Draft Branch Technical Position on Concentration Averaging and Encapsulation, Rev. 1

U.S. Nuclear Regulatory Commission

Office of Federal and State Materials and Environmental Management Programs

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BRANCH TECHNICAL POSITION ON CONCENTRATION AVERAGING AND ENCAPSULATION

CONTENTS

A. INTRODUCTION:

NRC licensing requirements for land disposal of radioactive waste (10 CFR Part 61) include four performance objectives. These performance objectives are:

- protection of the general population from releases of radioactivity,
- protection of inadvertent intruders,
- protection of individuals during operations, and
- stability of the disposal site after closure.

A low-level radioactive waste (LLRW) disposal facility must be designed, operated, closed, and controlled after closure in a manner that provides reasonable assurance that these performance objectives will be met. NRC assumes that, at some time after active institutional controls over the disposal site are removed, an individual unknowingly intrudes onto the disposal site and interacts with the waste. To protect this hypothetical individual, NRC developed a waste classification system (10 CFR § 61.55) that requires greater control measures for waste with greater radionuclide concentrations. As stated in 10 CFR § 61.13, "Technical analyses," analyses of the protection of individuals from inadvertent intrusion must include a demonstration that there is reasonable assurance that the waste classification requirements will be met.

This Branch Technical Position on Concentration Averaging and Encapsulation (BTP) provides guidance for waste generators and processors classifying waste for disposal. This BTP presents acceptable methods by which radionuclide concentrations in specific waste streams or mixtures of these waste streams may be averaged over the volume or mass of a waste package. This BTP provides guidance on complying with § 61.55(a)(8) as it applies to the classification of waste for disposal under 10 CFR Part 61. The NRC is revising the BTP to improve its clarity; to update the position on LLRW blending, as directed by the Commission (NRC, 2010); and to align the BTP with the agency's direction of providing a risk-informed performance-based regulatory approach.

The U.S. Nuclear Regulatory Commission (NRC) regulations require that the waste class be identified for each disposal container in a shipment of radioactive waste to a licensed LLRW land disposal facility. This information is reported on a shipping manifest as specified in Appendix G, 10 CFR Part 20, of NRC's regulations. Licensees shipping waste are required to certify that each waste package listed on the manifest is properly classified as Class A, B, or C in accordance with 10 CFR § 61.55. As the waste class increases from Class A to Class C, the hazard to an inadvertent intruder increases. This BTP addresses the classification of individual waste containers to help facilitate compliance with the Appendix G requirements. Guidance for averaging across multiple waste containers is outside the scope of this BTP.

For classifying wastes as Class A, B, or C, 10 CFR § 61.55(a)(8) states that "…The concentration of a radionuclide may be averaged over the volume of the waste, or weight of the waste if the units are expressed as nanocuries per gram." This BTP provides guidance on complying with § 61.55(a)(8) as it applies to the classification of specific wastes and mixtures of wastes for disposal under 10 CFR Part 61. The basis for the averaging provisions in this BTP is protection of the inadvertent intruder, i.e., averaging constraints and criteria are specified which will ensure that the intruder will continue to be protected. This guidance does not in any way alter a licensee's obligation to meet the waste classification concentration limits in § 61.55.

The NRC's waste classification system is generic; that is, it applies to all LLRW disposal sites. It can be used by all generators and waste processors that ship waste to any licensed disposal site, and helps to ensure that the disposal facility that receives the waste applies the required control measures assigned to each waste class to ensure safe disposal. The generic 10 CFR § 61.55 waste classification tables do not take into account any site-specific features or considerations, but licensees could perform site-specific intruder analyses to justify alternative waste classification provisions. Under 10 CFR § 61.58, the Commission could approve these alternative provisions if it found that there was reasonable assurance of compliance with the 10 CFR Part 61, Subpart C, performance objectives, including the performance objective for protection of an inadvertent intruder in 10 CFR § 61.42.

The averaging provisions recommended in this document are also generic, i.e., the staff believes they are suitable for use by any licensed disposal facility or generators or processors shipping waste to a licensed disposal facility. Although this approach may simplify classification for generators, there may be instances in which generators, processors, or disposal facility operators wish to apply site-specific averaging approaches, approved by the regulator of the facility. This BTP provides examples of site-specific considerations for averaging that may be useful to licensees and regulators in proposing averaging approaches different from those in this BTP.

Although Agreement States are required to adopt waste classification regulations that are essentially identical to the NRC's in 10 CFR § 61.55,[1] they may use averaging approaches different from those contained in this guidance. Waste generators should therefore ensure that the disposal facility license conditions related to waste classification and averaging are met before shipping waste to a licensed disposal facility. Consultation with disposal facility operators and/or appropriate regulatory authorities may be needed. In many cases, shipments of LLRW are routine and consultation would not be required. In some cases, such as shipments of blended ion exchange resins from multiple sources, there may need to be assurance that the disposal facility has ensured that these types of waste are acceptable for disposal, and additional waste acceptance criteria may be specified for them. It is expected that Agreement States that either approve a change in equipment or procedures related to intentional blending during processing of LLRW, also called large-scale blending, or that regulate the disposal of these types of blended wastes, would consult with one another to ensure that these types of wastes are acceptable for disposal.

B. RELATIONSHIP BETWEEN 1983 BTP, 1995 BTP AND THIS BTP:

On May 11, 1983, NRC published the "Final Waste Classification and Waste Form Technical Position Papers" (NRC, 1983). The 1983 guidance described overall procedures acceptable to

[1] 10 CFR § 61.55 is NRC compatibility category B. This category is for activities that have direct and significant transboundary implications.

NRC staff that may be used by licensees to determine the presence and concentrations of the radionuclides listed in § 61.55, and thereby classify waste for near-surface disposal. The initial Technical Position on Waste Classification included section C.3, "Concentration Volumes and Masses," that provided guidance to waste generators on the interpretation of 10 CFR § 61.55(a)(8). On January 17, 1995, the NRC replaced Section C.3 of the 1983 Technical Position addressing concentration averaging in accordance with 10 CFR § 61.55(a)(8) with the "Branch Technical Position on Concentration Averaging and Encapsulation," (U.S. NRC, 1995). The other sections of the 1983 Technical Position remain in effect, with the exception of the corrections noted in the footnote below.[2]

In the *Federal Register* Notice announcing the availability of the 1995 BTP (60 FR 4451), the NRC stated that the BTP was developed for two reasons. First, it was considered desirable to attempt to achieve consistent waste classification positions among the Commission and Agreement State regulatory authorities. Second, the staff noted that the waste classification positions could impact other programs (e.g., the U.S. Department of Energy's (DOE) program to accept Greater-Than-Class C waste).

In addition, after the finalization of Part 61, there were a number of well-publicized accidents involving small, highly radioactive sealed sources. The nature of these accidents led the NRC to consider individual gamma-emitting items that might survive in a LLRW disposal facility and to consider the possibility that their radioactive nature would not be recognized by an inadvertent intruder. To ensure that individual gamma-emitting items do not compromise the protection of the inadvertent intruder, the 1995 BTP introduced exposure scenarios that assessed the possible dose consequences to an inadvertent intruder unknowingly handling an individual LLRW item 500 years after disposal. The results from the technical analysis of the handling scenarios are the basis for the majority of the positions in the 1995 BTP. These positions limit "hot spots" (highly concentrated item(s)) in mixtures of wastes and these positions also set limits on encapsulation practices. Like the 1995 BTP, this updated BTP provides guidance for classifying different "waste types." As used in this BTP, waste types include: various homogeneous types (e.g., spent ion exchange resins, contaminated soils, and filter media); activated metals; contaminated materials; cartridge filters and sealed radioactive sources. Appendix A provides a glossary of terms used in this Position.

This BTP replaces the 1995 BTP on Concentration Averaging and Encapsulation. Consistent with NRC policy, this revision is more risk-informed and performance-based than the 1995 BTP. The technical basis for the positions in this BTP, and a brief description of the changes between the 1995 BTP and this BTP are provided in Appendices B and D respectively.

C. TECHNICAL POSITION:

The following paragraphs provide guidance on acceptable approaches for concentration averaging, including mixing and encapsulation practices for the classification of LLRW. This guidance is not intended to address all unique waste types or waste packaging methods, and other provisions for the classification or encapsulation may be deemed acceptable, as discussed under Section 3.9, "Alternative Approaches for Averaging."

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[2] The following corrections should be made to the May 1983, Technical Position: (1) p.1 first para., fourth line—delete the words, "or processor"; and (2) p.6, fourth line and p.12, second para., fifth line—replace "biannual" with "biennial."

To improve clarity, flowcharts of the BTP's guidance are presented in Figures 1 and 2. The Figure 1 flowchart outlines the steps for classifying mixtures of items of waste in a single waste container and homogeneous waste types. The Figure 2 flowchart outlines the steps for classifying individual items. The position on encapsulation of sealed sources and other solid LLRW is provided in Section 3.5.

3.1 Waste Characterization:

Waste characterization is the first step in waste classification. Waste characterization requires information about the volume and concentration of each nuclide in each item of waste. Waste classes are defined by radionuclide concentrations given in 10 CFR § 61.55, Tables 1 and 2. The concentrations in the tables were derived to protect an inadvertent intruder. The May 1983 Technical Position provides guidance on how to determine radionuclide concentrations. This BTP provides guidance on how to measure the volume of the waste for the purposes of classification in Section 3.6, "Measuring Waste Volumes."

In general, the volume and nuclide concentration information about each individual item of waste must be sufficient to determine 10 CFR § 61.55 nuclide concentrations. If an item or a mixture of items contains more than one nuclide listed in Table 1 or in Table 2 of 10 CFR § 61.55, the volume and nuclide information must be used to calculate the "sum of fractions," as explained in 10 CFR § 61.55(a)(7). The individual pieces in a mixture should be evaluated to determine if there are hot spots that could compromise the safety of the inadvertent intruder. If hot spots exist, they should be removed from the mixture and classified as individual items using the process shown in Figure 2. Classification of an individual item is addressed in Section 3.4 of this BTP, "Classifying Individual Items." After removal of the more concentrated items, the remaining mixture should be reevaluated using Figure 1. Once the mixture is brought within limits established in this BTP, the mixture can be classified based on the average concentration of all items remaining in the mixture.

If the sum of fractions exceeds 1 for the Table 1 values or exceeds 1 for the column 3 of the Table 2 values, then the mixture exceeds the Class C limits and the licensee should determine if the mixture can be reconstituted to bring the sum of fractions below 1.

Assuming that the sum of fractions for a mixture does not exceed 1 (for Table 1 or column 3 of Table 2), the first decision (decision node A) in Figure 1 is whether the disposal container holds a single item or multiple items. Homogeneous waste types (Section 3.2) are considered single items for this Position. A container of solidified or absorbed liquids is considered a homogeneous waste type and the contents may be concentration averaged over the final volume or mass (Figure 2).

The next decision (node B) is whether all items in the mixture are of a similar waste type. Waste types are wastes that are grouped together for the purposes of this concentration averaging and waste classification BTP. Waste types include, but are not limited to: various homogeneous waste types (e.g., spent ion exchange resins, contaminated soils, and filter media); activated metals; contaminated materials; cartridge filters, and sealed radioactive sources. A drum containing pieces of activated metal is an example of a container of wastes that are of a similar waste type.

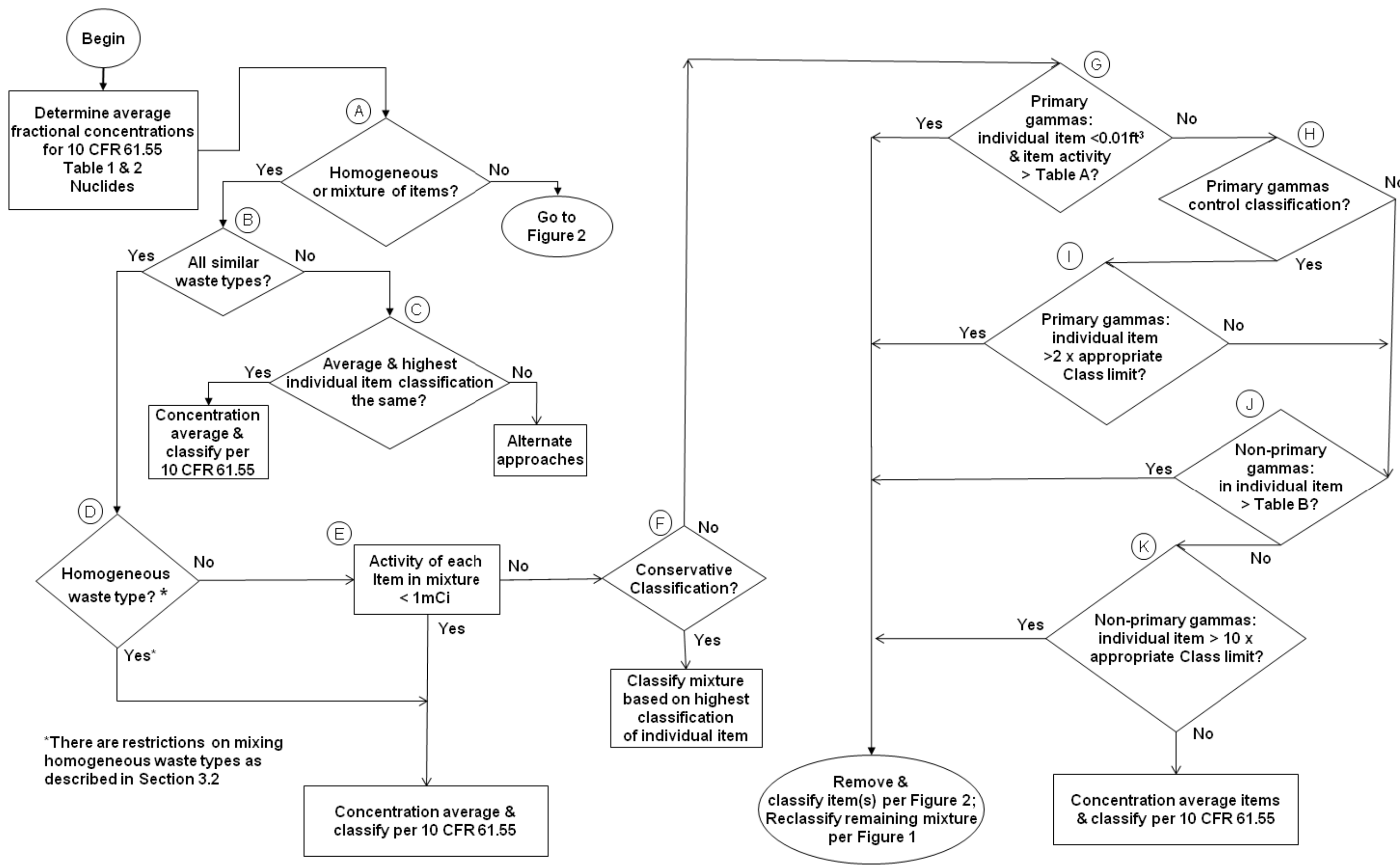

Figure 1. Classification of Homogeneous Waste Types and Mixtures of Activated Metals, Contaminated Materials and Cartridge Filters

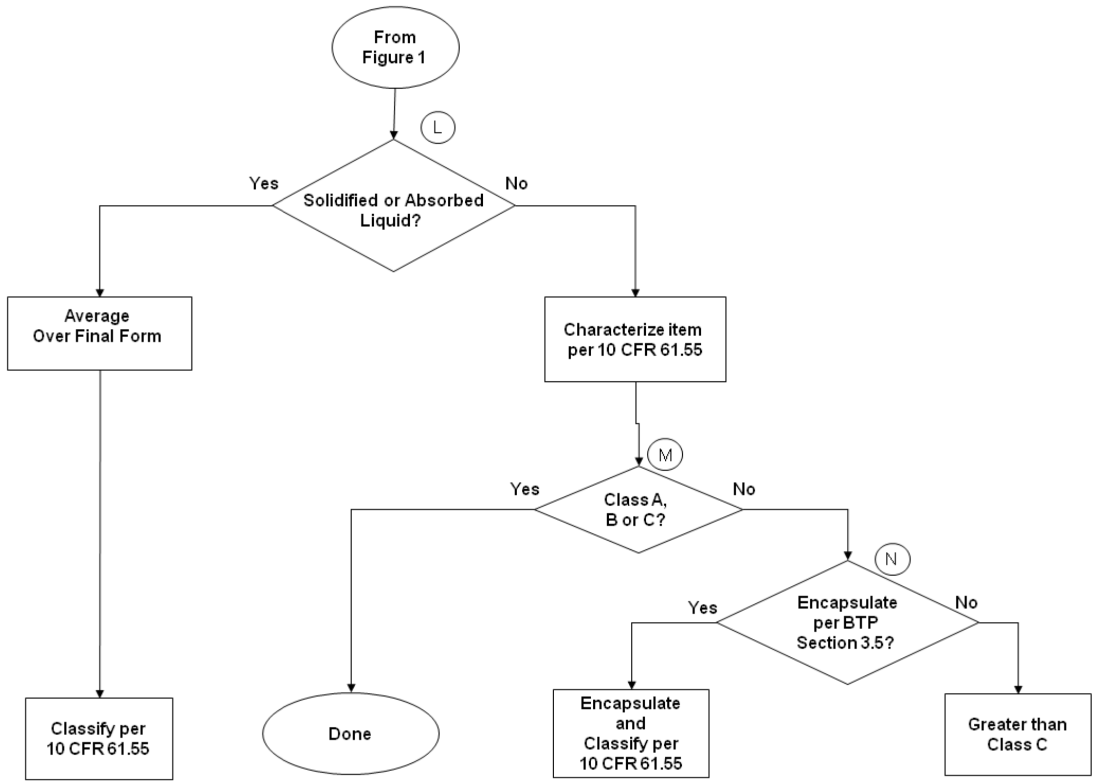

Figure 2. Classification of Individual Items

An example of a container of dissimilar waste types is a drum containing miscellaneous trash (a homogeneous waste type) mixed with pieces of activated metal. If the disposal container holds a mixture of dissimilar waste types, and if the highest waste classification of any individual item of the mixture is not higher than the waste classification to the total mixture (average of the total activity over the total volume or mass), then the classification based on the average concentration may be used (node C). A container of dissimilar waste types that does not meet this criterion should be reconfigured, or the licensee can propose classifying the mixture consistent with the approaches outlined in Section 3.9, "Alternative Approaches for Averaging."

If the container holds multiple items of the same waste type, the next decision (node D) is whether the waste is a homogeneous waste type. Guidance on identifying and classifying homogeneous waste types is presented in Section 3.2. Guidance for classifying mixtures of other similar waste types (e.g., a container holding pieces of activated metals or contaminated materials or cartridge filters) is presented in Section 3.3.

3.2 Classifying Homogeneous Waste Types and Mixtures of Homogeneous Waste Types:

Guidance in this section is applicable to wastes that are amenable to physical mixing to homogenize radionuclide concentrations. Waste is radiologically homogeneous for classification if the classification-controlling radionuclide[3] concentrations are likely to approach uniformity in the context of reasonably foreseeable intruder scenarios. In the context of LLRW disposal, reasonably foreseeable intruder scenarios are based on intruder activities that are likely to occur within the next few hundred years,[4] considering the capabilities of intruder barriers, site characteristics, and area land use trends and plans. These scenarios are usually site-specific. In this guidance, the term "homogeneity" is used to designate radiological homogeneity unless physical homogeneity is specified.

Waste homogeneity is relevant to intruder protection (i.e., by limiting the potential "hotspots" an intruder could encounter) and to waste classification. Guidance regarding waste homogeneity (Sections 3.2.1 and 3.2.2) is based on protection of inadvertent intruders. Additional guidance is provided regarding demonstration of waste classification for homogeneous waste (Section 3.2.3).

3.2.1 Homogeneous Waste Types:

Certain wastes typically may be treated as homogeneous waste types for the purpose of waste classification. These wastes include solidified or absorbed liquid, spent ion-exchange resins, filter media, evaporator bottom concentrates, ash, contaminated soil, and containerized dry

[3] In most cases, the risk-significant and concentration-controlling radionuclides will be the same. However, it is possible that the risk to an inadvertent intruder could be dominated by a radionuclide that is not included in Tables 1 and 2 of 10 CFR § 61.55 (e.g., depleted uranium). In these cases, intruder protection is maintained by the 10 CFR § 61.42 performance objective for protection of individuals against inadvertent intrusion.

[4] If the radiological hazard will persist beyond the next few hundred years, licensees should consider intruder activities typical of generic scenarios (e.g., NUREG-0782 (U.S. NRC, 1981), NUREG-0945 (U.S. NRC 1982), NUREG/CR-4370 (U.S. NRC, 1986) that are plausible within the compliance period considering the capabilities of intruder barriers and the natural evolution of site characteristics. Use of generic scenarios limits excessive speculation about future human activity.

active waste (DAW). Solidified and absorbed liquids are considered homogeneous waste types because radionuclide concentrations are expected to be uniform at the time of disposal. Spent ion-exchange resins, filter media, evaporator bottom concentrates, ash, and contaminated soil are considered homogeneous waste types because they are flowable, and the radionuclides in these waste streams are expected to be uniformly distributed when exhumed under reasonably foreseeable intruder scenarios. DAW, which may be composed of a variety of miscellaneous materials, may be considered a homogeneous waste type for purposes of waste classification when placed in containers because it is expected to degrade within approximately 100 years to a more soil-like state in which it will be mixed if exhumed by an intruder. For each of these homogeneous waste types, even if waste is not completely mixed as it is exhumed and spread on the surface, intruder exposure may be further averaged when the hypothetical intruder spends time in different locations at the site.

To the extent that contaminated trash and contaminated soil are packaged in a disposal container to achieve ≥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. The activity of small concentrated microcurie sources or gauges (< 3.7 MBq [100 µCi]) that may be mixed with contaminated trash may be averaged over the trash volume.

Although these wastes are assumed to be well mixed after they are exhumed, flowability is not a guarantee that the waste will be well mixed as it is disposed in a waste site. While an intruder exhuming many waste packages (e.g., an individual constructing a dwelling) will naturally homogenize waste over a relatively large volume, an intruder exhuming a relatively small volume of waste (e.g., a well driller) is more susceptible to encountering hotspots in the waste and averaging the exhumed waste over a much smaller volume.

In general, radiological heterogeneity within a disposal container is unlikely to pose a significant risk to an intruder in most reasonably foreseeable scenarios largely because the total amount of radioactivity a well driller (or other intruder exposed to a small volume of waste) is exposed to is limited by the small amount of waste exhumed. In addition, because of the low likelihood that an intruder exhuming a small amount of waste would encounter a hotspot in a waste that typically is expected to be homogeneous, the NRC staff does not believe that any benefits realized by making measurements for the purpose of quantifying the homogeneity of these wastes justify the additional dose incurred by workers making those measurements. Instead, available information (e.g., process knowledge, surveys performed to characterize waste for transportation) should be used to verify the presumed homogeneity of these wastes to the extent possible. Specifically, these wastes may be considered homogeneous unless available information indicates the waste contains a sub-volume with a height of 0.3 m (1 ft) or greater that has a sum of fractions exceeding 10 times the class limit. If this type of hotspot is detected, the appropriate action depends on the physical characteristics of the waste. If it is detected in a container of waste composed of individual items that may be retrieved (e.g., uncompacted DAW), the item or items exceeding ten times the class limit should be removed. If this type of heterogeneity is detected in a container of another waste type listed in this section from which waste is more difficult to retrieve, the licensee should determine the cause of the heterogeneity and take practical measures to eliminate this type of vertical feature in subsequent containers of the same waste type.

Although licensees are not required to demonstrate homogeneity of wastes specifically listed as a homogeneous waste type, additional measurements may be required to demonstrate that the waste meets the classification limit if the hotspot causes the average radionuclide concentration in the container to approach the limit (see Section 3.3.3).

3.2.2 Intentional Blending During Waste Processing:

Similar flowable waste streams may be physically blended irrespective of their initial radionuclide concentrations. When such blending occurs as part of a facility's design (e.g., a single holding tank is used for ion exchange resins from different processes), the waste is assumed to be a homogeneous waste type and should be treated as described in Section 3.2.1. This type of mixing is not expected to cause the same risk to an inadvertent intruder as intentional blending during waste processing[5] (i.e., large-scale blending). Waste resulting from large-scale blending may pose an increased risk to inadvertent intruders because 1) waste resulting from large-scale blending is expected to have a sum of fractions closer to the classification limit than incidentally blended waste, and (2) processors engaging in large-scale blending of waste are expected to produce more blended waste than generators who blend waste incidentally. The first factor could increase risk to an intruder by increasing the consequences of intruder interaction with the waste. The second factor could increase risk to an intruder by increasing the probability that an intruder constructing a dwelling or well (or otherwise disrupting the site) at a random location on site will interact with blended waste near the classification limit. Blending of physically dissimilar flowable waste streams (e.g., mixing ion exchange resins with soils) should be considered on a case-by-case basis.

Appropriate methods to demonstrate waste homogeneity depend on the identities and average concentrations of classification-controlling radionuclides in the waste. If waste classification is controlled by gamma-emitting radionuclides or radionuclides that may be reliably scaled to gamma-emitting radionuclides, it may be practical to demonstrate the homogeneity of individual waste containers. For example, if dose-to-curie ratios are reliable, homogeneity of waste in a container may be shown if surveys of waste in outlet piping show no notable deviations exceeding 10 times the classification limit. In this case, a notable deviation would correspond to enough waste to create a volume with a height exceeding 0.3 m (1 ft) in any area of the container (i.e., not necessarily a complete layer).

Instead of evaluating homogeneity of each waste package, demonstration of waste homogeneity may be based on process knowledge. In the simplest case, if the inputs to a blending process all are known to have radionuclide concentrations (on a sum of fractions basis) less than 10 times the relevant classification limit, the waste may be considered homogeneous (although additional methods may be required to demonstrate whether the blended waste meets the classification limit, as discussed in Section 3.5.3). If the

[5] Blending may also be used in conjunction with other processing methods, such as thermal treatment. In such cases, non-radioactive materials added to the mixture should have a purpose other than reducing the waste class, such as waste stabilization or process control. Consistent with other provisions in this BTP, extreme measures to lower the waste classification should be avoided.

demonstration of homogeneity is based on the characteristics of the input waste streams, processors should verify radionuclide concentrations provided by the generator.

To base a determination of homogeneity on process knowledge, a licensee also could demonstrate that (1) the process and equipment used reliably eliminate pockets of waste of 0.03 m^3 (1 ft^3) exceeding 10 times the classification limit, and (2) the process and equipment used have not changed since that demonstration. To demonstrate waste is reliably homogenized (condition 1), the material used in the demonstration should be physically similar to the waste to be blended. In addition, the test inputs should have a similar or larger concentration difference than the intended influent waste streams. For example, if a cold test is performed, the ratio of the tracer concentrations in the influent streams (higher concentration to lower concentration) should be larger than the ratio of the sum of fractions (higher concentration) in the wastes to be blended. The appropriate methods to demonstrate that certain equipment and processes generate homogeneous waste may depend on specific process features. For example, if continuous surveys can be performed while waste is mixed (e.g., if a survey can be performed on a pipe as waste is recirculated) it may be practical to survey a significant fraction of the volume of the waste to determine if any detectable fraction has a concentration exceeding 10 times the concentration limit. In this case, the detectable fraction should correspond to approximately 0.03 m^3 (1 ft^3) of waste to demonstrate homogeneity. Whether an elevated concentration in this quantity of waste can be detected may depend on the configuration of equipment (e.g., piping diameter) and process parameters (e.g., flow rate).

3.2.3 Classification of Homogeneous Waste:

The classification of containers of homogeneous waste may be based on the total radionuclide activity in the container divided by the waste volume (or mass, as appropriate) in the waste container. The acceptable uncertainty in the average concentration of classification-controlling radionuclides depends on how close the sum of fractions is to the classification limit. The Waste Classification BTP (NRC, 1983) indicates that more sophisticated waste classification programs should be used for waste for which minor process variations may cause a change in waste classification.

This section provides examples of classification calculations for three different wastes. The first example illustrates the minimal testing and calculations required to demonstrate classification of wastes with mean classification-controlling radionuclide concentrations far below the class limit (i.e., sum of fractions of 0.1 or less). The second example illustrates the calculations required to account for spatial variability in waste that has a sum of fractions closer to 1. The third example demonstrates calculations that account for multiple sources of uncertainty in radionuclide concentrations in blended waste. Specific values used in this section, such as numbers of survey readings or samples, are intended only to illustrate a calculation and should not be interpreted as recommended values. The appropriate number of survey readings or samples will vary on a case-by-case basis, as illustrated in Examples 2 and 3.

Example 1- Classification of DAW

A 200 L drum of DAW contains 4 $\cdot 10^{-6}$ Ci Sr-90, 2 $\cdot 10^{-5}$ Ci Ni-63, and 1.5 $\cdot 10^{-3}$ Ci Cs-137. No survey measurements were taken after the waste was placed in the drum. Because DAW is *designated as a homogeneous waste type and no process knowledge or survey data exist to indicate otherwise, the waste is assumed to be homogeneous and the radionuclide inventories are averaged over the 200 L drum volume. Classification is controlled by the § 61.55 Table 2 Class A sum of fractions, which is 0.008. The waste is Class A waste.*

More sophisticated statistical measurements are appropriate for more concentrated waste. If radionuclide concentrations are near the class limit, sufficient measurements should be taken to demonstrate that the mean sum of fractions is at least one standard error[6] (se) below the classification limit (i.e., sum of fractions < 1 – se). If a batch of generated or processed waste will be placed in a single disposal container, measurements may be taken either before or after waste is placed in the disposal container. If a batch of waste will span multiple containers but: (1) the waste treatment process (e.g., blending) has been demonstrated to create homogeneous waste (Section 3.5.2), and (2) the waste remains mixed at all points until, and including, the point at which it is sluiced into disposal containers, it is acceptable to apply the statistical test to the batch of processed waste instead of each waste container. Limited surveys of filled waste containers would suffice to verify radionuclide concentrations in each container.

<u>Example 2 - Classification of Spent Ion Exchange Resin</u>

Ion exchange resin from a single process in a plant is recirculated in a holding tank prior to being placed in a container. Because resin is a homogeneous waste type, no measurements are required specifically to demonstrate homogeneity. However, because the waste is near the Class A limit, several readings are required to demonstrate that the sum of fractions is below 1. Twenty survey readings are taken on the recirculation loop at regular intervals while waste is being mixed. The time between survey readings is long enough to yield measurements of independent sub-volumes of the waste (i.e., sequential readings are not correlated).

Waste classification is controlled by Table 2 radionuclides. Samples of three individual resin beads indicate there is little variability in the scaling factors (e.g., coefficient of variation less than 10%) used to scale other radionuclides to Cs-137, so the error in the scaling factors is neglected. The survey readings correspond to a mean sum of fractions of 0.85 of the Class A limit with a sample standard deviation of 0.25. The standard error of the mean is 0.056. The waste is Class A waste because the measured sum of fractions is less than one minus the standard error.

Because waste that is intentionally blended as part of waste processing (i.e., large-scale blended waste) is expected, by definition, to contain components with different radiological characteristics and, potentially, with different scaling factors, several samples of a batch of waste may be required to demonstrate the reliability of dose-to-curie ratios. The necessary number of samples will depend on the sample variability and the acceptable uncertainty in the final concentration values, which, in turn, will depend on how close the sum of fractions is to the class limit (see Example 3). The physical size of the samples will depend, in part, on the

[6] The standard error of the mean is the sample standard deviation divided by the square root of the number of samples. Assuming the variation in the sample values is normally distributed and a sufficient number of measurements have been made and using a one-tailed test, showing that the sample mean sum of fractions is one standard error below the classification limit corresponds to an 85% confidence that the true sum of fractions is below the class limit.

physical characteristics of the final waste form. If the waste inputs retain their original form (e.g., bead and powdered resins), choosing very small samples (e.g., individual resin beads) will not provide the necessary information about the scaling factors in the final blended waste form. Instead, a sample representative of all of the inputs should be used. If waste is processed so that the original physical forms of the waste streams are made more uniform (e.g., by incineration), the physical size of samples may be based on counting statistics or other practical considerations.

<u>Example 3 - Classification of Blended Spent Ion Exchange Resins</u>

Ion exchange resins from four sources are physically blended to produce a 20 m^3 (710 ft^3) batch of waste. To demonstrate homogeneity, survey readings are taken continuously in a recirculation line while the waste is mixed. The volumetric flow rate on the recirculation line is used to calculate a time interval corresponding to 0.03 m^3 (1 ft^3) of waste flowing past the survey instrument. Because no survey readings of the calculated interval indicate a pocket of waste exceeding 10 times the Class A limit, the licensee treats the waste as homogeneous.

To determine the waste classification, twenty survey readings are taken at regular intervals while the waste is sluiced into a 2.8 m^3 (100 ft^3) container. The time between survey readings is long enough to yield measurements of independent sub-volumes of the waste (i.e., sequential readings are not correlated). Survey readings are dominated by Cs-137, while both Cs-137 and Ni-63 control the waste classification. The twenty survey readings have a mean of 0.005 Gray (Gy)/h [0.5 Roentgen (R)/h] with a standard error of 0.002 Gy/h (0.2 R/h) due to spatial variability in the waste. The Cs-137 dose-to-curie ratio at 1 m (3 ft) is $1.2 \cdot 10^8$ (Gy/h)/Becquerel (Bq) [0.33 (R/h)/Ci] and is shown to have minimal variability.

The uncertainty in the radionuclide scaling factor of Ni-63 to Cs-137 is based on 4 samples taken from the batch. The measured scaling factor is 2 Bq Ni-63 per Bq Cs-137 (2 Ci Ni-63 per Ci Cs-137), with a standard error of 0.8 Bq Ni-63 per Bq Cs-137 (0.8 Ci Ni-63 per Ci Cs-137).

The Cs-137 inventory is given by

$$\frac{0.50 \pm 0.20\,\frac{R}{h}}{0.33\,\frac{R/h}{Ci}} = 1.5 \pm 0.61\ \text{Ci Cs-137}$$

where 1 Ci equals $3.7 \cdot 10^{10}$ Bq and 1 R is approximately equivalent to 0.01 Gy. The resulting Ni-63 inventory is given by[7]

$$1.5 \pm 0.61\ \text{Ci Cs-137}\ \times 2.0 \pm 0.80\,\frac{\text{Ci Ni-63}}{\text{Ci Cs-137}} = 3.0 \pm 1.7\ \text{Ci Ni-63},$$

The resulting concentrations in the 2.8 m^3 (100 ft^3) container are given by

$$\frac{1.5 \pm 0.61\ \text{Ci Cs-137}}{2.8\,m^3} = 0.54 \pm 0.22\,\frac{Ci}{\text{m}^3}\text{Cs-137 and}$$

[7] For products, the fractional standard errors add in quadrature (i.e., $(S_Z / Z)^2 = (S_X / X)^2 + (S_Y / Y)^2$ where S_X, S_Y, and S_Z are the standard errors in the variables X, Y, and Z, respectively.

$$\frac{3.0 \pm 1.7 \text{ Ci Ni-63}}{2.8\, m^3} = 1.1 \pm 0.61 \frac{Ci}{\text{m}^3}\text{Ni-63.}$$

The resulting Class A sum of fractions contributions are given by

$$\frac{0.54 \ \pm \ 0.22\ Ci/m^3}{1.0\ Ci/m^3} = 0.54 \ \pm \ 0.22 \ \textit{ for Cs-137 and}$$

$$\frac{1.1 \ \pm \ 0.61\ Ci/m^3}{3.5\ Ci/m^3} = 0.31 \ \pm \ 0.17 \ \textit{ for Ni-63.}$$

The final sum of fractions is given by[8]*:*

$$0.54 \ \pm \ 0.22 \ + 0.31 \pm 0.17 = 0.85 \pm 0.28$$

The licensee has not demonstrated the waste to be Class A waste because the measured sum of fractions is not less than 1 – the standard error. Reducing the error in the Ni-63 to Cs-137 scaling factor by taking additional samples or reducing the uncertainty in the Cs-137 inventory by taking additional survey measurements may enable the licensee to demonstrate the waste is Class A (i.e., the sum of fractions is less than 1 – the standard error).

3.3 Classifying a Mixture of Activated Metals or Contaminated Materials or Cartridge Filters:

This section provides guidance on the classification of a container of multiple items of activated metals, or contaminated materials, or cartridge filters. Activated metals include neutron-activated materials or metals, or components incorporating radioactivity in their design. This position on classifying a container of similar waste type items includes a number of criteria to ensure that individual hot spots (higher activity items) do not compromise the safety of the inadvertent intruder. These criteria are detailed in the next three subsections. This position does not apply to homogeneous waste types which are addressed in Section 3.2.

If a larger component is cut into pieces for operational considerations (e.g., packaging for transportation), the activities may be averaged over the volume of the original larger component, provided the pieces pass the Table A and Table B criteria, and provided the individual pieces are all placed in the same container. Passing the Table A criteria means that no individual piece: (1) has a volume less than 0.01 ft^3 and (2) has primary gamma activity that exceeds the values shown in Table A. Passing the Table B criteria means that no individual piece has activity that exceeds the values shown in Table B. Both the Table A and Table B tests are explained more fully in the following sections.

If a waste container or liner contains pieces from more than one component, it is the characteristics of the original component that are evaluated using the following criteria. As a

[8] For sums, the standard errors add in quadrature (i.e., $S_Z^2 = S_X^2 + S_Y^2$ where S_X, S_Y, and S_Z are the standard errors in the variables X, Y, and Z, respectively.

simple example, assume that a larger activated metal component is cut into four individual pieces for operational considerations and those four individual pieces each pass the Table A and Table B tests, and then the four pieces are combined with five more pieces of activated metal in a single container; the four pieces (from the single larger component) are assessed as a single piece, along with the five additional pieces (assessed as six pieces--one large component plus five additional pieces).

The first decision is if each item in the mixture has an activity less than 1 mCi (node E), if so, the entire mixture may be concentration-averaged over the volume or mass of the waste.

3.3.1 Conservative Classification Based on Highest Individual Contributor:

The second decision (node F) is whether the mixture of pieces can be conservatively classified according to the contributor item in the mixture with the highest classification. One may always classify a mixture conservatively based on the highest classification of any individual item in the mixture. Thus, if a mixture of items in a waste drum includes a single item classified as Class C based on 10 CFR § 61.55, and the remaining items are classified as Class A, the entire waste drum may be conservatively classified as Class C LLRW. Using the example above, the conservative classification option is assessed as if there were six pieces in the container (one large component plus five additional pieces), and the option would not be applied to the nine individual pieces that actually exist in the container.

If the mixture cannot be conservatively classified or averaged because all pieces are <1 mCi per item, the mixture should be screened to ensure there are no radiological hot spots. Section 3.3.2 and 3.3.3 describe the screening criteria for classifying mixtures of activated metals, or contaminated materials, or cartridge filters. Appendix B provides justification for the screening criteria presented in Sections 3.3.2 and 3.3.3.

3.3.2 Averaging Involving Primary Gamma Emitters:

As used in this BTP, the “primary gamma-emitting” nuclides are Co-60, Nb-94, and Cs-137/Ba-137m. If (1) the volume of any item in the mixture is less than 0.01 ft^3, and (2) the activity of that item exceeds the values shown in Table A (node G), the item should be removed and treated as an individual item per Figure 2. Such items are similar to sealed radioactive sources and should be managed individually.

Table A. Activity Levels of Primary Gamma Emitters in Individual Items Potentially Requiring Piecemeal Consideration in Classification Determinations

Nuclide	Waste Classified as Class A	Waste Classified as Class B	Waste Classified as Class C
Co-60	>1.1 TBq (140 Ci)	No limit.	No limit.
Nb-94	>37 MBq (1 mCi)	>37 MBq (1 mCi)	>37 MBq (1 mCi)
Cs-137/Ba-137m	>266 MBq (0.0072 Ci)	> 26.6 GBq (0.72 Ci)	>4.8 TBq (130 Ci)

After these items have been removed, the remaining mixture is further evaluated for gamma-emitting hot spots. If the primary gamma emitters control the classification of the mixture (node H), and if the concentration of a classification-controlling primary gamma-emitting nuclide in any item of the mixture is greater than two times the classification limit, for the classification of the mixture and for that nuclide, that item should be removed and treated as an individual item per Figure 2 (node I). The sum of fractions for the mixture cannot exceed one. As a simple example, if there are multiple pieces of activated metal in a container and Nb-94 is the only nuclide, and the classification of the mixture is Class A--no individual item should have a Nb-94 concentration equivalent greater than 0.04 Ci/m^3 (two times the Class A limit for Nb-94).

This Factor of Two Rule does not apply if the classification of the mixture, as a result of radionuclides other than primary gamma emitters, is higher than the class derived from the primary gamma emitters. The Factor of Two Rule also does not apply to individual pieces, if the primary gamma-emitting nuclide activity is less than 37 MBq (1 mCi) in the piece.

3.3.3 Averaging Involving Radionuclides Other Than Primary Gamma Emitters:

As used in this BTP, "radionuclides other than primary gamma emitters" are all 10 CFR § 61.55 tabulated radionuclides in the disposal container, other than Co-60, Nb-94, or Cs-137. If any item in the mixture exceeds the values shown in Table B (node J), these items should be removed and treated as individual items per Figure 2.

Table B. Activity Levels of Radionuclides other than Primary Gamma Emitters in Individual Items 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)

* Other nuclides listed in the tables in 10 CFR § 61.55 are not expected to be of importance in determining waste classification.

The remaining mixture is further evaluated for radiological hot spots using the following criterion (node K). The concentrations of all 10 CFR § 61.55-tabulated radionuclides in the disposal container, other than the primary gamma emitters, may be based on the volumetric- or weight-averaged concentrations of the combined materials if the concentrations of the classification-controlling individual nuclides in each item are within a factor of 10 of the classification limit, for that nuclide, for the classification of the mixture. A classification-controlling nuclide is a nuclide in the waste in concentrations greater than 1% of the concentration of that nuclide listed in Table 1 of 10 CFR Part 61 or 1% of the applicable class-dependent concentration of that nuclide in Table 2 of 10 CFR Part 61, Column 2 or 3, and present in a relative fractional abundance such that the concentration of the individual radionuclide (or a combination of controlling radionuclides) are the specific basis for transition from one waste class to another. Note that a nuclide may be significant for reporting purposes under Section 4 of the May 1983 Technical Position and yet not be a classification-controlling nuclide.

Individual items whose concentration exceeds the Factor of 10 Rule above should be removed and managed as individual items per Figure 2. If the concentrations of all remaining nuclides in all remaining pieces are below the Factor of 10 Rule, the classification of the mixture may be based on the volumetric- or weight-averaged concentrations of the combined materials.

3.4 Classifying Individual Items:

Figure 2 provides guidance for classifying individual items. For individual items, which originated from liquid wastes (node L), classification of the mixture may be based on the volumetric- or weight-averaged concentrations of the combined materials.[9]

For individual items other than those originating from liquid forms, the individual items are first characterized (node M) in accordance with 10 CFR § 61.55. If this determination finds that individual items exceed Class C activity concentrations and are therefore not generally acceptable for near-surface disposal, one may establish, following the guidance in Section 3.5, if the item can be encapsulated and the concentration averaged over the final waste form to a value less than the Class C upper limit (node N).

3.5 Encapsulation of Sealed Sources and Other Solid Low-Level Radioactive Wastes:

Encapsulation can mitigate waste dispersion, provide additional shielding to limit external radiation, and satisfy the stability requirement of 10 CFR § 61.56(b) and technical requirements for land disposal facilities of 10 CFR § 61.52(a). However, the amount of credit allowed for encapsulation should be limited so that extreme measures cannot be taken solely for the purposes of lowering the waste classification. To limit extremely large point sources of radioactivity in the disposal site that could pose an unacceptable risk to an inadvertent intruder, the staff has developed generally acceptable values for minimum and maximum encapsulated waste volume and mass, nuclide activities, and radiation levels. These generally acceptable bounding conditions are as follows:

(1) The minimum solid volume or mass used to encapsulate should be sufficient to make handling the radioactive waste by an inadvertent intruder prohibitively difficult. The size or weight of the encapsulated radiation source should be enough to preclude movement without the assistance of mechanical equipment.

(2) For determining the classification of an encapsulated source (or multiple sources in a single container), the maximum volume or mass should be 0.2 m^3 or 500 kg. For physically encapsulating a single source, the volumes and masses may be larger than 0.2 m^3 or 500 kg to allow for disposal of a sealed source in its shielded housing and/or

[9] In the use of solidification or absorbent materials for liquid wastes, extreme measures to lower the waste classification should not be employed. The added materials should be generally sufficient to solidify or immobilize the waste.

source device. The shape of the final encapsulated package does not have to be a cylinder.

(3) Multiple sources may be encapsulated together in a single 0.2 m^3 container, so long as the final encapsulated package meets the other criteria described herein.

Other guidance for encapsulation is as follows:

(4) The maximum amount of any radionuclide that should be encapsulated in a single 0.2 m^3 disposal container should not cause the average concentration in the container to exceed the maximum concentration limits for Class C waste, as defined in Tables 1 and 2 of 10 CFR § 61.55, when averaged over the waste and the encapsulating media. For example, a Ni-59 source should not exceed 1.5 TBq (40 Ci) and a Pu-239 source should not exceed 1110 MBq (30 mCi).

(5) The maximum gamma-emitting radioactivity (e.g., from Cs-137/Ba-137m, Nb-94 and Co-60) acceptable for encapsulation is that which would result in a dose rate of less than 0.2 μSv/hr (0.02 mrem/hr) on the surface of the encapsulated package after decaying for 500 years. Furthermore, the maximum Cs-137/Ba-137m gamma activity acceptable for encapsulation in a single disposal package is 266 MBq (0.0072 Ci) for Class A disposal, 26.6 GBq (0.72 Ci) for Class B disposal and 4.8 TBq (130 Ci) for Class C disposal. The maximum Nb-94 activity acceptable for encapsulation for Class A, B, or C disposal is 37 MBq (1 mCi). There is a 5.2 TBq (140 Ci) limit for Class A disposal of Co-60 and no activity limit for Class B or C disposal of encapsulated Co-60 sources.

(6) In all cases when an individual 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 medium.

3.6 Determining the Volume of the Waste:

The May 1983 Technical Position provides NRC's guidance for determining nuclide concentrations. Table C below provides guidance for determining waste volumes.

Table C. Volume and Mass for Determination of Concentration

Waste Type	Allowable Classification Volume or Mass
Contaminated trash or soil or DAW	Reasonable fill volume of container or mass of waste (<10% void)*
Solidified or absorbed liquids	Volume or mass of solidified or absorbed mass
Solidified ion-exchange resins	Volume or mass of solidified mass**
Dewatered ion-exchange resins in High-Integrity Containers (HICs) or liners	Displaced (bulk) volume of waste (interstitial space may be included) or dewatered mass of ion-exchange resins
Filter cartridges in HICs or liners	Envelope volume or mass of filters* The envelope volume is the volume obtained

	using the outer dimensions of the filter (interstitial volume is included in the envelope volume)
Activated components, components containing radioactivity in their design, or contaminated materials	Full density volume (major void volumes subtracted from envelope volume) or mass of components*
Encapsulated filter cartridges or sealed sources	Volume or mass of solidified mass when encapsulated in accordance with the guidance provided in this Position
* Mixtures of waste streams subject to additional guidance defined in Section 3.2. **If homogeneity is maintained in the solidified mass.	
For wastes stabilized by emplacement within High Integrity Containers (HICs), the volume or weight used to determine classification should be based on the displaced volume or weight of the waste itself, rather than the gross volume or weight of the HIC.	

3.7 Quality Assurance Program:

In accordance with Appendix G of 10 CFR Part 20, the licensee classifying the waste must have in place a quality assurance program to ensure compliance with the waste classification provisions of 10 CFR § 61.55. As part of this quality assurance program, if the classification of a mixture is based on the volumetric- or weight-averaged nuclide concentration of a mixture, 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 analysis. It is generally expected that this record or analysis, in and of itself, should be sufficient to show that the mixing was undertaken consistent with the guidance found in this BTP.

3.8 Alternative Requirements for Waste Classification (10 CFR § 61.58):

Under 10 CFR § 61.58, the Commission may, upon request or on its own initiative, authorize other provisions for the classification and characteristics of waste on a specific basis, if, after evaluation, of the specific characteristics of the waste, disposal site, and method of disposal, it finds reasonable assurance of compliance with the performance objectives in subpart C of Part 61. The waste classification requirements for near-surface disposal are contained in 10 CFR § 61.55. Section 61.55 identifies specific radionuclides and concentrations for determining the class of waste (A, B, C, or Greater-Than-Class C). Classification involves consideration of both long-lived radionuclides, whose potential hazard will persist long after such precautions such as institutional controls, improved waste form, and deeper disposal have ceased to be effective and shorter-lived radionuclides, for which such precautions can be effective. Classification is used to determine which waste characteristic requirements in § 61.56 are necessary.

Certain minimum requirements contained in 10 CFR § 61.56 apply to all classes of waste, but the stability requirements in 10 CFR § 61.56 apply only to Classes B and C because of their higher activity. Stability is necessary for Class B and C waste to limit exposures to inadvertent intruders. Stability is defined as the ability of waste to maintain gross physical properties and identity over a 300 year period.

In 10 CFR § 61.58, the NRC allows the flexibility to establish alternate requirements for waste classification and characteristics when justified by site-specific conditions and the unique characteristics of the waste. These alternative provisions would not affect the generic waste classifications established in 10 CFR § 61.55. Thus, the radionuclide concentrations in the waste define the class of the waste in accordance with the 10 CFR § 61.55 waste classification tables. If it can be demonstrated that the performance objectives of 10 CFR Part 61 would be met, then, for example, waste that contains Class B concentrations of radionuclides could be authorized for disposal in a Class A disposal cell using 10 CFR § 61.58. The NRC is currently developing a rule that will require the performance of site-specific performance and intruder assessments for disposal facilities licensed under 10 CFR Part 61. These assessments are necessary to ensure that disposal facilities continue to meet the performance objectives in 10 CFR §§ 61.41 and 61.42. Such assessments could show that the actual designs and engineered barriers in use at disposal sites could ensure protection of an intruder for concentrations of waste greater than those authorized by the license for a given waste class. In such a case, either a 10 CFR § 61.58 approval or an exemption from the waste classification requirements in the license would be needed to enable disposal of such materials.

3.9 Alternative Approaches for Averaging:

The approaches in Sections 3.1 – 3.5 of this BTP may be used by generators and waste processors to classify LLRW for shipment to a licensed disposal site. Most of the approaches are generic and apply to all LLRW disposal sites. Other methods may be used by licensees, however, and the following guidance discusses considerations for site-specific methods and other approaches to intruder protection that could potentially justify concentration averaging positions different from those in this BTP:

Encapsulation of Sealed Sources:

This position on encapsulation in Section 3.5 is considered generally suitable for all LLRW disposal facilities licensed under 10 CFR Part 61, or the equivalent Agreement State regulation. Other provisions may be authorized on a specific basis for the encapsulation of sealed sources and if, after an evaluation of the specific characteristics of the waste form, the disposal site, and the method of disposal, there is reasonable assurance of compliance with the inadvertent intruder performance objective in 10 CFR § 61.42.

As long as the proposed alternative provisions for an encapsulated source meet the § 61.55 waste classification requirements, licensees do not need to seek authorization under § 61.58 or request an exemption. For example, if a licensee's proposal is determined to justify disposal of a 33 TBq (900 Ci) Cs-137 sealed source in a tungsten shielded cask buried 12 m deep, in a 0.5 m^3 encapsulated waste form, a § 61.58 authorization or an exemption is not necessary, because 33 TBq (900 Ci) of Cs-137 in 0.5 m^3 is well within the § 61.55 Class C limits of 4,600 Ci/m^3 for Cs-137. Alternative encapsulation proposals for encapsulating individual items that would exceed the § 61.55 waste classification limits would require use of § 61.58 or an exemption.

Due to sealed source accidents, the NRC is concerned that highly radioactive items might survive for long time periods in a disposal facility and be unrecognized by the intruder as hazardous. Given this concern, the BTP used a gamma source carry-away scenario to establish the 130 Ci limit for disposal of Cs-137 sealed sources. The source carry-away scenario is based on the assumption that 500 years in the future, the encapsulating media has fallen away, and a sealed source is exposed at the land surface by a civil works project. It is further assumed that the intruder does not recognize the hazard and places the sealed source in a pocket for 4 hours and later in the home on a shelf.

Alternative proposals should provide reasonable assurance that the above referenced scenario is highly unlikely, so long as the source strength exceeds the criteria set in this position (i.e., 130 Ci of Cs-137 or 0.2 times the § 61.55 limits for the non-gamma nuclides), and that another scenario is appropriate. Factors that could provide reasonable assurance the gamma source-carry away scenario at 500 years is not credible include, but are not limited to:

a) disposal of the source in a robust and long-lived case that cannot be opened easily in the field (the entire package would still require encapsulation), and;

b) disposal of the encapsulated source at depths greater than 10 m, with evidence that the depth of burial will be maintained for the period that the hazard exists.

In preparing a proposal that justifies a different approach, the proposal should contain the following types of information:

- A detailed description of the sealed source(s)
- A review of the BTP's existing position on encapsulation
- An overview of the proposed alternative provision (e.g., depth of burial and/or other factors), and how the alternative provision protects the intruder
- A description of site characteristics pertinent to the proposal
- A description of any source containing devices and encapsulating media
- An analysis of the effects of degradation on packaging and engineered barriers over the period that the source remains hazardous to an intruder

<u>Activated Metals, Contaminated Materials and Cartridge Filters</u>

The BTP states that activated metals, contaminated materials and cartridge filters should be characterized as individual items when averaged over the volume of a container. As such, they are subject to the averaging constraints in this position. This position is based on the premise that activated metals, contaminated materials and cartridge filters will not become soil-like within the time frame that they are hazardous. Stainless steel, for example, would be resistant to structural degradation and may be intact at the time that an intruder is postulated. Thus, an intruder could unknowingly be exposed to scenarios that would result in a radiation exposure higher than if they had become soil-like. If a licensee can demonstrate that either specific types of cartridge filters or contaminated materials become soil-like at the time of intrusion, this could be a basis for considering them to be homogeneous wastes. There is a wide range of materials, configurations, and designs for these items, and while these waste types should generally be considered as individual items in classification, some could potentially be classified as homogeneous waste. Justifications for treating cartridge filters as homogeneous wastes, instead of individual items, should be reviewed and approved by the appropriate regulator.

Considering the Likelihood of Intrusion

Inadvertent intrusion is only expected if required markers, barriers, active and passive institutional controls and societal memory are lost. This makes inadvertent intrusion unlikely, but possible, especially as time passes after closure of the disposal facility. However, there is no scientific basis for quantitatively predicting the nature or probability of a future human activity. Therefore, an inadvertent intruder assessment typically does not consider the probability or likelihood of inadvertent intrusion occurring. Rather, the assessment assumes reasonably bounding scenarios that could occur and evaluates the radiological consequences that could be experienced by individuals who might actually intrude onto the disposal site if institutional controls or societal memory were lost (NCRP 2005).

As such, an intruder assessment is considered “stylized” in that it typically constrains the scenario by assuming the intruder directly contacts the disposed waste (i.e., the probability is 1 that intrusion will occur). Because of this assumption, the scenario analysis and the source term are the most significant parameters in an intruder assessment.

Notwithstanding the above, there may be limited circumstances in which the likelihood of intrusion can be considered in justifying averaging approaches different from those specified in this BTP. As an example, DOE’s Order 435.1, “Radioactive Waste Management,” allows for consideration of probability of intrusion. Its use of this provision has been limited, according to DOE, and has been based in part on the government’s extended, long-term control of sites, a factor that may not be available for commercial disposal facilities. A licensee could consider such an example, however, in submitting a justification for positions different from those in this BTP.

Large Components

The positions in this BTP are based on averaging over containers, such as 55 gallon drums, Sections 3.5 and 3.6 of this BTP on encapsulation and volume for averaging address averaging over containers of radioactive waste, such as a 55 gallon drum or high-integrity container. Other averaging volumes may be acceptable, however, and can be approved on a case-by-case basis. For example, regulators have approved disposal of large reactor components, such as reactor vessels and steam generators using averaging approaches unique to the waste types involved. In 1998, the State of Washington authorized the Portland Gas and Electric Co. to dispose of the Trojan nuclear plant reactor vessel with components grouted into the vessel and averaged over the volume of the vessel (Washington Department of Health, 1998). On December 30, 1999, the NRC approved a Topical Report for encapsulation of cartridge filters in 200 ft^3 liners, subject to certain conditions defined in the approval (NRC 1999).

3.10 Implementation:

This BTP describes, and makes available to the NRC licensees, Agreement States, and the public, methods that the NRC believes may be acceptable for implementing specific parts of the Commission's regulations, and to provide guidance to regulated entities. The positions in this document are not intended as substitutes for regulations, and compliance with them is not required. Applicants and licensees may use the information in this Branch Technical Position when developing applications for initial licenses, amendments to licenses, or requests for NRC regulatory approval. Licensees may use the information in this Branch Technical Position for actions that do not require prior NRC review and approval. Licensees may also use the information in this Branch Technical Position to assist in attempting to resolve regulatory or inspection issues. Current licensees may continue to use the previous guidance found acceptable for complying with specific portions of the regulations as part of their license approval process.

In addition to the guidance in this BTP, licensees that ship waste for disposal in a 10 CFR Part 61 or Agreement State equivalent facility should ensure that the waste meets the concentration averaging provisions in the disposal facility license, if any, or separate waste acceptance criteria. Where there are conflicts with this guidance, the disposal facility license conditions are controlling.

3.11 References:

National Council on Radiation Protection and Measurements (NCRP), "Performance Assessment of Near-Surface Facilities for Disposal of Low-Level Radioactive Waste," Recommendations of the National Council of Radiation Protection and Measurements, Bethesda, MD, NCRP Report No. 152, December 31, 2005.

NRC, 1981, "Draft Environmental Impact Statement on 10 CFR Part 61, 'Licensing Requirements for Land Disposal of Radioactive Waste'," NUREG-0782, September 1981.

NRC, 1982, "Final Environmental Impact Statement on 10 CFR Part 61 'Licensing Requirements for Land Disposal of Radioactive Waste'," NUREG-0945, November 1982.

NRC, 1983, "Final Waste Classification and Waste Form Technical Position Papers," dated May 11, 1983, *Federal Register,* Volume 48, No. 110, page 26295.

NRC, 1986, “"Update of the Part 61 Impacts Analysis Methodology," NUREG-CR/4370.

NRC, 1991, Waste Form Technical Position, Revision 1. (ML033630746).

NRC, 1995, "Branch Technical Position on Concentration Averaging and Encapsulation," dated January 17, 1995, *Federal Register,* (60 FR 4451).

NRC, 1999, letter from Thomas Essig, NRC, to Charles Jensen, Diversified Technologies Services. (ML003672318).

NRC, 2010, Staff Requirements Memorandum—SECY-10-0043,"Blending of Low-Level Radioactive Waste." October 13, 2010.

Price, Alan, Dominion Nuclear Connecticut, May 15, 2002, letter to Document Control Desk, U.S. Nuclear Regulatory Commission. (ML021500428).

Washington Department of Heath, 1998, “Technical Evaluation Report” for disposal of Trojan Nuclear Reactor. ML112170287.

Appendix A - Glossary

Blending	As used in this BTP, blending is the mixing of LLRW with different concentrations of radionuclides, which results in a relatively homogeneous mixture for disposal in a licensed facility.
Classification-controlling radionuclides	A nuclide in the waste in concentrations greater than: 1% of the concentration of that nuclide listed in Table 1 of 10 CFR Part 61 or 1% of the applicable class-dependent concentration of that nuclide in Table 2 of 10 CFR Part 61, Column 2 or 3 and present in a relative fractional abundance such that the concentration of the individual radionuclide (or a combination of controlling radionuclides) are the specific basis for transition from one waste class to another.
Encapsulation	The process of surrounding a radioactive sealed source, a collection of such sources, or other materials in a binding matrix, within a container, where the activity remains within the dimensions of the original source(s) or other materials.
Homogeneous Waste	Waste in which the classification-controlling radionuclide concentrations are likely to approach uniformity in the context of reasonably foreseeable intruder scenarios.
Nuclides other than Primary Gamma-Emitting Nuclides	All 10 CFR § 61.55 tabulated radionuclides other than Co-60, Nb-94, or Cs-137/Ba-137m.
Primary Gamma-Emitting Nuclides	Cobalt-60 (Co-60), Niobium-94 (Nb-94), and Cesium-137/Barium-137m (Cs-137/Ba-137m).
Solidification	The process of incorporating radioactive material a binding matrix, in a manner to create a solid, radiological homogeneous material.
Waste Types	Wastes that are grouped together of the purposes of this concentration averaging and waste classification BTP. Waste types include, but are not limited to: a variety of homogeneous waste types (e.g., spent ion exchange resins, contaminated soils, and filter media); activated metals; contaminated materials; cartridge filters, and sealed radioactive sources. Activated materials include neutron-activated materials or metals, or components incorporating radioactivity in their design.

Appendix B

Technical Basis for Concentration Averaging and Encapsulation Guidance

Introduction:

This Appendix provides the technical basis to support the BTP's guidance for the disposal of individual items, mixtures of individual items or homogeneous waste types. The NRC developed this technical basis to ensure that the disposal of these wastes does not result in a dose to an inadvertent intruder that exceeds 500 mrem/year as defined in the environmental impact statement (EIS) supporting 10 CFR Part 61. This BTP provides separate guidance for: (1) primary gamma emitters [Co-60, Nb-94, and Cs-137/Ba-137m], and (2) radionuclides other than primary gamma emitters. This subdivision is necessary because "hot spots" of gamma activity may be more significant to potential intruder doses than hot spots associated with the other nuclides.

Background:

The concentration values shown in Tables 1 and 2 of § 61.55 for Class A, B and C low-level radioactive wastes (LLRW) are based on potential doses to an inadvertent intruder. The Part 61 environmental impact statement (EIS) uses three exposure scenarios to assess these potential intruder doses. For all three of the exposure scenarios, the NRC assumed that the intruder resides on a closed LLRW disposal site and inadvertently exhumes LLRW. In one EIS scenario the waste containers and barriers remain intact and the intruder soon recognizes the hazard and receives only a "discovery" dose. The results of this intruder-discovery scenario provide the basis for the Class B limits shown in Table 2.

In the other two EIS scenarios (intruder-construction and intruder-agriculture), the NRC assumed that the exhumed waste is indistinguishable from soil and as a result, the intruder is unaware of their interaction with the LLRW. Many LLRWs are soil-like even at the time of burial. These soil-like wastes are classified as homogeneous waste types in this guidance and include filter media, solidified and absorbed liquids, evaporator bottom concentrates, contaminated soil, ash, and spent ion exchange resins. Other homogeneous wastes types, such as contaminated trash, will become soil-like over time. The intruder-construction and intruder-agriculture dose scenarios are the basis for the Class A and C limits shown in Table 1 and 2 of § 61.55. In the Draft and Final EISs, the NRC increased the Class A limit for Cs-137 by a factor of 20 based on the expectation that average concentrations of Cs-137 would be far below the peak allowable concentrations. In addition, in the Final EIS, the NRC increased the Class C limits by a factor of 10 over the initial values because of (1) the reduced likelihood of significant exposures due to passive warning device (markers, for example, which contain an inscription describing the nature of the hazard, can be emplaced at the disposal facility), (2) the difficulty of contacting wastes disposed of at greater depths and (3) the expectation that average concentrations will be lower than peak allowable concentrations.

After the finalization of Part 61 with its Table 1 and Table 2 Class A, B and C limits, a number of well-publicized accidents occurred that involved small, highly radioactive sealed sources. The sealed sources were typically quite small (less than one-hundredth of a cubic foot (0.01 ft^3)) and some were composed of corrosion-resistant stainless steel. These accidents raised the concern at the NRC that highly radioactive items might survive for long time periods in a disposal facility and not be recognized as a hazard by an intruder. This scenario, in which a highly radioactive item would survive 500 years and not be recognized by an inadvertent intruder is new; it was not considered by the NRC in the Part 61 EIS.

The worst of these accidents occurred in Brazil and resulted in large social disruptions, a very expensive cleanup, and radiation doses leading to deaths (IAEA, 1988). This accident in Brazil as well as accidents in the Republic of Georgia, Morocco and other locations demonstrated that the radiation hazard associated with small items is not always recognizable. Although these sources were not secured and were in locations such as abandoned buildings that were readily accessible to members of the public, the NRC decided that it would be prudent to consider the consequences of exposure to small items of LLRW. Unlike the actual events, these items in a disposal facility will be less likely to be contacted by an intruder. The disposal facility will have passive institutional controls in place, and NRC expects licensees to dispose of LLRW beneath the surface of the earth, in some cases in canisters. Some of the disposal sites are in remote locations, as well.

Therefore, a major purpose of the revised BTP is to provide guidance for the disposal of individual highly-radioactive items or mixtures of this waste that fall within the “envelope of safety” defined in the EIS for Part 61. This guidance is based on two gamma source handling scenarios: (1) the gamma sealed source carry-away scenario and (2) the gamma source large items carry-away scenario.

Further, the BTP also provides guidance on waste classification for mixtures of homogeneous waste types. This guidance is included in the revision in response to recent proposals to blend physically mixable wastes with various waste class concentrations into a mixture that meets the limits for a lower waste class.

<u>Overview of Gamma-Emitting Sealed Source Carry-Away Scenario (Basis for the Encapsulation Position for Gamma Emitters):</u>

Scenario

Five hundred years after closure of a LLRW landfill, the LLRW containers have decayed and the homogeneous wastes and encapsulating materials have become soil-like. However, a stainless steel Cs-137 sealed radioactive source has survived as a individual, recognizable item.

As a result of a public works project, such as the construction of a regional pipeline, a trench is cut through the former LLRW landfill. The construction crew notices soil conditions are different, but the crew has been contracted to cut kilometers (miles) of trench and they continue their excavations. An individual finds the sealed radioactive source in the excavated soil. The small piece of metal looks very old. There is no indication of a hazard. The individual takes this interesting piece of metal home, where it is placed with other curios on a shelf in the living room. For the first 4 hours, the sealed source is in the individuals coat pocket (3 cm exposure distance) and after that, on average, the individual is 2 meters from the sealed source, reading or performing some other activity for 15 hours per week, 48 weeks out of the year.

NRC Analysis

Using MicroShield, the NRC determined that a 130 Ci Cs-137 source (at the time of disposal) would result in a 500 mrem dose to the intruder at 500 years. Thus Cs-137 sources should be limited to 130 Ci at the time of disposal as Class C LLRW to ensure that intruder doses do not exceed 500 mrem. If this same scenario is applied 100 years after site closure (Class A) the limit is 0.0072 Ci at the time of disposal, and the limit is 0.72 Ci at 300 years for Class B disposal.

Using the above scenario with a Co-60 sealed source, the NRC determined the calculated activity is 30 Ci for Class A (100 years) at the time of disposal, with no limit to the size of a Co-60 source that can be disposed as Class B (300 years) or Class C (500 years). For Table A, "Activity Levels of Primary Gamma Emitters in Individual Items Potentially Requiring Piecemeal Consideration in Classification Determinations" (Section 3.3.2), and for the encapsulation guidance (Section 3.5), the staff has increased the Class A value for Co-60 from 30 Ci to 140 Ci. The staff selected 140 Ci because it is the amount of Co-60 that could be disposed in a 0.2 m^3 (55 gallon) drum at the Class A limit. The dose from a 140 Ci Co-60 source will be 500 mrem/yr at 111 years. Therefore, the new value of 140 Ci continues to protect the intruder because of Co-60's short half life.

If this same scenario is applied to a point source of Nb-94, the activity constraint at the time of disposal, at 100 years, at 300 years, and at 500 years would be less than 1 mCi; however the slightly higher limit of 1 mCi was selected for practical considerations.

Additional Modeling Details:

- Disposal of a Cs-137 sealed source (500 years) -- The NRC assumed that the source is an elongated cylinder of CsCl (density = 2.7 g/cc) which is 2.7 cm tall and 1.5 cm in diameter lined with 0.47 cm of stainless steel.

- Disposal of Cs-137 sealed sources (100 years and 300 years) -- The NRC assumed that the source is an elongated cylinder of CsCl which is 1 cm tall and 0.56 cm in diameter lined with 1 cm of stainless steel.

- Disposal of Co-60 sealed sources (100 years) -- The NRC assumed that the source is a square cylinder of Co-60 1 cm tall and 1 cm in diameter.

Disposal of Alpha- and Beta-Emitting Sealed Sources (Basis for the Encapsulation Position for Non-gamma Emitters):

If an alpha- or beta-emitting sealed source is inadvertently excavated, the only exposure pathways are ingestion or inhalation (breathing re-suspended material or ingesting material from contaminated foodstuffs). Neither of these pathways depends on localized hotspots as long as the average concentration over a large area is unaffected. Therefore, the NRC believes that the curie limits for alpha- and beta-emitting sealed sources are constrained by the source activities averaged over the weight or volume of the encapsulated source (typically a 0.2 m^3 (55 gallon) drum). For alpha or beta sources, this limit is 0.2 times the 10 CFR § 61.55 class limit for that nuclide. For example, a Ni-59 source should not exceed 40 Ci (220 Ci/m^3 x 0.2 m^3). The largest activity of a transuranic nuclide, other than Pu-241 and Cm-242, that is generally acceptable for encapsulation in 0.2 m^3 is about 1.1 GBq (30 mCi), presuming the density of the encapsulating mass is 1.3 g/cm^3. When calculating mass-based concentrations, it is generally acceptable to take credit for the actual density of the material if the density is less than 2.2 g/cm^3.

<u>Disposal of Primary Gamma Emitters in Activated Metals or Contaminated Materials or Cartridge Filters (Basis for Table A and the Factor of Two Rule):</u>

The guidance for the disposal of primary gamma emitters evolved from the NRC's work on sealed sources. If the gamma-emitting activity of sealed sources were contained in individual pieces of activated metals, or cartridge filters or contaminated materials, the hypothetical intruder would not sustain a dose greater than that calculated for sealed sources because of the typical distribution of the activity over a larger volume and in materials that may exhibit a degree of self-shielding.

The NRC used this analysis to create Table A, "Activity Levels of Primary Gamma Emitters in Individual Items Potentially Requiring Their Piecemeal Consideration in Classification Determinations," in Section 3.3.2. Sealed source-like items that are smaller than 280 cc (0.01 ft^3) and that exceed the Table A values, are sealed source-like and should be managed individually, for the purpose of waste classification. The NRC derived the Table A values at 100 years after disposal for Class A waste, at 300 years after disposal for Class B waste, and at 500 years after disposal for Class C waste using the gamma source carry-away scenario described above.

Finally, since sealed sources, activated materials and metal, and components containing radioactivity in their design may be disposed of in the same disposal container with other waste of similar type containing the same gamma-emitting nuclide, acceptable concentration averaging guidance is included for these situations. The Table A guidance is introduced to ensure that gamma-emitting sealed source-like materials are removed from mixtures and managed separately. The remaining contents can always be classified based on the highest classification of any specific item in the container. Averaging is also acceptable if the concentration of each primary gamma-emitting nuclide in each individual item in the disposal container does not exceed two times the classification limit for that nuclide, for the classification of the mixture (Class A or B or C). This Factor of Two Rule precludes "hot spots" in gamma-emitting waste from significantly affecting projected intruder doses irrespective of whether the intruder is exposed through the intruder-agricultural scenario or through direct interactions with the waste (e.g., handling scenarios). The NRC used the following handling scenario to set the Factor of Two Rule that limits gamma-emitting hot spots in a container holding individual items.

<u>Gamma-Emitting Larger Items Carry-Away Scenario</u>:

Scenario

Five hundred years after closure of a LLRW landfill, a 2.55 m^3 (90 ft^3) LLRW container (a B-25 box) in the landfill has decayed leaving the individual pieces of activated stainless steel. It is assumed that there are 1.7 m^3 (60 ft^3) of activated stainless steel pieces in the container. One half of the pieces 0.85 m^3 (30 ft^3) contain Nb-94 at two times the Class C limit and one half of the pieces contain Nb-94 at well below the Class C limit.

As a result of a public works project such as the construction of a regional pipeline, a trench is cut through the landfill. The construction crew notices the large pieces of steel in the excavated soil. There is no indication of a hazard and the crew uses their construction equipment to move the pieces of steel to their shop for storage and resale to a scrap metal dealer 6 months later. For computational ease it is assumed that only the higher activity pieces are removed and that each piece of steel is a 0.028 m^3 (1 ft^3) square. Each piece of metal is moved three times and the cumulative exposure time for each piece is 21 minutes (7 minutes per move) at 6 inches. In the crew's shop the individual is exposed for 5 hours per week for 6 months at a distance of 2 m (6.6 ft) from the 0.85 m^3 (30 ft^3) stack of blocks.

NRC Analysis

Using MicroShield and the above parameters, the projected dose to the intruder is 505 mrem. Thus, individual pieces of activated metal should not exceed two times the Class C limit to ensure intruder doses do not exceed 500 mrem. This rule is applicable to a mixture that is classified as Class C, but would not be protective if applied to a Class A or B mixture. Therefore this rule is linked to the classification of the resulting mixture. Simply stated, the concentration of a primary gamma-emitting nuclide in any item of the mixture should not exceed two times the classification limit for that nuclide, for the classification of the mixture (Class A or B or C). This Factor of 2 Rule removes gamma-emitting hot spots from mixtures of items and the Factor of 2 Rule also places an absolute limit on the boundary between Class C and Greater-Than-Class C (GTCC) for individual items in a mixture, where the primary gamma emitters control the classification.

<u>Disposal of Nuclides other than Primary Gamma Emitters in Activated Metals, or Contaminated Materials or Cartridge Filters (Basis for Table B and the Factor of 10 Rule):</u>

In this case, the BTP defines a "mixing" constraint that is within the context of the general waste classification rationale expressed in the documentation that supports the Part 61 regulation. In defining this constraint, it was noted that the § 61.55 concentration values that delineate the boundaries between different waste classes (i.e., A, B, and C) typically differ by more than one order of magnitude. To prevent the mixing of items from different waste classes, this BTP allows concentration averaging of the alpha and beta emitting activity in individual items, if all the concentrations in the individual items within a disposal container are within an order of magnitude of the average concentration over all items in the container. This Factor of 10 Rule also places an absolute limit on the boundary between Class C and Greater-Than-Class C (GTCC) for individual items in a mixture, where the non-primary gamma emitters control the classification.

The rationale used to construct Table B is consistent with the encapsulation position in the BTP for non-primary gamma emitters and the position is the same as the rationale used to construct Table A. Since any potential intruder dose is essentially independent of alpha and beta (or non-primary gamma-emitter) "hot spots," the numerical values in Table B reflect the maximum activity that would be allowed if the activity was contained in a sealed source encapsulated in a 0.2 m^3 drum, and a minimum volume criterion is not necessary.

Waste Homogeneity Intrusion Scenarios (Basis for the Test for Homogeneity of Blended Homogeneous Waste Types):

As discussed above, the NRC based the waste classification limits in 10 CFR § 61.55 on hypothetical scenarios in which an individual constructs a dwelling on a waste site and another individual subsequently lives in that dwelling, exposing each to LLRW. Individuals disrupting multiple waste packages would likely be exposed to waste at or below the class limit because waste in multiple containers that each meet the class limit cannot, in aggregate, exceed the class limit. Individuals exhuming a small amount of waste, however, are more susceptible to encountering hot spots in the waste because they may exhume waste from only one part of a waste package. Thus, an intruder exhuming only a small amount of waste is the limiting scenario that needs to be considered with respect to waste homogeneity. Typically, individuals exhuming only a small amount of waste are protected by the small inventory they encounter. However, in some cases, an intruder exhuming a small amount of waste could receive a dose comparable to an intruder exhuming multiple packages (if the small volume of waste is more concentrated and spread in a smaller area).

The NRC expects that the range of reasonably foreseeable intrusion scenarios at a particular disposal site will depend on site-specific conditions. However, the NRC believes that well drilling is a reasonably foreseeable activity under a variety of site and disposal conditions.

Scenario

The NRC based the homogeneity guidance in this document on the doses to an individual unknowingly drilling a well into a waste site (acute scenario) and another individual subsequently living and gardening in the area in which the drill cuttings were spread (chronic scenario). Specifically, the NRC assumed that 100 years after closure of an LLRW landfill (for Class A waste) or 500 years after closure (for Class C waste), an individual inadvertently intrudes on the site, drills a water well, and spreads drill cuttings on the surface. Subsequently, another individual lives on the land and creates a garden that includes the area in which the drill cuttings have been spread. Although certain common well drilling methods isolate cuttings in a pit or tank (e.g., mud rotary drilling), thereby reducing exposure to the cuttings, well construction methods that may result in cuttings distribution on the surface (e.g., cable tool drilling, auger drilling) are expected to be reasonably foreseeable at many sites.

NRC Analysis

The acute intruder is exposed through direct exposure, dust inhalation, incidental soil ingestion, and gas immersion and inhalation. The chronic intruder is exposed through these pathways as well as consumption of plants grown in the garden. The NRC also considered doses from the consumption of groundwater for the chronic intruder; however, the NRC found that the doses based on leaching from the exhumed material alone were minimal. Groundwater doses based on leaching from an entire disposal site may be important to an intruder dose analysis, depending on site-specific conditions, but were not included in this analysis because they did not help to define the homogeneity criteria. In general, the NRC found that doses to the chronic intruder were more limiting than doses to the individual drilling the well.

The NRC used a model developed in the simulation software package GoldSim® to conduct its analyses. The analyses treated the garden area, well diameter, cuttings distribution area, well depth, occupancy factors, and several environmental parameters (e.g., soil sorption coefficients, plant uptake factors) probabilistically. The model assumed that waste was mixed poorly and contained pockets of waste with significantly greater than average concentrations. The model also assumed that waste filled a container unevenly (i.e., not in complete horizontal layers) such that, in one location of the container, more than 10% of the depth of waste could exceed 10 times the concentration limit while the entire container still meets the classification limit. The NRC calculated the volume of waste that could be exhumed at 10 times the classification limit while maintaining an intruder dose below 5 mSv yr (500 mrem/yr) for a series of hypothetical wastes, each dominated by one of the 10 CFR § 61.55 listed nuclides. In estimating the total dose to the intruder, the NRC assumed that approximately half of the dose was attributable to the small volume of waste exceeding the class limit and half of the dose was attributable to other waste in the drill column (i.e., from the remainder of waste in the waste container with the hot spot and from containers above and below that container). For waste at the Class A limits evaluated at 100 years or waste at the Class C limits evaluated at 500 years, the NRC found that exhumed volumes exceeding ten times the classification limit should be limited to less than approximately 0.3 m (1 ft) depth to protect individuals from chronic exposure to drill cuttings.

The most limiting radionuclide at the Class A limit is Cs-137, with a dose primarily due to external exposure. For waste at the Class C limit, the largest doses are caused by Nb-94, Np-237, several other transuranic elements, and Cs-137. Because waste disposed as activated metal is not consistent with the underlying assumptions of the chronic drilling scenario (i.e., it is not expected to be soil-like at 500 years), the NRC did not base the limiting volume on the Nb-94 dose. Similarly, because very little Np-237 is disposed in commercial LLRW, the NRC did not use the Np-237 dose to determine the limiting volume. The Nb-94 and Np-237 doses are approximately a factor of six and four, respectively, greater than the next highest doses. Thus, in the very unlikely case that a chronic intruder in a well-drilling scenario encounters waste from a 0.03 m^3 (1 ft^3) hotspot dominated by either Nb-94 or Np-237 at 10 times the class limit, the dose would be within a factor of six or four of the limit if approximately half of the dose is attributable to the hotspot and half is attributable to the remaining exhumed waste. Doses from Cs-137 as well as several transuranic elements all support a 0.03 m^3 (1 ft^3) limit on the volume of waste that could exceed 10 times the Class C dose limit. These doses are attributable to direct exposure (Cs-137), plant ingestion (transuranic elements and, to a lesser extent, Cs-137), and dust inhalation (transuranic elements).

The NRC also considered smaller volumes with greater concentrations. Because the NRC assumes that the waste is mixed when it is exhumed and spread on the surface, smaller volumes at higher concentrations did not yield significantly different results. Although the guidance is stated in terms of a 0.03 m^3 (1 ft^3) volume of waste, smaller volumes at larger concentrations also would be contrary to the guidance if the concentration was large enough to cause the average concentration in the surrounding 0.03 m^3 (1 ft^3) volume to exceed 10 times the class limit.

Appendix C - Analysis of Public Comments on the Concentration Averaging and Encapsulation Branch Technical Position

Background:

In developing this revision to the January 17, 1995, Branch Technical Position on Concentration Averaging and Encapsulation, the NRC solicited public input on potential revisions to the document. On January 26, 2011, the staff published a Federal Register notice (76 FR 4739) containing questions related to potential revisions. These questions and other issues related to revising the BTP were discussed by stakeholders with the staff at a February 24, 2011, workshop held in Rockville, MD. In addition, members of the public could respond to the questions and other issues related to potential BTP revisions in writing. The comment period closed on April 15, 2011.

Comments received from the public related to revisions to the BTP are addressed below and were considered by the staff in developing this draft revision. This appendix contains a summary of how the public's issues and concerns were addressed by the staff in this draft revision.

Stakeholder Input:

The following are the documents related to stakeholder input on potential revisions to the CA BTP.

Document Type	Author	Date	Organization	ADAMS ML #
Federal Register Notice, Vol. 76, No. 17, page 4739. Includes Sandia draft of BTP mentioned in public comments below.	NRC staff	January 26, 2011	NRC	N/A
Meeting Summary, February 24, 2011, Workshop	Maurice Heath	March 30, 2011	NRC	ML110880417
Meeting Transcript, February 24, 2011, Public Workshop on CA BTP	N/A	February 24, 2011	NRC	ML110600395

Letter	John LePere	April 15, 2011	WMG Inc.	ML11111A132
Letter	J. Scott Kirk	April 15, 2011	Waste Control Specialists, Inc.	ML11111A133
Letter	Thomas Magette	April 15, 2011	EnergySolutions	ML11119A021
Letter	Abigail Cuthbertson	April 18, 2011	Department of Energy, National Nuclear Security Administration	ML11119A022
Letter	Edward F. Maher	April 22, 2011	Health Physics Society	ML11116A125
Letter	Lisa Edwards	May 13, 2011	Electric Power Research Institute	ML11138A230
1995 Concentration Averaging BTP	NRC	January 17, 1995	NRC	ML033630732
2011 Draft revision to Concentration Averaging BTP	Sandia Labs		Sandia Labs	ML103430088

Analysis of Comments:

The staff analyzes the public comments received In the sections below. The comments are grouped by issues. Each issue is described, analyzed, and a staff conclusion or resolution of the issue is presented.

1. Homogeneous Wastes, Including Blending:

Removal of Current Constraints on Homogeneous Wastes

One commenter asked that the constraints on averaging of homogeneous materials be eliminated. In a related comment, another stakeholder requested that the NRC remove the factor of 10 applied to batches before mixing.

Staff Response:

In SECY-10-0043, the NRC proposed to remove the constraint that, before wastes may be mixed, radionuclide concentrations in those wastes must be within a factor of 10 of the average concentration in the final mixture (called the “factor of 10” rule). The NRC indicated that this rule, because it is based on the inputs to a process rather than the outputs, was not performance based. In the Staff Requirements Memorandum (SRM-SECY-10-0043), the Commission agreed with staff's proposed option, which included eliminating the factor of 10 rule for mixtures of homogeneous wastes. The revised BTP reflects that decision and does not include constraints on the inputs to mixtures of homogeneous wastes. Instead, the BTP provides guidance on criteria that mixtures of homogeneous wastes created through large-scale blending should meet before being considered homogeneous. Waste streams that are designated as homogeneous waste types (i.e., solidified liquid, spent ion-exchange resins, filter media, evaporator bottom concentrates, contaminated ash, contaminated soil, and containerized dry active waste (DAW) may continue to be regarded as homogeneous unless available information indicates significant heterogeneities, as discussed in Section 3.2.1 of the BTP.

Sampling and Measurements

One commenter suggested that the NRC should provide specific requirements on the types of measurements and numbers of samples from blending equipment needed to demonstrate that the average concentration and measurement uncertainty are known to a limit that would be acceptable to the NRC and the Agreement States. Another argued that licensees need to understand the measurement uncertainty in relation to potential impacts to the intruder and recommended that the NRC provide specific examples on acceptable methods to address the five sources of uncertainty in the Interim Guidance (NRC's March 17, 2011 letter to the Agreement States, ADAMS ML110480850). The commenter also suggested that there should be a requirement for waste processors to collect independent verification samples from the generators' waste stream for large scale blending.

Staff Response:

As discussed in the BTP, the number of samples necessary to demonstrate waste classification requirements have been met depends on the magnitude and sources of uncertainty in the final concentration values and how close the average sum of fractions is to the class limit. Section 3.2.3 of the BTP provides guidance on determining the appropriate number of samples to demonstrate waste classification requirements have been met and handling of associated uncertainties.

The NRC expects that the types of measurements appropriate for demonstrating the average concentration and associated uncertainty of waste intentionally blended during waste processing will depend on specific features of the blending process and input wastes. For example, some processes may be amenable to surveys conducted while waste is being re-circulated, while others may not have appropriate survey locations or may not use wastes amenable to quantification through surveys and may require waste to be sampled from a holding tank or disposal container. Thus, the types of measurements used will be chosen by the licensee based on specific waste and process features. The revised BTP does recommend independent verification of waste streams that are processed by intentional blending if the demonstration of homogeneity or waste classification is based on process knowledge and the properties of the incoming waste streams. If homogeneity and waste classification are, instead, based on testing of the final waste form, incoming waste streams should be verified to whatever extent necessary for the processor to maintain good process control.

Radiation Doses to an Inadvertent Intruder:

One commenter noted that Enclosure 2 of the current BTP contains an analysis of the radiation doses to an intruder encountering waste at the upper end of Class C limits. The commenter encouraged NRC to include a similar analysis for waste blended to the upper end of Class A.

Staff response:

As noted by the commenter, Enclosure 2 of the 1995 BTP includes a summary of an analysis of the radiation doses to an intruder encountering waste at the upper end of the Class C limit. The enclosure included this analysis because it formed the basis for the 1995 BTP guidance on the disposal of sealed sources. Appendix B of the revised BTP includes a summary of analyses of a well driller encountering a relatively small volume of waste at a concentration exceeding either Class A or Class C limits because these analyses form the technical basis for the revised BTP guidance on demonstrating waste homogeneity. Specifically, the analyses determine the volume of waste with concentrations exceeding 10 times the relevant class limits that would cause an intruder a dose of 0.5 mSv/yr (500 mrem/yr). Waste exceeding 10 times the classification limit was considered because it exceeds the range of concentrations that is recommended in the BTP for mathematical averaging. The results of the analyses were used to determine the size of a sub-volume of waste that would constitute an intruder hazard and, therefore, indicated that a waste should be more thoroughly mixed before being considered homogeneous.

Coordination among Agreement States

One commenter asked that the BTP address the need for coordination between Agreement States that regulate processing/blending of LLRW and those that regulate disposal facilities. Such coordination was recommended by NRC in the Interim Guidance on LLRW blending issued on March 17, 2011.[10]

Staff Response:

The staff agrees. New text has been added to Section 1.0 to address coordination between Agreement States.

Exemptions from Blending Constraints

One commenter noted that mixing or blending of LLRW streams occurs at licensed facilities as a matter of facility design and that this practice was recognized by NRC subsequent to the 1983 position (i.e., in the 1995 BTP). The commenter recommended that the exclusion that applies to operational efficiency and worker dose reduction should continue to apply in the revised BTP.

Staff Response:

[10] See ADAMS ML110480839 and ML110480850.

The NRC understands that a certain amount of mixing of waste streams occurs at licensed facilities because of the facility design (e.g., if a single holding tank is used for multiple resin waste streams) or for reasons of operational efficiency or worker dose reduction. This type of mixing is not expected to cause the same risk to an inadvertent intruder as intentional blending during waste processing (i.e., large-scale blending). Disposal of large-scale blended waste potentially poses an increased risk because: (1) waste resulting from large-scale blending is expected to have a sum of fractions closer to the classification limit than incidentally blended waste, and (2) processors engaging in large-scale blending of waste are expected to produce more blended waste than generators who blend waste incidentally. The first factor could increase risk to an intruder by increasing the consequences of intruder interaction with the waste. The second factor could increase risk to an intruder by increasing the probability that an intruder constructing a dwelling or well (or otherwise disrupting the site) at a random location on site will interact with blended waste near the classification limit. For these reasons, use of the term large-scale blending in this BTP excludes the incidental blending described by the commenter. The specific exclusion from the factor of 10 constraint on mixing homogeneous waste types is not included in the revised BTP because the factor of 10 constraint on mixing has been eliminated.

Other:

In Section 5 (homogeneous wastes) of the revised draft published for public comment on January 26, 2011, (the “Sandia draft),” the commenter recommended the removal of the last paragraph as not being applicable to this section. (The last paragraph reads, “If a waste container holds a mixture of similar waste types that are not radiologically homogeneous (node C), proceed to Section 6, “Classifying a Mixture of Items of the Same Waste Type”).

Staff Response:

This paragraph has been removed.

2. Classification of Individual Wastes, Including Factors of 1.5 and 10:

Commenters requested that the NRC eliminate these factors for “primary and non-primary gamma emitters” in the BTP, noting that mixing during the intruder scenario eliminates the need for these constraints. One commenter specifically requested that NRC remove the constraints on averaging irradiated hardware including eliminating the factor of 1.5 for averaging Nb-94. Another stated that, based on historical disposal data, it is evident that the factor of 1.5 for gamma driven classification of waste packages is arbitrarily limiting and does not result in any appreciable additional protection. The commenter also argued that application of the factor of 10 in all cases results in an appropriate limitation to mathematical averaging of heterogeneous wastes within a package where physical blending cannot reasonably occur.

Staff Response:

The NRC has conducted an additional analysis and determined that, to protect an inadvertent intruder, it is necessary to limit gamma-emitting hot spots in mixtures of contaminated materials or activated metals or cartridge filters. The proposed new position limits hot spots in a mixture to no more than 2 x the appropriate Class limit for the classification-controlling primary gamma emitters. This limit applies if the classification is determined by the primary gamma-emitting isotopes. The current 1995 position limits gamma hot spots to 1.5 x the average concentration of the mixture. While the 1995 position ensures uniformity in the waste concentrations, limiting the variability to 1.5 x the *average* concentration of the mixture is not based on intruder protection. Rather, individual pieces that are averaged as part of a mixture need to be constrained around the classification limit to protect the intruder.

3. Cartridge Filters**:**

One commenter stated that cartridge filters are physically, chemically, and radiologically more like DAW and should be treated as homogeneous wastes in the same context as DAW. Currently, the BTP treats them the same as activated metal. The commenter supported their argument with the following statements:

1. Cartridge filters account for a comparatively small volume and activity contribution to the overall source term.

2. Achieving disposability through processing has little impact on disposal site risk or in the total activity received.

3. Total annual activity generation for all cartridge filter accounts for only about half of the amount of activity annually disposed of in Class A resins prior to the closure of Barnwell.

4. Disposal volumes of cartridge filters typically account for few hundred cubic meters per year.

Staff Response:

The current version of the BTP does not denote cartridge filters as homogeneous; therefore, they are considered individual items that are subject to certain averaging constraints. Being individual items, Section 3.5 of the 1995 BTP requires cartridge filters be classified by dividing activity by weight or volume of the filter. Mixing of cartridge filters is permissible and concentration averaging is allowed using certain constraints that are applicable to non-homogeneous waste. It is also permissible to conservatively base the classification on the highest classification associated with any single filter.

The distinguishing characteristic of homogeneous wastes is that their radionuclide concentrations are likely to approach uniformity in the context of reasonably foreseeable intruder scenarios. The staff believes this will not be the case with at least some cartridge filter designs. Some filters (e.g., pressurized water reactor (PWR) primary system filters) are much more durable in the disposal environment than others. These would most likely not degrade as quickly leaving the enclosed filter media, which should degrade like other homogeneous waste, unavailable for mixing with surrounding soil per the intruder scenarios. Based on observations of filters, the staff believes that the enclosure could continue to retain the filter media and radioactivity, thereby preventing the radionuclide concentrations from approaching uniformity, at least for some intruder scenarios. In addition, cartridge filters from reactor coolant systems, spent fuel clean-up, etc., are typically classified as Class B or C whereas the majority of DAW is classified as Class A. In intruder scenarios, the consequence of an encounter with a hot spot is greater with filters than with DAW. Staff has therefore determined that cartridge filters in general should continue to be classified using the existing guidelines. At the same time, the staff recognizes that some cartridge filters could likely be considered as homogeneous, i.e., that their radionuclide concentrations would become nearly uniform in the context of reasonably foreseeable intruder scenarios. In Section 3.9 of the revised draft BTP, the staff has added cartridge filters as one of the items that can be considered for alternative provisions under the BTP.

4. Definitions:

Classification-Controlling Radionuclides

One stakeholder noted that the "reporting purposes" caveat is missing from the definition of "classification-controlling" in the Sandia draft and should be added. According to the commenter, nuclides that are classification-controlling should be those in which the activity of that nuclide in one or more components in the averaging groups exceeds the class limit so that it would actually be subject to averaging to meet the class limits.. Another commenter stated that, for the definition of "classification-controlling radionuclides," the definition should be expanded to recognize that not only must a radionuclide be >1% of its applicable table value to be considered classification-controlling but must also be present in a relative fractional abundance such that the concentration of the individual radionuclide (or a combination of controlling radionuclides) are the specific basis for transition from one waste class to another. The commenter stated that this is the only means by which a generator can determine if the factor of 1.5 or 10 will be applicable in a concentration averaging scenario.

Staff Response:

The NRC agrees that the definition should be expanded to recognize that not only must a radionuclide be >1% of its applicable table value to be considered classification-controlling but must also be present in a relative fractional abundance such that the concentration of the individual radionuclide (or a combination of controlling radionuclides) are the specific basis for transition from one waste class to another. Appropriate changes have been made to the text of the BTP.

Blending and Dilution

One commenter stated that there is a need to define or distinguish between "blending" and "dilution," and to specify the conditions under which "dilution" is acceptable. These terms should first be defined in the BTP, and later in a Part 61 rulemaking. The commenter also believes that the BTP should discuss potential for introduction of other uncontaminated materials (such as stabilization reagents, coal combustion products, or other process additives) that may be added in the waste treatment or blending process, and should provide guidance on whether the volume of uncontaminated materials may be considered in waste classification calculations. Finally, the commenter believes that the BTP should ensure that waste treatment doesn't change the waste characteristics such that Resource Conservation and Recovery Act (RCRA) materials are produced.

Staff Response:

The current version of the BTP specifies conditions under which non-radioactive materials may be considered for concentration averaging. For example, sealed sources may be encapsulated in concrete in a 55 gallon drum and the activity averaged over the volume of the drum. The circumstances under which non-radioactive materials are relied on for concentration averaging are limited in the BTP. The staff has not added a definition of dilution to the BTP, since staff interprets dilution, in the context of LLRW blending and the BTP, to mean the mixing of clean materials with contaminated materials, including liquids and gases, and release to the general environment, and these topics are not within the scope of the BTP. The scope of the BTP is narrow, and the conditions under which non-radioactive materials can be used in averaging are well-defined and limited. The BTP states that extreme measures should not be taken to lower the classification of the waste in stabilizing wastes to meet the 10 CFR § 61.56 requirements, for example. As a result of the comment, the staff has also added language that states that process additives during waste treatment should have a purpose in treatment other than reducing the concentration of the final mixture, and that extreme measures should not be used to lower the waste classification. With respect to blending, the staff has added a definition of blending to the BTP, consistent with the definition provided in SECY-10-0043, “Blending of Low-Level Radioactive Waste.” Blending of certain wastes is within the scope of the BTP. With respect to defining these terms in a rule, the staff will consider whether blending should be defined in its SSA rulemaking to require a site-specific analysis for intruder protection. Blended wastes are within the scope of that rulemaking. With respect to the term “dilution,” if NRC makes comprehensive revisions to 10 CFR Part 61 at a later date, the staff will consider whether this term should be defined in that rulemaking. Defining the term will depend in part on the scope of the potential revisions, which are not known at this time.

With respect to the comment regarding hazardous waste and RCRA, the commenter did not provide a reason for adding language regarding RCRA to the BTP. Absent any specific concern, a licensee is always responsible for meeting the requirements of RCRA any time a RCRA material is introduced into its process, and is subject to enforcement if it does not. The staff does not believe that RCRA needs to be addressed in the BTP given that there are regulations in place that would apply to any waste treatment activities involving hazardous materials.

<u>Homogeneity</u>

One commenter stated that the definition of homogeneity in the Interim Guidance is vague. (The staff issued Interim Guidance on LLRW blending to the Agreement States on March 17, 2011.[11] The guidance addresses how Agreement States can review proposals for large-scale blending).The commenter recommended that the NRC include a more robust definition that includes measurable parameters.

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[11] See ADAMS ML110480839 and ML110480850.

Staff Response:

The revised BTP defines homogeneous waste as waste in which the classification-controlling radionuclide concentrations are likely to approach uniformity in the context of reasonably foreseeable intruder scenarios. This definition is performance based and does not include specific measureable parameters because the range of reasonably foreseeable intruder scenarios is expected to be site-specific. However, the NRC expects that a well-drilling scenario, as described in Appendix B of the revised BTP, is likely to be reasonably foreseeable under many different disposal conditions. A well drilling scenario also is expected to impose greater constraints on waste homogeneity than a scenario in which more waste is exhumed (e.g., dwelling construction) because the exhumed waste will be mixed over a smaller volume as it is exhumed. Based on this well-drilling scenario, the revised BTP provides guidance on certain measurable parameters that are expected to be sufficient to demonstrate homogeneity. Specifically, the guidance recommends that licensees intentionally blending waste during waste processing demonstrate that the as-disposed waste does not have sub-volumes of waste greater than 0.03 m^3 (1 ft^3) that exceed 10 times the relevant class limit. Different means of demonstrating homogeneity may be appropriate under different site-specific conditions.

Homogeneous Waste

One commenter noted that the homogeneous waste definition can be applied to a single, as-generated waste type as described in the current BTP or the resulting waste from a combination of physically similar types, of similar radionuclide relative fractional abundance but dissimilar radionuclide concentrations.

Staff Response:

The NRC agrees that the term “homogeneous waste” can be applied to a single, as generated waste type designated as “homogeneous” in the BTP (i.e., solidified liquid, spent ion-exchange resins, filter media, evaporator bottom concentrates, contaminated ash, contaminated soil, and containerized DAW) or to a mixture of wastes that has been demonstrated to be homogeneous. Homogeneous waste types are discussed in Section 3.2 of the revised BTP. Methods for demonstrating the homogeneity of a mixture of homogeneous waste types are discussed in Section 3.2.1

Homogeneous Waste Type (in the Sandia draft)

One commenter stated that the definition of homogeneous waste should continue to apply to as-generated waste types such as spent resins, flowable filter media, solidified liquids, evaporator concentrates, contaminated soil, and containerized DAW. The commenter suggested that, as in earlier BTP documents, the only wastes excluded from this definition would be activated hardware and potentially cartridge filters, depending on the source of generation, processing applied, and packaging.

Staff Response:

The revised BTP continues to designate certain waste types (i.e., solidified liquid, spent ion-exchange resins, filter media, evaporator bottom concentrates, contaminated ash, contaminated soil, and containerized DAW) as homogeneous waste types. Solidified liquid is considered a homogeneous waste type because radionuclide concentrations are expected to be uniform at the time of disposal. Spent ion-exchange resins filter media, evaporator bottom concentrates, ash, and contaminated soil are considered a homogeneous waste type because they are flowable, and the radionuclides in these waste streams are expected to be uniformly distributed when exhumed under reasonably foreseeable intruder scenarios. DAW, which may be composed of a variety of miscellaneous materials, may be considered a homogeneous waste type for purposes of waste classification when placed in containers because it is expected to degrade within approximately 100 years to a more soil-like state in which it will be mixed if exhumed by an intruder. In each case, additional averaging of an intruder's exposure to the waste is expected to occur by the natural movement of the intruder around the site, even if waste is not completely mixed as it is exhumed and spread on the surface.

Other waste types that are not considered homogeneous include activated hardware, sealed sources, contaminated items that are not disposed of as containerized DAW, and cartridge filters.

Component and Item

One commenter requested that the terms "component" and "item" as used in the Sandia draft be clarified. "Item" implies that a cut up component needs to be classified individually, apart from its original classification when part of the component. Another commenter, in addressing Section 7 of the Sandia draft, "Classifying individual items," stated that this section should be retitled, "Classification of Irradiated Components and Associated Cartridge Filters" and be comprised of the entire content of Section 3.3 of the original 1995 BTP, including Figure 1. The commenter stated that it was critically important that the definition of "component" described in the 1995 BTP be retained for purposes of concentration averaging and that re-characterization of sub-pieces that result from sectioning of the larger component for packaging efficiency not be required. Such an interpretation would result in orphaned waste and is completely contrary to the original intent and purpose of the 1995 BTP, according to the commenter. The "piece" rule (0.01 cubic feet) contained in Section 3.3.2 of the original BTP was designed specifically to address those situations where individual pieces may require separate consideration for classification purposes.

Staff Response:

The staff agrees that the draft of the BTP that was made available for public comment omitted the 1995 BTP's policy that allows a larger "component" to be cut into pieces, and still be classified based on the classification of the original component, provided the pieces of the component meet certain criteria. The BTP text has been revised to include the 1995 policy on classifying larger components that are sectioned. Also, what was previously titled Section 7 in the draft BTP that was made available to the public has been renamed "Classifying a Mixture of Activated Metals or Contaminated Materials or Cartridge Filters," which is similar to the commenter's recommendation.

Heterogeneous Waste Mixture

One commenter stated that the term "heterogeneous waste mixture" should be revised to better define "reasonably similar" radionuclide concentrations. Assuming wastes originate from different sources and contain dissimilar radionuclide concentrations but similar relative fractional abundance, then the mixture of materials could reasonably approach uniformity in the context of the intruder scenario, according to the commenter. It would be more appropriate to define heterogeneity as a function of differing radionuclide concentrations of classification-controlling radionuclides present in each portion of the overall waste mixture. Application of the factor of 10 to the average would be an appropriate control to impose on mixtures of materials with differing relative radionuclide concentrations.

Staff Response:

The staff agrees that the use of this phrase was not clear. The phrase "heterogeneous waste mixture" has been removed, and replaced with the phrase, "Classifying a Mixture of Activated Metals or Contaminated Materials or Cartridge Filters." The NRC also agrees that heterogeneity should be based on classification-controlling radionuclides and the BTP has been revised accordingly.

Encapsulation

A commenter suggested that the term, "encapsulation" be defined in the BTP and suggested the following definition of "encapsulation" be added to the BTP--"The process of surrounding a discrete radioactive source, or collection of discrete sources in an approved binding matrix, within a container, where the activity remains within the geometric dimensions of the source(s), thereby providing additional separation from the environment and an additional and readily recognizable waste form with regard to potential inadvertent intrusion."

Staff Response:

The staff agrees and a definition of encapsulation has been added to the BTP.

Solidification

The same commenter that asked that "encapsulation" be defined, suggested that the following definition of "solidification" be added to the BTP—"The process of incorporating radioactive material in an approved binding matrix, in a manner to achieve homogeneity within a container, where the activity is distributed throughout the final monolith thereby providing additional separation from the environment and an additional and readily recognizable waste form with regard to potential inadvertent intrusion."

Staff Response:

The staff agrees and a definition of solidification has been added to the BTP.

Discrete Item

One commenter stated that the term, "discrete item" should be reserved for individual contributions to a waste package where the higher radionuclide concentration within the item has the potential to vary from the average concentrations within other items or contributions to the package by more than a factor of 10. This would generally apply to activated hardware and sources.

Staff Response:

For consistency and clarity, the staff uses the term “individual item” throughout the BTP when referring to a single piece or item. The Sandia draft of the BTP had used the terms interchangeably. Individual items may be averaged as part of a mixture, or may require separate classification (in accordance with Figure 2), depending upon their characteristics.

<u>Contribution or Contributor</u>

One commenter stated that the term, “contribution” or “contributor” to the overall waste package would be an appropriate means to distinguish between separate volumes of resins, batches of concentrates/liquids, cartridge filters or batches of contaminated materials from differing generation sources for purposes of evaluation of heterogeneity/homogeneity of the total waste package during classification.

Staff Response:

The staff agrees, in general, and “contributor” is used to describe the contributors to a mixture from different origins.

5. BTP Should be an Interim Guidance Document:

Several stakeholders stated that the BTP should be an interim measure, either until the site-specific analysis (SSA) rulemaking or the more comprehensive Part 61 revision is completed. One commenter stated that the BTP should be kept in place until the “Part 61 revision process” is completed [the “Part 61 revision process” includes an ongoing SSA rulemaking, and potentially a more comprehensive revision to Part 61 at a later date]. Another stakeholder believes that the BTP should be eliminated after the site-specific analysis rule is completed, since both deal with intruder protection and the rulemaking can suffice for that purpose.

Staff Response:

The Commission approved the SSA rulemaking in the staff requirements memorandum for SECY-08-0147, “Analysis of Depleted Uranium.” One of the purposes of the rule is to require that a site-specific analysis be conducted to demonstrate protection of an inadvertent intruder, rather than relying solely on the waste classification system and other existing 10 CFR Part 61 requirements. Longer term, the Commission, in its staff requirements memorandum for SECY-08-0147,[12] requested that the staff consider more comprehensive revisions to 10 CFR Part 61. In SECY-10-0165, the staff identified five potential options for such comprehensive revisions, and outlined an approach for obtaining additional stakeholder views on such a rulemaking. The

[12] Commission Staff Requirements Memorandum for SECY-08-0147, “Response to Commission Order CLI-05-20 Regarding Depleted Uranium, March 18, 2009. ML090770988.

staff committed to providing the Commission with an analysis of public comments on the options and a recommendation by the end of 2012.

With respect to the SSA rulemaking, which is ongoing, its final provisions and scope will not be known until it is completed. Thus, whether the final rule will affect guidance provided in the CA BTP is not known at this time. The NRC is coordinating the development of the BTP revisions with the SSA rulemaking. The staff will evaluate impacts to the BTP and whether any revisions to the BTP are necessary after the SSA rulemaking is completed. The NRC believes that as long as the waste classification tables in 10 CFR § 61.55 are applicable to generators and disposal sites, some limits on averaging will be necessary in order to demonstrate compliance with the class limits.

6. Relationship Between BTP and the Site-Specific Analysis (SSA) Rulemaking**:**

One commenter noted that the SSA rulemaking will allow for the development of site-specific waste acceptance criteria which can eliminate the need for classifying waste shipped from a generator and the waste classification tables in 10 CFR Part 61. Another commenter requested that the BTP address the radiological risks to an intruder encountering waste at the upper end of Class A limits. The same commenter recommended that a site-specific intruder analysis be conducted to address intruder risks, and the need for additional controls, such as deeper burial. The commenter specifically requested that the BTP discussions be broadened to include risk-informed methods to demonstrate intruder protection.

Staff Response:

As noted above, NRC already has underway a SSA rulemaking that was approved by the Commission in the staff requirements memorandum for SECY-08-0147, "Analysis of Depleted Uranium." One of the purposes of the rule is to require a site-specific analysis to demonstrate protection of an inadvertent intruder. Additional controls for a disposal facility might be required from the analysis conducted. However, the waste classification tables will continue to apply to generators and disposal facilities after the rulemaking is completed, and guidance covering acceptable averaging approaches under 10 CFR § 61.55(a)(8) will be needed.

With respect to risks associated with disposal of blended waste at the upper end of the Class A limits, protection of the intruder from these risks is addressed in Appendix B, "Technical Basis for Concentration Averaging and Encapsulation Guidance." Based on the analysis, NRC has recommended constraints on homogeneity which are incorporated into Section 3.2.2 of the BTP.

With respect to the expanding the scope of the BTP to include site-specific intruder analysis considerations, the scope of the BTP is generic and for the classification of mixtures of items and encapsulation of sources in accordance with 10 CFR § 61.55. See response to item 7 below for additional information.

7. Use of Site-Specific Intruder Analysis in Lieu of BTP:

Several commenters felt that site-specific intruder analyses could be used to protect an inadvertent intruder and would eliminate the need for the BTP averaging provisions. They asked that the BTP provide guidance on site-specific intruder protection (a NUREG-1854 approach). Another stated that if additional controls or barriers are needed to protect the intruder, additional engineering analysis may also be needed to ensure that the controls or barriers will not degrade or fail to perform for as long as the radiological consequences are unacceptably high. The commenter encouraged NRC to broaden the discussion in the BTP of using risk-informed methods to demonstrate intruder protection, addressing site-specific performance assessments, the development of site-specific waste acceptance criteria (WAC) and site-specific averaging provisions. According to the commenter, such an approach would harmonize LLRW regulations at NRC with DOE program and its Waste Incidental to Reprocessing program.

Staff Response:

The NRC agrees that site-specific intruder analyses could be used to demonstrate protection of the inadvertent intruder. However, the staff believes there is value for generators and processors in maintaining a BTP that provides “generic,” look-up guidance for the classification of mixtures of items and encapsulation of sealed sources in accordance with 10 CFR § 61.55. When a licensee performs a site-specific analyses, the licensee can review the section titled, “Alternative Approaches for Averaging” in the BTP which describes in detail how a site-specific intruder analysis might be used to justify higher limits based on such factors as waste form and site characteristics and depth of burial. With respect to eliminating the need for the BTP, see response to Item 6.

8. Scenario Selection for Inadvertent Intruder:

A commenter stated that the NRC should not postulate scenarios different from those in the Draft Environmental Impact Statement (DEIS) technical basis for Part 61, especially the new “driller” and “intruder handling” scenarios. If a drilling scenario is postulated and used as a basis for averaging constraints, it should be realistic. Specifically, the commenter noted, if the driller encounters a solid block of concrete, drilling would be stopped. If a driller encounters a source, credit should be allowed for soil above and below the source.

Staff Response:

The inadvertent intruder performance objective in 10 CFR § 61.42 states that the disposal facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after active institutional controls over the disposal site are removed. While the waste classification tables in 10 CFR § 61.55 were based on generic scenarios analyzed in the DEIS, there may be instances in which other reasonably foreseeable intruder scenarios could occur, such as drilling or handling of individual items, that could affect intruder protection. With deeper disposal, as is common practice today, the DEIS scenarios may not be that applicable for the intruder, because the depth of disposal of waste is deeper than the home foundation postulated in the DEIS. In these cases, postulation of well drilling, as a reasonably foreseeable event under a variety of site conditions, is appropriate to ensure continued intruder protection. Further, the Commission (in SRM-SECY-10-0043) directed the staff to consider homogeneity in the context of reasonably foreseeable intrusion scenarios. The staff agrees that credit should be allowed for mixing soil with radioactive materials, both above and below the radioactive source in the drilling scenario. The drilling scenario used as the basis for the homogeneity guidance in this revised BTP did include mixing with soil above and below the waste.

With respect to the intruder "handling" scenario, after the finalization of Part 61, there were a number of accidents involving small, highly radioactive sealed sources. The nature of these accidents led NRC to consider individual gamma-emitting items that might survive in a LLRW disposal facility and their radioactive nature not be recognized by an inadvertent intruder. To ensure that individual gamma-emitting items do not compromise the protection of the inadvertent intruder, the 1995 BTP introduced exposure scenarios that assessed the possible dose consequences to an inadvertent intruder unknowingly handling a recognizable LLRW item 500 years after disposal. While the DEIS postulated that an intruder could be exposed to individual items, it was for a limited period of time, resulting in low exposures to radioactivity.

With respect to a driller ceasing activities upon encountering concrete, the staff positions in the BTP are conservatively based on radioactive material not being surrounded by concrete. However, if a specific site has concrete vaults in its design, or other concrete barriers, it may be appropriate to assume that drilling is stopped when the concrete is reached. The licensee should consider the effect of reasonably foreseeable processes on the degradation of the vault's mechanical properties that would be relied upon to limit access to the waste. Some of these processes, which are site-specific, may include seismic activity, cementitious material degradation such as acid leaching or corrosion of the reinforcing steel. The licensee or applicant should also consider local drilling practices and estimate when currently used technology would likely penetrate the vault given its estimated degradation of mechanical properties. For instance, the likelihood of breaching the concrete vault would likely occur earlier in regions of the country where hard-rock drilling is common compared to regions where hard-rock drilling is not common. These justifications could be considered in an alternative approaches analysis described in Section 3.9 of the BTP. The drilling scenario used as the basis for the homogeneity guidance did not assume the individual would drill through concrete.

9. Sealed sources:

<u>Maximum Size of Sources for Disposal</u>:

Several commenters noted the significant constraints that the current BTP recommends for sealed sources, especially Cs-137 sources. If a source is encapsulated in concrete in a 55 gallon drum, the maximum Cs-137 source size is 30 Ci. If the source were averaged over the volume and the Class C limit used, the maximum source size would be 920 Ci. Commenters asked that this recommended limit be re-examined and raised if possible. In a related matter, one commenter asked that the basis for whatever limits the BTP recommends be clear. The current BTP was developed in part to address Goiania type events, but this is not clear from the text in the BTP. Goiania was a significant safety event in Brazil in 1988 involving a sealed radioactive source being inadvertently handled by members of the public.

Staff Response:

The NRC agrees and staff completed an extensive review of the basis for the 30 Ci limit for Cs-137 in the 1995 BTP. The NRC's review included an analysis of the basis for the 1995 policy and an analysis of accidents involving sealed radioactive sources, and a review of approaches used by other countries to regulate disposal of sealed sources.

Based on the results of this extensive review, NRC finds it is appropriate to set limits on disposal of highly-radioactive items that could survive intact in a LLRW landfill, and not be recognized as being hazardous. After the review, the NRC revised the scenario-basis for the encapsulation policy and used a more realistic "gamma sealed source carry away scenario." Using the new scenario, the limit for disposal of encapsulated Cs-137 sealed sources has been raised. Also the revised BTP addresses how higher limits might be justified for Cs-137 and other nuclides. Finally, the revised BTP clarifies that there are no intruder-based limits for Class B or C disposal of Co-60 sealed sources.

Use of Other Protective Measures to Increase Source Size:

Several commenters asked that the BTP acknowledge that other measures might be used to increase the size of sources acceptable for disposal. For example, NRC should provide guidance on engineered controls to protect an intruder, since the intruder "discovery" scenario does not provide sufficient protection. These engineered controls could include concrete canisters and disposal at greater depth. Another commenter noted that the BTP could allow credit for shielding during disposal to limit doses to an inadvertent intruder. Credit for shielding other than concrete (lead, depleted uranium, and tungsten) could be acknowledged in the BTP. A related comment was that sources are often contained in transfer shields and the BTP should allow for encapsulation of larger activity sources contained within their transfer shields (or equivalents) such that activity can be averaged over the encapsulating mass up to the applicable waste class limits for the specific source radionuclide. The commenter stated that the combination of shield and encapsulation media can provide sufficient barrier to the inadvertent intruder under the discovery or construction scenarios and the addition of the transfer shield should be sufficient to prevent access in a well drilling scenario.

Staff Response:

The revised BTP provides a new section titled, "Alternative Approaches for Averaging," which describes in detail how a site-specific intruder analysis might be used to justify higher limits based on waste form and site characteristics and depth of burial. Long-lived shielding and depth of burial are two factors cited in the revised BTP that might provide site-specific justification for higher limits.

Package Size Limit for Sources:

A commenter asked that NRC increase the package size limit from 55 gallons so that sources in shields can be disposed of (these are too large to fit into 55 gallon drums).

Staff Response:

The staff agrees. The revised BTP states that "for determining the classification of an encapsulated source (or multiple sources in a single container), the maximum volume or mass should be 0.2 m3 or 500 kg. *For physically encapsulating a single source, the volumes and masses may be larger than 0.2 m3 or 500 kg to allow for disposal of a sealed source in its shielded housing and/or source device*. The shape of the final encapsulated package does not have to be a cylinder."

<u>Encapsulation of Multiple Sources:</u>

One commenter suggested a revision to Section 9, Item (2) of the Sandia draft—that the last sentence read "Encapsulation of multiple sources in a larger volume is acceptable so long as the maximum .2 cubic meters of encapsulate per discrete source is retained and all other requirements of this section are met."

Staff Response:

The staff agrees and the revised BTP allows encapsulation of multiple sources in a 0.2 m^3 encapsulated volume.

<u>Alternative Provisions for Sealed Source Disposal:</u>

One commenter stated that if NRC does not incorporate its suggestions for sealed sources, the BTP should elaborate on "generally acceptable" practices and bounding conditions, as well as additional guidance on the anticipated or expected content of a request for approval for alternative provisions for classification and disposal.

Staff Response:

The revised BTP includes a new section titled, "Alternative Approaches for Averaging," which describes in detail how a site-specific intruder analysis might be used to justify higher limits based on waste form and site characteristics and depth of burial.

10. Volume for Averaging:

One commenter stated that heterogeneity should be considered in context of averaging volume (e.g., home foundation). Waste should be assumed to be evenly mixed, and container non-uniformity does not affect long-term risk. Another commenter felt that the BTP should allow for averaging over a volume greater than the container, and suggested that the use of a site-specific performance assessment and WAC should be the mechanism to define averaging and waste volumes. Such an approach could be used for large components that are cut up to facilitate transportation and disposal, as well as for wastes from the remediation of a decommissioned site.

Staff Response:

The NRC agrees that heterogeneity should be considered in the context of reasonably foreseeable intruder scenarios. With the modern practice of placing wastes many meters below the surface, a reasonable foreseeable scenario might be the well drilling scenario (and not the basement scenario). If the well drilling scenario is reasonable foreseeable, then sub-container heterogeneity might be important and not heterogeneity across multiple packages.

If the wastes are near the surface, the intruder scenarios could involve waste volumes larger than the shipping container volume that is the basis for the positions in the BTP. As noted in Section 5 of this Appendix, a disposal facility operator could perform a site-specific intruder analysis and then specify waste acceptance criteria (WAC) for generators that would ensure that the assumptions regarding the waste form, class, concentration, nuclides, etc. were consistent with the assumptions in the analysis conducted for intruder protection. The WAC could address such areas as concentration limits, waste form, packaging, physical and chemical forms, paperwork required, etc. The WAC could also include constraints on averaging as well, based on the site-specific analysis. However, as long as the 10 CFR § 61.55 tables remain in Part 61, generators will have to demonstrate compliance with them before they make shipments to a disposal site, and using appropriate averaging approaches should be useful for demonstrating compliance.

The NRC agrees that in many cases, waste can be assumed to be evenly mixed after it is exhumed. Even if waste is not perfectly homogenized during exhumation, natural movement of an intruder around the site would be expected to average their exposure. NRC expects a well-drilling scenario would be reasonably foreseeable under many different disposal conditions. For some waste types, such as sealed sources or activated metals, there may not be mixing of the waste with soil. The BTP specifies averaging positions based on the Appendix B technical bases for these wastes that retain their form over long periods of time.

Container non-uniformity could affect an intruder exhuming a small amount of waste (e.g., a well driller) in certain waste configurations (e.g., if vertically-aligned features of high concentration exist). Waste stratification into even layers is not expected to affect an intruder. For stratification to affect dose, an intruder would need to exhume only the layers of waste in a disposal container that have the greatest radionuclide concentration. While possible (e.g., if dwelling construction disturbed only the top half of a layer of waste containers and all of the higher-concentration waste had risen to the top of the containers), this scenario is expected to be unlikely and is not considered to be reasonably foreseeable.

With respect to large components that are cut up and remediation wastes, the scope of the BTP includes wastes that are in containers. While the staff agrees that averaging of large components and separate shipments of remediation waste at a disposal facility could be considered in a site-specific assessment, the shipper would need to demonstrate compliance with the waste classification provisions currently in 10 CFR § 61.55.

11. Other:

<u>Treatment of Sealed Sources and Activated Metals should not be the same:</u>

One commenter stated that BTP should not treat sealed sources the same as activated metals and other discrete reactor items. The commenter noted that activated metals, cartridge filters, and contaminated items are subject to factors of 1.5 and 10 constraints on averaging. Sealed sources are allowed credit for a 23 fold reduction in concentration through encapsulation, so the BTP is not consistent.

Staff Response:

The revised BTP used two scenarios to define positions for protecting the intruder from hot spots. One scenario is appropriate for small (sealed source) items that could be placed in a pocket, and the other scenario is appropriate for larger pieces that would require equipment to move. The sealed source scenario involves 4 hours of exposure in a coat pocket at a distance of 1 cm. The larger pieces scenario involves exposure at 15 cm for 21 minutes. The two scenarios result in different BTP policies and it would be inappropriate to apply the sealed source scenario (with 1 cm exposure distance for 4 hours) to large pieces of metal. However very small pieces of activated metal may be sealed-source like and those pieces should continue to be identified (using Table A) and managed separately.

<u>Consideration of "Likelihood" of Intrusion in BTP:</u>

One commenter believes that NRC should assume a probability of "1" for the intruder. Another commenter noted that DOE allows for consideration of likelihood of intrusion. DOE has done it once so far and used expert elicitation. DOE Order 435.1, "Radioactive Waste Management," allows for credit for institutional controls of longer than 100 years and this was a factor in choosing a probability of less than one. Finally, another commenter felt that a probability of intrusion of less than one could be allowed in some cases. In particular, the commenter argued, it is not realistic to assume that a probability of intrusion is one immediately after the 100 years of institutional controls. These controls are likely to continue to be in place after 100 years.

Staff Response:

The NRC notes that there is no scientific basis for quantitatively predicting the nature or probability of a future human activity. This is in contrast to a natural process for which a scientific basis may be developed to support a probability of occurrence. Therefore, an inadvertent intruder assessment typically does not consider the probability or likelihood of inadvertent intrusion occurring. Rather, the assessment assumes reasonably bounding scenarios (conservative, but not overly conservative scenarios) that could occur and evaluates the radiological consequences that could be experienced by individuals who might actually intrude onto the disposal site should active and passive controls fail, societal memory be lost and the site be unrecognizable as a disposal site. In this approach, the staff assumes intrusion occurs and examines the consequences rather than truly evaluating the risk (consequence x probability).

The staff has addressed likelihood of intrusion in a new section of the BTP titled, "Alternative Approaches for Averaging." In this section, the staff recognizes that there may be circumstances in which likelihood of intrusion can be considered, with other factors, in justifying averaging approaches different from those specified in the BTP.

It should also be noted that NRC has acknowledged a reduced likelihood of exposures to inadavertent intruders (see, e.g., 59 FR 17052, "New England Coalition on Nuclear Pollution, Inc.; Denial of Petition for Rulemaking). In addition, the intruder dose limit is 500 mrem/yr instead of 25 mrem/yr– essentially acknowledging a 5% probability for intrusion. For the Class C limits, probability was one of several factors used to justify increasing the Class C limits by a factor of 10.

Initial Waste Classification:

One commenter stated that in the Sandia draft of the BTP, issued with the Federal Register notice requesting comments on the BTP (76 FR 4739), the concept of an "initial waste classification" is inconsistent with concept of waste classification in the regulations. The regulations, in 10 CFR Part 20, Appendix G, require classification at the time of shipment for disposal. The commenter stated that the BTP should call this initial description something else, e.g., "Initial characterization."

Staff Response:

The staff agrees that waste must undergo characterization first; the waste is then classified based on its characteristics. The term, "initial waste classification" has been replaced with "waste characterization." Waste is not required to be classified in NRC's regulations (10 CFR Part 20, Appendix G) until it is ready for disposal. Thus, use of this term "classification" to describe wastes that are not yet packaged for disposal is inconsistent with the regulations.

Greater-Than-Class-C Waste (GTCC):

One commenter stated that GTCC waste should be classified at the time of shipment, like other waste classes. Another stated that if new BTP positions make it so hard to dispose of waste, industry may concentrate it and make it a Federal responsibility.

Staff Response:

The BTP is consistent with the existing regulations for LLRW classification, which do not require waste to be classified until it is ready for shipment. In the Commission decision on LLRW blending (SRM-SECY-10-0043), the Commission directed the staff to not include GTCC concentrations in the scope of the ongoing SSA rulemaking, which will address in part blended LLLRW. The Commission noted in the SRM that GTCC waste is a Federal responsibility and should not be made into a State responsibility, even if the waste has been blended into a lower classification. NRC plans to publish questions in the proposed rulemaking related to this issue and will analyze those in preparing the final rulemaking package.

Heterogeneity:

One commenter stated that there is no need to provide guidance on this issue for most waste forms. Other than wastes that retain their form over an extended period of time, the others become homogeneous over time and when mixed by the intruder. NRC can address heterogeneity in the uncertainty portion of a site-specific analysis. NUREG-1854 already has guidance that can be used here. For discrete sources, allow averaging over packages.

Staff Response:

The staff has addressed the relationship between a site-specific analysis and the BTP in Sections 5, 6, and 7 of this Appendix. NRC agrees it would be appropriate to address waste heterogeneity in the uncertainty portion of a site-specific intruder analysis. Homogeneity guidance is provided in the revised BTP because the “factor of 10” rule on mixing wastes was eliminated. Without some guidance on final waste form heterogeneity, extremely concentrated wastes could be disposed of as Class A waste, if the disposal container is large enough. Specifically, the guidance has two purposes:

- To protect an intruder who exhumes a small amount of waste (e.g., a well driller) from hitting a pocket of waste far exceeding the class limits that has been mathematically averaged to meet the class limits.

- To provide guidance to processors engaged in intentional blending on when the waste has been sufficiently mixed.

<u>Basis for Table B is not clear in BTP:</u>

One commenter stated that the basis for Table B, which defines the maximum size of components of non-primary gamma-emitting items, is not clear.

Staff Response:

NRC agrees and the revised BTP addresses the basis of the Table B values.

<u>Performance-Based License Conditions:</u>

One commenter requested that the BTP provide examples of performance-based license conditions.

Staff Response:

The purpose of the BTP is to address a wide variety of waste types and averaging concerns for LLRW, to ensure that the waste classification requirements in 10 CFR § 61.55 are met, and to protect an inadvertent intruder into a disposal facility. Most disposal facility licenses reference the BTP as a whole in a license condition.

Performance-based criteria have the following attributes: (1) measurable, calculable or objectively observable parameters exist or can be developed to monitor performance; (2) objective criteria exist or can be developed to assess performance; and (3) licensees have flexibility to determine how to meet the established performance criteria in ways that will encourage and reward improved outcomes. With respect to the first two criteria, many of the positions in the BTP could be converted to performance-based license conditions. Homogeneity criteria, and the limits on variability of waste concentrations are two examples. With respect to the third criterion, licensees could submit license amendments requests to approve alternative approaches, as described in Section 3.9 of the BTP. Another performance-based approach to averaging would be to conduct a site-specific intruder analysis, as discussed in Section 3.9 of the BTP. However, as noted in these sections, this approach is currently limited in its usefulness for averaging because of the need for a generator to classify waste before shipping to a disposal facility.

<u>Concentration of Waste:</u>

One commenter stated that NRC should require licensees to concentrate waste as much as possible. In his view, it is better to have smaller and more concentrated volumes.

Staff Response:

In 1981, NRC published a Policy Statement that encourages licensees to volume reduce their LLRW. This document is a policy statement, not a regulation, and therefore licensees have flexibility in deciding whether to volume reduce their waste. Because of the high cost of waste disposal, licensees have achieved substantial volume reduction since the policy statement was issued. The staff does not believe that it is desirable to require licensees to concentrate their waste as much as possible. If NRC were to require waste volume reduction to the greatest extent possible, most LLRW would not have a disposal option, because waste would likely be concentrated to Greater-Than-Class C (GTCC) and would have to be stored until a GTCC disposal facility is developed, which is not expected for many years. Such a policy would thwart disposal of waste as Class A, B, or C, an undesirable outcome since disposal is the preferred option for waste, over storage. NRC is currently revising its Volume Reduction Policy statement to specifically recognize that other factors may be considered in licensees decisions on whether to volume reduce their waste or not.

Introduction to Sandia Draft:

One commenter cited a statement in the draft Sandia BTP, “This 61.55(a)(8) requirement applies to packages of reasonably homogeneous waste” and noted that the stated limitation is not in the regulation. The commenter noted that one can argue that the BTP authors may have had that in mind, but that’s not stated or implied in the regulation. The commenter appears to be implying that the statement should be deleted.

Staff Response:

The staff agrees that the 10 CFR § 61.55(a)(8) requirement was not written specifically for individual waste packages, and the sentence has been removed. The BTP, however, recommends certain constraints on averaging, as noted by the commenter.

Removal of Items from Container:

One commenter stated that text in Paragraph 2 of Section 3 of the Sandia draft, and the attendant flow charts, introduce a limitation on the concentration averaging process that was not intended by the original version of the 1995 BTP. In the commenter’s view, requiring the removal of higher concentration contributors to the overall package is completely contrary to the intent and concept of the 1995 BTP. The commenter believes, rather, the demonstration that a specific collection of wastes within the container that meet the averaging limitations such that the higher concentration contributors can be considered to meet the class concentration limits is the intent.

Staff Response:

In developing the BTP, the NRC was concerned that long-lived gamma hot spots might compromise the protection of the inadvertent intruder and some constraints on averaging needed to be specified. These recommended constraints allow for a demonstration that a specific collection of wastes within a container can have their concentrations averaged to meet the classification limits in 10 CFR § 61.55, and that some higher concentration contributors averaged with lower contribution contributors. At the same time, certain items that are outside of the constraints defined in the BTP should be identified and managed separately to ensure intruder protection.

Consolidation of Sections of the BTP:

One commenter stated that the consolidation of activated metals, contaminated materials and cartridge filters in the Sandia draft creates problems. The commenter stated that the draft Section 4 imposes terminology and limitations on all wastes that were specifically intended to address the significant variation in activity and concentrations associated with activated hardware. Section 3.3 (3.3.1-3.3.6) including the flow chart Figure 1 of the original BTP lists the specific guidance to be applied to activated hardware. In the commenter's opinion, imposition of these criteria on other wastes is impractical and serves no benefit in terms of improved protection of the public or the environment. According to the commenter, relocation of Section 3.3 in its entirety (including Figure 1) into Section 7 to the revised BTP will provide the specific guidance necessary to address activated hardware while allowing streamlining of the process for all other wastes, according to the commenter.

Staff Response:

The NRC carefully reviewed the guidance set out in the 1995 BTP for activated materials, contaminated material and cartridge filters and found the requirement to be all but identical for all three waste types and that applying one set of criteria to all three waste types was simple and appropriate. The staff believes this consolidation of these sections is an improvement to the document. The staff did not intend to effect changes to the original positions, only to make the BTP better organized and improve its readability. The staff will consider any other comments on this consolidation of these sections in this draft in preparing the final BTP.

Averaging of Similar Materials:

One commenter on Section 4 ("Initial Waste Classification" of the Sandia draft, stated that, "For similar materials (i.e., resin and resin, soil and soil), originating from different sources, classification can be based on the volume or mass weighted concentrations from each source averaged over the final volume or mass."

Staff Response:

The NRC agrees that the classification of a mixture of similar homogeneous waste types can be based on the total activity and total volume (or mass, as appropriate) of the waste. The 1995 BTP Factor of 10 Rule for mixing similar homogeneous waste types has been removed and replaced with a test for the homogeneity of blended similar homogeneous waste types.

Averaging of Dissimilar Materials:

One commenter on Section 4 of the Sandia draft stated that for dissimilar materials (i.e., resin and soil, resin and filters) classification can be determined by the highest individual waste type contributor (refer to Section 6.1)

Staff Response:

The comment refers to a statement made in Section 4 of the Sandia draft BTP, which states that "If the disposal container holds a mixture of *dissimilar waste types*, and the highest waste classification of any individual item of the mixture is not higher than the waste classification of the total mixture (average of the total activity over the total volume or mass), then the classification can be based on the average concentration." This statement in the publically available draft is consistent with the Section 3.8 of the 1995 BTP, which states that, *dissimilar waste types* can be mixed and then classified using the average of the total activity over the total volume or mass of the waste in the container, so long as "the classification of the mixture is not lower than the highest waste classification of any individual components of the mixture."

<u>Classification of Discrete Items:</u>

One commenter stated that references to "discrete items" and classification in accordance with Section 7 should be removed from Section 4 [of the Sandia draft]. [Section 4 addresses initial characterization of waste and Section 7 addresses classification of individual discrete items].

Staff Response:

The statement in Section 4, of the Sandia draft BTP is correct as written and is meant to guide the reader to the Section where individual items are addressed.

<u>Section 6 of Sandia Draft, "Classifying a Heterogeneous Mixture of Similar Waste Types":</u>

One commenter asked that Section 6 of the Sandia draft be revised to read "Classifying a Heterogeneous Mixture of Dissimilar Waste Types" (not similar waste types).

Staff Response:

Section 6 of the draft released for public comment, has been renamed "Classifying a Mixture of Activated Metals or Contaminated Materials or Cartridge Filters" and is written for classifying mixtures, where all the pieces in the mixture are of *same* waste type (activated or contaminated or cartridge filters).

<u>Section 6 of Sandia Draft, "Classifying a Heterogeneous Mixture of Similar Waste Types":</u>

Section 6.1 should be titled; "Conservative Classification Based on Highest Individual <u>*Contributor*</u>" (the term used in the Sandia draft in place of "contributor is "item").

Staff Response:

The NRC agrees with this comment, and text has been revised.

Section 6 of Sandia Draft, “Classifying a Heterogeneous Mixture of Similar Waste Types”:

Paragraph 2 should be revised to delete references to 1 mCi per item, which is applicable only to activated metals.

Staff Response:

The 1995 BTP, for activated metal *and contaminated materials*, allowed concentration averaging over the volume or mass of the mixture, if all contributors to the mixture have activities less than 1 mCi. The revised BTP now extends that policy to mixtures of cartridge filters.

Section 6 of Sandia Draft, “Classifying a Heterogeneous Mixture of Similar Waste Types”:

The commenter recommended that paragraph 3 of the Sandia draft should be revised to address classification of individual contributions to the total package. The commenter stated that classification should be based on the highest waste class concentration of any individual contribution of each *dissimilar waste type* within the package. The commenter suggested that, if *dissimilar but homogeneous waste streams* (e.g., resin and soil) are mixed and the highest waste class is equal to the average waste class, then a licensee may classify the mixture based on the total activity divided by total volume or mass.

Staff Response:

Section 4 of the Sandia draft BTP states that “If the disposal container holds a mixture of dissimilar waste types, and the highest waste classification of any individual item of the mixture is not higher than the waste classification of the total mixture (average of the total activity over the total volume or mass), then the classification can be based on the average concentration.” This statement in the Sandia draft is consistent with the Section 3.8 of the 1995 BTP, which states that, dissimilar waste types can be mixed and then classified using the average of the total activity over the total volume or mass of the waste in the container, so long as “the classification of the mixture is not lower than the highest waste classification of any individual components of the mixture.” The revised BTP is consistent with the above. The commenter did not provide any reasons for changing the previous (and current) position, and because staff agrees with the previous (and current) position, it has not made any changes.

The NRC disagrees with the commenter’s recommendation that the classification of a mixture of items of *dissimilar but homogeneous waste streams* (e.g., resin and soil) should never be lower than the greatest classification of the inputs. This guidance instead recommends that such mixing should be evaluated on a case by case basis. Averaging based on the total activity and total volume of both wastes may be permissible in some cases. This position is the same as the 1995 BTP position. The commenter did not provide any reasons why the position should be changed and because the staff agrees with the position, it has not been changed.

Section 6 of Sandia Draft, “Classifying a Heterogeneous Mixture of Similar Waste Types”:

One commenter referenced sections 6.2 and 6.3, and stated that since gamma activity at 100 years post closure is reduced (Co-60 activity is essentially non-existent and Cs-137 activity is reduced by a factor of ten), the factor of 1.5 is only applicable to Nb-94 in activated hardware or cartridge filters generated during activated hardware cutting activities. Tables A and B were developed to control classification of irradiated hardware and should be captured in section 7 (relocation of section 3.3 of the original BTP into section 7 of the revision will accomplish this).

Staff Response:

As noted in the Technical Basis for the 1995 BTP, the Table A test is made to ensure that gamma-emitting sealed source-like items of activated metal *and contaminated materials* are removed from a mixture and managed separately. The 1995 BTP is not clear on the origin of the Table B test for non-primary gammas, but the purpose of the Table B test is to ensure that non gamma-emitting sealed source-like items of activated metal *and contaminated materials* are removed from a mixture and managed separately.

Section 8 of Sandia Draft, "Determining the Concentration and Volume of the Waste":

One commenter stated that the table in section 8 is appropriate as presented with one minor modification, "solidified ion exchange resins" should be modified to read "solidified solid materials" [may have their concentration averaged over the volume or mass of the solidified mass, and should retain the requirement that "if homogeneity is maintained in the solidified mass."

Staff Response:

The text has been changed to solidified masses, rather than just ion exchange resins.

References:

One commenter recommended that Section 12, References, include the U.S. NRC 1991 Waste Form Technical Position, Rev. 1, dated January 24, 1991.

Staff Response:

The staff has added that document to the list of references.

Appendix D – Major Changes from 1995 to Current BTP

1. Added Glossary of Terms.
2. Changed the definition of "classification-controlling" to limit definition to those nuclides present in a relative fractional abundance such that the concentration of the individual (or a combination of controlling radionuclides) are the specific basis for transition from one waste class to another.
3. Guidance for classifying activated metals, contaminated materials and cartridge filters is combined. The 1995 BTP provided separate guidance for classifying (1) activated metals, (2) contaminated materials, and (3) cartridge filters.
4. Removed the Factor of 10 Rule for mixing similar homogeneous waste types, consistent with Commission decision in SRM-SECY-10-0043.
5. Absorbed liquids can now be treated as homogeneous wastes, like solidified wastes, because intruder protection is still ensured when designated as this waste type.
6. Added a test for homogeneity for mixing similar homogeneous waste types.
7. Removed "designed collection of homogeneous waste from a number of sources within a licensee's facility, for purposes of operational efficiency or occupational dose reduction," consistent with Commission decision in SRM-SECY-10-0043.
8. Changed Factor 1.5 Rule to Factor of Two Rule based on a new large item gamma source carry-away scenario. Factor of Two Rule is now tied to the classification limit (Class A, B or C) and not the average classification of the mixture, making it more risk-informed.
9. Factor of 10 Rule now linked to classification limit (Class A, B or C) and not based on the average classification of the mixture, making it more risk-informed.
10. Changed the Cs-130 Ci source Class C limit from 30 Ci to 130 Ci based on a new sealed source scenario.
11. Changed the Co-60 Ci source activity limits for Class A from 700 Ci to 140 Ci, and for Class B from 700 Ci to no limit, based on a new sealed source scenario.
12. Clarified use of 10 CFR § 61.58 as applicable to alternatives to certain regulatory *requirements* as defined in § 61.58, and not applicable to alternatives to guidance in the BTP.
13. Added Alternative Approaches for Averaging section to BTP.
14. Altered and clarified the Technical Basis for Concentration Averaging and Encapsulation Guidance (Appendix B).