94 contribution of 50% to the 10 CFR 61 Table 1 sum of fractions, indicates that a dry tube can be blended if it has a Table 1 sum of fractions of up to about 4.4.

Appendix A-3 estimated that dry tubes would have a 10 CFR 61 Table 1 sum of fractions of about 4.6, assuming the hot and cold ends were placed in the same container. This is slightly above the typical 1 mCi Nb-94 exemption level; therefore, dry tubes can become GTCC LLW.

Results. Under the high case, which assumes no concentration averaging, all dry tubes would be classified as GTCC LLW; the CAF equals 1. Under the base case, some would be classified as GTCC LLW; the CAF equals 0.25. Under the low case, a small proportion of the dry tubes would be classified as GTCC LLW; the CAFs equal 0.1.

3.1.2.2 PWR Routine Components. The practice of combining different types of components in the same container is not as prevalent at pressurized water reactors as it is at BWRs. This is because only instrument strings typically exceed Class C limits. Moreover, other PWR components, like burnable poison rod assemblies and reactor control cluster assemblies, rarely have activities high enough to use as blending materials with instrument strings (i.e., rarely are radionuclide concentrations in these components within the required factor for instrument string activities to qualify for the Alpha/Beta Rule of 10 or the Nb-94 Rule of 1.5). Thus, concentration averaging practices are usually confined to blending instrument strings of different activity levels.

Unlike BWRs, there are also differences in material compositions and physical characteristics among the components for the three PWR reactor manufacturers: Westinghouse, Babcock & Wilcox (B&W), and Combustion Engineering. The operations components, identified in Appendix A-3, are discussed below in the context of concentration averaging.

1. Westinghouse Thimble Plug Assemblies

Thimble plug assemblies are used to restrict water flow through fuel assemblies and are positioned in the top of selected assemblies. See Appendix A-3 for a description of estimated volumes, activities, and generation rates for thimble plug assemblies. These components are discharged only when damaged. Although positioned above the active fuel region, their relatively long in-core residence times can result in some units exceeding Class C limits.

Comparable components in other plants are the B&W orifice rod assemblies and Combustion Engineering control element assembly plugs. However, a negligible fraction of these B&W and Combustion Engineering components exceed Class C limits, and should not be a concern for the GTCC LLW Program. Therefore, these B&W and Combustion Engineering components were not included in the GTCC LLW volume and activity estimates.

The Westinghouse thimble plug assemblies qualify for the 1 mCi Nb-94 exemption under the 1993 NRC draft Branch Technical Position. Appendix A-3 estimates that these units would have 10 CFR Table 1 and Table 2 sums of fractions of 1.0 and 1.3, respectively. These facts indicate that thimble plug assemblies can easily be blended.

Results. Under the high case, which assumes no concentration averaging, all thimble plug assemblies that individually exceed Class C limits would be classified as GTCC LLW; the CAF equals 1. Under the base and low cases, no such assemblies would be classified as GTCC LLW; the CAFs equal 0.

2. In-Core Instrument Strings

Instrument strings consist of flux monitor probes and inconel or stainless steel flux wires. They are inserted through instrument tubes in the fuel assemblies. See Appendix A-3 for a description of estimated instrument string volumes, activities, and generation rates. The common names of the instrument strings and their characteristics vary with each reactor vendor. This study uses the general term "instrument string" to refer to the following components within each reactor type.

Thimble tubes	-	Westinghouse
In-core detectors	-	B&W
Instrument strings	-	Combustion Engineering

Westinghouse plants use eight fixed and four movable in-core detectors, which are inserted into thimble tubes located throughout the core. Appendix A-3 estimates that Westinghouse thimble tubes that individually exceed Class C limits have 10 CFR 61 Table 1 and Table 2 sums of fractions of about 3.3 and 4.3, respectively. The Westinghouse in-core detectors generally do not exceed Class C limits.

B&W plants have locations to accommodate 52 in-core detectors. Appendix A-3 estimates that B&W in-core detectors that individually exceed Class C limits have 10 CFR 61 Table 1 and Table 2 sums of fractions of about 0.8 and 2.1, respectively.

Combustion Engineering plants use between 28 and 61 in-core instrument strings. Appendix A-3 estimates that Combustion Engineering instrument strings that individually exceed Class C limits have 10 CFR 61 Table 1 and Table 2 sums of fractions of about 3.3 and 4.1, respectively.

Under the 1993 NRC draft Branch Technical Position, all of these instrument strings qualify for the 1 mCi Nb-94 exemption. The following are the allowable Nb-94 concentrations at the 1 mCi maximum and the corresponding allowable 10 CFR 61 Table 1 sum of fractions at the typical Nb-94 contribution of 50%. Since the actual Table 1 sums of fractions for all three components are well below the allowable sums listed, it is apparent that these components can easily be blended.

Instrument string type	Allowable Nb-94 concentration, to keep Nb-94 activity within 1 mCi ($\mu\text{Ci}/\text{cm}^3$)	Allowable Table 1 sum of fractions, to keep Nb-94 activity within 1 mCi (assuming Nb-94 contributes 50% of Table 1 sum of fractions)
Westinghouse - thimble tubes with in-core detectors	0.6	6
Babcock & Wilcox - in-core detectors	0.35	3.5
Combustion Engineering - instrument strings	0.5	5

Results. Under the high case, which assumes no concentration averaging, all instrument strings that individually exceed Class C limits would be classified as GTCC LLW; the CAF equals 1. Under the base case, a small proportion of these would be classified as GTCC LLW; the CAF equals 0.13. Under the low case, essentially none would be classified as GTCC LLW; the CAF equals 0.01.

3. Primary Sources

Each PWR reactor uses two primary sources in the first fuel cycle to start the reactor; the primary sources are then removed and stored as waste in the spent fuel pool. These stored primary sources make up the only significant 1993 inventory of GTCC LLW at LWRs, other than decommissioning GTCC LLW at LWRs that have already shut down. There is typically no ongoing generation of primary source wastes. See Appendix A-3 for a description of estimated volumes and activities for these sources. The Westinghouse sources of interest to the GTCC LLW Program are plutonium-beryllium. The B&W sources are stainless steel-clad americium-beryllium. The Combustion Engineering GTCC source materials are plutonium-beryllium.

Under current practices, the plutonium-beryllium and the americium-beryllium source rods exceed Class C limits due to the high transuranic content. Under the 1993 NRC draft Branch Technical Position, the alpha blending Rule of 10 would apply to the alpha-emitting transuranic sources, but suitable alpha-bearing blending material (i.e., with radionuclide concentrations far enough below Class C limits, but high enough to meet the Rule of 10) is not available. Encapsulation of plutonium-beryllium primary sources would also be unacceptable, since the activity exceeds 50 mCi (the limit for encapsulation, as explained in Section 2.2.4 of this report).

Results. Essentially all LWR transuranic primary sources are GTCC LLW in all concentration averaging cases; the CAFs equal 1 for all cases.

3.1.2.3 BWR Decommissioning Components. Activated metals that individually exceed Class C limits in a BWR include some of the reactor internal structural components. These components include the core shroud and the top fuel guide, and are generated when a reactor shuts down and is decommissioned. See Appendix A-3 for a description of estimated volumes and activities for these components. CAFs for these components are discussed below. All CAFs are estimated based on activation levels of metal components in a reactor assumed to be operating for 40 years prior to shutdown.

1. Core Shroud

The shroud is a large cylindrical type 304 stainless steel structure that surrounds the core and provides a barrier to separate the upward flow through the core from the downward flow in the annulus.

Appendix A-3 estimates that, for the two BWR reactor models evaluated, the core shroud will have 10 CFR 61 Table 1 sums of fractions of 1.8 and 3.0, and Table 2 sums of fractions of 1.9 and 3.5.

Due to the large size of this component, it would be sectioned into many pieces for shipment; this study assumes that all of the pieces individually exceed Class C limits. Thus, the concentration averaging factors presented below apply to the entire component.

Results. Under the high case, which assumes no concentration averaging, core shrouds that individually exceed Class C limits would be classified as GTCC LLW; the CAF equals 1. Under the base and low cases, some pieces could be blended, leaving most of this component GTCC LLW; the CAFs equal 0.75.

2. Top Fuel Guide

The top fuel guide is a stainless steel structure that provides lateral support for the top section of the fuel assemblies. It is composed either of stainless steel beams joined at right angles to form square openings, or of a thick stainless steel plate with machined holes, where the fuel assemblies are supported. Due to its large size, it will be sectioned into several pieces for shipment.

Appendix A-3 reported that the BWR top fuel guide is far above Class C limits with Table 1 sums of fractions of 12 and 24 for the two BWR reactor models evaluated, and Table 2 sums of fractions of 11 and 25. It is therefore highly unlikely that this component or significant pieces thereof can be blended under any of the cases considered.

Results. For all cases, all top fuel guides would be classified as GTCC LLW; the CAFs equal 1.

3.1.2.4 PWR Decommissioning Components. Activated metals that individually exceed Class C limits in a PWR include some of the reactor internal structural components. These internals include the core baffle (shroud), the core barrel, and the upper and lower core support plates. All CAFs are estimated based on activation levels of metal components in a reactor assumed to be operating for 40 years prior to shutdown.

In the absence of more extensive field data, it is not clear whether sufficient PWR blending material will be available to support much concentration averaging of decommissioning LLW. For example, it is not known whether thermal shields, the primary source of blending material, will have radionuclide concentrations at or above 0.5 times the Table 1 Class C limits.

1. Core Baffle (Shroud)

The baffle, or shroud, is a structure of type 304 stainless steel that surrounds the core. In Westinghouse plants, the baffle is held in place by structures called former plates. Appendix A-3 estimated that, depending on the reactor model, the core baffle would have 10 CFR 61 Table 1 sum of fractions of about 22 to 48, and Table 2 sum of fractions of about 17 to 37. It is highly unlikely that this component or significant pieces thereof can be blended under any of the cases considered.

Results. For all cases, all core baffles would be classified as GTCC LLW; the CAFs equal 1.

2. Lower Core Barrel

The lower core barrel is a type 304 stainless steel cylinder that provides lateral support for the core and directs the flow of coolant water.

Appendix A-3 estimates that, depending on the reactor model, the lower core barrel would have 10 CFR 61 Table 1 sum of fractions of about 1.1 to 4.6, and Table 2 sum of fractions of about 0.9 to 3.9. This component could probably be blended depending on reactor design.

Due to its large size, the lower core barrel will be sectioned into several pieces for shipment. Some pieces of the barrel may be too highly activated to be suitable for blending in that they could not satisfy the Nb-94 Rule of 1.5 under the 1993 NRC draft Branch Technical Position. Thus, the concentration averaging factors given below represent, for lower core barrel sections that individually exceed Class C limits, the proportion that would be classified as GTCC LLW under the various cases.

Results. Under the high case, which assumes no concentration averaging, all lower core barrel sections that exceed Class C limits would be classified as GTCC LLW; the CAF equals 1. Under the base and low cases, half of such lower core barrel sections would be classified as GTCC LLW; the CAFs equal 0.5.

3. Lower Core Support Plate

The lower core support plate is a type 304 stainless steel cylindrical plate below the fuel. It is attached to the core barrel and supports fuel assemblies laterally. Recent experience with a PWR (Reference 2) indicates that perhaps not all of the support plate may be suitable for blending. Under the 1993 NRC draft Branch Technical Position, the pieces of this component sent to a LLW disposal facility would have to satisfy the Nb-94 Rule of 1.5; proportions of the plate may not be able to meet the criteria with the other blending material available.

Appendix A-3 reports that, depending on the reactor model, the lower core support plate has Table 1 sum of fractions of about 1.1 to 13 and Table 2 sum of fractions of about 1.1 to 12.

Results. Under the high case, which assumes no concentration averaging, all lower core support plates that individually exceed Class C limits would be classified as GTCC LLW; the CAF equals 1. Under the base and low cases (applying specific guidance from the 1993 NRC draft Branch Technical Position), most of such lower core support plates would be classified as GTCC LLW; the CAFs equal 0.75.

4. Upper Core Support Plate

The upper core support plate is a type 304 stainless steel cylindrical plate above the fuel. It rests on the core barrel and supports fuel assemblies laterally. In Combustion Engineering plants, this component is referred to as the fuel assembly alignment plate, and in B&W plants, it is referred to as the upper plenum assembly. Under the 1993 NRC draft Branch Technical Position, the pieces of this component sent to a LLW disposal facility would have to satisfy the Nb-94 Rule of 1.5; however, proportions of the plate may not be able to meet the criteria with the other blending material available.

Appendix A-3 reports that this component will probably not exceed Class C limits in either Combustion Engineering or in B&W plants. For the two Westinghouse models evaluated, however, the Table 1 sums of fractions are 1.4 and 2.1 and Table 2 sums of fractions are 1.2 and 2.1.

Results. Under the high case, which assumes no concentration averaging, all Westinghouse upper core support plates that individually exceed Class C limits would be classified as GTCC LLW; the CAF equals 1. Under the base and low cases (applying specific guidance from the 1993 NRC draft Branch Technical Position), half of such upper core support plates would be classified as GTCC LLW; the CAFs equal 0.5.

3.1.3 Process Wastes From LWRs

Process wastes consist of the wastes that are generated as a result of cleaning up (e.g., ion exchange, filtering) liquids that contain soluble and insoluble radioactive constituents.

At power plants, these wastes are in the form of ion-exchange resins or cartridge filters. These waste forms can exceed Class C limits due to concentrations of Cs-137 and Sr-90, which have 10 CFR 61 Table 2 limits of 4,600 and 7,000 $\mu\text{Ci}/\text{cm}^3$, respectively. The Class C status of some cartridge filters is also affected by the presence of Ni-63, another Table 2 radionuclide with a Class C limit of 700 $\mu\text{Ci}/\text{cm}^3$. Where plants have operated with failed fuel, the concentrations of transuranics and C-14 can also exceed Class C limits of 100 nCi/g and 8 $\mu\text{Ci}/\text{cm}^3$, respectively.

The concentration averaging assumptions used for process wastes are as follows:

- **High case**—No concentration averaging
- **Base case**—Concentration averaging according to the 1993 NRC draft Branch Technical Position
- **Low case**—Concentration averaging according to the 1993 NRC draft Branch Technical Position, same as for the base case. No alternative provisions are assumed to apply.

Table 3 estimates that none of the process wastes would be classified as GTCC LLW after concentration averaging. The basis for the CAF estimates is discussed below.

Table 3. GTCC LLW concentration averaging factors—process wastes.

	High case CAF	Base case CAF	Low case CAF
1. BWR decontamination resins			
a. Full system—fuel in	1	0	0
2. PWR decontamination resins			
a. Full system—fuel in	1	0	0
3. BWR cartridge filters			
a. Control rod drive	1	0	0
b. Fuel pool/underwater vacuum	1	0	0
4. PWR cartridge filters			
a. Miscellaneous filters	1	0	0
- Reactor coolant system			
- Seal water injection			
- Cavity drain			
- Fuel pool			
b. Crud Tank (B&W only)	1	0	0

3.1.3.1 Decontamination Resins. Decontamination processes deposit crud and scale removed from reactor internal surfaces onto deep bed resins. Each process involves several steps and uses different types of resins, which include cation, mixed, and anion resin beds. The cation resins can contain up to 75% of the total activity removed during the decontamination. The cation resins thus have the highest curie loading and under current practices could exceed Class C limits.

Decontamination processing can be done with or without fuel assemblies in the system. If decontamination resins exceed Class C limits, it is primarily due to the transuranic content removed from fuel assemblies. Removing the fuel assemblies before decontamination essentially eliminates the potential for GTCC LLW resins. Thus, the following discussion is confined to resins that could be generated with fuel assemblies in the system.

- **BWR and PWR Reactor Coolant Systems (Fuel In)**

See Appendix A-3 for a description of the type, volume, activity, and generation process for resins resulting from BWR and PWR decontamination processes. As a homogeneous waste under the 1993 NRC draft Branch Technical Position, resins are allowed to be blended using the Rule of 10. Since resins that exceed Class C limits are only 10 to 15% of the total waste resin volumes produced during a full reactor coolant system (RCS) decontamination, these resins can easily be blended.

Results. Under the high case, which assumes no concentration averaging, all resins would be classified as GTCC LLW; the CAF equals 1. Under the base and low cases, none of these resins would be classified as GTCC LLW; the CAFs equal 0. This assumes that the weight% of chelating agents in the resins does not disqualify the waste for disposal as Class A, B, or C waste, due to hazardous waste classification under the Resource Conservation and Recovery Act (i.e., mixed waste); Appendix E-2 indicates a very low possibility of these resins being mixed waste.

3.1.3.2 Cartridge Filters. Reactors use cartridge filters throughout the primary and secondary systems. Due to their relatively small volumes and high activities, individual filters can exceed Class C limits. See Appendix A-3 for a description of the volumes, activity levels, and generation rates of the following types of filters.

- **BWR Control Rod Drive (CRD) Strainers**

Each BWR control rod drive contains three small metallic strainers that remove particulates; two of the strainers, on the "spud" end, have a small volume and may exceed Class C limits. These strainers are replaced when control rod drives are refurbished or replaced.

- **BWR Fuel Pool/Underwater Vacuum Filters**

The BWR fuel pool filters are located upstream or downstream of fuel pool purification demineralizers and consist of cartridge-type filter elements with metal retention screens. The vacuum filter units consist of large and small micron cartridge

filters with metal retention screens. These filters can exceed Class C limits if they remain in the fuel pool during BWR refueling.

- **PWR Miscellaneous Cartridge Filters**

Most of the PWR cartridge filters that can individually exceed Class C limits are common to all PWR reactor types. This category includes the following filter types:

Reactor coolant system filters are among the highest activity filters generated by PWRs. They consist of small to medium micron-size cartridge filters with metal retention screens that purify water returning to the volume control or makeup tank.

Seal water injection filters are small micron metal or fiber retention elements used to purify water from the volume control tank.

Cavity drain filters, also called seal water return filters, are usually relatively low-activity filters, except in those infrequent cases when the PWR reactor cavity is decontaminated. They consist of medium micron metal or fiber retention elements.

Fuel pool filters are also relatively high activity. They are located upstream or downstream of fuel pool purification demineralizers, and can be generated as GTCC LLW during PWR refueling outages, when the spent fuel pool and reactor cavity are vacuumed. They have cartridge-type filter elements with metal retention screens.

- **PWR Crud Tank Filters (B&W only)**

The crud tank filters are found only in B&W plants, and thus are listed separately in the DOE database. They are the highest-activity filters in all PWRs. These filters collect the media backflushed from etched disk filters.

Operationally, cartridge filters can be changed out when they reach a Class C radiological activity level to prevent generation of GTCC LLW in most cases. BWR CRD filters cannot be changed out before they reach a radiological activity level above Class C, since they are removed during routine control rod drive maintenance. However, BWR CRD filters and other filter types that individually exceed Class C limits can be concentration averaged for disposal as LLW.

Under the 1993 NRC draft Branch Technical Position, filters are allowed to be blended within the Alpha/Beta Rule of 10 and the Cs-137 Rule of 1.5. Thus, filters with transuranics and C-14 (limited by 10 CFR 61 Table 1) and Ni-63 (limited by Table 2) can be blended to within a factor of ± 10 of the waste container's average concentrations. When the smaller CRD spud filters are blended with the other CRD filters, these criteria should be readily satisfied. Cs-137 is not present in high concentrations on cartridge filters due to its solubility. Thus, the Cs-137 Rule of 1.5 is not a problem. If an individual filter occasionally fails to meet the criteria for the Alpha/Beta Rule of 10 or the Cs-137 Rule of 1.5, it can be readily encapsulated and disposed of as Class A, B, or C LLW.

Results. Under the high case, which assumes no concentration averaging, all the filters that individually exceed Class C limits would be classified as GTCC LLW; the CAF equals 1. Under the base and low cases, none of these cartridge filters would be classified as GTCC LLW; the CAFs equal 0.

3.2 GTCC LLW from Sealed Sources

Sealed sources consist of small capsules, usually stainless steel, that contain relatively high concentrations of a single radionuclide. Sealed sources are used for a wide range of industrial and medical applications. For disposal planning, sealed sources can be divided into two distinct groups: (a) those containing transuranics, and (b) those containing other radionuclides (nontransuranics). A recent study³ analyzed the potentially GTCC sealed source types. The data used in that study were acquired by surveying sealed source specific licensees. The survey responses were then statistically analyzed to calculate the numbers of potentially GTCC sealed sources that are held by specific licensees. This report evaluates the effects of concentration averaging on the sealed source types identified in Reference 3.

The following chart presents the 10 CFR 61 Table 1 and Table 2 Class C concentration limits for transuranics and nontransuranics of interest in evaluating sealed sources.

Radionuclide	10 CFR 61 Table 1 or Table 2 Class C concentration limit
Transuranics	
Am-241, Cm-244, Pu-238, Pu-239, U-238	100 nCi/g
Pu-241	3,500 nCi/g
Nontransuranics	
Cs-137 ^a	4,600 mCi/cm ³
Sr-90 ^a	7,000 mCi/cm ³
C-14	8 Ci/m ³
Ni-63	700 Ci/m ³
Tc-99	3 Ci/m ³

a. Primary radionuclides of concern for this study

Reference 3 characterized and estimated the number of potentially GTCC sealed sources, and categorized them by the following device types:

- Calibration
- Medical
- Well logging
- Portable gauge
- Irradiation

- Fixed gauge
- X-ray fluorescence
- Others (including radiography and nuclear batteries).

Table 4 summarizes the activities of the potentially GTCC sealed sources described in Reference 3 for each radionuclide of interest, listed according to the various device types. These are sources whose activities exceed both 1 mCi and 10 CFR 61 limits when the concentrations are averaged over the source volume. Many of the potentially GTCC sources enumerated in Reference 3 can and will be disposed of at Class A, B, or C LLW disposal facilities by concentration averaging practices. The following section develops a method for identifying sealed sources that will likely be classified as GTCC LLW.

3.2.1 GTCC LLW Activity Limits

Currently, the Barnwell LLW disposal facility in South Carolina⁴ allows concentration averaging over the volume of a 0.2 m³ container (55-gal drum) (see Attachment 3). The 1993 NRC draft Branch Technical Position allows a similar concentration averaging practice. Using these concentration averaging guidelines, Table 5 lists the largest activities that can be disposed of at a Class C LLW disposal facility.

In 10 CFR 61 Table 1, the activity limits for transuranics are based upon mass; however, the activity limits for nontransuranics are based on volume. Therefore, two sets of assumptions were used to develop the high, base, and low cases for sealed sources.

3.2.1.1 Transuranics. The 1993 NRC draft Branch Technical Position assumes a density of 1.3 g/cm³ for the filled disposal container when calculating a GTCC limit for transuranics; however, it allows concentration averaging in media with a maximum density of up to 2.5 g/cm³ for the filled disposal container (as does the Barnwell LLW disposal site). Hence, Table 5 gives two values for the transuranic activity limits (per container) under the NRC method.

This report assumes that these are reasonable estimates of future GTCC activity limits. Based on these estimates, the proportions of potentially GTCC sources that will be classified as GTCC LLW after concentration averaging are calculated for the high, base, and low case.

- **High case**—The high case uses the lowest activity limits shown in Table 5 to derive the highest number of GTCC sources
- **Base case**—The base case, being the "best" estimate, uses the average of the 1993 NRC draft Branch Technical Position's low and high limits for these radionuclides
- **Low case**—The low case uses the highest activity limits shown in Table 5 to derive the lowest number of GTCC sources.

The resulting GTCC activity limits are shown in Table 6.

Table 4. Summary of the activities of potentially GTCC sealed sources as observed in a 1993 survey of specific licensees.^a

Device type	Isotope	Minimum activity (mCi)	Maximum activity (mCi)	Mean activity (mCi)
Calibration	Am-241	1	550	536
Calibration	C-14	1	50	20
Calibration	Cm-244	1	500	93
Calibration	Cs-137	9	1,947,000	33,777
Calibration	Ni-63	2	90	34
Calibration	Np-237	7	7	7
Calibration	Pu-238	482	482	482
Calibration	Pu-239	1	1,877,000	25,186
Calibration	Pu-241	8	8	8
Calibration	Sr-90	16	800	170
Calibration	Tc-99	1	10	4
Calibration	U-238	1	6	5
Medical	Am-241	7	8,000	30
Medical	Cs-137	92	1,230,000	865
Medical	Sr-90	140	500	197
Medical	Tc-99	1,000	1,000	1,000
Medical	U-238	18	1,289	212
Well logging	Am-241	1	20,000	7,690
Well logging	Cs-137	125	2,500	1,576
Well logging	Pu-238	360	16,700	10,454
Well logging	Pu-241	42,500	42,500	42,500
Portable gauge	Am-241	1	4,000	45
Portable gauge	Cs-137	100	1,000	510
Irradiation	Am-241	1	2,000	656
Irradiation	Cs-137	200	12,000,000	1,460,802
Irradiation	Sr-90	1,360	10,000	5,680
Fixed gauge	Am-241	1	33,000	932
Fixed gauge	C-14	5	5	5
Fixed gauge	Cm-244	10	40	20
Fixed gauge	Cs-137	14	200,000	361
Fixed gauge	Pu-238	500	500	500
Fixed gauge	Sr-90	25	1,000	223
General neutron applications	Am-241	1	52,000	557
General neutron applications	Pu-238	220	70,000	14,465
General neutron applications	Pu-239	1	9,198	1,747
X-ray fluorescence	Am-241	1	5,070	89
X-ray fluorescence	Cm-244	10	300	92
X-ray fluorescence	Pu-238	8	100	44
Other	Am-241	1	20,000	552
Other	C-14	1	100	21
Other	Cm-244	1	1,000	159
Other	Cs-137	1	2,000,000	230
Other	Ni-63	2	180	15
Other	Np-237	13	13	13
Other	Pu-238	1	21,452	4,860
Other	Pu-239	2	10,000	1,717
Other	Pu-241	1,000	2,000	1,600
Other	Sr-90	1	50,000	1,363
Other	Tc-99	1	3,000	2,539
Other	U-238	1	859	66

a. This table is an extension of Table B-4 in Reference 3.

Table 5. Summary of activity limits resulting from Barnwell and 1993 NRC draft Branch Technical Position concentration limits on sealed sources that can be disposed of as Class C LLW.

			NRC Technical Position ^a (encapsulating material mass density)	
	Isotope	Barnwell	1.3 g/cm ³	2.5 g/cm ³
Transuranics				
- Alpha emitters	Am-241	50 mCi	26 mCi	50 mCi
	Cm-244	50 mCi	26 mCi	50 mCi
	Np-237	50 mCi	26 mCi	50 mCi
	Pu-238	50 mCi	26 mCi	50 mCi
	Pu-239	50 mCi	26 mCi	50 mCi
	U-238	50 mCi	26 mCi	50 mCi
- Beta emitter	Pu-241	50 mCi	0.91 Ci	1.75 Ci
			Activity limits ^b for encapsulated nontransuranics (0.2 m ³ total volume of container, a 55-gal drum)	
Nontransuranics				
	C-14	10 Ci	1.6 Ci	
	Cs-137	10 Ci	30 Ci	
	Ni-63	10 Ci	140 Ci	
	Sr-90	10 Ci	1,400 Ci	
	Tc-99	10 Ci	0.6 Ci	

a. In the 1993 NRC draft Technical Position, an encapsulating mass density of 1.3 g/cm³ is "presumed." However, the guidance will allow a density of up to 2.5 g/cm³.

b. In the 10 CFR 61 Tables 1 and 2, the activity limits for nontransuranics are volume-based, as opposed to mass-based activity limits for transuranics. Therefore, the encapsulating material mass density is irrelevant when calculating limits for nontransuranics. The volume used to calculate the activity limit is 0.2 m³ (55-gal drum).

Table 6. GTCC sealed source activity limits for the high, base, and low cases.

	Isotope	High	Base	Low
Transuranics				
- Alpha emitters	Am-241	26 mCi	38 mCi	50 mCi
	Cm-244	26 mCi	38 mCi	50 mCi
	Np-237	26 mCi	38 mCi	50 mCi
	Pu-238	26 mCi	38 mCi	50 mCi
	Pu-239	26 mCi	38 mCi	50 mCi
	U-238	26 mCi	38 mCi	50 mCi
- Beta emitter	Pu-241	50 mCi	1.33 Ci	1.75 Ci
Nontransuranics				
	C-14	1.6 Ci	1.6 Ci	10 Ci
	Cs-137	10 Ci	30 Ci	30 Ci
	Ni-63	10 Ci	140 Ci	140 Ci
	Sr-90	10 Ci	1,400 Ci	1,400 Ci
	Tc-99	0.6 Ci	0.6 Ci	10 Ci

3.2.1.2 Nontransuranics. In 10 CFR 61 Tables 1 and 2, the concentration limits for nontransuranics are based on volume, as opposed to the mass-based concentration limits established for transuranics. For this reason, Table 5 lists the activity limit resulting from NRC's guidance as that calculated to correspond to 0.2 m³ (a 55-gal drum). The Barnwell activity limit is 10 Ci for all nontransuranic sources.

The high, base, and low cases use the following activity limits to derive the respective proportions of potentially GTCC nontransuranic sealed sources that will be classified as GTCC after concentration averaging.

- **High case**—The high case uses the lowest activity limits shown in Table 5 to derive the highest number of GTCC sources
- **Base case**—The base case, being the "best" estimate, uses the 1993 NRC draft Branch Technical Position's limits for these radionuclides
- **Low case**—The low case uses the highest activity limits shown in Table 5 to derive the lowest number of GTCC sources.

These limits are also shown in Table 6.

3.2.2 Concentration Averaging Factors

The sealed source CAFs represent the proportion of potentially GTCC sources that will be classified as GTCC LLW under the three cases of concentration averaging, that is, the proportion exceeding the limits given in Table 6 for each isotope.

The CAFs for sealed sources are shown in Table 7. For example, under the low case assumptions, roughly half of the Am-241 calibration sources that are potentially GTCC will be classified as GTCC; the CAF equals 0.54. For more detailed information on sealed sources that are potentially GTCC, see Reference 3.

The overall impact of the listed CAFs is that, under the high case, about one-third of the sealed sources that are potentially GTCC (documented in Reference 3) would be classified as GTCC; the CAF equals 0.34. For the base and low cases, the CAFs equal 0.33 and 0.16 respectively.

Table 7. Concentration averaging factors for GTCC LLW sealed sources, listed by source isotope and principal use.

Device type	Isotope	High	Base	Low
Calibration	Am-241	0.66	0.63	0.54
Calibration	C-14	0.0	0.0	0.0
Calibration	Cm-244	0.40	0.40	0.40
Calibration	Cs-137	0.19	0.17	0.17
Calibration	Ni-63	0.0	0.0	0.0
Calibration	Np-237	0.0	0.0	0.0
Calibration	Pu-238	1.00	1.00	1.00
Calibration	Pu-239	0.90	0.90	0.90
Calibration	Pu-241	0.80	0.80	0.80
Calibration	Sr-90	0.0	0.0	0.0
Calibration	Tc-99	0.0	0.0	0.0
Calibration	U-238	0.0	0.0	0.0
Medical	Am-241	0.27	0.27	0.04
Medical	Cs-137	0.0029	0.0029	0.0029
Medical	Sr-90	0.0	0.0	0.0
Medical	Tc-99	1.00	1.00	0.0
Medical	U-238	0.88	0.75	0.63
Well logging	Am-241	0.86	0.85	0.84
Well logging	Cs-137	0.0	0.0	0.0
Well logging	Pu-238	1.00	1.00	1.00
Well logging	Pu-241	1.00	1.00	1.00
Portable gauge	Am-241	0.94	0.94	0.025
Portable gauge	Cs-137	0.0	0.0	0.0
Irradiation	Am-241	0.73	0.71	0.71
Irradiation	Cs-137	0.70	0.64	0.64
Irradiation	Sr-90	0.33	0.0	0.0
Fixed gauge	Am-241	0.90	0.90	0.87
Fixed gauge	C-14	0.0	0.0	0.0
Fixed gauge	Cm-244	0.20	0.20	0.0
Fixed gauge	Cs-137	0.0041	0.002	0.002
Fixed gauge	Pu-238	1.00	1.00	1.00
Fixed gauge	Sr-90	0.0	0.0	0.0
General neutron applications	Am-241	0.89	0.88	0.84
General neutron applications	Pu-238	1.00	1.00	1.00
General neutron applications	Pu-239	0.87	0.85	0.80
X-ray fluorescence	Am-241	0.41	0.29	0.25
X-ray fluorescence	Cm-244	0.97	0.71	0.71
X-ray fluorescence	Pu-238	0.98	0.45	0.43
Other	Am-241	0.50	0.40	0.37
Other	C-14	0.056	0.056	0.056
Other	Cm-244	0.60	0.50	0.40
Other	Cs-137	0.0096	0.0074	0.0074
Other	Ni-63	0.0	0.0	0.0
Other	Np-237	0.0	0.0	0.0
Other	Pu-238	0.99	0.99	0.99
Other	Pu-239	0.73	0.71	0.70
Other	Pu-241	1.00	0.67	0.67
Other	Sr-90	0.012	0.0	0.0
Other	Tc-99	0.98	0.98	0.0
Other	U-238	0.35	0.26	0.22

4. SUMMARY AND CONCLUSIONS

This section summarizes the effects of the 1993 NRC draft Branch Technical Position regarding concentration averaging on the estimated volumes of LLW from the nuclear industry's light water reactors (LWRs) and from sealed sources. Using estimates of the number of waste components that individually exceed Class C limits, this report calculates the proportion, or concentration averaging factor, that would be classified as GTCC LLW after applying concentration averaging practices to dispose of as much LLW as possible in Class A, B, or C low-level waste disposal facilities. This report defines three possible concentration averaging cases (high, base, and low). The study results are summarized in the following sections.

Wastes considered in this report are divided into three main groups: (a) activated metals from LWRs, (b) process wastes from LWRs, and (c) sealed sources. The following section discusses the first two groups, and Section 4.2 addresses sealed sources.

4.1 Nuclear Utility LWR Components

Three concentration averaging cases are considered for LWR components. The high case assumes no concentration averaging. The base case assumes that specific guidance from the 1993 NRC draft Branch Technical Position would apply to all waste groups. The low case assumes that some variances provided to the 1993 NRC draft Branch Technical Position would apply, so that the Nb-94 criteria would be increased from 1.5 to a factor of 3 for activated metals.

Table 8 lists the LWR waste types that potentially include some GTCC LLW, and their CAFs for the high, base, and low cases. For LWRs, the high case CAFs all equal 1, since concentration averaging is assumed to not occur.

For the base and low cases, the CAFs for LLW from LWRs are considerably less than 1. For process wastes, virtually all spent resins and cartridge filters can be blended under the 1993 NRC draft Branch Technical Position. This essentially eliminates process waste as GTCC LLW for the base and low cases. For activated metals waste generated during routine operations, the base and low case CAFs are small because the 1993 NRC draft Branch Technical Position provides for a 1 mCi Nb-94 exemption that can be satisfied by most of the smaller components. These components usually do not exceed Class C limits by significant amounts, and so are easy to blend.

For the larger activated metal components that arise from decommissioning, the 1 mCi Nb-94 exemption in the 1993 NRC draft Branch Technical Position does not usually apply. Thus, the Nb-94 Rule of 1.5 applies, and decommissioning activated metal components and pieces cannot be blended if they have a 10 CFR 61 Table 1 sum of fractions greater than about 1.5.

Table 8. GTCC LLW concentration averaging factors—LWR components.

	High case CAF	Base case CAF	Low case CAF
Activated metals			
1. BWR operations			
Control rod blades	1	0.1	0
LPRM strings	1	0.13	0.01
Dry tubes	1	0.25	0.1
Poison curtains	1	0	0
2. PWR operations			
Thimble plug assemblies	1	0	0
Instrument strings	1	0.13	0.01
Primary sources	1	1	1
3. BWR decommissioning			
Core shroud	1	0.75	0.75
Top fuel guide	1	1	1
4. PWR decommissioning			
Core baffle (shroud)	1	1	1
Lower core barrel	1	0.5	0.5
Upper core support plate	1	0.5	0.5
Lower core support plate	1	0.75	0.75
Process wastes			
1. BWR & PWR decontamination resins			
Full RCS with fuel in	1	0	0
2. Cartridge filters			
All BWR and PWR filters	1	0	0

The low case assumes that some variances to the 1993 NRC draft Branch Technical Position concerning Nb-94 would be acceptable for both operations and decommissioning activated metals. This case essentially eliminates operations activated metals as GTCC LLW. It does not reduce the estimated amount of GTCC LLW that may result from decommissioning, however, since the amount of Nb-94 in these components is expected to exceed the limits assumed under the low case.

Considering the results of this study, it is clear that the greatest area of uncertainty in concentration averaging of LLW is in predicting radionuclide concentrations in decommissioning activated metals. The study documented in Appendix A-3 expanded the available information in this area; however, large uncertainties still exist for vendor-specific PWRs and BWRs.

4.2 Sealed Sources

The sealed source data in this report are based on newly acquired information (Reference 3) that is much more detailed than data previously available. The sealed sources identified as potentially GTCC are categorized by the following device types:

- Calibration
- Medical
- Well logging
- Portable gauge
- Irradiation
- Fixed gauge
- X-ray fluorescence
- Others.

Three concentration averaging cases are considered for sealed sources. The high case uses the lowest activity limits shown in Table 5 to derive the highest number of GTCC sources. The base case uses the average of the 1993 NRC draft Branch Technical Position's low and high limits for transuranics, and uses the 1993 NRC draft Branch Technical Position limits for nontransuranics. The low case uses the highest activity limits shown in Table 5 to derive the lowest number of GTCC sources.

Table 7 lists the proportion of potentially GTCC sealed sources that could be classified as GTCC LLW after concentration averaging for the high, base, and low cases. For all of these sealed source device types combined, the high case assumes that approximately one-third of the sources identified in Reference 3 as potential GTCC LLW will be classified as GTCC LLW; the CAF equals 0.34. The base case CAF equals 0.33, and the low case CAF equals 0.16.

4.3 Conclusions

This report indicates that using the 1993 NRC draft Branch Technical Position for concentration averaging will allow a substantial amount of waste components that individually exceed Class C limits to be concentration averaged for disposal in a Class A, B, or C low-level waste disposal site. The base case for activated metals and process wastes estimates that more than half of all waste components that individually exceed Class C limits can be concentration averaged for disposal as Class A, B, or C waste. The base case for sealed sources estimates that two-thirds of all potentially GTCC sealed sources can be concentration averaged for disposal as Class A, B, or C waste.

It is important to note that the findings presented in this report are based on the authors' knowledge to date. It is the authors' recommendation to further study the vendor-specific PWR and BWR data for which large uncertainties still exist—for example, activation levels of reactor decommissioning metal components.

5. REFERENCES

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Attachment 1

Summary of 1991 DOE/LLW-114, Appendix I

Attachment 1

Summary of 1991 DOE/LLW-114, Appendix I

Introduction

In August 1991, DOE issued DOE/LLW-114, *Greater-Than-Class C Low-Level Radioactive Waste Characterization: Estimated Volumes, Radionuclide Activities, and Other Characteristics*. EG&G Idaho contracted with WMG Inc. to prepare Appendix I of that report, *Impact of Concentration Averaging Greater-Than-Class C low-Level Radioactive Waste Volumes*. The purpose of Appendix I was to evaluate and bound the impact that concentration averaging might have on quantities of greater-than-Class C low-level radioactive waste (GTCC LLW). This attachment summarizes the results of that 1991 study (Reference 1). Information from the 1991 study was used as input into the DOE GTCC LLW computer model to project future amounts of GTCC LLW.

Three objectives were specified for the study:

- Define the three concentration averaging cases for high, base, and low projections of GTCC LLW
- Identify the waste types that could include components that individually exceed Class C limits
- Quantify the impact of the three defined cases on GTCC LLW amounts.

To reasonably bound the volumes of GTCC LLW that could be generated, the study considered both current (1991) and prospective LLW disposal practices. The base case was defined to reflect requirements at the Barnwell, South Carolina, LLW disposal site (Attachment 3), as well as the 1991 views of the Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC) pertaining to the subject. The high case, which does not allow for concentration averaging, was assumed to reflect the most conservative criteria that might be incorporated into the future requirements of some compact host states. The low case was assumed to reflect 1991 requirements at the Richland, Washington, LLW disposal site, which would yield a reasonable minimum estimate for the amount of GTCC LLW for which DOE would be responsible.

A master list was prepared of LLW types that might include some components that individually exceed Class C limits (see Appendix A-3). Waste types that were already included in the DOE data base, and the reason for their inclusion, were reviewed and revised. The waste types were characterized and the amount of LLW exceeding Class C limits was estimated; this work was documented in DOE/LLW-114F, published in 1991. That study developed the basis for determining whether a LWR waste type did, in fact, include components that individually exceed Class C limits.

That master list of LLW types provided the starting point for this study. Each waste type was evaluated to determine how much would be GTCC LLW under the different concentration averaging cases. The study results were reported in Reference 1 in 1991. This summary attachment is included to allow comparison with the results found in Attachment 2 of this report, thereby giving better understanding of the impact of the 1993 NRC draft Branch Technical Position on GTCC LLW projections.

1991 GTCC LLW Projection Cases

Bounding the volumes of GTCC LLW that could be generated required some assumptions about future disposal criteria. To determine the impact of alternative concentration averaging criteria, the following bounding conditions were assumed:

- **High case**—The prospective criteria for a few compacts represented a very restrictive reading of 10 CFR 61 requirements (i.e., no concentration averaging). These criteria were selected to represent the high case. Contaminated solid commingling, use of stabilization media volumes, and encapsulation would all be prohibited.
- **Base case**—The criteria in effect at the Barnwell site in 1991 represented the disposal practices for most LLW. These criteria were selected to represent the base case. They included (a) using the Rule of 10 for activated metals,^d (b) including stabilization media volume for resins and incinerator ash, (c) commingling contaminated solids, and (d) encapsulating nontransuranic sources with activities up to 10 Ci.
- **Low case**—The criteria in effect at the Richland disposal site in 1991 were consistent with the 1991 NRC reading of 10 CFR 61, although the criteria represented disposal practices for only a proportion of the LLW (about 25% by volume) that was disposed of at that time. These criteria were selected to represent the low case. They provided for (a) determining Class C status based on a waste container's total activity and volume including the stabilization media and (b) encapsulating all sources.

Table 1-1 (Table 3-1 in Reference 1) summarizes these cases and criteria as they apply to the three general types of waste considered.

Table 1-2 (Table 2-1 in Reference 1) lists the LLW types that the 1991 study identified as including some waste that exceeded Class C limits. The table also presents estimates of the percentage of LLW that could be GTCC LLW for each concentration averaging case.

d. The Barnwell Rule of 10 allows concentration averaging among similar types of components, but limits radionuclide concentrations among individual components to a factor of 10. For example, instrument strings with relatively high concentrations of 10 CFR 61 radionuclides cannot be combined with control rod blades of lower radionuclide concentrations, unless the concentrations for the two components are within a factor of 10 of each other. Once the Rule of 10 is satisfied, the classification status is determined by dividing the total activity of the combined components by the total volume.

Table 1-1. GTCC volume projection cases and concentration averaging criteria for each waste type from the 1991 study.

Waste category	Low case (Richland disposal criteria)	Base case (Barnwell disposal criteria)	High case (No concentration averaging)
1. Activated metals	Activity in liner divided by waste volume in liner Stabilization media volume included	Activity in liner divided by waste volume in liner Concentrations of components/types within a factor of 10	Activity in component divided by component volume
2. Process waste	Activity in liner divided by waste volume in liner Stabilization media volume included for resins and filters	Activity in liner divided by waste volume in liner Stabilization media volume included for resins; not for filters	Activity in liner divided by waste volume in liner Stabilization media volume not included
3. Sealed sources	Activity in liner divided by waste volume in liner Encapsulation media volume included for all	Activity in source divided by source volume Encapsulation media volume included for non-TRU sources <10 Ci	Activity in source divided by source volume Encapsulation media volume excluded

Table 1-2. 1991 waste type summary—percentage of GTCC LLW after concentration averaging from the 1991 study.^a

	Percent GTCC LLW for high case	Percent GTCC LLW for base case	Percent GTCC LLW for low case
Activated metals			
1. BWR operations			
Control rod blades—control cell	25	10	0
Control rod blades—normal	10	1	0
LPRM strings	75	10	0
Dry tubes	100	10	0
2. PWR operations			
Thimble plug assemblies	10	1	0
Instrument strings	75	10	0
Primary sources	100	100	100
3. BWR decommissioning			
Core shroud	100	100	100
4. PWR decommissioning			
Core baffle (shroud)	100	100	100
Lower core barrel	100	25	0
5. Other reactor internals			
Research	100	100	0
Test	100	1	0
Process wastes			
1. BWR & PWR decon resins			
Full RCS with fuel in	50	1	0
2. Cartridge filters			
BWR control rod drive	50	10	0
Other BWR & PWR	25	1	0
Sealed sources^b			
1. TRU bearing sources			
Gamma gauges	100	100	50
X-ray fluorescent	100	100	0
Well logging	100	100	100
Moisture gauges	100	100	0
Smoke detectors	100	100	0
Pacemakers	100	100	0
2. Other sources			
Med. teletherapy	100	100	0
Gamma gauges	50	1	0
Beta gauges	50	1	0
Well logging	50	1	0
Calibration	50	25	0
Gamma irradiators I, II, III, IV	100	100	0
Gas chromatography	100	1	0
Beta eye applicators	100	1	0

a. This table presents the percentage of GTCC LLW out of all LLW for each waste type in 1991. It can be compared to Tables 2-1 and 2-2 in Attachment 2, but should not be compared to Table 8 of this report.

b. This table presents sealed source information. The differences between Table 7 of this report and Table 1-2 are due not only to the 1993 NRC draft Branch Technical Position, but also to the new information gathered by the GTCC LLW Program that was not available at the time Reference 1 was released. Since the currently available information is much more detailed, a strict correlation between the two tables is not possible.

Attachment 2

Methodology Used to Derive Concentration Averaging Factors for LWR Components

Attachment 2

Methodology Used to Derive Concentration Averaging Factors for LWR Components

Introduction

The methodology used to evaluate greater-than-Class C low-level radioactive waste (GTCC LLW) from light-water reactors (LWRs) is to first determine which LLW types could include waste components that individually exceed Class C limits (see Appendix A-3). Then, applying assumptions of the various concentration averaging cases (see Section 1, Table 1), the percentage of GTCC LLW is determined for each LLW type. This analysis results in three different percentages for each LLW type—the high, base, and low case percentages, which are listed in tables later in this section.

It is important to note that the percentages shown in the tables were derived from evaluating the volume of *all* LLW components, not just the components that individually exceed Class C limits. In order to use the DOE computer models to calculate the actual amount of waste that would be classified as GTCC after concentration averaging is applied, the percentages were manipulated mathematically to produce "concentration averaging factors" (CAFs). For LLW components that individually exceed Class C limits, these CAFs represent the proportion that would be classified as GTCC LLW after applying concentration averaging. Figure 2-1 illustrates the concepts of percentages and CAFs as discussed in this attachment.

Sealed sources are not included in this analysis of methodology because the sealed source CAFs were calculated directly. Therefore, no mathematical conversion was required to derive the CAFs.

Figure 2-1. LWR waste percentages must be converted to concentration averaging factors.

Calculating Concentration Averaging Factors

As illustrated in Figure 2-1, the following conversions were made to the percentages to derive the CAFs for LWR components:

$$\text{High Case CAF} = \frac{B}{B} = 1$$

$$\text{Base Case CAF} = \frac{C_{\text{base}}}{B} = \frac{\text{Base case percentage}}{\text{High case percentage}}$$

$$\text{Low Case CAF} = \frac{C_{\text{low}}}{B} = \frac{\text{Low case percentage}}{\text{High case percentage}}$$

These CAFs represent the amount of actual GTCC LLW expected in the high, base, and low cases after concentration averaging, with respect to the amount of LLW that individually exceeds Class C limits, and are normalized to the high case.

The high case assumes no concentration averaging; high case percentages were obtained from Appendix A-3, written by the same authors as this report. Estimates of base and low case percentages were estimated as part of this study. All case estimates are based on the authors' considerable experience and knowledge in the practice of LWR waste classification, and all CAFs for decommissioning components are based on metal activation levels for an assumed 40-year reactor operating life.

Qualitative Descriptors

The following qualitative descriptors were used by the authors to help define percentages of GTCC LLW:

- **100%**—Essentially all of the LLW type will be GTCC LLW.
- **75%**—Most of the LLW type will be GTCC LLW.
- **50%**—About half of the LLW type will be GTCC LLW.
- **25%**—Some of the LLW type will be GTCC LLW.
- **10%**—A small proportion of the LLW type will be GTCC LLW.
- **1%**—Essentially none of the LLW type will be GTCC LLW.
- **0%**—It is certain that no GTCC LLW will be generated by the waste type.

These qualitative descriptors are used below in the various Results sections to describe percentages of GTCC components out of all LLW components. The descriptor (and hence the percentage) for each waste type was assigned by the authors, based on their experience and knowledge.

GTCC LLW from LWR Components

This information supplements the main body of the report, which only reports the CAFs. In addition to the CAFs, the tables and text included in this attachment also show percentages representing the estimated ratios of GTCC LLW to all LLW for each waste type, for the high, base, and low cases. The CAF columns reflect the calculations shown above to normalize the percentages to just that proportion of the LLW comprising individual pieces that exceed Class C limits.

Activated Metals

Table 2-1 shows the percentages and CAFs for activated metals. The following text explains the results of applying concentration averaging to activated metals, both in percentages and the corresponding CAFs.

Operations BWR Components

1. Control Rod Blades (CRBs)

Results. Under the high case, which assumes no concentration averaging, Appendix A-3 reports that some (25%) controlled cell CRBs and a small proportion (10%) of conventional mode CRBs would be GTCC LLW; this yields a CAF of 1. Under the base case, essentially none (1%) of both types of CRBs would be GTCC LLW. This produces a CAF of $1/10 = 0.1$ for conventional mode CRBs. The calculated CAF for controlled cell CRBs is $1/25 = 0.04$. However, for simplicity in the database calculations, and to be conservative, the same CAF (0.1) was used for both conventional mode and controlled cell CRBs. It is highly unlikely that a CRB would exceed a 10 CFR 61 Table 1 sum of fractions of 3, so none (0%) of both types of blades will be GTCC LLW under the low case.

2. Local Power Range Monitor Strings

Results. Under the high case, which assumes no concentration averaging, Appendix A-3 reports that most (75%) LPRMs would be GTCC LLW; this yields a CAF of 1. However, under the 1 mCi Nb-94 exemption in the 1993 NRC draft Branch Technical Position, most LPRMs could be blended. Therefore, under the base case, a small proportion (10%) of LPRMs blades would be GTCC LLW, with a CAF of $10/75 = 0.13$; under the low case, essentially none (1%) of these LPRMs would be GTCC LLW, with a CAF of $1/75 = 0.01$.

3. IRM/SRM Dry Tubes

Results. Under the high case, which assumes no concentration averaging, Appendix A-3 reports that essentially all (100%) dry tubes would be GTCC LLW; this yields a CAF of 1. Under the base case, some (25%) of the dry tubes would be GTCC LLW; the CAF equals $25/100 = 0.25$. Under the low case, a small proportion (10%) of dry tubes would be GTCC LLW; the CAF equals $10/100 = 0.1$.

Table 2-1. GTCC LLW concentration averaging—activated metals (1993 percentages and corresponding CAFs).

	High case % ^a	High case CAF ^b	Base case %	Base case CAF	Low case %	Low case CAF
1. BWR operations						
a. Control rod blades (CRBs) ^c						
—Conventional mode	10	1	1	0.1	0	0
—Controlled cell	25	1	1	0.1 ^c	0	0
b. LPRM strings	75	1	10	0.13	1	0.01
c. Dry tubes	100	1	25	0.25	10	0.1
2. PWR operations						
a. Thimble plug assemblies	25	1	0	0	0	0
b. Instrument strings	75	1	10	0.13	1	0.01
c. Primary sources	100	1	100	1	100	1
3. BWR decommissioning						
a. Core shroud	100	1	75	0.75	75	0.75
b. Top fuel guide	100	1	100	1	100	1
4. PWR decommissioning						
a. Core baffle (shroud)	100	1	100	1	100	1
b. Lower core barrel	100	1	50	0.5	50	0.5
c. Lower core support plate	100	1	75	0.75	75	0.75
d. Upper core support plate	50	1	25	0.5	25	0.5

a. The percentages column for each case represents the ratio of GTCC LLW to all LLW for each waste type. The low and base cases reflect concentration averaging practices per the 1993 NRC draft Branch Technical Position.

b. The CAF column for each case represents the GTCC LLW after concentration averaging, *normalized to just that proportion of the LLW components that individually exceed Class C limits*.

c. The calculated CAF for controlled cell CRBs is 0.04. However, for simplicity in the database calculations, and to be conservative, the same CAF (0.1) was used for both conventional mode and controlled cell CRBs.

Operations PWR Components

1. Thimble Plug Assemblies

Results. Under the high case, which assumes no concentration averaging, Appendix A-3 reports that some (25%) Westinghouse thimble plug assemblies would be GTCC LLW; the CAF equals 1. Under the base and low cases, no (0%) assemblies would be GTCC LLW; the CAFs equal 0.

2. In-Core Instrument Strings

Results. Under the high case, which assumes no concentration averaging, Appendix A-3 reports that most (75%) instrument strings would be GTCC LLW; the CAF equals 1. Under the base case, a small proportion (10%) of instrument strings would be GTCC LLW; the CAF equals $10/75 = 0.13$. Under the low case, essentially none (1%) would be GTCC LLW; the CAF equals $1/75 = 0.01$.

3. Primary Sources

Results. Appendix A-3 reports that primary sources have very high concentrations of 10 CFR 61 radionuclides. Therefore, essentially all (100%) transuranic sources are GTCC LLW in all concentration averaging cases; the CAFs equal 1.

BWR Decommissioning Internals

1. Core Shroud

Results. Under the high case, which assumes no concentration averaging, Appendix A-3 reports that essentially all (100%) of this component would be GTCC LLW; the CAF equals 1. Under the base and low cases some pieces could be blended, making most (75%) of this component GTCC LLW; the CAFs equal $75/100 = 0.75$.

2. Top Fuel Guide

Results. Appendix A-3 reports that essentially all (100%) of this component would be GTCC LLW; the CAFs equal 1 for all cases.

PWR Decommissioning Internals

1. Core Baffle (Shroud)

Results. Appendix A-3 reports that essentially all core baffles (100%) would be GTCC LLW; the CAFs equal 1 for all cases.

2. Lower Core Barrel

Results. Under the high case, which assumes no concentration averaging, Appendix A-3 reports that essentially all (100%) of this component would be GTCC LLW; the CAF equals 1. Under the base and low cases (applying the proposed NRC Technical Position), half (50%) of this component would be GTCC LLW; the CAFs equal $50/100 = 0.5$.

3. Lower Core Support Plate

Results. Under the high case, which assumes no concentration averaging, Appendix A-3 reports that essentially all (100%) of this component would be GTCC LLW; the CAF equals 1. Under the base and low cases (applying the proposed NRC Technical Position), most of this component (75%) would be GTCC LLW; the CAFs equal $75/100 = 0.75$.

4. Upper Core Support Plate

Results. Under the high case, which assumes no concentration averaging, Appendix A-3 reports that about half (50%) of these components would be GTCC LLW (this is because upper core support plates in the B&W and Combustion Engineering reactors will not be GTCC LLW, while those in the Westinghouse reactors will be); the CAF equals 1. Under the base and low cases (applying the proposed NRC Technical Position), some of this component (25%) would be GTCC LLW; the CAFs equal $25/50 = 0.5$.

Process Wastes From LWRs

Table 2-2 shows the percentages and the normalized CAFs for process wastes. The following text provides the results of applying concentration averaging to process wastes, both in percentages and corresponding CAFs.

Decontamination Resins—BWR and PWR Reactor Coolant Systems (Fuel-In)

Results. Under the high case, which assumes no concentration averaging, Appendix A-3 reports that half (50%) of these cation resins would be GTCC LLW; the CAF equals 1. Under the base and low cases, none of these resins (0%) would be GTCC LLW; the CAFs equal 0. This assumes that the weight% of chelating agents in the GTCC LLW cation resins do not disqualify the waste for disposal as Class A, B, or C LLW, due to hazardous waste classification under the Resource Conservation and Recovery Act (i.e., mixed waste). Appendix E-2 indicates a very low possibility of these resins being mixed waste.

Table 2-2. GTCC LLW concentration averaging—process wastes (percentages and corresponding CAFs).

		High case % ^a	High case CAF ^b	Base case %	Base case CAF	Low case %	Low case CAF
1.	BWR decontamination resins						
a.	Full system—fuel in	50	1	0	0	0	0
2.	PWR decontamination resins						
a.	Full system—fuel in	50	1	0	0	0	0
3.	BWR cartridge filters						
a.	Control rod drive	50	1	0	0	0	0
b.	Fuel pool	25	1	0	0	0	0
c.	Underwater vacuum	25	1	0	0	0	0
4.	PWR cartridge filters						
a.	Seal water injection	25	1	0	0	0	0
b.	Seal water return	25	1	0	0	0	0
c.	Reactor coolant system	25	1	0	0	0	0
d.	Letdown	25	1	0	0	0	0
e.	Fuel pool	25	1	0	0	0	0
f.	Crud tank filters (B&W only)	25	1	0	0	0	0

a. The percentages column for each case represents the ratio of GTCC LLW to all LLW for each waste type. The low and base cases reflect concentration averaging practices per the 1993 NRC draft Branch Technical Position.

b. The CAF column for each case represents the GTCC LLW after concentration averaging, *normalized to just that proportion of the LLW components that individually exceeds Class C limits.*

Cartridge Filters

Results. Under the high case, which assumes no concentration averaging, Appendix A-3 reports that half (50%) of the BWR control rod drive filters would be GTCC LLW; the CAF equals 1. For other types of cartridge filters, Appendix A-3 reports that some (25%) would be GTCC LLW under the no concentration averaging scenario (high case); the CAF equals 1. Under the base and low cases, none of these cartridge filters (0%) would be GTCC LLW; the CAFs equal 0.

Attachment 3

Barnwell Guidance for Concentration Averaging

Attachment 3

Barnwell Guidance for Concentration Averaging

This attachment summarizes how 10 CFR 61 requirements are met by concentration averaging at the Barnwell low-level radioactive waste (LLW) disposal site in South Carolina. The Barnwell guidance was used in Reference 1 (the 1991 concentration averaging study) to define the base case. It is presented here (a) to provide a basis for comparison with the 1993 Nuclear Regulatory Commission (NRC) draft Branch Technical Position (see Attachment 4), and (b) because the guidance is used to develop part of the low and high cases for nontransuranic sealed sources and part of the low case for transuranic sealed sources (see Tables 5 and 6). The Barnwell criteria for commingling wastes varies with each waste group, as follows:

- **Activated Metals From LWRs**

Packages containing activated metals must satisfy what is commonly referred to as the Barnwell Rule of 10. Application of this rule allows concentration averaging among the same types of components, but limits concentration averaging among individual components to a factor of 10. For example, LPRMs with relatively high concentrations of 10 CFR 61 radionuclides cannot be combined with control rod blades of lower radionuclide concentrations, unless the concentrations of radionuclides for the two components are within a factor of 10 of each other. Once the Rule of 10 is satisfied, the classification status can be determined by dividing the total activity of the combined components by the total volume.

The Barnwell Rule of 10 described above applies to all 10 CFR 61 Table 1 and 2 radionuclides; the difference between the lowest and highest concentrations within components packaged in the same container cannot exceed a factor of 10. In contrast, the 1993 draft NRC Branch Technical Position Rule of 10 does not apply to gamma-emitting radionuclides in activated metals. For alpha and beta emitters, it limits the difference between the *average* concentrations of radionuclides within a container and the highest and lowest concentrations in individual components within the container.

- **Process Wastes From LWRs**

If different batches of resins or filters are placed in the same container, the classification status is determined using the standard calculation for concentration averaging—divide the total activity of the waste by the total volume of the waste. If different types of waste (e.g., resins and filters) are combined in the same container, the classification status of each waste type is determined separately. The radioactivity of each waste type is divided by the volume for each waste type and documented separately.

Adding cement or other stabilization media to waste increases the volume and mass of the waste and, correspondingly, reduces the concentration of 10 CFR 61 radionuclides.

- **Sealed Sources**

A prevalent practice is to emplace sealed sources in another medium such as cement to provide shielding. This provides an additional barrier between the LLW and the environs and is referred to as encapsulation. On a case-by-case basis, Barnwell (with NRC approval) will allow disposal of encapsulated sources with use of the encapsulation media volume to calculate radionuclide concentrations. Generally, encapsulated sources containing nontransuranic radionuclides with activities up to 10 mCi and those with transuranic activities up to 50 mCi are approved for disposal.

The most recent 1993 Barnwell site license^e provides for use of encapsulation media volume to determine the classification of encapsulated sealed sources, using media guidance similar to that provided by the NRC. In this recent Barnwell guidance, nontransuranic sources are still limited to 10 Ci activity, and transuranic sources are still addressed on a case-by-case basis.

This study uses Barnwell's 10 mCi limit for defining limits for some nontransuranic radionuclides in the low and high cases. It uses the 50 mCi limit for Pu-241 in the high case.

e. South Carolina Department of Health and Environmental Control, letter to William B. House of Chemical Systems, Inc., pertaining to *Renewal of South Carolina Radioactive Material License 097*, July 26, 1993.

Attachment 4

1993 NRC Draft Branch Technical Position on Concentration Averaging

SEP 16 1993

ATTENTION: Commission Licensees

SUBJECT: REISSUANCE OF PROPOSED CONCENTRATION AVERAGING AND
ENCAPSULATION TECHNICAL POSITION, REVISION IN PART

The regulation, "Licensing Requirements for Land Disposal of Radioactive Waste," 10 CFR Part 61, establishes a waste classification system based on the concentration of specific radionuclides contained in the waste. The regulation also states, at §§61.55(a)(8), that, "the concentration of a radionuclide [in waste] may be averaged over the volume of the waste, or weight of the waste if the units [on the values tabulated in the concentration tables] are expressed as nanocuries per gram" [text added for clarity].

On June 26, 1992, Commission licensees were sent copies of a proposed "Concentration Averaging and Encapsulation Technical Position, Revision in Part," on which comments were solicited. A notice of availability of the proposed Technical Position was also published in the Federal Register on June 30, 1992 (57 FR 29105). In response, nineteen comment letters were received suggesting the need for further expansions of and several modifications to the Technical Position. Consideration of these comments has resulted in modifications and a further expansion of the Technical Position. The modified Technical Position is enclosed (Enclosure 1) and, because of the significant additions and interest expressed by commenting parties, is again being issued for comment in proposed form. Also, enclosed (Enclosure 2) is a summary of the major comments together with the Nuclear Regulatory Commission staff's responses.

Comments on this revised Technical Position should be received prior to November 15, 1993, and sent to Chief, Rules Review and Directives Branch, U.S. Nuclear Regulatory Commission, Washington, DC 20555. Questions may be referred to William LaHS, U.S. Nuclear Regulatory Commission, Mail Stop 5E-4, One White Flint North, Washington, DC 20555, telephone (301) 504-2569.

A final technical position will be issued following NRC staff review of the comments received. The information collections contained in the Technical Position have been approved under the Office of Management and Budget number 3150-0014.

A handwritten signature in black ink, appearing to read "Paul H. Johnson" with a stylized flourish at the end. The word "for" is written in smaller script below the signature.

John T. Greeves, Director
Division of Low-Level Waste Management
and Decommissioning
Office of Nuclear Material Safety
and Safeguards

Enclosures: As stated

**BRANCH TECHNICAL POSITION ON CONCENTRATION AVERAGING
AND ENCAPSULATION**

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[Proposed] Technical Position on Concentration Averaging and Encapsulation

A. INTRODUCTION

The overall acceptability of low-level radioactive waste disposal requires a performance assessment of the disposal facility which demonstrates compliance with the performance objectives stated at §61.41. In addition, to provide protection for individuals from inadvertent intrusion (i.e., §61.42), the suitability of radioactive waste for near-surface disposal necessitates the proper classification of that waste. The regulation, "Licensing Requirements for Land Disposal of Radioactive Waste," 10 CFR Part 61, establishes a waste classification system based on the concentration of specific radionuclides contained in the waste. The regulation also states, at §§61.55(a)(8), that, "The concentration of a radionuclide [in waste] may be averaged over the volume of the waste, or weight of the waste if the units [on the values tabulated in the concentration tables] are expressed as nanocuries per gram" [text added for clarity].

A technical position on Radioactive Waste Classification was initially developed in May 1983. This initial position included a section, "Concentration Volumes and Masses," which provided guidance to waste generators on the interpretation of §§61.55(a)(8) as it applies to a variety of different types and forms of low-level waste. This position expands upon, further defines, and replaces that guidance which was provided in Section C.3 of this original 1983 Technical Position. The other sections of this 1983 Technical Position remain in effect with the exception of the corrections noted in the footnote below.¹ The recommendations and guidance provided in this Section C.3 revision represent acceptable methods by which specific waste streams or mixtures of these waste streams may be classified against the tabulated concentration values defined in Tables 1 and 2 of §61.55. The guidance may not specifically address all unique waste types or waste packaging methods. Other provisions for the classification of these specific wastes or waste mixtures may be

¹ The following corrections should be made to the May 1983, Rev. 0, Technical Position: (1) pg. 1, 1st para., 4th line -- delete the words, "or processor"; and (2) pg. 6, 4th line and pg. 12, 2nd para., 5th line -- replace "biannual" with "biennial".

deemed acceptable as discussed under the "Alternative provisions" paragraph of this revision.

B. DISCUSSION

Each shipment of radioactive waste to a licensed operator of a land disposal facility must be accompanied by a shipment manifest. In the manifest, the shipper/consignor-licensee must classify and clearly identify waste as Class A, Class B, or Class C, in accordance with §61.55. Determination of the classification of waste involves two considerations. First, consideration must be given to the concentration of long-lived radionuclides in the waste with respect to the values in Table 1 of §61.55. Second, consideration must be given to the concentration of short-lived radionuclides in the waste with respect to the values in Table 2 of §61.55.

Waste is determined to be generally unacceptable for near-surface disposal if it contains any of the radionuclides listed in Tables 1 and 2 of §61.55 in concentrations exceeding the applicable limits established for the individual radionuclides.

C. REGULATORY POSITION

* * * * *

3. Volumes and Masses for Determination of Concentration²

Paragraph 61.55(a)(8) states that, for the purposes of waste classification, the concentration of a radionuclide may be averaged over the volume of the waste, or the weight of the waste for those concentration units in §61.55 Table 1 that are expressed as nanocuries per gram. This requirement needs interpretation because of the different types and forms of low-level waste. Principal considerations include: (1) whether the distribution of

² It should be noted that waste acceptance requirements for Agreement State disposal facilities (e.g., requirements for encapsulated wastes or activated metals) may differ from this guidance. Waste generators should consult with disposal site operators or appropriate regulatory authorities prior to classifying these wastes.

radionuclides within the waste can be considered to be reasonably homogeneous; (2) whether the "as-generated" waste has been processed and, if so, what is the mass/volume of the processed waste; (3) whether the waste includes mixtures of various waste types (i.e., a waste stream with a particular set of physical characteristics); (4) whether the waste includes mixtures of the same waste type but at differing radioactivity concentration levels; and (5) whether the volume of the waste container, if used to represent the volume of the waste, is significantly larger than the volume of the waste itself, and the differential volume consists largely of void space.

With respect to the above considerations, many waste types may be considered to be homogeneous for purposes of waste classification. A homogeneous waste type is one in which the radionuclide concentrations are likely to approach uniformity in the context of the intruder scenarios used to establish the values included in Tables 1 and 2 of §61.55. Such waste types would include, for example, spent ion-exchange resins, filter media, solidified liquid, evaporator bottom concentrates, or contaminated soil. Contaminated trash waste, which is composed of a variety of miscellaneous materials, may be considered homogeneous for purposes of waste classification when placed in containers. To the extent that contaminated trash and contaminated soil are reasonably packaged in a disposal container (i.e., $\geq 90\%$ fill), the volumetric-averaged concentration of radionuclides in these waste types can be based on the fill-volume of the container. Alternatively, the volume of the waste can be calculated from the weight of the container contents divided by the density of the contents. A representative density based on a representative distribution of materials as they occur in waste may be used.

For spent ion-exchange resins and filter media, care needs to be taken to differentiate between the volume of the waste form and the volume of the waste container. Although free volume should be reduced to the extent practicable, these wastes may be contained within a disposable demineralizer, liner, or high integrity container (HIC) with some waste-free volume. In such cases, the volume or weight used for waste classification should be the displaced or bulk volume (interstitial space may be included) or dewatered weight of the resins or filter media rather than the gross internal volume of the container or the weight of the resins prior to dewatering.

The following paragraphs provide guidance on specifically acceptable classification or encapsulation practices. Other provisions for classification or encapsulation of specific waste may also be deemed acceptable as discussed in the "Alternative provisions" paragraph at the end of this section.

Mixing of homogeneous waste types or streams

Mixing of similar homogeneous waste types (e.g., spent ion-exchange resins or contaminated soils) is permissible. However, mixing with the sole intent to dilute radionuclide concentrations to lower a waste's classification is not permitted. Note: A designed collection of homogeneous waste types from a number of sources within a licensee's facility for purposes of operational efficiency or occupational dose reduction is not considered "mixing" for purposes of this position. Under this guideline the classification of the mixture using the sum of fractions rule specified in §61.55 should be based on either (a) the highest nuclide concentrations in any of the individual waste types contributing to the mixture; or (b) the volumetric- or weight-averaged nuclide concentrations of the mixture, provided that the concentrations of the individual waste type contributors to the mixture are within a factor of 10 of the concentration of the resulting mixture.

Mixing of dissimilar homogeneous waste streams may also be permissible but should receive appropriate regulatory approval under the "Alternative provisions" paragraph of this position.

In any of the above cases, in accordance with Section III of Appendix F to 10 CFR Part 20, the licensee classifying the waste must have in place a quality control program to ensure compliance with the waste classification provisions of §61.55. As part of this quality control program, if the classification of a mixture is based on the volumetric- or weight-averaged nuclide concentration of the mixture (e.g., as allowed under (b) above), the licensee responsible for classification of the waste should prepare, retain with manifest documentation, and have available for inspection, a record documenting the licensee's waste classification analyses. This record or analyses should be sufficient to show that the mixing was not undertaken solely to lower the classification of a waste stream contributing to the mixture.

Solidified and absorbed liquids

Classification of evaporator concentrates, filter backwashes, liquids or ion-exchange resins solidified in a manner to achieve homogeneity and meet the stability criteria of §61.56 should be based on solidified nuclide activity divided by the volume or weight of the solidified mass. Because absorbed liquid wastes do not appreciably bind nuclides, classification of absorbed liquids should be based on the adsorbed activity divided by the volume or mass of the liquids prior to absorption.

Mixing of activated materials or metals, or components incorporating radioactivity in their design

For neutron-activated materials or metals, or components incorporating radioactivity in their design, the waste classification volume or weight should be taken to be the total weight or displaced volume of the material, metal, or component (i.e., major void volumes subtracted from the envelope volume).

Mixtures of these materials, metals, or components in a disposal container or liner are permissible. In determining the classification of such a mixture, it is always permissible to conservatively base the mixture classification on the highest classification associated with any piece, section or component within a disposal container or liner. It is also permissible, under the following constraints, to average the concentrations of the radionuclides listed in §61.55 Table 1 and Table 2 over the contents of the disposal container or liner. Because of the potential non-homogeneity of the waste, the classification of the combined waste may be affected by whether or not the waste contains the predominantly gamma-emitting nuclides (Co-60, Nb-94, or Cs-137/Ba-137). In determining the classification of the container/liner, one or more of the following paragraphs may apply as indicated in the logic diagram (Figure 1) on pages 10 and 11.

Averaging involving predominant gamma-emitters

For the purpose of classifying a mixture of items or components containing Co-60, Nb-94, or Cs-137/Ba-137, their individual nuclide concentrations may be

based on the volumetric-averaged concentration of the combined materials provided that the concentrations within the individual items or components in the disposal container or liner are within a factor of 1.5 of the respective averaged concentration value for each nuclide. Averaging is always allowed for a specific gamma-emitting nuclide if its activity within an item or component is less than 37 MBq (1 mCi).

Averaging of sections or pieces of larger components
containing Co-60, Nb-94, or Cs-137/Ba-137

Individual sections of pieces of larger components that may result from operational considerations (e.g., packaging for transportation) should be considered as discrete items if:

- (a) the volume of the piece or section is less than one-hundredth of a cubic foot (0.01 ft^3) or 0.00028 cubic meters (0.00028 m^3) -- such a piece will typically weigh less than ten pounds (10 lbs) or 4.54 kilograms (4.54 kg), and
- (b) the specific nuclide activity in the piece or section is greater than the respective value shown in Table A.

Furthermore, if all sections or pieces of the whole component are not contained in the same disposal container, regardless of their volume or activity, they should be considered as discrete items in classification determinations.

TABLE A

Activity Levels in Individual Sections or Pieces of Larger Components Potentially Requiring Their Piecemeal Consideration in Classification Determinations.

<u>Nuclide</u>	<u>For Waste Classified as Class A or B</u>	<u>For Waste Classified as Class C</u>
Co-60	>26 TBq (700 Ci)	N.A.
Nb-94	>37 MBq (1 mCi)	>37 MBq (1 mCi)
Cs-137/Ba-137	>111 MBq (3 mCi)	>1.1 TBq (30 Ci)

Averaging involving radionuclides other than primary gamma-emitters

For the purpose of classifying a mixture, the concentrations of all §61.55 tabulated radionuclides in the disposal container or liner, other than Co-60, Nb-94 or Cs-137/Ba-137, may be based on the volumetric- or weight-averaged concentrations of the combined materials. In this case, all the concentrations of the "classification-controlling" individual nuclides³ within all the individual items should be within a factor of 10 of their respective averages over all items in the mixture.

Averaging involving sections or pieces of larger components containing other than primary gamma-emitters

Individual sections or pieces of larger components in a disposal container that may result from operational considerations (e.g., packaging for transportation) should be considered as distinct items if the nuclide activity in the piece or section exceeds the appropriate value indicated in Table B.

Mixtures containing multiple radionuclides

For activated materials, metals, or components containing combinations of tabulated nuclides, the sum of the fractions rule described in §61.55(a)(7) would apply. This sum-of-the-fractions rule would involve summing the fractions of the appropriate §61.55 Table 1 or 2 concentration values as described in §§61.55(a)(7). The sum of the fractions rule could involve summing the fraction of the appropriate §61.55 Table 1 or Table 2 concentration values associated with the predominately gamma-emitting nuclides and the fractions of tabulated concentrations associated with the other

³ A "classification-controlling" nuclide is one which is contained in waste in concentrations greater than 0.01 times the concentration of that nuclide listed in Table 1 or 0.01 times the applicable Class-dependent concentration of that nuclide in Table 2, Column 2 or 3. Note that a nuclide may be significant for reporting purposes under Section 4 in the May 1983 Technical Position and yet not be a "classification controlling" nuclide.

TABLE B

Activity Levels in Individual Sections or Pieces of Larger Components
Requiring Their Piecemeal Consideration in Classification Determinations.

Nuclide	For Waste Classified as Class A or B	For Waste Classified as Class C
H-3	>0.3 TBq (8 Ci)	N.A.
C-14	>0.04 TBq (1 Ci)	>0.4 TBq (10 Ci)
Ni-59	>0.15 TBq (4 Ci)	>1.5 TBq (40 Ci)
Ni-63	>0.26 TBq (7 Ci)	>55 TBq (1500 Ci)
Alpha emitting TRU with half-life greater than 5 years (excl. Pu- 241 and Cm-242)	>111 MBq (3 mCi)	>1110 MBq (30 mCi)

nuclides. The respective fractions contributing to the sum can be calculated by using the "highest concentration" existing in any item within the mixture or, if applicable, the concentration determined by using the "averaging" methods described previously.

Independent of the method chosen, in accordance with Section III of Appendix F to 10 CFR Part 20, the licensee classifying the mixture of items must have in place a quality control program to ensure compliance with the waste classification provisions of §61.55. As part of this quality control program, if the classification of the mixture of items is based on the volumetric- or weighted-averaged nuclide concentrations of the disposal container/liner contents, as allowed above, the licensee responsible for classification of the waste should prepare, retain with manifest documentation, and have available for inspection, a record documenting the licensee's waste classification analyses. This record or analyses should be sufficient to show that the averaging of concentrations over all the contents in the disposal container/ liner was not undertaken solely to lower the classification of any of the individual items in the disposal container.

Example 1: Three equally sized control rod blades are contained in a liner. The blades (0.6 ft^3 or 0.017 m^3) respectively contain concentrations of Nb-94 which are 0.9, 0.7, and 0.5 of the §61.55 Table 1 value for Nb-94 of 0.2 curies per cubic meter. The blades also contain Ni-59 in concentrations of 44, 22, and 11 curies per cubic meter. These concentrations are 0.2, 0.1, and 0.05 of the §61.55 Table 1 value for Ni-59 of 220 curies per cubic meter. The Nb-94 concentrations in the three blades are all within a factor of 1.5 of the average concentration within three blades (i.e., 0.14 curies per cubic meter). Likewise, the Ni-59 concentrations in the three blades are all within a factor of 10 of the average concentration within the three blades (i.e., 26 curies per cubic meter). The sum of the fractions for the blades in the liner would be calculated by summing, 0.7 (the averaged Nb-94 fraction for the blades) and 0.12 (the fraction for the Ni-59 activity averaged over all three blades). The sum, 0.82, would qualify the liner as containing Class C waste.

Example 2: The cruciform section of a boiling-water reactor control rod blade (0.6 ft^3 (0.169 m^3) and 200 lbs. (90.8 kg)) contains a Nb-94 concentration of 0.16 curies per cubic meter, a Ni-59 concentration 22 curies per cubic meter, and a Ni-63 concentration of 5000 curies per cubic meter. The blade, as a whole, would be classified as Class C waste (i.e., Nb-94 fraction (0.8) + Ni-59 fraction (0.1) = 0.9, using the sum of the §61.55 Table 1 fractions; the Ni-63 concentration is less than the respective Table 2, column 3 value). The blade, however, is sectioned into four equal pieces to facilitate shipment. The "hottest" piece contains 80% of the blade's activity. This piece would contain a concentration of Nb-94 above the §61.55 Table 1 value. However, if all pieces of the blade are contained in the same disposal container, the container could be classified as Class C waste, based on the blade as a whole, because the volume of each piece exceeds 0.01 cubic feet (0.00028 m^3).

FIGURE 1 LOGIC DIAGRAM FOR CLASSIFYING WASTE COMPRISING ACTIVATED METAL OR COMPONENTS CONTAINING RADIOACTIVITY IN THEIR DESIGN

* IMPORTANT: Note that averaging is always allowed if the specific gamma-emitting nuclide activity within an item or component is less than 37 MBq (1mCi)

Example 3: A liner contains 4 local power range monitor (LPRM) strings.

Note: In actual cases, liners could contain more than this number. Each string has a volume of 0.1 ft³ (0.0028 m³) and weighs 50 lbs (22.7 kg). The activity of the principal "classification controlling" nuclides in each string are shown below along with the nuclides concentration expressed as a fraction (frac) of the appropriate §61.55 Table 1 or Table 2, Column 3 concentration values.

	LPRM #1		LPRM #2		LPRM #3		LPRM #4		AVE
NUCLIDE	Ci	frac	Ci	frac	Ci	frac	Ci	frac	
Nb-94	0.0004	0.71	0.0003	0.53	0.00035	0.62	0.0005	0.89	0.69
Ni-59	0.12	0.20	0.09	0.15	0.1	0.17	0.13	0.22	0.19
C-14	0.02	0.09	0.015	0.07	0.017	0.08	0.02	0.09	0.08
TABLE 1 TOTAL		1.00		0.75		0.87		1.2	0.96
Ni-63	18.0	0.92	13.5	0.69	15.75	0.81	22.0	1.12	0.89
TABLE 2 TOTAL		0.92		0.69		0.81		1.12	0.89

The strings need to be cut into three pieces for packaging and this sectioning leads to essentially all of the activity being contained in a piece which has a volume of 0.017ft³ (0.00048 m³) and weighs 8.5 lbs (3.9 kg).

It would be permissible to average the Nb-94 concentration over all four strings since no string contains more than 37 MBq (1 mCi) of Nb-94. Furthermore, all the concentrations of the individual strings are within a factor of 1.5 of the average concentration (i.e., $0.69 \times 0.2 \text{ Ci/m}^3 = 0.138 \text{ Ci/m}^3$). Likewise the concentrations of the other tabulated nuclides are within a factor of 10 of their average concentrations. If the strings were shipped as a whole, the waste would be classified as Class C since the sum-of-the-Table 1 fractions is 0.96 and the Ni-63 concentration is less than (i.e., 0.89 times) the Class C limit of 7000 curies per cubic meter. Although the cutting operation could increase concentrations in the "hottest" piece by about a factor of 6, this sectioning would not affect the classification of the waste since (1) the volume of the "hottest" piece is greater than 0.01ft³ (0.00028 m³), (2) the largest Nb-94 activity in any piece, 0.5 mCi, is less

than the 1 mCi value in Table A, (3) the activities of the other nuclides in the "hottest" piece are less than Table B values, and (4) all pieces of the sectioned string are placed in the same disposal container.

Contaminated materials

Contaminated materials typically involve components or metals on which radioactivity resides near the surface in a fixed or removable condition. Classification of individual items may be determined by representative swipes or radiation survey measurements from which the total activity of radionuclides may be estimated through the use of scaling factors. In these cases, the volume or weight of the contaminated item should be the total weight or displaced volume of the item (i.e., major void volumes subtracted from envelope volume).

Mixtures of contaminated materials in a disposal container are permissible. In these situations, the total activity of contained radionuclides may also be determined by representative swipes or radiation survey measurements of the container's contents. The volume or weight of the mixture should be the total weight or displaced volume of all the material contributing to the mixture.

In determining the classification of a mixture of contaminated materials, it is always permissible to conservatively base the mixture classification on the highest classification associated with any piece, section, or component within a disposal container. It is also permissible, under the following constraints, to average concentrations of the radionuclides listed in §61.55 Table 1 and Table 2 over the contents of the disposal container. Again, because of the potential non-homogeneity of the waste, the classification of the combined waste may be affected by whether or not the contaminated waste contains the predominantly gamma-emitting nuclides (e.g., typically, Co-60 and Cs-137/Ba-137). In determining the classification of the container, one or more of the following paragraphs may apply.

Averaging involving predominant gamma-emitters

For the purpose of classifying a mixture containing Co-60 or Cs-137/Ba-137 contamination, their individual nuclide concentrations may be based on

the volumetric-averaged concentration of the combined contaminated materials provided that the concentrations associated with the individual items in the disposal container are within a factor of 1.5 of the respective averaged concentration value for each nuclide. Averaging is always allowed for a specific gamma-emitting nuclide if its activity on a contaminated item is less than 37 MBq (1 mCi).

Averaging of sections or pieces of larger components
containing Co-60, Nb-94, or Cs-137/Ba-137

Individual sections of pieces of larger components that may result from operational considerations (e.g., packaging for transportation) should be considered as discrete components if:

- (a) the volume of the piece or section is less than one-hundredth of a cubic foot (0.01 ft^3) or 0.00028 cubic meters (0.00028 m^3) -- such a piece will typically weigh less than ten pounds (10 lbs) or 4.54 kilograms (4.54 kg),
and;
- (b) the specific nuclide activity contaminating the material or component would be greater than the respective values shown in Table A; or

Furthermore, if all the contaminated sections or pieces of the whole component are not contained in the disposal container, regardless of their volume or activity, they should be considered discrete items in classification determinations.

Averaging involving radionuclides other than primary gamma-emitters

For the purpose of classifying a mixture, the concentrations of all the §61.55 tabulated radionuclides in the disposal container, other than the Co-60, Nb-94, and Cs-137/Ba-137, may be based on the volumetric-or weight-averaged concentrations of the combined materials. In this case, all the concentrations of the "classification-controlling" individual nuclides within all the contaminated items should be within a factor of 10 of their respective averages over all items in the mixture.

Averaging involving sections or pieces of larger contaminated items
or components containing other than primary gamma-emitters

Individual sections or pieces of larger contaminated items or components in a disposal container that may result from operational considerations (e.g., packaging for transportation) should be considered as distinct components if the specific radionuclide activity on the contaminated piece or section exceeds the appropriate value in Table B.

Mixtures containing multiple radionuclides

For contaminated components or metal containing combinations of tabulated nuclides, the sum of the fractions rule described in §§61.55(a)(7) would apply. This sum of-the-fractions rule would involve summing the fractions of the appropriate §61.55 Table 1 or 2 concentration values as described in §§61.55(a)(7). The sum of-the-fractions rule could involve summing the fractions of the appropriate §61.55 Table 1 or Table 2 concentration values associated with the predominately gamma-emitting nuclides and the fractions of tabulated concentrations associated with the other nuclides. The respective fractions contributing to the sum can be calculated using the "highest concentration" existing in any item within the mixture or, if applicable, the concentration determined using the "averaging" methods previously described.

Independent of the method chosen, in accordance with Section III of Appendix F to 10 CFR Part 20, the licensee classifying the mixture of contaminated materials must have in place a quality control program to ensure compliance with the waste classification provisions of §61.55. As part of this quality control program, if the classification of the mixture of contaminated materials is based on the volumetric- or weighted-averaged nuclide concentrations of the disposal container contents, as allowed above, the licensee responsible for classification of the waste should prepare, retain with manifest documentation, and have available for inspection, a record documenting the licensee's waste classification analyses. This record or analyses should be sufficient to show that the averaging of concentrations over all the contaminated material in a disposal container was not undertaken solely to lower the classification of any specific contaminated item in the disposal container.

Mixing of cartridge filters

The classification of cartridge filters should be based on the nuclide activity contained on the filter divided by the displaced volume (interstitial space within the filters may be included) or weight of the filter.

Mixing of multiple cartridge filters in a disposal container or liner is permissible. In determining the classification of the multiple filters, it is always permissible to conservatively base the classification on the highest classification associated with any single filter. It is also permissible, under the following constraints, to average the concentrations of radionuclides listed in §61.55 Table 1 and Table 2. Because of the potentially non-homogeneity of the filters, the classification of the combined filters may be affected by whether or not the waste contains the predominantly gamma-emitting nuclides (typically, Co-60 or Cs-137/Ba-137). However, the classification of most cartridge filters is more likely to be controlled by C^{14} or transuranic concentrations. In determining the classification of a container of filters, one or more of the following paragraphs may apply.

Averaging involving predominant gamma-emitters

For the purpose of classifying multiple cartridge filters containing Co-60 or Cs-137/Ba-137, their individual nuclide concentrations may be based on the volumetric-averaged concentration of the combined filters, provided that the concentrations within the individual filters in the disposal container or liner are within a factor of 1.5 of the respective averaged concentration values of each nuclide. This factor of 1.5 does not apply if the classification of the combined filters, as a result of other nuclides, is higher than the class derived from the predominantly gamma-emitter concentrations.

Averaging involving radionuclides other than primary gamma-emitters

For the purpose of classifying multiple cartridge filters, the concentrations of all §61.55 tabulated radionuclides in the disposal container or liner, other than Co-60, Nb-94, and Cs-137/Ba-137, may be based on the volumetric- or weight-averaged concentrations of the combined materials. In this case, all the concentrations of the "classification-controlling" individual nuclides within all the individual filters should be within a factor of 10 of their respective averages over all items in the mixture.

Mixtures containing multiple radionuclides

For cartridge filters containing combinations of tabulated nuclides, the sum-of-the-fractions rule described in §61.55(a)(7) would apply. For cartridge filters, this rule would typically involve summing the fractions of the appropriate §61.55 Table 1 or Table 2 concentration values of the nuclides other than the predominantly gamma-emitters. The respective fractions contributing to the sum can be calculated by using the "highest concentration" associated with any filter or, if applicable, the concentration determined by using the "averaging" methods described previously.

Independent of whether the "highest concentration" or "averaging" method is used to classify multiple filters in a disposal container/liner, in accordance with Section III of Appendix F to 10 CFR Part 20, the licensee classifying the mixture of filters must have in place a quality control program to ensure compliance with the waste classification provisions of §61.55. As part of this quality control program, if the classification of the mixture of filters is based on the volumetric- or weight-averaged nuclide concentrations of the disposal container/liner contents, as allowed above, the licensee responsible for classification of the waste should prepare, retain with manifest documentation, and have available for inspection, a record documenting the licensee's waste classification analyses. This record or analysis should be sufficient to show that the averaging of concentrations over all the contents in the disposal container/liner was not undertaken solely to lower the classification of any specific cartridge in the disposal container/liner.

Example: A liner contains 4 cartridge filters. Note: In actual cases, more than this number could be contained in a liner. The filter volumes, weights and principal "classification-controlling" nuclide activities are shown below along with the nuclides' concentration expressed as a fraction (frac) of appropriate Table 1 concentration values. A Cs-137 concentration is also presented.

	Fuel Pool Filter #1		Fuel Pool Filter #2		Reactor Coolant Filter #1		Reactor Coolant Filter #2	
Volume (ft ³)	0.85		0.85		0.45		0.45	
(m ³)	0.024		0.024		0.0127		0.0127	
Weight (lbs)	20		20		9		9	
(kg)	9.08		9.08		4.09		4.09	
<u>Nuclide</u>	<u>Ci</u>	<u>frac</u>	<u>Ci</u>	<u>frac</u>	<u>Ci</u>	<u>frac</u>	<u>Ci</u>	<u>frac</u>
C-14 0.01	0.01	⁰ 0.52	0.009	0.047	0.005	0.05	0.002	0.02
Pu-241	0.008	0.25	0.007	0.22	0.01	0.71	0.004	0.28
TRU	0.0004	0.44	0.0003	0.33	0.0005	1.24	0.0002	0.49
Table 1								
Total		0.74		0.60		2.00		0.79
Cs-137	<u>concentration</u> 1.5 x 10 ⁻² Ci/m ³		<u>concentration</u> 1 x 10 ⁻² Ci/m ³		<u>concentration</u> 1 x 10 ⁻¹ Ci/m ³		<u>concentration</u> 4 x 10 ⁻² Ci/m ³	

The Cs-137/Ba-137 activity in all the filters is sufficiently small such that the classification of the filters will not be determined by this gamma-emitting nuclide. Similarly, other nuclides to which Table 2 values may apply have not been listed since their values will not affect cartridge filter classification. Thus, the four filters listed could be placed in a single disposal container/liner since all the listed nuclide concentrations are within an order of magnitude of the averaged concentrations. The sum-of-the-fractions for the three nuclides would be: C-14, (0.04) + Pu-241, (0.32) + TRU, (0.53) = 0.89, indicating that the multiple filters could be classified as Class C waste.

Waste in high-integrity containers

In the case of cartridge filters stabilized by emplacement within high integrity containers, the volume or weight used to determine waste classification should be calculated over the displaced volume (interstitial space within the filters may be included) or weight of the cartridge filter itself rather

than the gross volume or weight of the container. Similarly, the volume and mass considered for purposes of waste classification of dewatered ion-exchange resins, filter backwashes, and filter media placed into high integrity containers should be the volume and mass of the contained waste. In both these cases, disposal in a high integrity container is not considered to alter the as-buried concentrations of radioactivity.

Encapsulation of solid material

For routine wastes such as filters, filter cartridges, or sealed sources centered in an encapsulated mass, classification may be based on the overall volume of the final solidified mass, provided that: (1) the volume and attributes of the encapsulated waste comply with the constraints established in Appendix C in this [expansion of the] Technical Position; (2) the solidified mass meets the waste form structural stability criteria of §61.56 for Class B and Class C waste; and (3) the disposal unit containing the encapsulated mass is segregated from disposal units containing class A wastes which do not meet the structural stability requirements in §§61.56(b). Under the above provisions, additional protection is provided through the shielding, lack of dispersibility, or identifiability of the encapsulated mass; and, for Class C encapsulated waste, by the land disposal facility operational requirements in §§61.52(a)(2). This additional protection has been considered in the classification position developed in Appendix C and has been balanced against the hypothetical radiological impact caused by potential interactions between assumed intruders and the encapsulated mass.

Mixing of dissimilar waste streams (different waste types)

Classifications may also be needed in situations involving a mixture of miscellaneous waste materials -- e.g., situations in which contaminated valves, piping, or similar components are placed in containers mixed with other trash; or miscellaneous trash or components are mixed with other radioactive materials such as resins or filters. In such cases, because of potential differences in waste interactions with the disposal environment, waste classification involving averaging the total activity over the total volume or mass of the waste in the container would be accepted if the classification of the mixture is not lower than the highest waste classification of any

individual components of the mixture. This provision does not apply to small concentrated microcurie sources (<3.7 MBq (100 μ Ci)) of waste such as check sources or gauges which may be mixed with contaminated trash waste streams. The activity of such check sources or gauges may be averaged over the trash volume. Other classification practices may be determined to be acceptable under the "Alternative provisions" paragraph which follows.

Alternative provisions

Under §61.58, the Commission, upon request, may 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 10 CFR Part 61.

Alternatives to the determination of radionuclide concentrations for waste classification purposes, other than those defined in this technical position, may be considered acceptable. For example, the physical form of certain discrete wastes (e.g., activated metals) may be such that intruder exposure scenarios, other than those used to establish the values in Tables 1 and 2 of §61.55, may be appropriate. A case in point could be the disposal of a large intact activated component filled with a structurally stable medium (e.g., cement) or enclosed in a massive robust container capable of meeting structural stability requirements. A request that demonstrates with reasonable assurance that the performance objectives in Subpart C of 10 CFR Part 61 are met may be used to justify that the waste is acceptable for near-surface disposal. Alternatives would require the approval of, or otherwise be authorized by, the NRC or Agreement State regulatory agency. In some cases (e.g., if the approaches in this technical position had been incorporated as disposal facility license conditions), the disposal facility may need to apply for a license amendment from the NRC or Agreement State regulatory agency to incorporate the alternative provision in its license.

Table C provides a summary of the primary aspects of the above guidance.

Table C Volumes and Masses for Determination of Concentration

<u>Waste Type</u>	<u>Allowable Classification Volume or Mass</u>
Contaminated trash or soil	Reasonable fill volume of container/mass of waste (<10% void) [±]
Absorbed liquids	Volume/mass of liquid prior to absorption
Solidified liquids	Volume/mass of solidified mass
Solidified ion-exchange resins	Volume/mass of solidified mass*
Dewatered ion-exchange resins in high integrity containers or liners	Displaced (bulk) volume (interstitial volume may be included)/dewatered mass of ion-exchange resins
Filter cartridges in high integrity containers or liners	Displaced volume (interstitial volume may be included)/mass of filters [±]
Activated components, components containing radioactivity in their design, or contaminated materials	Full density volume/(major void volumes subtracted from envelope volume)/mass of components [±]
Encapsulated filter cartridges or sealed sources	Volume/mass of solidified mass when encapsulated in accordance with the guidance provided in Appendix C in this expansion of the Technical Position

*If homogeneity maintained in solidified mass

[±]Mixtures of waste streams subject to additional guidance defined in text.

* * * * *

APPENDIX C

POSITION ON ENCAPSULATION OF SEALED SOURCES AND OTHER SOLID LOW-LEVEL RADIOACTIVE WASTES

Encapsulation can mitigate dispersion of waste and can also provide additional shielding to limit external radiation fields. If provided to meet the stability criteria of §61.56(b) and coupled with the technical requirements for land disposal facilities in subpart D of 10 CFR Part 61 (specifically, §61.52), encapsulation will limit the impacts from both (1) the direct exposure, inhalation, and ingestion pathways associated with potential intruder-waste interactions and (2) the potential exposure pathways to individual members of the public involving groundwater and agricultural products.

The amount of credit allowed for encapsulation, though, needs to be limited so that extreme measures cannot be taken solely for the purposes of dilution. To be consistent with the NRC's policy on volume reduction and to limit extremely large "point sources" of radioactivity in the disposal site, generally acceptable values for minimum and maximum encapsulated waste volumes and masses, nuclide activities and radiation levels are established.

These generally acceptable bounding conditions are as follows:

- (1) A minimum solidified volume or mass for encapsulation should be that which can reasonably be expected to increase the difficulty of an inadvertent intruder moving the waste by hand following the loss of institutional control over the disposal site. This minimum size or weight should preclude any significant movement without the assistance of mechanical equipment.
- (2) A maximum solidified volume or mass for encapsulation (from which concentrations are determined) should be 0.2m³ or 500Kg (typical 55-gallon drum). Larger volumes and masses may be used for encapsulation but, in general, unless a specific rationale is provided, no credit beyond the volume or mass indicated should be considered when determining waste concentrations.

Note: The bounding volumes and weights in (1) and (2) will ensure that the potential radiological impacts from encapsulated-discrete source disposals are within the envelope of impacts which would be calculated if the radioactivity was homogeneously distributed throughout the encapsulating media.

- (3) A maximum amount of gamma-emitting radioactivity (e.g., Cs-137/Ba-137, Nb-94) or radioactive material generally acceptable for encapsulation is that which, if credit is taken for a 500-year decay period, would result in a dose rate of less than 0.2μSv/hr (0.02mrem/hr) on the surface of the encapsulating media (refer to footnote 1, following page). The calculation to determine compliance with this criterion may consider the (minimum attenuation factor provided by the shielding properties of the

encapsulating media but, in general, this factor should not exceed an attenuation factor that would be provided by 15 inches of concrete encapsulating material (refer to footnote 2). Furthermore, the maximum Cs-137/Ba-137 gamma-emitting generally acceptable for encapsulation in a single disposal container is 1.1 TBq (30 curies) (refer to footnote 3).

- (4) A maximum amount of any radionuclide that should be encapsulated in a single disposal container intended for disposal at a commercial LLW disposal facility is that which, when averaged over the waste and the encapsulating media, does not exceed the maximum concentration limits for Class C waste as defined in Tables 1 and 2 of §61.55 (refer to footnote 4, following page).
- (5) In all cases when a discrete source of radioactive solid waste is encapsulated, written procedures should be established to ensure that the radiation source(s) is reasonably centered within the encapsulating media.

Footnotes

- 1 Presuming the inadvertent intruder has contact with the encapsulated waste as generally defined in the intruder-agricultural scenario (reference NUREG-0945), this dose rate would result in an annual exposure of less than 1/10 of that which would be received if the radioactivity was homogenized over a soil volume equivalent to the encapsulating media. This factor of 10 takes into consideration the possibility that the intruder may be exposed to both (1) other encapsulated waste which may be excavated from the disposal trenches without mixing with uncontaminated cover material and (2) other homogenized waste.
- 2 The 15 inches of concrete shielding is that necessary to ensure that an encapsulated 30 Ci source of Cs-137/Ba-137 could satisfy the $0.2\mu\text{Sv/hr}$ (0.02 mrem/hr) dose criteria. Additional shielding thicknesses from the encapsulating or disposal unit materials could be expected to be in existence after 500 years, but because of uncertainties regarding shielding orientations and effectiveness following this time period, no greater credit is considered generally appropriate. Furthermore, absent any shielding, intruder doses would still be expected to be similar to doses which would be received from homogeneous waste at concentrations permitted in §61.55.
- 3 The 30-curie value for Cs-137/Ba-137 results from the application of the dose rate and shielding criteria in bounding condition 3.
- 4 Reasserting the applicability of Tables 1 and 2 of §61.55 emphasizes that, for alpha- or beta-emitting radionuclides, encapsulation under bounding conditions 1 through 3 does not provide an exemption to the classification tables in the regulations. As a result, the largest activity of a transuranic nuclide, other than Pu-241 and Cm-242, that is generally acceptable for encapsulation in 0.2m^3 is about 1.1GBq (30 mCi), presuming the density of the encapsulating mass is 1.3 g/cm^3 . For determining mass-based concentrations, it is generally acceptable to take credit for the actual density of the material if the density is less than $2.5/\text{cm}^3$.

ANALYSIS OF AND RESPONSE TO COMMENTS ON
"CONCENTRATION AVERAGING AND ENCAPSULATION TECHNICAL POSITION"

On June 20, 1992, the Nuclear Regulatory Commission noticed in the Federal Register the availability of a proposed technical position on concentration averaging and encapsulation for low-level radioactive waste intended for land facility disposal. The proposed position would expand upon and revise, in part, the Technical Position on Radioactive Waste Classification which was issued in May 1983. Comments on the proposed position were solicited and, in response, 19 comment letters were received. These responses included eleven from nuclear utilities and one from their association, the Edison Electric Institute. Both disposal facility operators responded as did the Department of Energy (twice), the Department of the Navy, a firm active in the waste classification field, and a State regulatory agency. These letters raised the following major issues:

- (1) the position, as a whole, significantly modifies the process and intent of NRC's regulations as defined in 10 CFR Part 61 and, as such, has not been sufficiently justified;
- (2) the position does not go far enough in defining whether certain existing "averaging" practices are acceptable;
- (3) the approach taken to classify waste containing gamma-emitting nuclides listed in the tables of §61.55 is overly conservative;
- (4) the position will drive wastes (e.g., activated metals, cartridge filters) to higher classifications resulting in increased costs without any commensurate benefit; and
- (5) the major approaches defined in the position should be incorporated into NRC's 10 CFR Part 61 regulations.

In responding to some of these comments (e.g., (2) and (4)), the proposed technical position has been significantly expanded. A summary description of the expanded position, as well as NRC's responses to the other major comments are provided below:

1. Position Justification

In the environmental impact statement (EIS) supporting the promulgation of 10 CFR Part 61, the concentration values that appear in Tables 1 and 2 of §61.55 were based on potential exposures to inadvertent intruders. The intruder dose calculations included a scenario which presumed that the waste is exhumed from its disposed location and spread over the land surface. The waste was assumed to be indistinguishable from soil and, as such, factors accounting for mixing of the contaminated soil with clean interstitial and cover material were included in the dose projections. The basis for this revision to the 1983 Technical Position recognizes this fact and, in large part, has attempted to define "concentration averaging and encapsulation" positions for the disposal of discrete wastes or mixtures of such wastes that will fall within the "envelope of safety" defined in the EIS. Thus, the position reflects the possibility that an intruder may be exposed to discrete wastes with localized concentrations of radionuclides that can be larger than in the exhumed contaminated soil assumed in the EIS. As a result, the position defines a subset of what would constitute acceptable practices for characterizing either the volumes or masses of specific wastes that should be used for waste classification purposes. To establish what constitutes an "acceptable practice" for meeting the performance objectives at §61.42, the position considers exposure scenarios that are more likely to apply to intruder interactions with discrete waste than with waste that is indistinguishable from soil (e.g., handling scenarios). These exposure scenarios underlie the revised technical position and lead, for example, to the differing approaches for defining acceptable concentration averaging or encapsulation positions based on the predominant type of radiation incorporated in the waste.

With regard to the treatment accorded to mixtures of "homogeneous" wastes, the position reflects the fact that specific volumes of Class A, B and C wastes were defined in the EIS analyses. Thus, while it is theoretically true that homogeneous Class B and C wastes could be diluted with less concentrated waste

so as to eventually qualify a mixture as Class A waste, this was not the general rationale behind the Part 61 regulation. Instead of allowing unlimited dilution or mixing, the regulation imposes waste stability requirements at §61.56, and, for Class C waste, additional measures to be taken at the disposal facility to protect against inadvertent intrusion [see §§61.55(a)(2)(iii) and 61.7(b)(5)].

Under the above rationales, a number of reasonable concentration averaging/encapsulation positions could be developed and justified. Since it was recognized that Agreement States will play a major role in the licensing and regulation of disposal facilities and that, as a result, there was a need to foster, to the greatest extent possible, the use of uniform guidance, the proposed position was formulated in cooperation with the E-5 Committee on Radioactive Waste Management of the Conference of Radiation Control Program Directors (CRCPD). Thus, the original proposed position provided guidance on concentration averaging and encapsulation practices that were likely to be generally accepted. It was the intent that the classification or encapsulation of a specific waste not generally addressed in the position could be deemed acceptable under the "Alternative provisions" paragraph of section C.3. This concept has now been emphasized and has been specifically stated at an early point in the position and, as the response to issue 2 indicates, the position has been further expanded to define other specific practices which would be considered acceptable.

2. Position Expansion to Address Current Practices

Most commenters stated that, notwithstanding the "Alternative provisions" paragraph, the position should specifically address the acceptability of certain current practices. In particular, these commenters highlighted the need for a further definition of acceptable "concentration-determination or averaging" practices as applied to resins, activated metals, contaminated materials, cartridge filters and, where applicable, to the classification of waste items which may be "sectioned" or "cut up" for operational reasons.

In response, the position has been significantly expanded. As a result, the following specific practices are addressed:

- (a) single-point collection of resins from different systems within a facility which occur as a result of reasonable design or operational practices is not considered "mixing";
- (b) criteria have been added for determining whether sectioned pieces should be considered as individual items for classification purposes;
- (c) a small range of concentration differences between individual items containing or contaminated with the predominantly gamma-emitting nuclides (Co-60, Nb-94, and Cs-137) has been specified over which concentration averaging can take place, and averaging is always permitted for the specific gamma-emitting nuclide if its activity within or on an item or component is less than 37 MBq (1 mCi).

Items (b) and (c) above have added a significant amount of detail to the position which has, in turn, necessitated the further addition of example cases and a logic diagram figure for the classification of activated metals.

3. Treatment of Gamma-Emitting Wastes

Absent the explanation provided in issue 1, most commenters stated that the approach taken to classify waste which contains the predominantly gamma-emitting nuclides listed in Tables 1 and 2 of §61.55 is overly conservative.

Given the distinction between "discrete waste" and "waste indistinguishable from soil", and the regulatory significance of intruder exposures, the NRC staff continues to believe that a distinction between gamma- and alpha- or beta- containing waste can and should be made within the context of the Part 61 regulations (see response to issue 5). However, the staff believes that some limited flexibility should be provided in the averaging of a mixture of such wastes and that further explicit guidance on the acceptability of specific practices is necessary. The technical position has therefore been revised to allow concentration averaging between items containing or contaminated with the predominantly gamma-emitting nuclides, if the concentrations within the individual items are within a factor of 1.5 of the averaged individual nuclide concentrations. The averaged concentration value within a disposal container would be used to determine waste classification as described in §61.55. Under this constraint, a practical degree of flexibility is achieved in cases where components may contain §61.55 tabulated nuclides

with concentrations near the "classification table breakpoints." Since the averaged values would still be compared with §61.55 values, this small degree of flexibility is not considered to compromise the objectives of the classification system in protecting the inadvertent intruder and will minimize occupational exposures associated with unnecessary waste segregation. Under the proposed constraint, the protection provided to the potential intruder would also be well-within the envelope of safety being provided through the encapsulated source position. Averaging of a specific gamma-emitting nuclide is also permitted if contained within or on an item or component in a quantity less than 37 MBq (1 mCi).

As far as more explicit guidance is concerned, the position has been revised to include criteria for determining when "sectioned" or "cut up" pieces of larger components should be considered as separate items for classification purposes. The criteria involve the volume, weight, and activity of the individual pieces, as well as conditions involving the disposition of the pieces with regard to the whole (i.e., whether all pieces are placed in the same disposal container).

4. Impact on Current Disposals

Several commenters believed two aspects of the proposed position would cause significant increase in waste samplings and associated paperwork: (1) the separate consideration of the predominantly gamma- and non-gamma-emitting nuclides in determining concentrations for waste classification purposes, and (2) the approach taken with regard to classification of activated or contaminated components which need to be "sectioned" or "cut-up" for operational considerations. These commenters also generally believed that the proposed position would cause both an increase in the amount of LLW and an overall shift toward higher classifications.

The intent of the proposed technical position was not only to provide generally acceptable concentration-averaging and encapsulation guidance but to also include a procedure through which other acceptable positions could be proposed, reviewed by appropriate regulating authorities, and, if approved, documented in a disposal facility's license conditions. This latter procedure was described in the "Alternative provisions" paragraph of the proposed

technical position. Through this procedure, it was expected that most, if not all, current practices would be justified and approved; thus, significant increases in samplings and paperwork, and shifts to higher waste classifications were not anticipated. However, the NRC staff agrees, as indicated in the issue 2 discussion, that a reasonable attempt to address the universe of useful concentration-averaging and encapsulation practices (specifically, current practices) should be made. As a result, the position has been expanded not only to further address acceptable current practices but to provide explanatory logic diagrams and supporting examples. The staff still believes, however, that the "Alternative positions" section is a significant feature of the position since a number of decisions involving concentration-averaging or encapsulation will need to be made on a case-by-case basis.

5. Need to Incorporate Position into Regulations

Several commenters stated their belief that the proposed position was a significant departure from the conclusions of the Environmental Impact Statement for 10 CFR Part 61, and, as such, should be promulgated through the rulemaking process. The staff notes that the 10 CFR Part 61 regulations at §§61.55(a)(8) state that for determining concentrations in waste, "The concentration of a radionuclide may be averaged over the volume of the waste, or weight of the waste..." The staff believes that the regulations provide considerable flexibility in defining the volumes or masses of waste that are appropriate for classification purposes. For example, the EIS recognized the need to set out classification limits for all wastes, and then consider potential allowances for particular waste streams. The EIS also recognized that the applicability of the intruder-discovery or -agricultural scenarios could be dependent on case-by-case evaluation of specific waste forms. The NRC staff believes that the position provides guidance which is based on these factors and is entirely consistent with 10 CFR 61. Therefore, a rulemaking on the subject is not necessary. Furthermore, the position has been clarified to point out that the concentration averaging and encapsulation guidance represents only a subset of practices which could be judged to be potentially acceptable. These further practices may be approved as described in the "Alternative provisions" paragraph.