Concentration Averaging and Encapsulation Branch Technical Position, Revision 1

Volume 1

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1. INTRODUCTION

The U.S. Nuclear Regulatory Commission's (NRC's) licensing requirements for land disposal of radioactive waste in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste," include four performance objectives:

- 10 CFR 61.41, "Protection of the general population from releases of radioactivity":
- 10 CFR 61.42, "Protection of individuals from inadvertent intrusion";
- 10 CFR 61.43, "Protection of individuals during operations"; and
- 10 CFR 61.44, "Stability of the disposal site after closure."

A low-level radioactive waste (LLW) disposal facility must be designed, operated, closed, and controlled after closure so that there is reasonable assurance that these performance objectives will be met. This document provides guidance for one aspect related to the 10 CFR 61.42 performance objective regarding protection of an inadvertent intruder (i.e., the averaging of radionuclide concentrations for determining the classification of the waste). Specifically, this Concentration Averaging (CA) Branch Technical Position (BTP) provides guidance on complying with 10 CFR 61.55(a)(8), "Determination of concentrations in wastes," as it applies to the classification of waste for disposal under 10 CFR Part 61.

1.1 Background

In developing the regulations in 10 CFR Part 61, the NRC implemented an approach for managing the risk to an individual who hypothetically could inadvertently intrude on LLW. That approach has a number of different components. Concentration averaging, the subject of this document, is one of those components. First, a 100-year institutional control program is specified in 10 CFR 61.59 to help ensure that individuals will not intrude into the disposal facility after it is closed. The 100-year period allows for substantial decay of shorter-lived radionuclides so that the remaining hazard is significantly less than when the waste was first disposed. After 100 years, no credit can be taken for the existence of active institutional controls. Next, the NRC postulates that an individual unknowingly intrudes onto the disposal site after the 100-year institutional control period ends and interacts with the waste. To protect this hypothetical[1] individual, the NRC developed a waste classification system in 10 CFR Part 61 that requires segregation of LLW into classes based on radionuclide concentrations, as well as greater control measures for waste with higher 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

[1] NRC discusses the hypothetical nature of intrusion in the draft Environmental Impact Statement (draft EIS) for 10 CFR Part 61 (NRC, 1981) as well as the final EIS for Part 61 (NRC, 1982). NRC reaffirmed the hypothetical nature of intrusion in the "Denial of Petition for Rulemaking Submitted by the New England Coalition on Nuclear Pollution," Docket No. PRM-61-2, March 29, 1994, Agencywide Documents Access and Management System (ADAMS) Accession No. ML093490607.

requirements will be met. The waste classification requirements are designed to limit the potential radiation exposure to such an intruder to 5 mSv/yr (500 mrem/yr).[2]

The radiation hazard to an intruder is dependent in part on the particular radionuclides involved and their concentrations. Therefore, 10 CFR Part 61 includes a waste classification system that categorizes waste based on these characteristics of the waste. Three classes (A, B, and C) are defined, and the controls used to manage risk, such as engineered barriers, increase with increasing waste class. Class A waste, the lowest hazard class, has no special provisions for intruder protection, since it contains types and concentrations of radionuclides that typically will decay during the 100-year institutional control period to levels that present an acceptable hazard to an intruder. Class C waste, on the other hand, presents a greater long-term hazard and requires protection for 500 years by an intruder barrier, such as deeper disposal or an engineered structure. The Class A, B, and C waste classes specified in 10 CFR 61.55 are defined by specific radionuclides and their concentrations. For example, ^{137}Cs has a Class A limit of 3.6×10^{10} Becquerel (Bq) per cubic meter (m^3) (1 Curie (Ci) / m^3), a Class B limit of 1.6×10^{12} Bq/m^3 (44 Ci/m^3) and a Class C limit of 167×10^{12} Bq/m^3 (4600 Ci/m^3).

The NRC's waste classification system is also generic (i.e., it applies to all LLW disposal sites, regardless of their location in the United States). All generators and waste processors that ship waste to a licensed disposal site must use this system. The 10 CFR 61.55 waste classification tables do not take into account any site-specific features or considerations, but licensees could perform site-specific or waste-specific intruder analyses in requesting regulatory approval for alternative waste classification provisions (10 CFR 61.58). This CA BTP addresses regulatory considerations for obtaining such approvals (Section 3.7).

Like the waste classification system in 10 CFR Part 61, most of the averaging provisions specified in this document are also generic (i.e., they are suitable for use by any licensed disposal facility or generators or processors shipping waste to a licensed disposal facility). This approach might simplify classification for generators, but there might be instances in which generators, processors, or disposal-facility operators (hereafter referred to as "licensees") might decide to apply site-specific averaging approaches. This CA BTP provides examples of site-specific considerations for averaging that might be useful to licensees that propose alternative averaging approaches and to disposal facility regulators that review these proposals. See Section 3.8, "Alternative Approaches for Averaging," for additional details.

1.2 Purpose of This Guidance Document

The concentration limits for various radionuclides in the 10 CFR Part 61 waste classification system in 10 CFR 61.55 were developed for *average* concentrations of wastes. The NRC does not specify in the regulations how radiological "hot spots" are to be averaged, other than to specify in 10 CFR Part 61.55(a)(8) that averaging of waste

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2 This dose limit was used in the draft EIS for 10 CFR Part 61 (NRC, 1981) to develop the waste classification tables in 10 CFR 61.55, "Waste classification."

concentrations is acceptable.[3] The regulations do not define the conditions and constraints[4] on such averaging.

This CA BTP is designed to answer questions such as: "How much waste above the class limits is permissible in a waste mixture?" and "How much more concentrated than the limit can a portion of this waste be?" and "Over what volume are these concentrations to be measured?" Because non-radioactive material is also sometimes added to LLW to make it more physically or chemically stable, this CA BTP also answers the question, "How much credit can be taken for non-radioactive material that is mixed with LLW?" The CA BTP states that extreme measures of adding non-radioactive material, diluting the waste to circumvent stricter disposal requirements, should not be used. All of the constraints on averaging specified in this CA BTP are designed to help ensure that an inadvertent intruder into a disposal site, upon contacting hot spots in waste, will not receive an unsafe exposure to radioactivity.

The guidance in this CA BTP may be used to help demonstrate compliance with the following NRC regulations:

- 10 CFR 61.55. This provision specifies concentrations of various radionuclides and other instructions for determining the classification of waste. It includes 10 CFR 61.55(a)(8), which states that concentration averaging is permissible in determining waste class.

- Appendix G, "Requirements for Transfers of Low-Level Radioactive Waste Intended for Disposal at Licensed Land Disposal Facilities and Manifests," to 10 CFR Part 20, "Standards for Protection Against Radiation," contains several provisions related to the classification of waste. Section C, "Disposal Container and Waste Information," item 12, requires that for wastes consigned to a disposal facility, the classification of the waste pursuant to 10 CFR 61.55 must be documented on the uniform shipping manifest for the waste and each disposal container of waste in the shipment. In addition, Section II, "Certification," requires an authorized representative of the waste generator, processor, or collector to certify that the transported materials are properly classified, among other things.

This guidance provides acceptable methods that can be used by waste generators, processors, disposal facility operators, Agreement State regulators, and others to perform concentration averaging of specific wastes and mixtures of waste for the purpose of determining their waste class for disposal. Although Agreement States are required to adopt waste classification regulations that are essentially identical to the NRC's in 10 CFR 61.55,[5] they may specify averaging approaches in their disposal facility licenses that differ from those contained in this guidance.[6] Licensees shipping waste for disposal

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[3] 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."

[4] As used in this document, "constraint" is used in its normal sense; that is, this guidance recommends limits (or constraints) on how much radionuclide concentrations can be averaged. This guidance is not using the word *constraint* as it is defined in 10 CFR 20.1003, "Definitions": "*Constraint (dose constraint)* means a value above which specified licensee actions are required."

[5] 10 CFR 61.55 is NRC compatibility Category B. This category is for activities that have direct and significant transboundary implications.

[6] In practice, current disposal facility licenses reference the CA BTP in whole or in part.

may therefore need to consult with disposal facility operators in order to comply with disposal facilities' license conditions.

Sections 3.1 – 3.7 represent NRC staff's most recent and best efforts to identify specific concentration averaging methods that will enable licensees to comply with the averaging provision in 10 CFR Part 61.55(a)(8). In Section 3.8, NRC staff gives examples of alternative approaches for averaging, different from those in Sections 3.1 – 3.7, that may be also be appropriate, and considerations for licensees and regulators in determining whether such approaches are safe. NRC staff strongly urges licensees to submit proposals for "alternative approaches" to the regulator for the disposal facility and to have in-depth discussions on the merits of the proposal with the regulator before classifying waste under the alternative provisions. Alternative approaches to averaging are generally complex, often involving selection of intruder scenarios, for example. Detailed discussions between staff of the regulatory agency for the disposal facility and licensee would help to ensure that waste is classified appropriately before shipment to and disposal at a licensed facility.

1.3 Document Organization

This CA BTP contains two volumes. Volume 1 is focused on the specific concentration averaging provisions that should be used in classifying waste. Volume 2 contains background information that may be of interest to readers who want to better understand the technical basis for the positions in the first volume. Volume 2 also addresses how issues raised by stakeholders on the 2012 draft of the CA BTP have been addressed by the staff. Volume 1 contains the following sections:

- Section 1 gives background information, describes the purpose of this CA BTP, describes the organization of the document, provides an overview of concentration averaging, and discusses the relationship between this CA BTP and other NRC guidance.

- Section 2 describes the NRC's Safety Culture expectations for individuals and organizations performing regulated activities, including the classification of LLW for disposal.

- Section 3 contains the positions on concentration averaging for a variety of different waste types. It includes the following subsections:

    - Section 3.1 describes considerations for the physical and radiological characterization of waste.

    - Section 3.2 discusses concentration averaging for blendable wastes, which typically do not have significant hot spots that would be a hazard to an inadvertent intruder.

    - Section 3.3 addresses concentration averaging for discrete items of a single waste type.

- Section 3.4 describes concentration averaging for mixtures of more than one waste type.

- Section 3.5 identifies the volumes and masses acceptable for using in concentration averaging for various waste streams and types.

- Section 3.6 describes the quality assurance program that should be used for classifying waste.

- Section 3.7 discusses the use of 10 CFR 61.58, "Alternative requirements for waste classification and characteristics," a regulatory provision which enables licensees to request regulatory approval of waste classification approaches different from those in 10 CFR 61.55.

- Section 3.8 discusses potential averaging approaches different from those in the above sections, and considerations for licensees' proposals to disposal facility regulators.

- Section 3.9 describes implementation considerations.

- Section 3.10 discusses backfit considerations.

- Section 4 identifies references for Volume 1 of the CA BTP.

Volume 1 also contains Appendix A, a glossary; Appendix B, a table which identifies the major changes from the 1995 CA BTP; and Appendix C, the NRC's Safety Culture Policy Statement.

Volume 2 of this CA BTP contains the technical basis for the averaging positions in Volume 1, as well as staff responses to public comments on a May 2012 draft of the CA BTP. Staff responses to public comments on previous drafts of the revised CA BTP are available in Appendices C, D, E, and F of the May 2012 draft.[7]

1.4 Overview of Concentration Averaging

Concentration averaging is the mathematical averaging of the radionuclide activities in waste over its volume or mass. This CA BTP provides guidance on appropriate volumes and masses to use in calculating average concentrations, as permitted by 61.55(a)(8). Once the average radionuclide concentrations are determined, then the waste classification process described in 10 CFR 61.55 is used to determine the class of the waste.

Figure 1 provides an overview of guidance in this document. This CA BTP addresses two broad categories of waste: blendable waste and discrete items. In general, blendable

[7] Available in ADAMS at Accession Number ML121170418.

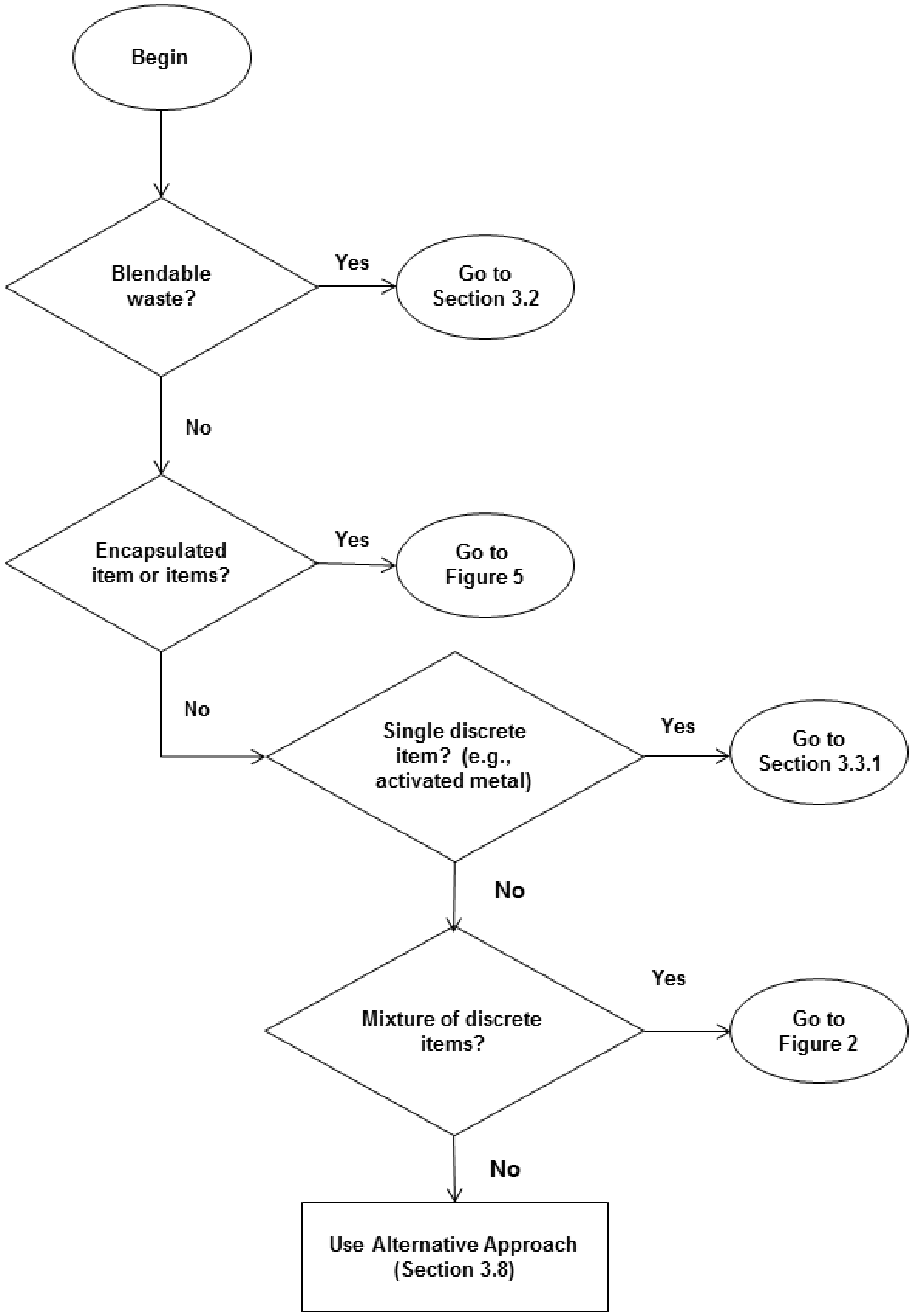

Figure 1. CA BTP Guidance Overview

wastes are subject to fewer averaging constraints than discrete items because blendable wastes are generally not expected to have hot spots that could pose a hazard to an inadvertent intruder.[8] In most cases, blendable waste may be averaged over the mass or volume of the waste without any demonstration of adequate blending. In cases in which highly concentrated blendable waste is combined with a blendable waste with much lower radionuclide concentrations, hot spots could be created if the waste is not adequately blended. This CA BTP provides guidance for when waste must be blended and how to demonstrate that waste is adequately blended.

The second category is discrete items. The CA BTP recommends constraints for discrete items based on their size and the amount or concentration of radioactivity they contain. The size, amount of radioactivity and concentration help to define the hazard to an inadvertent intruder who might directly handle the discrete item.

This CA BTP relies on the following key concepts:

- *Averaging Constraints:* Recommended restrictions on averaging radionuclide concentrations as allowed by 10 CFR 61.55(a)(8). Averaging constraints are designed to limit potential hot spots in waste. Different averaging constraints apply to blendable waste and discrete items.

- *Hot Spot:* A portion of the overall waste volume whose radionuclide concentrations are above the class limit for the entire container. Because averaging is permitted under the regulations, some exceedance of the limits is permissible for portions of the overall volume of the waste, as long as the average concentration of the container is within the class limit. Classification is based on the average radionuclide concentrations of waste in a container according to 10 CFR 61.55(a)(8), subject to certain constraints on hot spots.

- *Waste Stream*: Waste with relatively uniform radiological and physical characteristics. Often, the waste results from a single process. Examples of waste streams are provided in NRC Information Notice (IN) 86-20, "Low-Level Radioactive Waste Scaling Factors, 10 CFR Part 61" (ADAMS Accession No. ML103420436); for example, pressurized-water reactor (PWR) primary and secondary system ion-exchange resins are separate waste streams. Each facility may identify its own waste streams.

- *Waste Type:* Wastes with similar physical characteristics but which might have different radiological characteristics. Ion-exchange resins from either the primary or secondary coolant systems in a nuclear power plant are the same waste type.[9] However, ion-exchange resins, soils, and activated metals are different waste types.

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8 The BTP guidance for blendable wastes is based on a scenario similar to the "post-drilling" scenario in National Council on Radiation Protection & Measurements (NCRP) Report Number 152 (NCRP, 2005). The scenario is similar to the agricultural scenarios considered in the Draft Environmental Impact Statement for Part 61 (NRC, 1981) except that less waste is exhumed (see Volume 2, Section 4).

9 As defined in 10 CFR Part 20, and for purposes of this BTP, a waste type is a category of waste within a disposal container having a unique physical description (i.e., a specific waste descriptor code or description; or a waste sorbed on or solidified in a specifically defined media).

- *Waste characterization*: Waste characterization has many purposes, and in general, it means identifying the physical and radiological properties of LLW. For the purposes of applying the concentration averaging constraints described in this CA BTP, waste characterization includes the identification of the *waste stream* from which waste is produced (e.g., primary or secondary resins in a nuclear power plant), the *waste type* (i.e., wastes with similar physical characteristics), physical characterization (e.g., whether waste is "*discrete*" or "*blendable*," and radiological characterization (i.e., the determination of the presence and concentrations and amounts of radionuclides relevant to waste classification.

- *Waste classification*: the process of categorizing waste based on the concentration of certain key radionuclides important to protection of an inadvertent intruder into a LLW disposal facility. 10 CFR Part 61 defines three classes (A, B, and C). The controls used to manage risk to an inadvertent intruder, such as engineered barriers, increase with increasing waste class.

- *Discrete Items:* For the purposes of this CA BTP, discrete items are items belonging to one of the following waste types: activated metals, sealed sources, cartridge filters[10], contaminated materials, and components incorporating radioactivity into their design. Items belonging to these waste types are designated as discrete items in this guidance because (1) they are expected to be durable (i.e., remain intact at the time of intrusion) and (2) items belonging to these waste types often have relatively high amounts or concentrations of radioactivity.

- *Blending:* Blending is physically mixing two or more blendable waste streams to create a product with relatively uniform radionuclide concentrations. For the purposes of this CA BTP, a waste stream is considered to have the properties needed for blending (i.e., a waste stream is "blendable") if: (1) the waste can be physically mixed to create relatively uniform[11] radionuclide concentrations or (2) the waste is not expected to contain durable items with significant activity.[12] This CA BTP makes a distinction between waste that is "blendable," indicating that it has the properties needed for blending, and waste that is "blended," indicating two or more blendable waste streams have been physically mixed together.

- *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. This CA BTP provides guidance on the amount of encapsulating material can be included in concentration averaging.

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10 As described in Section 3.3.3, cartridge filters may be treated as blendable waste in some cases.

11 Radionuclide concentrations are "relatively uniform" if an intruder who encounters the waste is unlikely to encounter waste more concentrated than the class limit by a factor of 10.

12 Durable items with significant activity are defined as "discrete items." Although contaminated trash may contain durable items, any durable items in trash are not expected to contain significant activity. Durable items with significant contamination are considered to be "contaminated materials" instead of trash.

- *Alternative Approaches*: The averaging constraints specified in this CA BTP are generic, like the 10 CFR Part 61 waste classification system, and are suitable for use at any disposal facility. This CA BTP also provides guidance for *alternative approaches* to concentration averaging based on site- or waste-specific considerations that licensees may propose to the disposal facility regulator.

These terms and others important to this CA BTP are listed in the glossary in Appendix A.

1.5 Relationship to Other NRC Guidance

This CA BTP has evolved from a section in a guidance document published shortly after 10 CFR Part 61 was promulgated. The NRC's Final Waste Classification and Waste Form Technical Position Papers (NRC, 1983) described overall procedures acceptable to the NRC staff that could be used to determine the presence and concentrations of the radionuclides listed in 10 CFR 61.55. That information was also used by licensees to classify waste for near-surface disposal. The 1983 Technical Position on Waste Classification included Section C.3, "Concentration Volumes and Masses," which provided guidance to waste generators on the interpretation of 10 CFR 61.55(a)(8), "Determination of concentrations in wastes." This provision allows averaging of waste concentrations for determining the classification of the waste as Class A, B, or C.

On January 17, 1995, the NRC replaced Section C.3 of the 1983 Technical Position on Waste Classification with the "Branch Technical Position on Concentration Averaging and Encapsulation" (NRC, 1995a). A major purpose of the 1995 CA BTP was to provide guidance for the disposal of discrete, durable, gamma-emitting items or mixtures of such items. The 1995 guidance was designed to ensure that potential exposures from exhuming discrete items would be within the "envelope of safety" considered for inadvertent intrusion in the environmental impact statement (EIS) for Part 61. The EIS for Part 61 did not explicitly consider potential intruder exposures from discrete items. Instead, it considered the potential exposure of an inadvertent intruder who lives and grows food on a site where waste has inadvertently been exhumed and mixed with soil.

This document updates the 1995 CA BTP in its entirety.[13] However, some of the remaining guidance in the 1983 Technical Position on Waste Classification remains in effect. Specifically, Section C, "Regulatory Position" (including Sections C.1, "General Criteria;" and C.2, "Determination and Verification of Radionuclide Concentrations and Correlations"), and Appendix A, General Program for Classifying Wastes at Nuclear Power Plants," may continue to be used. As noted above, this 2015 document replaces Section C.3 addressing concentration averaging.[14] In addition, Section C.4, "Reporting on Manifests" has been superseded by a waste manifesting rule promulgated on March 28, 1995, "Low-Level Waste Shipment Manifest Information and Reporting," (NRC 1995b). Guidance for implementing that rule is contained in NUREG/BR-0204, "Instructions for Completing NRC's Uniform Low-Level Radioactive Waste Manifest" (NRC, 1998b).

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[13] As discussed in Section 3.10, use of this revised guidance is voluntary. Licensees and applicants may choose another method of demonstrating compliance with 10 CFR 61.55(a)(8). In particular, current licensees may continue to use the 1995 CA BTP.

[14] Corrections to the 1983 guidance identified in the 1995 BTP remain in effect, however. Specifically, in p. 6, fourth line, and p. 12, second paragraph, fifth line, replace "biannual" with "biennial."

The scope of this revised CA BTP is limited to the averaging of concentrations of radionuclides for the purpose of determining the classification of waste being shipped for disposal, as provided for by 10 CFR 61.55(a)(8). Licensees shipping waste for disposal must meet other requirements, including the disposal facility license conditions, and should follow other applicable NRC guidance documents that cover other aspects of LLW transportation and disposal (e.g., hydrogen generation[15] and waste form stability[16]).

2. SAFETY CULTURE

It is the NRC's expectation that individuals and organizations performing regulated activities, such as characterizing and classifying LLW for disposal, establish and maintain a positive safety culture commensurate with the safety and security significance of their activities and the nature and complexity of their organizations and functions. This applies to all licensees, certificate holders, permit holders, authorization holders, holders of quality assurance program approvals, vendors and suppliers of safety-related components, and applicants for a license, certificate, permit, authorization, or quality assurance program approval, subject to NRC authority. "Nuclear safety culture" is defined as the core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment. Individuals and organizations performing regulated activities bear primary responsibility for safely handling and securing these materials. Experience has shown that a positive safety culture exhibits certain personal and organizational traits. A trait, in this case, is a pattern of thinking, feeling, and behaving that emphasizes safety, particularly in goal conflict situations (e.g., production versus safety, schedule versus safety, and cost of the effort versus safety).

The NRC, as the regulatory agency with an independent oversight role, reviews the performance of individuals and organizations to determine compliance with requirements and commitments through its existing inspection and assessment processes. Licensees are not required by the regulations to incorporate the NRC's safety culture policy statement into their activities. However, many of the safety culture traits may be inherent to an organization's existing radiation safety practices and programs.

Refer to Appendix C for the NRC's Safety Culture Policy Statement. More information on NRC activities related to safety culture can be found at: http://www.nrc.gov/about-nrc/regulatory/enforcement/safety-culture.html.

3. TECHNICAL POSITION

This section provides guidance on acceptable methods of concentration averaging for classification of low-level radioactive waste in accordance with 10 CFR 61.55(a)(8). It also provides guidance on characterization and classification of waste for waste manifests contained in Appendix G to 10 CFR Part 20.

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15 See Information Notice 84-72 , "Clarification of Conditions for Waste Shipments Subject to Hydrogen Gas Generation," (NRC, 1984).

16 See Revision 1 of the "Waste Form Technical Position" (NRC, 1991).

3.1 Waste Characterization

Waste must be characterized to determine which averaging constraints apply for waste classification. In addition, LLW generators shipping waste for disposal, either directly or through a waste processor or collector, are required to characterize waste on the uniform shipping manifests prescribed in Appendix G to 10 CFR Part 20.[17] For the purposes of this CA BTP, waste is divided into one of two categories, blendable waste or discrete items. Different averaging constraints apply to each category. Discrete items are generally individually characterized, and therefore more characterization is required for discrete items than for blendable wastes.

3.1.1 Identifying Waste Streams

Waste is considered to be from a single waste stream if it has relatively uniform radiological and physical characteristics. Often, a waste stream results from a single process. Waste streams are considered distinct (i.e., different from one another) if the concentrations of radionuclides of concern (see the Glossary) typically differ by more than a factor of 10 (e.g., primary and secondary resins from nuclear power plants are distinct waste streams).

NRC IN 86-20, "Low Level Radioactive Waste Scaling Factors, 10 CFR Part 61" (NRC, 1986a), provides a list of typical waste streams at nuclear power plants. For example, for pressurized-water reactors (PWRs), IN 86-20 identifies these separate waste streams: primary purification filters, primary purification resins, chemical and volume control system evaporator bottoms, radwaste polishing resins, secondary system wastes (filters and resins), and contaminated trash. For Boiling Water Reactors (BWRs), IN 86-20 identifies these separate waste streams: cleanup filters and resins, condensate-polishing resins, evaporator bottoms, radwaste ion-exchange resins, and contaminated trash. These lists are provided only as examples and licensees may identify waste streams differently.

3.1.2 Identifying Waste Types

Waste is considered to be a single waste type if the waste has relatively uniform physical characteristics. For example, primary resin and secondary resin are the same waste type but resin and soil are different waste types.

3.1.3 Physical Characterization

Most LLW shipped for disposal is in a solid waste form and is subject to concentration-averaging constraints based on whether it is blendable waste or discrete items. Small amounts of gaseous waste may also be disposed of but are not subject to concentration-averaging constraints because the radiological concentrations in gases are expected to be uniform. Liquid waste, other than small amounts of free liquid in

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[17] A waste shipping manifest is not required from the generator when the radioactively contaminated material sent by a licensee becomes the waste processor's "residual waste." *Residual waste* is defined in Appendix G, 10 CFR Part 20, to mean low-level radioactive waste resulting from processing or decontamination activities that cannot be easily separated into distinct batches attributable to specific waste generators. This waste is attributable to the processor or decontamination facility, as applicable.

containers, is not authorized for disposal in a licensed disposal facility. However, liquid waste may be solidified or absorbed onto solid media in preparation for disposal.[18]

Blendable waste (see Section 3.2) includes waste types such as soils, resins, filter media, compactible trash, non-compactible trash, and ash. Blendable waste is not expected to contain discrete durable items that would be a hazard to an inadvertent intruder.

For the purposes of this CA BTP, discrete items (see Section 3.3) are items belonging to one of the following waste types: activated metals, sealed sources, cartridge filters,[19] contaminated materials, and components incorporating radioactivity into their design. Items belonging to these waste types are designated as discrete items in this guidance because (1) they are expected to be durable (i.e., remain intact at the time of intrusion) and (2) items belonging to these waste types often have relatively high amounts or concentrations of radioactivity. Process knowledge may be used to determine whether items are expected to have high amounts or concentrations of radioactivity.

Another physical characteristic important for waste classification is the volume to be used for the purposes of concentration averaging. Table 4 in Section 3.5 identifies constraints for the volume or mass that should be used in classifying waste. Most concentrations of radionuclides in the 10 CFR 61.55 waste classification tables are based on radioactivity per unit volume.[20] Weight may also be used and converted to equivalent volume for averaging purposes provided that a representative density is used, based on a representative distribution of materials.

3.1.4 Radiological Characterization

Sections C.1, "General Criteria," and C.2, "Determination and Verification of Radionuclide Concentrations and Correlations," of the 1983 Technical Position on Waste Classification describe acceptable procedures to determine the presence and concentrations of the radionuclides listed in 10 CFR 61.55.[21] As noted earlier, the concentration averaging guidance in Section C.3 of that 1983 document was replaced by the 1995 CA BTP, which has been updated in its entirety by this revised CA BTP.[22] However, Sections C.1 and C.2 of the 1983 guidance are still in effect.

Section C.2 of the 1983 Technical Position on Waste Classification identifies four different methods for radiological characterization of waste:

(1) compliance through materials compatibility,
(2) classification by source,

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18 Liquid waste may also be disposed of as a liquid effluent in accordance with the provisions of 10 CFR Part 20. This BTP only covers solid waste shipped for disposal at a licensed facility.

19 As described in Section 3.3.3, cartridge filters may be treated as blendable waste in some cases.

20 Transuranic radionuclide concentration limits are specified as radioactivity per unit of weight.

21 Other NRC guidance on radionuclide characterization may be used as well (see, for example, Information Notice 86-20, "Low-Level Radioactive Waste Scaling Factors, 10 CFR Part 61" (NRC, 1986a)). The 1983 Technical Position on Waste Classification is NRC's principal guidance on radionuclide characterization for the purposes of waste classification, however.

22 As discussed in Section 3.10, use of this guidance is voluntary. Licensees and applicants may choose another method of demonstrating compliance with 10 CFR 61.55(a)(8). In particular, current licensees may continue to use the 1995 CA BTP.

(3) gross radioactivity measurements, and
(4) measurement of specific radionuclides.

The extent of radiological characterization required depends on whether the wastes are blendable wastes or discrete items. Discrete items should generally be individually characterized because they are subject to averaging constraints in this CA BTP.

Blendable waste generally requires less characterization than discrete items. In some cases, blendable wastes (e.g., contaminated trash) may include durable items that have low activity of gamma-emitting radionuclides. These items do not need to be individually characterized, as explained in Section 3.2. In a few cases, mixtures of distinct blendable waste streams should be shown to be adequately blended, as discussed in Section 3.2.3.

For radiological characterization of contaminated materials (i.e., components or metals on which radioactivity resides near the surface in a fixed or removable condition), the staff provides the following guidance. For individual items, classification may be determined by representative swipes or radiation survey measurements from which the total activity of radionuclides may be estimated through the use of scaling factors. In these cases, the volume or weight of the contaminated material should be the total mass or displaced volume of the item (i.e., major void volumes subtracted from envelope volume). For mixtures of these contaminated items, the total activity of contained radionuclides may also be determined by representative[23] swipes or radiation survey measurements of the container's contents. The volume or mass of the mixture should be the total mass or displaced volume of all the material contributing to the mixture. It is also permissible under the constraints for discrete items in Section 3.3 to average concentrations of the radionuclides listed in Tables 1 and 2 of 10 CFR 61.55 over the contents of the disposal container.

If generators are shipping to a waste processor or collector, they do not need to classify the waste, because classification is only required for the final waste form presented for disposal. However, waste processors or collectors might need to rely on the physical and radiological characterization provided by generators for classifying the waste for disposal.

3.2 Blendable Waste

For the purposes of this guidance, a waste type is considered to have the properties needed for blending (i.e., a waste type is "blendable") if:

- the waste can be physically mixed to create relatively uniform[24] radionuclide concentrations or

- the waste is not expected to contain durable items with significant activity.

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[23] For swipes or radiation survey measurements to be representative of the mixture, discrete items in the mixture should meet the Factors of 2 and 10 described in Section 3.3, as appropriate for the mixture.

[24] Radionuclide concentrations are "relatively uniform" if an intruder who encounters the waste is unlikely to encounter waste more concentrated than the class limit by a factor of 10 or more.

This CA BTP makes a distinction between waste that is “blendable,” indicating it has the properties needed for blending, and waste that is “blended,” indicating two or more blendable waste streams have been physically mixed together. Different waste types (e.g., resins and soils) can be blended if the licensee documents the physical and chemical compatibility of the waste types being combined (see Section 3.2.2).

A waste type can be considered blendable if it meets either of the criteria listed in the previous paragraph. Ion-exchange resins, filter media, evaporator bottom concentrates, soil, and ash are each an example of a blendable waste type for the purposes of concentration averaging because each of these waste types, individually, can be physically mixed to create relatively uniform radionuclide concentrations. Contaminated trash is considered to be blendable because it is not expected to contain durable items with significant activity.[25] Process knowledge may be used to determine whether items are expected to have radioactivity in high amounts or concentrations. Similarly, those cartridge filters that can be demonstrated (e.g., through process knowledge) not to contain primary gamma emitters in excess of the values in Table 2 may be treated as blendable waste for the purposes of concentration averaging[26] (see Section 3.3.3). As used in this CA BTP, the primary gamma-emitting nuclides are cobalt-60 (^{60}Co), niobium-94 (^{94}Nb), and cesium-137 (^{137}Cs).[27]

3.2.1 Concentration Averaging for a Single Blendable Waste Stream

If a waste package contains a single blendable waste stream, radionuclide concentrations for waste classification may be averaged over the waste in the package. That is, an average radionuclide concentration may be based on its total activity in the package divided by the volume[28] or mass of the waste in the package. However, if waste fills 90 percent or more of a package, average radionuclide concentrations can be based on the entire interior volume of the container. Void spaces do not normally need to be accounted for in blendable waste[29].

Absorbed liquid (i.e., liquid radioactive waste that is absorbed onto an absorbent medium) may not be retained on the absorbent medium. Therefore, radionuclide concentrations should not be based on the volume or mass of the absorbent medium, but should be based on the original volume or mass of the liquid waste before absorption.

The activity of small concentrated sources or gauges (less than 3.7 MBq) (100 μCi) that may be mixed with contaminated trash may be averaged over the trash volume.

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25 The definition of discrete items in this CA BTP (i.e., activated metals, sealed sources, cartridge filters, contaminated materials, and components incorporating radioactivity into their design) is expected to cover all durable items with significant activity.

26 Note that the requirements in Section I.C.10 of Appendix G to 10 CFR Part 20 related to cartridge filters and contaminated equipment continue to apply even though these items may be treated as blendable waste for the purposes of concentration averaging.

27 Most ^{137}Cs decays to a metastable nuclear isomer, ^{137m}Ba. ^{137}Cs is not a gamma emitter, but ^{137m}Ba is. When this BTP refers to ^{137}Cs, it includes the ^{137m}Ba that is in equilibrium with it.

28 The volume of the waste can be calculated from the weight of the waste divided by its density. Licensees may use a representative density based on a representative distribution of materials as they occur in waste.

29 The staff expects that in most cases it would not be consistent with “as low as is reasonably achievable” (ALARA) principles to determine the internal void spaces in contaminated trash.

3.2.2 Concentration Averaging for Multiple Blendable Waste Streams

In some cases, blendable waste streams of the same waste type (e.g., primary and secondary resins) may be combined in the same container without blending. If the CA BTP Table 1 thresholds are not exceeded, the waste does not need to be blended and the radionuclide concentrations can be averaged over the volume of the waste or container as a single waste stream (i.e., as in Section 3.2.1). If the thresholds in CA BTP Table 1 are exceeded, the waste must be blended and a demonstration of adequate blending is needed. These thresholds are based on the sum of fractions of the most concentrated influent waste stream, the volume of the mixture, and the classification of the final mixture. Waste is adequately blended if there is reasonable assurance that there are no hot spots of waste 0.2 m^3 (7 cubic feet (ft^3)) or larger in size that have a sum of fractions greater than 10 relative to the blended product. Alternative approaches for demonstrating blending is adequate may be justified based on site-specific conditions (see Section 3.8). Radionuclide concentrations should not be averaged over more than one container.

An explanation and example of determining the sum of fractions is provided in 10 CFR 61.55(a)(7). In summary, the first step in determining “Sum of Fractions of the Most Concentrated Influent Waste Stream” listed in this revised CA BTP Table 1 is to determine the intended waste class of the blended product. Then the licensee should take the concentration of each nuclide in the most concentrated influent waste stream and divide it by the 10 CFR Part 61 concentration limit for that radionuclide, based on the waste class of the final blended product. The licensee should then sum the fractions over all the radionuclides in the influent waste stream. For example, if a licensee is blending waste to produce Class A waste, and the most concentrated influent waste stream has a ^{60}Co concentration of 20,000 Ci/m^3, the licensee would divide 20,000 Ci/m^3 by the 10 CFR 61.55 Table 2 Column 1 (Class A) limit for ^{60}Co of 700 Ci/m^3. If ^{60}Co were the only radionuclide in the most concentrated influent waste stream, then the “Sum of Fractions of the Most Concentrated Influent Waste Stream” would be 20,000 Ci/m^3 divided by 700 Ci/m^3, which is 28. In this case, based on the CA BTP Table 1, the licensee would either need to limit the volume the waste is averaged over to less than 60 m^3 (2,100 ft^3) or provide a demonstration of adequate blending.

A demonstration that waste is adequately blended can be based on process knowledge, reasoned conclusions, calculations, or direct measurements. For example, a licensee can show that a particular process blends waste adequately by testing the process with physically similar[30] but nonradioactive materials (e.g., resins colored with dye tracers). Direct measurements are not necessarily preferable to indirect methods because direct measurements are likely to require

[30] In this context, “physically similar” refers to characteristics that could affect physical mixing (e.g., particle size or liquid content).

Table 1. Thresholds for Demonstrating Adequate Blending

Characteristics of Most Concentrated Influent Waste Stream‡	Volume† of Mixture in m^3 (ft^3)		
	Class A Mixture	Class B Mixture	Class C Mixture
Sum of fractions less than 10	No limit	No limit	No limit
Sum of fractions between 10 and 20	No limit	No limit	50 (1800)
Sum of fractions between 20 and 30	60 (2100)	No limit*	20 (700)
Sum of fractions between 30 and 50	20 (700)	No limit*	6 (210)
Sum of fractions between 50 and 100	6 (210)	40 (1400)*	2 (70)

† Licensees using larger averaging volumes or more concentrated influent waste streams should demonstrate the waste has been adequately blended (see Section 3.2.3).
‡ Sum of fractions is based on the class of the blended product.
* In the draft EIS for Part 61, class limits were derived based on a dose calculation. In the final EIS for Part 61, adjustments were made differently to the Class A, B, and C limits (see Volume 2, Section 4.6).

closer proximity to the waste than indirect methods. Therefore, making direct measurements may not be consistent with "as low as is reasonably achievable" (ALARA) principles if indirect methods are available that can quantify relevant radionuclide concentrations adequately.

If multiple waste streams of a single waste type generated[31] at a licensee's facility are aggregated for the purposes of operational efficiency, occupational safety, or occupational dose reduction, the aggregated waste can be treated as a single waste stream for the purposes of this CA BTP (see Section 3.2.2). Table 1 of the CA BTP does not apply to this aggregated waste and no demonstration of adequate blending is needed. This reasoning does not apply to wastes that are blended after they have already been packaged separately for shipping (e.g., from a generator to a processor)—a demonstration of adequate blending may be necessary for such wastes.

Licensees combining one or more blendable waste types with each other or with discrete waste types (e.g., combining ion-exchange resins with soils, or ion-exchange resins with cartridge filters) should document the physical and chemical compatibility of the waste types and make the documentation available for inspection. Wastes that could interact to cause undesirable chemical reactions (e.g., unacceptable amounts of hydrogen

[31] This provision is not intended to apply to waste processors.

generation) should not be combined.[32] Additional constraints may be necessary to meet the Waste Acceptance Criteria of a specific disposal facility.

The 1983 Technical Position on Waste Classification indicates that more sophisticated waste classification analyses should be used for waste for which minor process variations may cause a change in waste classification. For example, if one or more influent waste streams in a blending process are much more concentrated than the waste class of the blended product, there is an increased chance of misclassifying waste because of radiological hot spots. If no practical means exist of demonstrating that waste streams are adequately blended, licensees should not exceed the threshold volumes in Table 1.

3.2.3 Classification of Solidified Waste

Solidification is the process of incorporating radioactive waste into a binding matrix to create a solid, physically and radiologically uniform waste form.[33] Examples of solidified waste include solidified liquids, solidified ion-exchange resins, and solidified shredded cartridge filters. Both NRC guidance (NRC, 1991) and industry standards (American National Standards Institute (ANSI)/American Nuclear Society (ANS)-55.1) state that solidified waste should be adequately mixed to produce a physically uniform product. The NRC staff expects that the degree of mixing required to create a physically uniform product will also eliminate radiological hot spots. Therefore, if solidification is performed to create a physically uniform waste form in accordance with NRC guidance for solidification and industry standards, the average radionuclide concentrations in solidified waste may be based on the total volume or mass of the solidified waste form. As discussed in Section 3.5, nonradioactive materials used in solidification should have a purpose (e.g., stabilization of waste), other than lowering the waste class.

3.3 Discrete Items

This section provides guidance on the classification of discrete items. For the purposes of this CA BTP, discrete items are items belonging to one of the following waste types: activated metals, sealed sources, cartridge filters, contaminated materials, and components incorporating radioactivity into their design. Items belonging to these waste types are designated as discrete items in this guidance because (1) they are expected to be durable (i.e., remain intact at the time of intrusion) and (2) items belonging to these waste types often have relatively high amounts or concentrations of radioactivity. This position applies to classifying a container of items of a single waste type and includes a number of criteria to ensure that individual items are unlikely to compromise the safety of an inadvertent intruder.

3.3.1 Concentration Averaging and Classification of Single Discrete Items

Individual discrete items may be classified based on the activity of their 10 CFR 61.55 radionuclides divided by the volume or weight of the item, as applicable. If an individual item is encapsulated, the concentration may be averaged over the volume or weight of the

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32 See, e.g., Information Notice 84-72, Clarification of Conditions for Waste Shipments Subject to Hydrogen Gas Generation." (NRC, 1984).

33 Encapsulation is different from solidification in that a discrete item is placed in a non-radioactive matrix without creating a uniform concentration of radioactivity.

final waste form, including the encapsulating material, subject to the constraints in Section 3.3.4.

3.3.2 Concentration Averaging and Classification of Mixtures of Discrete Items

This section addresses concentration averaging and classification of discrete items of waste within a single waste type. Classification of mixtures of different waste types is addressed in Section 3.4. Figure 2 is an overview of the averaging positions presented in this section.

3.3.2.1 Screening Criteria for Simplified Classification

In classifying a mixture of discrete items of the same waste type, screening criteria may be used to simplify classification of the waste (Figure 2). These screening criteria are conservative, may provide efficiencies to licensees, and are optional. If these screening criteria are not used, the averaging constraints in Section 3.3.2.2 apply.

- If each item has an activity less than 37 MBq (1 mCi), the radionuclide activities may be divided over the volume or mass of the entire mixture.

- If any item has an activity greater than 37 MBq (1 mCi), the mixture may be conservatively classified according to the discrete item with the highest classification. For example, if a mixture of items in a waste container 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 container may be conservatively classified as Class C LLW.

3.3.2.2 Classification of Mixtures of Discrete Items Within a Single Waste Type

If the screening criteria in Section 3.3.2.1 are not used, the concentration averaging constraints in this section should be used for classifying a mixture of items belonging to a single waste type. Figure 3 is a flow chart of the averaging positions presented in this section.

As used in this CA BTP, the primary gamma-emitting nuclides are cobalt-60 (^{60}Co), niobium-94 (^{94}Nb), and cesium-137 (^{137}Cs). These radionuclides are subject to averaging constraints because of the hazard they could present to an intruder handling a discrete item of waste.[34] As used in this CA BTP, radionuclides other than primary gamma emitters are all radionuclides from Tables 1 and 2 of 10 CFR 61.55 other than ^{60}Co, ^{94}Nb, or ^{137}Cs. If primary gamma-emitting radionuclides control the waste classification, more restrictive averaging constraints apply (see below). If radionuclides other than primary gamma-emitting radionuclides control the classification, less restrictive averaging constraints apply (see below).

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[34] The NRC staff does not expect other gamma-emitting radionuclides in the 10 CFR Part 61 waste classification tables to cause a hazard to an intruder who handles the waste.

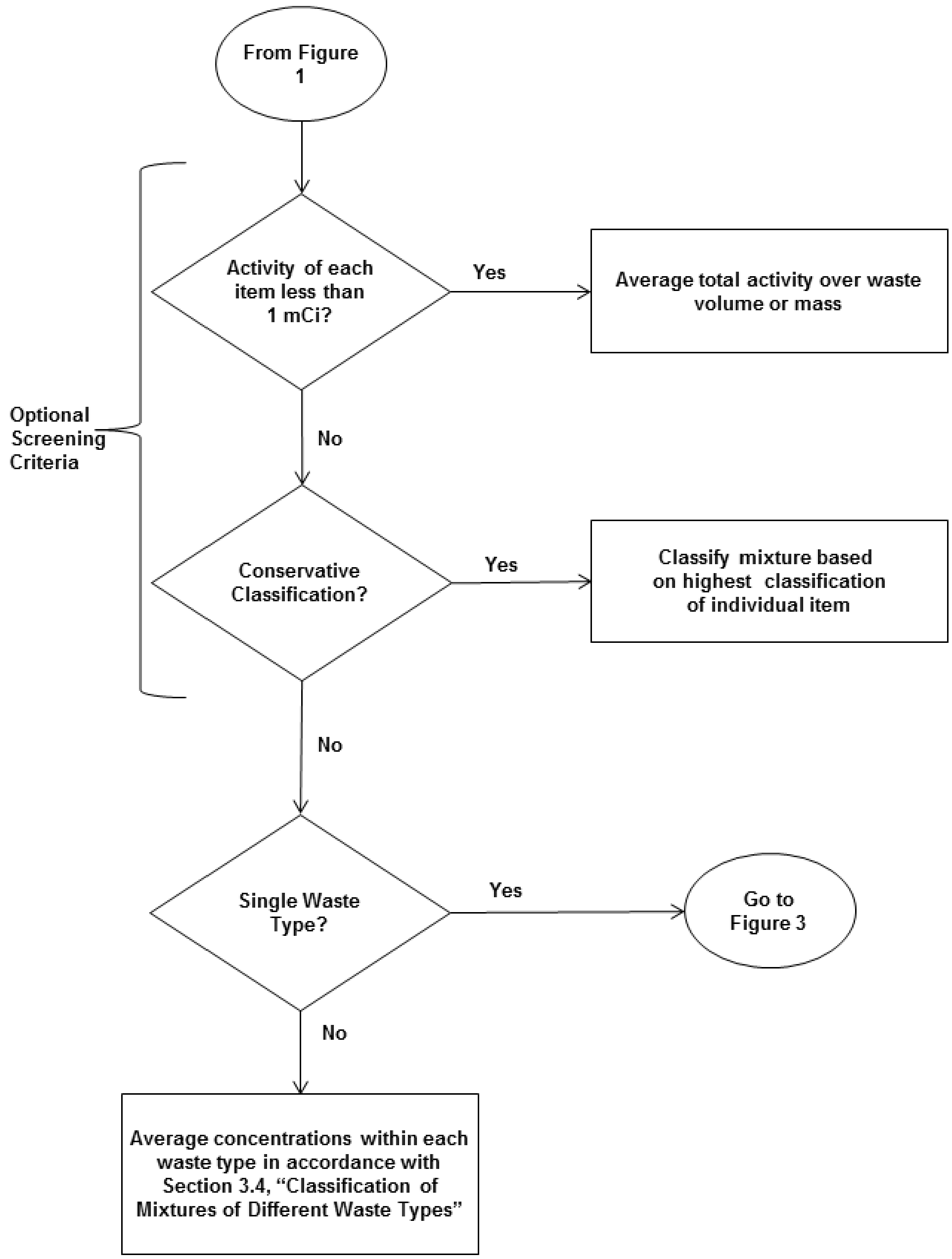
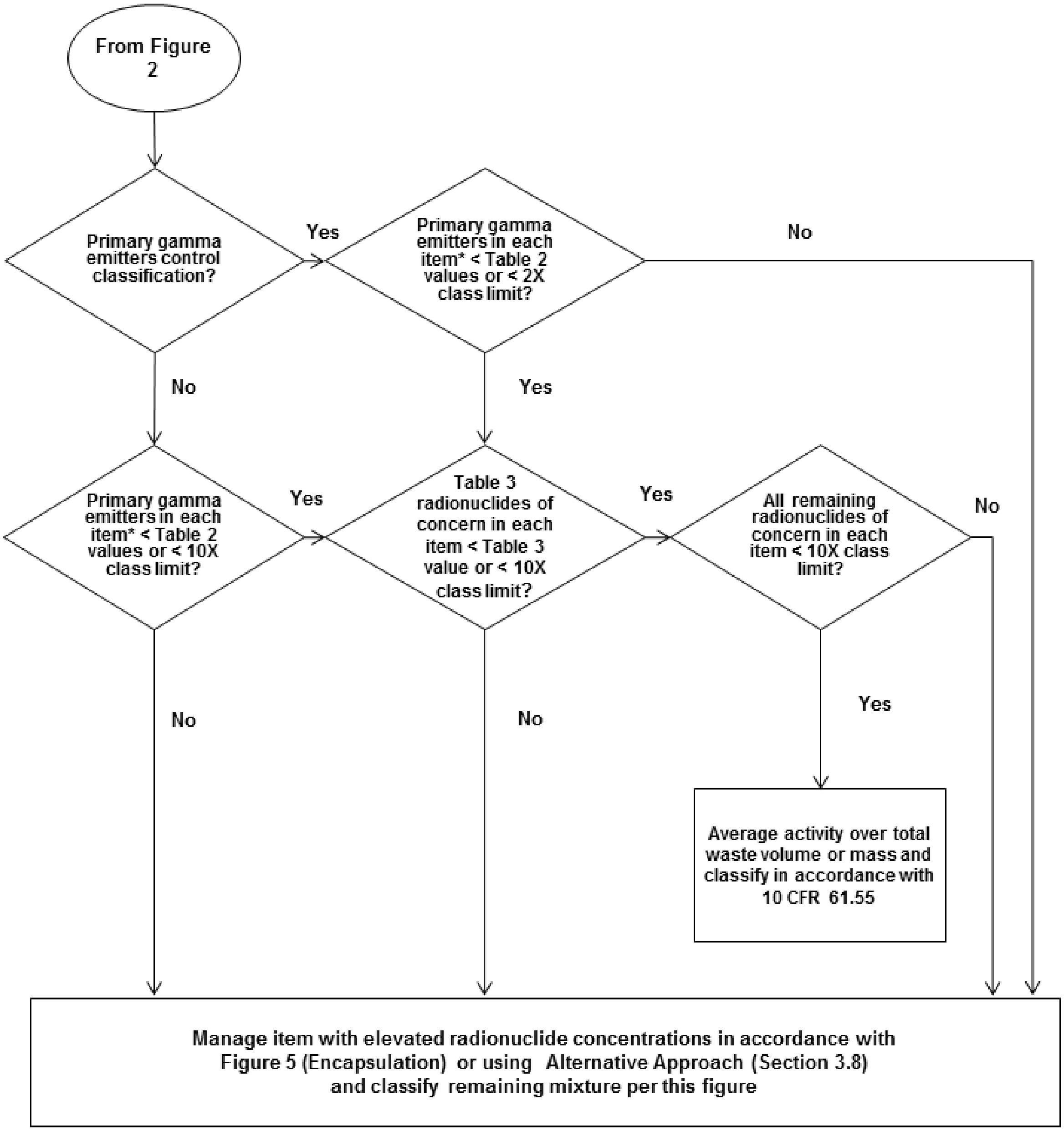


Figure 2. Overview of Classification of Mixtures of Discrete Items (Sections 3.3.2.1 and 3.3.2.2)



* For comparison to Table 2 values, items larger than 280 cc (0.01 ft^3) may be treated individually. Items smaller than 280 cc (0.01 ft^3) should be grouped together (see Section 3.3.2.2).

Figure 3. Classification of Mixtures of Discrete Items Within a Single Waste Type (from Section 3.3.2.2)

To determine whether the primary gamma emitters control the classification, the licensee should evaluate their relative significance as compared to the other radionuclides in the waste. The licensee should first determine the sums of fractions for 10 CFR 61.55 Tables 1 and 2.[35] Then the licensee should determine which 10 CFR 61 table would result in a higher waste classification. This is the more restrictive table. If Tables 1 and 2 of 10 CFR 61.55 result in the same waste classification, the table that has the greater sum of fractions is the more restrictive table. Finally, the licensee should determine the fractional contribution that the primary gamma emitters make to the sum of fractions in the more restrictive table. If the primary gamma emitters contribute more than 50 percent of the sum of fractions[36] in the more restrictive table, the primary gamma emitters are considered "classification controlling."

For discrete items, the licensee has a choice of applying an activity limit or concentration limit.[37] For primary gamma-emitting radionuclides, the activity limits are provided in Table 2. The appropriate concentration limit depends on whether the primary gamma-emitting radionuclides control the waste classification as follows:

- If the primary gamma-emitting radionuclides are classification-controlling, the appropriate concentration limit is the "Factor of 2" concentration limit. The Factor of 2 concentration limit specifies that the concentration of each primary gamma-emitting nuclide in each item should be less than 2 times the classification limit for that nuclide.

- If the primary gamma-emitting radionuclides are not classification-controlling but are radionuclides of concern, the appropriate concentration limit is the "Factor of 10" concentration limit. The Factor of 10 specifies that the concentration of each radionuclide of concern in each item should be less than 10 times the classification limit for that radionuclide.

Table 2. Recommended Activity Limits of Primary Gamma Emitters Potentially Requiring Piecemeal Consideration in Classification Determinations

Nuclide	Waste Classified as Class A	Waste Classified as Class B	Waste Classified as Class C
^{60}Co	5.2 TBq (140 Ci)	No limit	No limit
^{94}Nb	37 MBq (1 mCi)	37 MBq (1 mCi)	37 MBq (1 mCi)
^{137}Cs	266 MBq (7.2 mCi)	27 GBq (0.72 Ci)	4.8 TBq (130 Ci)

[35] An explanation and example of determining a sum of fractions is provided in 10 CFR 61.55(a)(7).

[36] For example, if the total sum of fractions for 10 CFR 61.55 Table 2 is 0.3, and ^{60}Co and ^{137}Cs together contribute 0.2 to the sum of fractions, the primary gammas contribute more than half to the Table 2 sum of fractions because 0.2/0.3 = 0.67 (67 percent).

[37] In general, the Table 2 limits are less restrictive for small items, and the Factor of 2 concentration limit is less restrictive for larger items. Because both limits are protective of an inadvertent intruder, the licensee may choose the less restrictive limit.

Table 3. Recommended Activity Limits of Radionuclides Other Than Primary Gamma Emitters Potentially Requiring Piecemeal Consideration in Classification Determinations

Nuclide*	For Waste Classified as Class A or B	For Waste Classified as Class C
^{3}H	0.3 TBq (8 Ci)	No limit
^{14}C	0.04 TBq (1 Ci)	0.4 TBq (10 Ci)
^{59}Ni	0.15 TBq (4 Ci)	1.5 TBq (40 Ci)
^{63}Ni	0.26 TBq (7 Ci)	55 TBq (1500 Ci)
Alpha-emitting transuranic (TRU) waste with half-life greater than 5 years (excluding ^{241}Pu and ^{242}Cm)	111 MBq (3 mCi)	1.1 GBq (30 mCi)

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

The Table 2 limits should be applied using a sum of fractions. The Factors of 2 and 10 are applied separately to each radionuclide (i.e., a sum of fractions is not applied). For comparison to Table 2 values, items larger than 280 cc (0.01 ft^3) may be treated individually. However, items smaller than 280 cc (0.01 ft^3) should be grouped together. That is, the sum of fractions should be based on the total inventory of each primary gamma-emitting radionuclide in the items smaller than 280 cc (0.01 ft^3). The Factors of 2 and 10 are applied to each item individually, irrespective of size.

In addition to applying concentration averaging constraints to primary gamma emitting radionuclides, licensees should also apply concentration averaging constraints to radionuclides of concern that are not primary gamma emitters. The licensee may choose to apply either the Table 3 values or the Factor of 10 concentration limit to radionuclides of concern other than primary gamma-emitting radionuclides.[38] Table 3 is applied separately to each radionuclide (i.e., the sum of fractions is not applied). The Factor of 10 and Table 3 are applied to each item individually, irrespective of size.

For radionuclides of concern that are not represented in Tables 2 or 3, the Factor of 10 concentration limit should be applied.

If an item in the mixture cannot meet the constraints described in this section, the item should be removed from the average and classified as an individual item[39] in accordance with Section 3.3.1. The classification of the remaining mixture may be based on the volumetrically averaged or weight-averaged concentrations of the mixture.

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38 In general, the Table 3 limits are less restrictive for small items and the Factor of 10 concentration limit is less restrictive for larger items. Because both limits are protective of an inadvertent intruder, the licensee may choose the less restrictive limit.

39 If items smaller than 280 cc (0.01 ft^3) collectively exceed the Table 2 limits, using a sum of fractions, and they do not individually meet the Factor of 2 or 10 (as applicable), their concentrations should not be averaged to meet the Factor of 2 or 10.

Example 1

If ^{94}Nb is classification-controlling in a Class A mixture of discrete items that are each larger than 280 cc (0.01 ft^3), then each individual item could have an ^{94}Nb activity of 37 MBq (1 mCi) (the Table 2 value) or a concentration up to 1.5 GBq/m^3 (0.04 Ci/m^3) (two times the Class A limit for ^{94}Nb). If ^{137}Cs or ^{60}Co were also radionuclides of concern in the Class A mixture, the licensee could choose to apply either the Table 2 or the Factor of 2 to these radionuclides. The Table 2 limits would be applied using a sum of fractions, but the Factor of 2 would apply to each primary-gamma emitting radionuclide individually. The licensee could choose to apply either the Table 3 or the Factor of 10 to other radionuclides of concern in the mixture.

Example 2

If ^{94}Nb is a nuclide of concern in a Class A mixture of discrete items that are each larger than 280 cc (0.01 ft^3) but primary gamma-emitting radionuclides are not classification-controlling, then each individual item could have an ^{94}Nb activity of 37 MBq (1 mCi) (the Table 2 value) or a concentration up to 7.5 GBq/m^3 (0.2 Ci/m^3) (ten times the Class A limit for ^{94}Nb). If ^{137}Cs or ^{60}Co were also radionuclides of concern, the licensee could choose to apply either the Table 2 or the Factor of 10 to these radionuclides. The Table 2 limits would be applied using a sum of fractions but the Factor of 10 would apply to each radionuclide individually. The licensee could choose to apply either the Table 3 or the Factor of 10 to other radionuclides of concern in the mixture.

3.3.2.3 Classification of Sectioned Components

If a component is sectioned for operational considerations (e.g., packaging for transportation), the activities of the pieces may be averaged over the volume (or mass, as appropriate) of the original larger component, provided that the individual pieces are all placed in the same container and the activities of radionuclides are less than the Table 2 and Table 3 values. For sectioning, meeting the Table 2 criteria means that no piece that is smaller than 280 cc (0.01 ft^3) has primary gamma activity that exceeds the values shown in Table 2. Meeting the Table 3 criteria means that no individual piece of any size has activity that exceeds the values shown in Table 3. As for individual items, the Table 2 limits are applied using a sum of fractions and the Table 3 limits are applied to each radionuclide individually.

Example 3

An activated metal component is cut into four individual pieces for operational considerations and the four individual pieces each meet the Table 2 and Table 3 criteria. The four pieces are then combined with other items in a single container. The four pieces (from the single larger component) are assessed as a single component in determining whether the averaging and classification constraints for discrete items are fulfilled.

Figure 4 is a flowchart of the positions in this section.

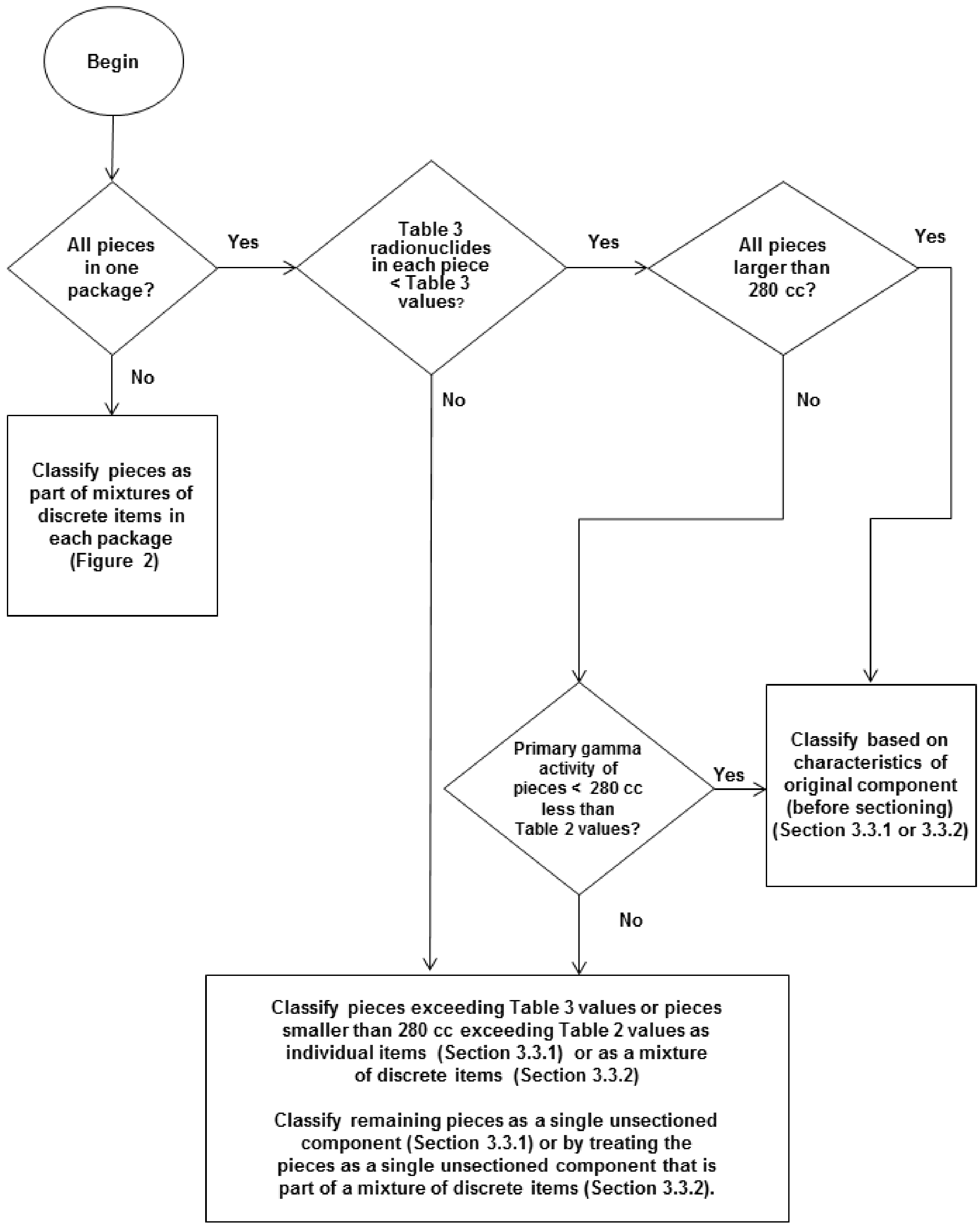

Figure 4. Classification of Sectioned Components (from Section 3.3.2.3)

3.3.3 Alternative Treatment of Certain Cartridge Filters

Cartridge filters do not necessarily need to be treated as discrete items. Cartridge filters that do not contain significant amounts or concentrations of long-lived gamma radioactivity may be treated as blendable waste for the purpose of concentration averaging, with justification. A justification should be documented and made available for inspection.

For cartridge filters, the justification should address these factors that potentially affect protection of an inadvertent intruder, such as:

- A history of the activity levels of primary gamma emitters in the filters covered by the analysis that is sufficient to demonstrate that their activity is within the Table 2 values in this CA BTP for the appropriate waste class and that the concentrations of non-primary gamma emitters are not greater than Class C. Because the recommended activity limits in Table 2 were developed for small items (< 280 cc (< 0.01 ft^3)) and are therefore conservative for larger[40] items, other activity limits may be proposed and justified.

- The items covered by the analysis (e.g., the design and manufacturer of the filter and the reactor system it is employed in).

- The physical characteristics of the filter design that justify not treating it as a discrete waste, such as:

  - the design characteristics of the filter that would enable radioactivity on the filter not to remain within the filter during an intrusion event, such as perforations in the filter housing; and

  - the filter medium (if, for example, it is non-metallic and expected to degrade during disposal and before intrusion occurs).

Individual cartridge filters that cannot be justified as blendable waste in accordance with the above are subject to the averaging constraints for discrete items in this CA BTP (see Section 3.3).

If cartridge filters are treated as blendable waste, the reporting requirements for filters in Sections I.C.10 and I.E.2 of Appendix G to 10 CFR Part 20 continue to apply. These sections state that for each disposal container of waste in a shipment, the identities and activities of individual radionuclides contained on filters within a container must be reported.

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[40] Larger items with the same activity would experience more self-shielding. In addition, intruders are expected to be exposed to larger items at a larger distance, because larger items would not be placed in a pocket.

3.3.4 Encapsulation of Discrete Items

Encapsulation is the process of surrounding discrete items of radioactive waste, such as sealed sources or cartridge filters,[41] in a non-radioactive binding matrix, where the activity remains within the dimensions of the original item of waste. Encapsulation differs from waste solidification, in which radioactive waste is uniformly mixed into a binding matrix to create a physically uniform final waste form. The advantages of encapsulation are that it can mitigate waste dispersion to the general environment after disposal, provide additional shielding to limit external radiation, and satisfy the stability requirements of 10 CFR 61.56(b) and the technical requirements for land disposal facilities of 10 CFR 61.52(a), when applicable. However, the amount of credit allowed for encapsulation in the averaging of radionuclide concentrations to determine the classification of waste should be limited, so that extreme measures cannot be taken solely for the purposes of lowering the waste classification. The positions identified below are acceptable for the encapsulation of low-level waste for disposal in a licensed facility.

- Volume of container/encapsulated mass

    - Containers up to 9.5 m^3 (331 ft^3) may be used for encapsulating waste provided that the minimum waste loading (volume of waste divided by the total volume, including encapsulating material) is at least 14 percent.

    - For waste loadings less than 14 percent (such as a single sealed source), the maximum volume or mass used in determining the average radionuclide concentrations and waste class should be 0.2 m^3 or 500 kg (approximately 55 gallons or 1,100 pounds). The volumes and masses may be larger than these values to allow for disposal of an item (such as a sealed source) in its shielded housing or source device or both, but no more than 0.2 m^3 or 500 kg may be used in the calculation of waste class. The shape of the final encapsulated package does not have to be a cylinder.

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

    - Larger volumes for encapsulation (such as grouting of reactor internals into a reactor pressure vessel) may be proposed on a case-by-case basis in accordance with Section 3.8.4, “Large Components.”

- Radioactivity constraints

    The constraints on the amount of radioactivity or concentrations of individual encapsulated items are similar to those that apply to mixtures of discrete items addressed in Section 3.3.2. As in Section 3.3.2, Table 2 is applied using a sum of

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41 Note that cartridge filters can also be treated as blendable waste when this is justified according to the provisions in Section 3.3.3.

fractions. Because it has a different technical basis (see Volume 2, Section 4), Table 3 is applied to each item individually (i.e., a sum of fractions is not used). The Factors of 2 and 10 also are applied to each radionuclide individually. For comparison to Table 2 values, items larger than 280 cc (0.01 ft^3) may be treated individually. However, items smaller than 280 cc (0.01 ft^3) should be grouped together. That is, the sum of fractions should be based on the total inventory of each primary gamma-emitting radionuclide in the items smaller than 280 cc (0.01 ft^3). The Factors of 2 and 10 are applied to each item individually, irrespective of size.

- For radionuclides other than primary gamma emitters, a licensee may choose *either* Table 3 or the Factor of 10 concentration limit for individual items. Demonstrating that either the Table 3 limit or the Factor of 10 concentration limit has been met is sufficient. These constraints on non-primary gamma-emitting radionuclides are the same irrespective of which radionuclides control the waste classification.

- For the gamma emitters:

  - If primary gamma-emitting radionuclides control the waste classification, the licensee may apply *either*
    - the Factor of 2 concentration limit to each item; *or*
    - the Table 2 activity limits.

  - If non-primary gamma emitters control the waste classification, the licensee may apply *either*
    - the Factor of 10 concentration limit to each item; *or*
    - the Table 2 activity limits.

  - A licensee may pick the less restrictive limits or may base the selection on other operational considerations. In choosing between these limits, the licensee is not restricted by the size of the item.[42]

- Multiple items may be encapsulated together, so long as the final encapsulated package meets the other criteria described herein.

- The maximum amount of any radioactive waste that should be encapsulated in a single disposal container is that which, when averaged over the waste and the encapsulating media, does not exceed the maximum concentration limits for Class C waste defined in Tables 1 and 2 of 10 CFR 61.55.[43]

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42 The size at which the Factor of 2 becomes less limiting is different for each radionuclide. However, in general, the Table 2 limits are less restrictive than the Factor of 2 limits for items smaller than 280 cc (0.01 ft^3) as well as for items slightly larger than 280 cc (0.01 ft^3). Thus, a licensee may choose to apply the Table 2 limits to items larger than 280 cc (0.01 ft^3).

43 For mass-based concentrations (such as for transuranic radionuclides), it is generally acceptable to take credit for the actual density of the encapsulating material) if the density is less than 2.5 g/cc (156 lbs/ft^3).

- For encapsulating media that are described in an approved Topical Report, the terms and conditions associated with the Topical Report approval apply.[44]

- In all cases in which one or more items are encapsulated, written procedures should be established to ensure that all such waste items are reasonably centered within the encapsulating media.

For encapsulated materials, Class B and C waste must also meet the structural stability criteria of 10 CFR 61.56, "Waste Characteristics," and be segregated from disposal units with unstabilized Class A waste, as specified in 10 CFR 61.56(b). Figure 5 is a flowchart depicting the decisions to be used for concentration averaging of encapsulated waste.

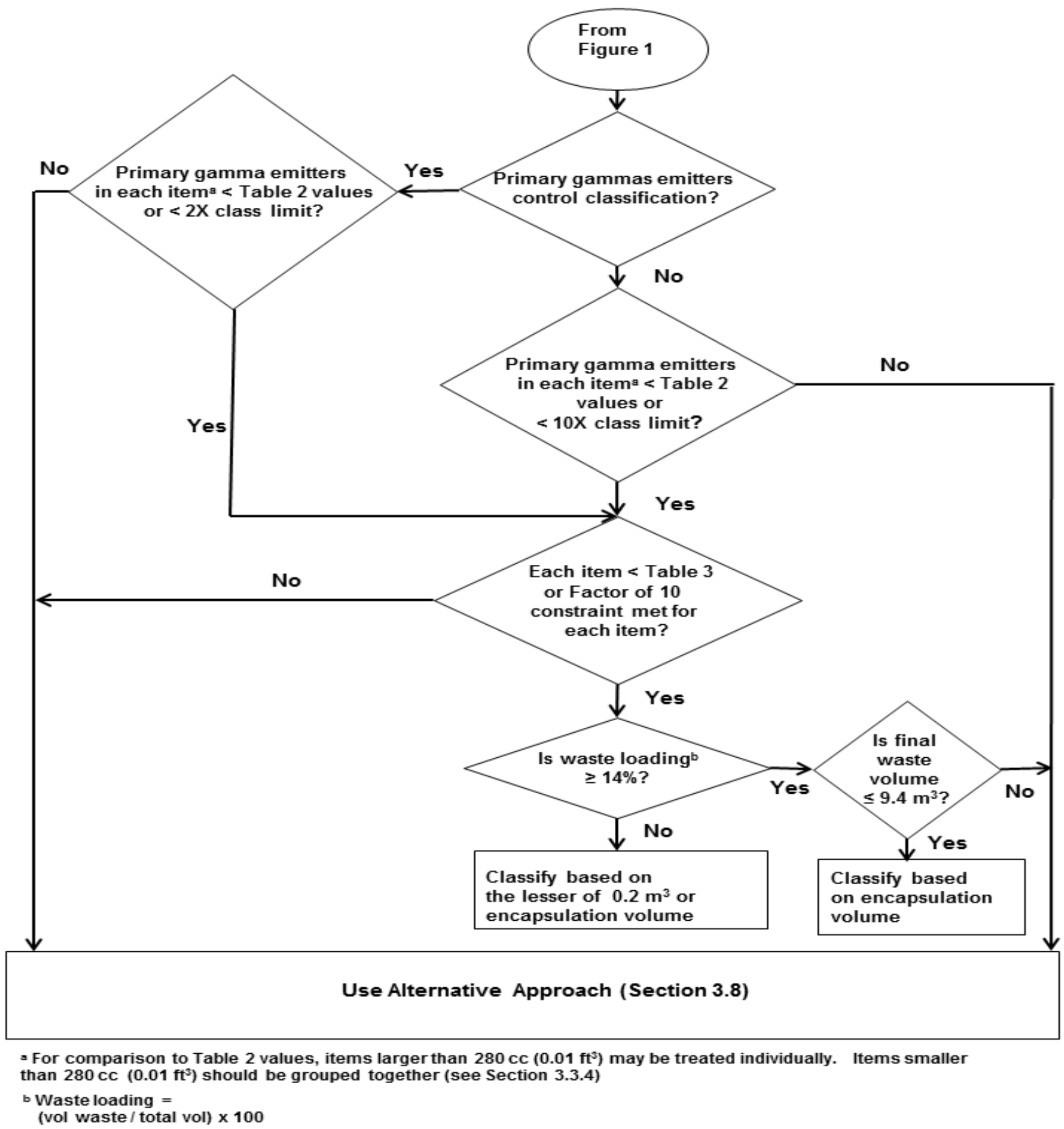

Fig. 5. Classification of Encapsulated Items

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44 A listing of the approved topical reports for encapsulation processes and materials at the time of publication of this revision can be found at ADAMS Accession No. ML14063A124.

3.4 Classification of Mixtures of Different Waste Types

Mixtures of different waste types are subject to different averaging constraints from those for mixtures within a single waste type. If one or more of the waste types in a mixture are blendable (e.g., mixing ion-exchange resins with soils or mixing ion-exchange resins with cartridge filters[45]), the licensee should document the physical and chemical compatibility of the waste types and make the documentation available for inspection (see Section 3.2.2). For mixtures of discrete items of different waste types, the classification of the entire mixture of waste types should be the highest classification of any of the individual waste types in the mixture. Individual waste types should be averaged in accordance with the provisions in Section 3.3. If discrete items are mixed with blendable wastes, the averaging constraints in Section 3.3 should be applied to the discrete items.

3.5 Determining the Volume or Mass of Waste

Table 4 contains guidance for determining the volume or mass that should be used in classifying waste. In general, waste volumes may be calculated from the mass of the waste divided by a representative density. The volumes and masses listed are those at the time the waste is ready for shipment to a licensed disposal site, consistent with the Part 61 requirements for waste classification.[46] Other averaging volumes may be acceptable as provided in Section 3.8, "Alternative Approaches," if there is reasonable assurance that the performance objectives of 10 CFR Part 61 will be met. See for example, Section 3.8.4, "Large Components."

For any wastes that include mixing of nonradioactive constituents with the LLW (such as for solidification, encapsulation, or additives used in thermal processing), nonradioactive materials added to the mixture should have a purpose other than reducing the waste class, such as waste stabilization or process control. To be consistent with other provisions in this CA BTP, extreme measures to lower the waste classification should be avoided.

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45 Licensees should document the physical and chemical compatibility of cartridge filters in a mixture of different waste types, one of which is blendable, whether the filters are treated as a discrete waste, or justified as blendable waste in accordance with Section 3.3.3, "Alternative Treatment of Cartridge Filters."

46 Waste is often processed before classification and shipment to a disposal facility, in some cases significantly changing its volume through compaction or incineration. This table does not apply to in-process waste volumes.

Table 4. Volume and Mass for Determination of Concentration

Waste	Allowable Classification Volume or Mass
Single blendable waste stream	If a waste container is more than 90% full of waste (by volume), the nominal interior volume ("fill volume") of the container may be used. For bulk waste, or for waste containers that are less than 90% full, the actual waste volume or mass should be used.[a]
Two or more blendable waste streams that have been combined (e.g., placed in a single container) but which have not been physically mixed together	Table 1 volumes.
Blended waste (i.e., two or more blendable waste streams that have been physically mixed together)	Table 1 volumes, or larger volumes if adequate blending is demonstrated.
Solidified waste (e.g., solidified liquid, solidified ion-exchange resins, or solidified shredded cartridge filters)	Volume or mass of solidified waste form.[b]
Absorbed liquids	Volume or mass of original liquid.
Cartridge filters treated as discrete items	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	Displaced volume (major void volumes subtracted from envelope volume) or mass of components.
Encapsulated cartridge filters, sealed sources, or other wastes	The encapsulating medium may be included in the volume or mass, subject to certain constraints (see Section 3.3.4).

[a] For ion-exchange resins, the volume and mass of the waste are the dewatered volume and mass. For cartridge filters treated as blendable waste, concentrations may be averaged over the total mass of the filters or their total envelope volume.

[b] Averaging over the solidified mass or volume is appropriate if the solidification creates a physically uniform waste form, in accord with relevant NRC guidance (NRC, 1991) and industry standards (e.g., ANSI, 1992) for solidified waste.

3.6 Quality Assurance Program

In accordance with Appendix G to 10 CFR Part 20, the licensee classifying the waste must have a quality assurance program in place 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 waste is based on the volumetrically averaged or weight-averaged nuclide concentration, 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 classification was undertaken in a way consistent with the guidance found in this CA BTP.

3.7 Alternative Requirements for Waste Classification (10 CFR 61.58)

Under 10 CFR 61.58, "Alternative Requirements for Waste Classification and Characteristics," the Commission may, upon request or on its own initiative, authorize other provisions for the classification and characteristics of waste on a specific basis if (after evaluation of the specific characteristics of the waste, disposal site, and method of disposal) it finds reasonable assurance of compliance with the performance objectives in Subpart C, "Performance Objectives," of 10 CFR Part 61. The waste classification requirements for near-surface disposal are contained in 10 CFR 61.55.

In 10 CFR 61.58, the regulation allows licensees the flexibility to establish alternate requirements for waste classification and characteristics when this is 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 could be demonstrated that the performance objectives of 10 CFR Part 61 would be met, waste containing Class B concentrations of radionuclides could be authorized for disposal in a Class A disposal cell using 10 CFR 61.58, for example. The averaging positions in the CA BTP were developed for waste classification under 10 CFR 61.55. Different requirements for waste classification may be approved under 10 CFR 61.58. The averaging constraints in this guidance were not developed for and do not have to be applied to 10 CFR 61.58 authorizations.

The NRC's waste classification system is generic (i.e., it could be applied to any near-surface disposal facility) and, as noted above, a site-specific approach for waste classification could be approved using 10 CFR 61.58. The averaging provisions of this CA BTP are also generic (i.e., suitable for use by any licensed disposal facility or generators or processors shipping waste to a licensed disposal facility). Although this generic approach may simplify classification, there might be instances in which generators, processors, or disposal facility operators may request review of site-specific averaging approaches by the disposal facility regulatory authority. This CA BTP provides examples of site-specific considerations for averaging, which might be useful to licensees in proposing alternative approaches and to regulators that review these proposals, in Section 3.8 below.

3.8 Alternative Approaches for Averaging

The approaches in Sections 3.2 through 3.5 of this CA BTP may be used to classify LLW for shipment to a licensed disposal site. Most of the approaches are generic and apply to all LLW disposal sites. Other averaging methods may be used, however, and the following guidance discusses considerations for site- and waste-specific methods and other approaches to intruder protection that could potentially justify concentration-averaging positions different from those in this CA BTP. Licensees also could propose other approaches different from those below for the disposal facility regulator's review.

NRC staff strongly urges licensees to submit proposals for alternative approaches to the regulator for the disposal facility and to have in-depth discussions on the merits of the proposal before classifying waste using the alternative approach. Alternative approaches to averaging are generally complex, often involving selection of intruder scenarios, for example. Detailed discussions between staff of the regulatory agency and licensee would help to ensure that waste is classified appropriately before shipment and disposal at a licensed facility, and that enforcement actions and/or return of waste to the shipper will not be necessary.

Alternative approaches as described in this section or other averaging approaches as may be reviewed by the disposal facility's regulator may be acceptable methods to demonstrate compliance with the provisions to determine the concentration of waste under 10 CFR 61.55(a)(8), depending on site-specific conditions. Use of 10 CFR 61.58 or an exemption is not necessary to invoke the provisions of this section.

3.8.1 Site-Specific Intruder Assessments

Site-specific concentration-averaging approaches that are different from those in Sections 3.2 through 3.5 may be proposed by disposal-facility licensees. Information provided to the regulatory authority should include, as applicable:

- An overview of the proposed alternative approach (e.g., depth of burial or other factors) and how it will protect an inadvertent intruder.

- A detailed description of the waste form(s) covered by the alternative averaging approach.

- An identification of the CA BTP's existing position for which an alternative is requested.

- For proposals based on inadvertent intruder exposure scenarios different from those in the CA BTP,[47] a discussion of how they were selected should be provided. The following criteria are applicable:

    - The scenario should be reasonably foreseeable in that it is based on the intruder performing normal activities consistent with regional social customs; current well drilling, excavation and construction practices; and land uses similar to land uses in the region currently or reasonably foreseeable in the near future (i.e., approximately 100 years or during the operational lifetime of a facility).

[47] See Volume 2, Section 4 for a discussion of the scenarios used as a basis for the technical positions in this CA BTP.

    - The time period for intrusion should be appropriate for the class of the waste (e.g., 100, 300, or 500 years) as discussed in 10 CFR 61.7(b). In some cases, averaging approaches based on depth of burial, or the use of intruder barriers or durable waste forms or containers, may be proposed.

- A description of site characteristics pertinent to the proposal.

- An analysis of the effects of degradation on packaging and engineered barriers over the period that the waste remains hazardous to an intruder.

Several NRC guidance documents might be useful in addressing the above considerations. NUREG-1854, "NRC Staff Guidance for Activities Related to U.S. Department of Energy Waste Determinations" (NRC, 2007), provides guidance for site-specific intruder assessments that might be of use to those preparing proposals, because it involves waste disposal using the performance objectives in Subpart C of 10 CFR Part 61. NUREG-1757, Volume 2, "Consolidated NMSS Decommissioning Guidance: Characterization, Survey and Determination of Radiological Criteria" (NRC, 2006), provides guidance on the evaluation of engineered barriers used in site decommissioning; it might be useful if similar barriers are used in land disposal of LLW. Finally, the NRC staff's "Summary of Existing Guidance That May Be Relevant for Reviewing Performance Assessments Supporting Disposal of Unique Waste Streams" (NRC, 2010a) also addresses site-specific performance assessments.

If the radiological hazard will persist beyond time frames used for the 10 CFR 61.55 waste classification tables (e.g., for disposal of large quantities of depleted uranium), licensees should consider intruder activities typical of generic scenarios (e.g., those discussed in NUREG-0782 (NRC,1981), NUREG-0945 (NRC,1982), and NUREG/CR-4370 (NRC,1986b)) 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.

3.8.2 Encapsulation of Discrete Items, Including Sealed Sources

The position on encapsulation in Section 3.3.4 is considered generally suitable for all LLW disposal facilities licensed under 10 CFR Part 61 or the equivalent Agreement State regulation. Other provisions may be used on a specific basis for the encapsulation of items if—after an evaluation of the specific characteristics of the waste form, the disposal site, intrusion scenarios, 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 item meet the 10 CFR 61.55 waste classification requirements, licensees do not need to seek authorization under 10 CFR 61.58 or request an exemption. For example, if a proposal is made to justify disposal of a 33 TBq (900 Ci) ^{137}Cs sealed source in a shielded cask buried 12 m (40 ft) deep, in a 0.5-m^3 (18-ft^3) encapsulated waste form, a 10 CFR 61.58 authorization or an exemption is not necessary, because 33 TBq (900 Ci) of ^{137}Cs in 0.5 m^3 (18 ft^3) is within the 10 CFR 61.55 Class C limits of 4,600 Ci/m^3 (4.8 TBq/ft^3) for ^{137}Cs. Alternative proposals for encapsulating individual items that would exceed the 10 CFR 61.55 waste classification limits would require use of 10 CFR 61.58 or an exemption.

The encapsulation guidance in Section 3.3.4 is based on the assumption that, in the future, the encapsulating media has fallen away, and a sealed source or other discrete item is exposed at the land surface (e.g., by a civil works project). Because the encapsulation is assumed to fail, the same assumptions are used for encapsulated items as are used for other discrete items (i.e., the small and large item carry-away scenarios). The full details are presented in Section 4 of Volume 2 of this CA BTP.

Proposals to use alternative intrusion scenarios should provide reasonable assurance that the scenarios for gamma-emitting items described in Section 4 of Volume 2 are very unlikely. Factors that could provide reasonable assurance that the applicable carry-away scenario is not credible for a specific disposal configuration (site and waste form) include, but are not limited to:

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

b) disposal of the encapsulated item at a sufficient depth to make the carry-away scenario not credible (e.g., 10 meters), 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 item(s), including physical and radiological characteristics;
- a description of how the alternative approach differs from the CA BTP's position on encapsulation in Section 3.3.4;
- an overview of the proposed alternative provision (e.g., depth of burial), and how the alternative provision protects the intruder;
- a description of site characteristics pertinent to the proposal;
- a description of any source-containing devices, encapsulating media, and any additional packaging proposed for disposal;
- an analysis of the effects of degradation of packaging and engineered barriers over the period that the item remains hazardous to an intruder, as applicable; and
- an identification of the proposed limits for items to be disposed, based on the alternative inadvertent intruder analysis.

3.8.3 Likelihood of Intrusion

Inadvertent intrusion is only expected if required active controls and passive controls (e.g., markers and barriers) and societal memory of the site 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 (NAS,1995; ICRP,1998, paragraph 62). Therefore, an inadvertent intruder assessment typically does not explicitly consider a probability or likelihood of less than one of the inadvertent intrusion occurring. Rather, the assessment assumes reasonably conservative scenarios that could occur and evaluates the radiological consequences that individuals who might actually intrude onto the disposal site could experience if active and passive controls and societal memory were lost (NCRP, 2005; IAEA, 2008).

Therefore, an intruder assessment typically is based on the assumption that the intruder directly contacts the disposed waste. This assumption sometimes is characterized as an assumption that the probability of intrusion is 1. While it is accurate to say that intrusion analyses typically result in estimates of consequences (i.e., dose) rather than risk (i.e., dose multiplied by probability), it would be inaccurate to say the staff assumes intrusion will occur. Because it is not possible to make precise estimates of the probability of intrusion, the likelihood of intrusion is acknowledged implicitly in the 5-mSv/yr (500-mrem/yr) dose limit used for intruder protection. For example, the NRC has previously indicated that it is appropriate to use an intruder dose limit of 5 mSv/yr (500 mrem/yr) instead of 1 mSv/yr (100 mrem/yr), the public dose limit in 10 CFR Part 20, because intrusion is a "hypothetical" event that might not occur (NRC, 1994). This higher limit essentially provides for a 20 percent probability of intrusion. Furthermore, the 5-mSv/yr (500-mrem/yr) limit is greater by a factor of 20 than the 0.25-mSv/yr (25-mrem/yr) limit established in 10 CFR 61.41, "Protection of the General Population from Releases of Radioactivity," for protection of the general population from releases of radioactivity. This difference is largely attributable to the difference between the hypothetical nature of intrusion and the more likely possibility of exposure to small offsite releases, implying a 5 percent probability of intrusion. In addition, the inaccessibility of Class C waste to intruders was explicitly considered in establishing the Class C limits in 10 CFR 61.55, further reducing the implied probability of intrusion into Class C waste.

In some circumstances, the likelihood of intrusion might be considered in justifying the selection of scenarios different from those used in this CA BTP (described in Section 4 of Volume 2). As an example, construction of an exploratory water well could be considered as possible, and a domestic drinking water well very unlikely, in areas without viable sources of groundwater. This is an example of a site-specific approach that could be considered in preparing a proposal for concentration-averaging methods different from those described in this CA BTP. This provision for alternative approaches in this CA BTP cannot be used, however, to justify or approve alternatives to the waste classification tables in 10 CFR 61.55.

Notwithstanding the difficulty in quantitatively predicting future human activities, DOE's Order 435.1, "Radioactive Waste Management," requires that inadvertent intruder assessments be conducted at all DOE-owned disposal facilities in the unlikely case that the government loses those institutional controls. DOE allows consideration of the likelihood of intrusion scenarios. Its use of this provision has been limited to date, according to DOE. Licensees for commercial disposal facilities under long-term DOE control and stewardship could develop an alternative averaging approach to submit to a regulator based on intrusion scenarios and/or likelihoods different from this CA BTP.

3.8.4 Large Components

Sections 3.3.4 and 3.5 of this CA BTP on encapsulation and volume for averaging respectively specify averaging positions for containers of radioactive waste, such as a 0.2-m^3 (~55-gallon) drum. Other averaging approaches may be proposed by the applicant or licensee to the disposal facility regulator. For example, regulators have approved the disposal of a reactor vessel with highly radioactive internal hardware grouted into the vessel cavity 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). This approval and its disposition of technical and safety issues can be used as a model for other similar types of disposals.

3.8.5 Time of Intrusion into Blendable Waste

As described in Section 3.2.3 of Volume 1 and Section 4 of Volume 2, both the threshold volumes in Table 1 and the criterion for demonstrating waste is adequately blended are based on the potential dose to an individual who inadvertently exhumes waste from a hot spot in blendable waste. This analysis was conducted assuming an intruder drills into Class A waste at 100 years, Class B waste at 300 years, or Class C waste at 500 years. In practice, many Class A and B wastes are disposed of with robust engineered intruder barriers. If Class A or B waste is disposed of with a barrier that meets the requirements of 10 CFR 61.52(a)(2) for Class C waste, it might be appropriate to consider intrusion at 500 years instead of 100 or 300 years. Depending on the nature of the barrier and the drilling technique, barriers that meet the requirements of 10 CFR 61.52(a)(2) could preclude drilling scenarios during the lifetime of the engineered barrier and it might be appropriate to consider the effects of the barrier on the timing of possible inadvertent intrusion.

This alternative approach is not likely to be useful if the waste classification is controlled by long-lived radionuclides because the additional decay time gained with a robust barrier is unlikely to affect projected doses. However, licensees are encouraged to consider this approach for wastes with short-lived radionuclides of concern disposed of with robust barriers to intrusion that could preclude drilling scenarios beyond the end of institutional controls. Direct measurements to demonstrate the homogeneity of these wastes are likely to be unnecessary as well as counter to efforts to minimize worker dose in accordance with ALARA principles if a reasoned argument based on barriers to intrusion would demonstrate homogeneity.

3.8.6 Legacy Wastes

"Legacy wastes" means wastes that were generated by past activities (typically decades ago), that may not be well characterized for the purpose of disposal. Additional technical studies, characterization, treatment, or resources may be required to ensure that there is reasonable assurance that the intruder-protection performance objective and waste classification requirements in 10 CFR Part 61 can be met. Opening waste containers, removing individual items of waste, and fully characterizing them for the purposes of meeting the averaging constraints in this guidance could cause additional hazards to workers and might not be justified. In some cases, licensees may document averaging approaches that demonstrate that the provisions of this CA BTP have been met. For example, expected radionuclide concentrations based on process knowledge could be considered. In other cases, to avoid unnecessary waste handling and to minimize worker doses, a licensee may propose averaging provisions different from those in this CA BTP, such as spot checking of discrete items of legacy wastes. The alternative approach should be identified, documented, justified, and discussed with the disposal facility regulator. Wastes packaged for disposal whose classification is based on the 1995 CA BTP should still be acceptable for disposal.

3.9 Implementation

This CA BTP describes and makes available (to NRC and Agreement State licensees, Agreement States, and the public) methods that the NRC believes are acceptable for implementing specific parts of the Commission's regulations. The positions in this document are not intended as a substitute for regulations, and compliance with them is not required. Agreement States may use this information in establishing waste acceptance criteria for their licensees who are operating waste disposal sites. Subject to the limitations in the last paragraph of this section, applicants and licensees may use the information in this CA BTP when developing applications for initial licenses, amendments to licenses, or requests for NRC regulatory approval. Licensees may use the information in this CA BTP for actions (i.e., in determining average radionuclide concentrations in waste) that do not require prior NRC review and approval. Licensees may also use the information in this CA BTP to assist in attempting to resolve regulatory or inspection issues. Agreement States and current licensees may continue to use the previous guidance for complying with the concentration averaging provision in 10 CFR 61.55(a)(8), i.e., the January 17, 1995, "Final Branch Technical Position on Concentration Averaging and Encapsulation." Current licensees may also voluntarily use positions in this revised CA 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 land disposal facility license. Where there are conflicts with this guidance, the land disposal facility license conditions issued by the regulatory authority (currently, an Agreement State in all cases) must be met.

3.10 Backfit Considerations

This CA BTP revision describes a voluntary method that the NRC staff considers acceptable for complying with the regulation in 10 CFR 61.55(a)(8) regarding averaging of radionuclide concentrations for the purpose of determining waste classification. Compliance with this CA BTP is not an NRC requirement and licensees and applicants may choose this or another method to achieve compliance with this provision in the 10 CFR Part 61. In particular, current licensees may continue to use the averaging positions in the 1995 CA BTP. This CA BTP does not require a backfit analysis as described in 10 CFR 50.109(c), because the NRC is not imposing a new or amended provision in the NRC's rules or presenting a regulatory staff position that interprets the NRC's rules in a manner that is either new or different from a previous staff position, and it does not require the modification of or addition to the systems, structures, components, or design of a facility or the procedures or organizations required to design, construct, or operate a facility.

4. REFERENCES

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APPENDIX A: GLOSSARY

Blending Physically mixing two or more blendable waste streams to create a product with relatively uniform radionuclide concentrations.

Blendable Waste For the purposes of this CA BTP, a waste type is “blendable” if: (1) the waste can be physically mixed to create relatively uniform[48] radionuclide concentrations or (2) the waste is not expected to contain durable items with significant activity.

Concentration Averaging The mathematical averaging of radionuclide concentrations in waste over its volume or mass, for the purpose of determining its classification in accordance with Tables 1 and 2 in 10 CFR 61.55, “Waste Classification.”

Contaminated Materials Components or metals on which radioactivity resides near the surface in a fixed or removable condition. This term does not include other materials, such as plastic, wood, or glass.

Discrete Item For the purposes of this CA BTP, discrete items are items belonging to one of the following waste types: activated metals, sealed sources, cartridge filters[49], contaminated materials, and components incorporating radioactivity into their design. Items belonging to these waste types are designated as discrete items in this guidance because (1) they are expected to be durable (i.e., remain intact at the time of intrusion) and (2) items belonging to these waste types often have relatively high amounts or concentrations of radioactivity.

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.

Hot spot A portion of the overall waste volume whose radionuclide concentrations are above the class limit for the entire container. Hot spots can occur in blendable waste, single discrete items, or mixtures of discrete items. Because averaging is permitted under 10 CFR Part 61, “Licensing Requirements for Land Disposal of Radioactive Waste,” some exceedance of the limits is permissible for portions of the overall volume of the waste, as long as the average concentration of the container is within the class limit.

Primary Gamma- Cobalt-60 (^{60}Co), Niobium-94 (^{94}Nb), and Cesium-137 (^{137}Cs).

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48 Radionuclide concentrations are “relatively uniform” if an intruder who encounters the waste is unlikely to encounter waste more concentrated than the class limit by a factor of 10.

49 As described in Section 3.3.3, cartridge filters may be treated as blendable waste in some cases.

Emitting Radionuclides

Radionuclides of Concern Any nuclides in the waste in concentrations greater than either 1 percent of the concentration of that nuclide listed in Table 1 in 10 CFR Part 61 or 1 percent of the applicable class-dependent concentration of that nuclide in Column 2 or 3 of Table 2 in 10 CFR Part 61.

Radionuclides other than Primary Gamma-Emitting Radionuclides All 10 CFR 61.55 Table 1 and Table 2 radionuclides other than ^{60}Co, ^{94}Nb, or ^{137}Cs.

Solidification The process of incorporating radioactive material in a binding matrix to create a solid, physically and radiologically uniform material.

Stability As defined in 10 CFR Part 61, means structural stability. In the context of the concentration averaging, stability is a property of waste or a waste form.

Waste Stream Waste with relatively uniform radiological and physical characteristics. Often, the waste results from a single process.

Waste Type As defined in 10 CFR Part 20, “Standards for Protection against Radiation,” and for purposes of this CA BTP, a category of waste within a disposal container having a unique physical description (i.e., a specific waste descriptor code or description or a waste sorbed on or solidified in a specifically defined media). For example, ion exchange resins, soils, and activated metals are different waste types.

APPENDIX B: MAJOR CHANGES FROM 1995 TO 2015 CA BTP

1. Reorganized to improve readability. Added background material in Section 1, "Introduction," and Section 3, "Technical Position;" and added a Glossary of Terms. Consolidated and reorganized sections addressing discrete items (i.e., activated metals, sealed sources, cartridge filters, contaminated materials, and components incorporating radioactivity into their design) into one section, rather than the three in the 1995 Concentration-Averaging Branch Technical Position (CA BTP), because most averaging positions for each of these waste types are the same.
2. Changed the definition of "classification-controlling" to match the common-sense meaning of the term (i.e., radionuclides are classification-controlling if they are the main contributors to the table in 10 CFR 61.55, "Waste Classification," that results in a higher waste classification; see text in Section 3.3.2.2 for specific guidance). A new term, "radionuclide(s) of concern," has been given to the 1995 term "classification controlling radionuclides" to better describe their meaning.
3. Removed the "Factor of 10" rule for mixing blendable wastes to be consistent with the U.S. Nuclear Regulatory Commission (NRC) decision in SRM-SECY-10-0043, "Blending of Low-Level Radioactive Waste" (NRC, 2010b). Replaced it with a demonstration of adequate blending when blendable waste might contain an unacceptable hot spot.
4. Revised the provision for considering operational factors when blending waste in a generator's facility to include non-radiological operational safety. Previously, the guidance indicated that the Factor of 10 constraint on blending waste (previously referred to as mixing homogeneous waste types) did not apply to a "designed collection of homogeneous waste from a number of sources within a licensee's facility, for purposes of operational efficiency or occupational dose reduction." The revised position, specifying a test for whether a homogeneity demonstration is needed, does not apply to wastes aggregated in a generator's facility for the purpose of "operational efficiency, occupational safety, or occupational dose reduction."
5. Defined conditions under which cartridge filters may be treated as a blendable waste.
6. Changed the "Factor of 1.5" rule to a "Factor of 2" rule for primary gamma emitters. In addition, both the Factor of 2 and Factor of 10 rules are now linked to the classification limit (Class A, B, or C) of the mixture rather than to the average concentration, making them more risk-informed.
7. Consolidated averaging constraints on discrete items, so that radionuclides in a discrete item must meet either the Table 2 activity constraint or the Factor of 2 or 10 concentration limit, as applicable, for primary gamma-emitting radionuclides, and either the Table 3 activity constraint or Factor of 10 concentration limit for other than primary gamma-emitting radionuclides.
8. Increased the recommended activity limit for discrete items containing ^{137}Cs (from 1.1 TBq (30 Ci) to 4.8 TBq (130 Ci)) for Class C items, based on a new intruder scenario for Class C items.
9. Changed the cobalt-60 (^{60}Co) Ci discrete item activity limits for Class A from 26 TBq (700 Ci) to 5.2 TBq (140 Ci) (140 Ci is the activity resulting from the product of

the Class A limit times the volume of a 0.02 m^3 (55 gal.) drum), and for Class B from 26 TBq (700 Ci) to no limit, based on a new sealed-source scenario. See Section 4.3.1, "Small Item Carry-Away Scenario (Basis for Table 2)" in Volume 2 for details.

10. Clarified use of 10 CFR 61.58, "Alternative Requirements for Waste Classification and Characteristics," as applicable to alternatives to certain regulatory *requirements* as defined in 10 CFR 61.58, and not applicable to alternatives to *guidance* in the CA BTP.

11. Added guidance which states that, for encapsulated waste, container volumes up to 9.5 m^3 (331 ft^3) may be used for averaging (previously was 0.2 m^3 (55 gallons)), if the waste loading is at least 14 percent and the Factors of 2 and 10 constraints are met.

12. Added Alternative Approaches for Averaging section to CA BTP that provides guidance on using averaging approaches different from those specified in the document.

13. Altered and clarified the Technical Basis for Concentration Averaging and Encapsulation Guidance (Section 4 of Volume 2) to support the homogeneity demonstration for blendable wastes, the Factor of 2 and Factor of 10 constraints on mixtures of discrete items, and the radioactivity constraints on these same items.

14. Added the Safety Culture Policy Statement in Appendix C to Volume 1 and added background on the Policy Statement to the body of the CA BTP.

15. Added section "Backfit Considerations" that states that either the 1995 CA BTP or this revised version can be used by licensees.

16. Added Implementation section that addresses the use of this guidance, including the relationship between this revised CA BTP, the 1995 version, and disposal facility license conditions regarding concentration averaging.

APPENDIX C: SAFETY CULTURE STATEMENT OF POLICY

The safety culture policy statement was published in the *Federal Register* (76 FR 34773) on June 14, 2011 and can be found at http://www.gpo.gov/fdsys/pkg/FR-2011-06-14/pdf/2011-14656.pdf. It is also posted in the U.S. Nuclear Regulatory Commission's (NRC's) Agencywide Documents Access and Management System (ADAMS) Accession Number ML11146A047.

Safety Culture Policy Statement

The purpose of this Statement of Policy is to set forth the Commission's expectation that individuals and organizations establish and maintain a positive safety culture commensurate with the safety and security significance of their activities and the nature and complexity of their organizations and functions. This includes all licensees, certificate holders, permit holders, authorization holders, holders of quality assurance program approvals, vendors and suppliers of safety-related components, and applicants for a license, certificate, permit, authorization, or quality assurance program approval, subject to NRC authority. The Commission encourages the Agreement States, Agreement State licensees, and other organizations interested in nuclear safety to support the development and maintenance of a positive safety culture as articulated in this Statement of Policy.

Nuclear Safety Culture is defined as the core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment. Individuals and organizations performing regulated activities bear the primary responsibility for safety and security. The performance of individuals and organizations can be monitored and trended and, therefore, may be used to determine compliance with requirements and commitments and may serve as an indicator of possible problem areas in an organization's safety culture. The NRC will not monitor or trend values. These will be the organization's responsibility as part of its safety culture program. Organizations should ensure that personnel in the safety and security sectors have an appreciation for the importance of each, emphasizing the need for integration and balance to achieve both safety and security in their activities. Safety and security activities are closely intertwined. While many safety and security activities complement each other, there may be instances in which safety and security interests create competing goals. It is important that consideration of these activities be integrated so as not to diminish or adversely affect either; thus, mechanisms should be established to identify and resolve these differences. A safety culture that accomplishes this would include all nuclear safety and security issues associated with NRC-regulated activities.

Experience has shown that certain personal and organizational traits are present in a positive safety culture. A trait, in this case, is a pattern of thinking, feeling, and behaving that emphasizes safety, particularly in goal conflict situations, e.g., production, schedule, and the cost of the effort versus safety. It should be noted that although the term "security'' is not expressly included in the following traits, safety and security are the primary pillars of the NRC's regulatory mission. Consequently, consideration of both safety and security issues, commensurate with their significance, is an underlying principle of this Statement of Policy.

The following are traits of a positive safety culture:

1. Leadership Safety Values and Actions—Leaders demonstrate a commitment to safety in their decisions and behaviors;
2. Problem Identification and Resolution—Issues potentially impacting safety are promptly identified, fully evaluated, and promptly addressed and corrected commensurate with their significance;
3. Personal Accountability—All individuals take personal responsibility for safety;
4. Work Processes—The process of planning and controlling work activities is implemented so that safety is maintained;
5. Continuous Learning—Opportunities to learn about ways to ensure safety are sought out and implemented;
6. Environment for Raising Concerns—A safety-conscious work environment is maintained where personnel feel free to raise safety concerns without fear of retaliation, intimidation, harassment, or discrimination;
7. Effective Safety Communication—Communications maintain a focus on safety;
8. Respectful Work Environment—Trust and respect permeate the organization; and
9. Questioning Attitude—Individuals avoid complacency and continuously challenge existing conditions and activities in order to identify discrepancies that might result in error or inappropriate action.

There may be traits not included in this Statement of Policy that are also important in a positive safety culture. It should be noted that these traits were not developed to be used for inspection purposes. It is the Commission's expectation that all individuals and organizations performing or overseeing regulated activities involving nuclear materials should take the necessary steps to promote a positive safety culture by fostering these traits as they apply to their organizational environments. The Commission recognizes the diversity of these organizations and acknowledges that some organizations have already spent significant time and resources in the development of a positive safety culture. The Commission will take this into consideration as the regulated community addresses the Statement of Policy.