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Implementation Guidance for the Nuclear Regulatory Commission Branch Technical Position on "Concentration Averaging and Encapsulation, Revision 1"

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Product Description

The United States Nuclear Regulatory Commission (US NRC) published a revision to the Branch Technical Position (BTP) on "Concentration Averaging and Encapsulation" in 2015. The US NRC refined many of the positions from the original 1995 BTP in order to provide more clarified guidance. Both revisions to the BTP remain in effect as valid guidance. The Electric Power Research Institute (EPRI) collaborated with an industry working group to develop this Implementation Guide for applying the BTP to nuclear power plant-specific waste streams.

Background

Starting in 2007, EPRI conducted research to better understand the bases of the BTP on "Concentration Averaging and Encapsulation" and 10 Code of Federal Regulations (CFR) 61 "Licensing Requirements for Land Disposal of Radioactive Waste." Through this research, EPRI identified three regulatory initiatives that could be pursued to enhance disposal options for the industry: the first was to revise the BTP to allow broader blending of compatible waste types; the second was to examine how 10 CFR 61.58 "Alternative requirements for waste classification and characteristics" could be used to allow alternative disposal criterion based on site-specific characteristics and end land use scenarios; and third was to develop a technical basis for risk informed disposal regulations in anticipation of 10CFR61 rulemaking. These initiatives directly follow the NRC strategic assessment, and by the summer of 2015, they had been broadly addressed and resulted in the NRC revising the BTP on "Concentration Averaging and Encapsulation."

Revision 1 to the BTP on "Concentration Averaging and Encapsulation" provides guidance to determine appropriate volumes and masses to use for calculating average concentrations to determine waste classification in accordance with 10CFR61.55 "Waste Classification." It introduces two broad categories of waste for the purposes of concentration averaging; blendable or discrete, and provides guidance on how to apply concentration averaging for both categories of waste in order to manage the risk to an individual who could hypothetically intrude on the low level radioactive waste (LLRW) in a disposal facility.

Objectives

To provide guidance for implementing Revision 1 of the US NRC Branch Technical Position on "Concentration Averaging and Encapsulation" to nuclear power plant-specific radioactive waste.

Approach

EPRI brought together a Working Group composed of individuals from the nuclear power plants, the NRC, LLRW disposal facilities, waste classification experts, and the state regulatory bodies to develop a guide for implementing the BTP to nuclear power plant radwaste. The Implementation Guide was developed in collaboration with the Working Group to ensure consistent application of the BTP during waste generation, packaging, processing, and disposal activities associated with nuclear power plant waste.

Results

The EPRI Implementation Guide summarizes the guidance in the BTP, explains any differences between the previous (1995) and the current (2015) versions of the BTP, and provides examples of applying the BTP to the types of radwaste that could be generated from nuclear power plants. The BTP and this EPRI Implementation Guide discuss waste characterization (both radiological and physical) and the concentration averaging of blendable wastes and discrete items. This document provides guidance for applying concentration averaging to nuclear power plant wastes such as primary resin, fuel pool resin, secondary resin, solidified evaporator concentrates, solidified resin, solidified shredded cartridge filters, control rod blades, sealed sources, activated metal bolts, activated fuel channels, encapsulated sealed sources, and encapsulated filters.

Application, Values, and Use

The disposal cost of LLRW depends on the class of the waste, with higher class LLRW (Class B/C) disposal costs more than lower class LLRW (Class A). The application of the BTP on concentration averaging with the assistance of this guidance will ensure that nuclear power plants can dispose of LLRW in accordance with waste classification and disposal regulations more cost effectively. International nuclear power plants, utilities, and regulatory bodies can review, benchmark, and apply the BTP and EPRI Implementation Guidance as appropriate in their own countries.

Keywords

Low level waste
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PRIMARY AUDIENCE: Nuclear Power Plant Radioactive Waste Managers and Shippers

SECONDARY AUDIENCE: Nuclear Power Plant/Utility Radiation Protection Managers responsible for the management of radioactive waste

KEY RESEARCH QUESTION

The United States Nuclear Regulatory Commission (US NRC) published Revision 1 of the Branch Technical Position (BTP) on "Concentration Averaging and Encapsulation" in 2015. This BTP provides guidance for establishing the weight and volume used to determine activity concentration and calculating the appropriate waste classifications. The BTP 2015 has refined many of the positions from the original 1995 BTP in order to provide more clarified guidance. Both revisions to the BTP remain in effect as valid guidance. The objective of this research project was to develop an implementation guide to support the consistent and compliant application of the BTP 2015 at nuclear power plants.

RESEARCH OVERVIEW

EPRI brought together a Working Group composed of waste classification experts, individuals from the nuclear power plants, the NRC, low level radioactive waste (LLRW) disposal facilities, and the agreement state regulatory bodies to develop a guide for implementing the BTP 2015 to nuclear power plant LLRW. The Implementation Guide was developed in collaboration with the Working Group to ensure consistent application of the BTP 2015 during waste generation, packaging, processing, and disposal activities associated with nuclear power plant waste. The EPRI Implementation Guide summarizes the guidance in the BTP, explains any differences between the previous (1995) and current (2015) versions of the BTP, and provides examples of applying the BTP to the types of LLRW that could be generated from nuclear power plants. The EPRI Implementation Guide provides guidance for applying concentration averaging to nuclear power plant wastes, such as primary resin, fuel pool resin, secondary resin, solidified evaporator concentrates, solidified resin, solidified shredded cartridge filters, control rod blades, sealed sources, activated metal bolts, activated fuel channels, encapsulated sealed sources, and encapsulated filters. In many cases, proper application of this guidance could result in lower volumes of Class B and C waste.

KEY FINDINGS

- The BTP 2015 is a significant improvement over the BTP 1995. The NRC has refined many of the positions in the interest of clarification, and recognized many of the processes that have developed over the years. It also reiterates past NRC positions on related topics and provides a perspective on what was originally intended by the BTP 1995.
- The BTP 1995 was inconsistent when describing the issue of blending. The term 'blending' was not used at all. Instead, the concept of homogeneity was discussed. The BTP 1995 did not specifically address the difference between waste types and waste streams. There was no clear definition for when a waste was homogeneous, although the same basic waste types were discussed as examples. **The BTP 1995** identified collections of homogeneous waste types from sources within a facility to not

of the mixture average as a limitation on a 'mixture' of waste types. Since **the constraints were based on the average concentration of the mixture rather than the waste classification limits**, situations resulted where a mixture of two components could meet the concentration limits and constraints for a particular waste class, but the addition of lower activity material in the same waste class would seem to require a higher waste classification. **The guidance in the BTP 2015 is based on the waste classification limits** and is more technically defendable and consistent with the risk assessment inherent in the waste classification system.

- **The constraints on mixing 'blendable' waste are essentially removed.** The BTP 1995 limited the concentration of blended waste streams to within a factor of 1.5 or 10 of the package average. The BTP 2015 establishes volumes of waste with concentrations relative to the waste class limit beyond which a demonstration of mixing is required, but not otherwise constraining the ability to blend. The BTP 2015 adjusts the position of the BTP 1995 that an aggregation of wastes within a licensee's facility combined for operational efficiency, occupational safety, or occupational dose reduction may be considered the same waste stream and is not subject to demonstrations of blending.
- The use of the term 'discrete items' is subtly different than that found in the BTP 1995. The BTP 2015 clearly includes activated metal objects as discrete items. High activity contaminated items such as valve components or cartridge filters from primary systems that are 'durable' in the disposal environment could represent an exposure risk in one of the carry-away scenarios and are therefore treated as discrete items. The treatment of these types of items for concentration averaging is consistent with the BTP 1995 with the exceptions that (1) the factors of 1.5 and 10 are now factors of 2 and 10 and are applied at the classification level rather than the package average, (2) the licensee has the option of applying BTP 2015 Tables 2 and 3 instead of the Factors of 2 and 10. While the BTP 2015 and the BTP 1995 treat these items similarly, their labeling is different. The BTP 1995 labeled these items 'components' and reserved the term 'discrete' for a subset of these items. The BTP 2015 more broadly applies the definition of a discrete item. The terminology is different, but the intended treatment remains similar.
- **The BTP 2015 provides alternate methods to classify cartridge filters.** By definition, they are discrete items and should be evaluated as discussed above. However, an evaluation can be performed and documented to show that the type of cartridge filter or the manner in which activity is contained in or on it will not remain durable in the disposal environment or the filter will otherwise not exhibit the same characteristics of a discrete item. In this case, the cartridge filter may be treated as a blendable waste form. The BTP 1995 did not contain any similar guidance.
- **The BTP 2015 provides alternate approaches to concentration averaging to be evaluated and approved by the appropriate disposal site regulator.** This is a new pathway for evaluation and approval of approaches not described in the BTP that could be acceptable **without the need to implement the approval by the US NRC** in accordance with the provisions of 10CFR61.58.

WHY THIS MATTERS

LLRW disposal costs depend on the class of the waste. Generally, higher class LLRW (e.g. Class B/C) costs more to dispose of than lower class LLRW (e.g. Class A.) Furthermore, in the United States there is currently no disposal option for Greater than Class C (GTCC) wastes. The application of the BTP on concentration averaging with the assistance of the EPRI Implementation Guide will ensure that nuclear power plants can dispose of LLRW in accordance with waste classification and disposal regulations more cost effectively. Also, the application of concentration averaging can help nuclear power plants reduce the cost associated with storing GTCC wastes on-site. International nuclear power plants, utilities, and regulatory bodies can review, benchmark, and apply the BTP and EPRI Implementation Guidance as appropriate in their own countries.

HOW TO APPLY RESULTS

Nuclear power plant radioactive waste managers should review the US NRC Branch Technical Position on "Concentration Averaging and Encapsulation, Revision 1" (2015) and the EPRI Implementation Guide, and implement concentration averaging as appropriate to LLRW classification at their sites. In some cases, changes to operational practices and/or design modifications should be considered in order to increase the efficiency of blending multiple waste streams.

LEARNING AND ENGAGEMENT OPPORTUNITIES

- The EPRI Low Level Waste Technical Strategy Group (LLW TSG) provides a forum for additional technical discussions, knowledge transfer, benchmarking, and research. If desired by members of the LLW TSG, additional technical discussion and knowledge transfer on the use of the BTP can be arranged.

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Abbreviations and Conversions

Pound (lb)	=	454	grams (g)
	=	0.454	kilograms (kg)
Cubic Foot (ft^3)	=	2.83E-02	Cubic Meters (m^3)
	=	2.83E+04	Cubic Centimeters (cm^3)
Curie (Ci)	=	3.70E+10	Bequerels (Bq)
	=	37	Gigabequerels (GBq)
	=	0.037	Terabequerels (TBq)
Millicurie (mCi)	=	37	Megabequerels (MBq)
Microcurie (µCi)	=	37	Kilobequerels (KBq)
Nanocurie (nCi)	=	37	Bq
Millirem (mrem)	=	0.01	Millisievert (mSv)

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Section 1: Introduction

EPRI began research in 2007 to better understand the basis of the Branch Technical Position (BTP) on "Concentration Averaging and Encapsulation", published as Revision 0 in 1995, and 10 CFR 61 "Licensing Requirements for Land Disposal of Radioactive Waste". This research identified three regulatory initiatives that could be pursued to enhance disposal options for the industry. [1] [2] These initiatives directly follow the United States Nuclear Regulatory Commissions (NRC) strategic assessment issued in 2007. [3] The first initiative was to revise the BTP to allow broader blending of compatible waste types. The second was to examine how Title 10 Code of Federal Regulations (CFR) Section 61.58 "Alternative requirements for waste classification and characteristics" could be used to allow for an alternative disposal criterion based on site-specific hydro-geological characteristics and end land use scenarios. And, the third was to develop a technical basis for risk informed disposal regulations in anticipation of a 10 CFR 61 ("Licensing requirements for land disposal of radioactive waste") rulemaking. These initiatives were broadly addressed by the initial EPRI research and more specifically addressed in comments to the NRC as part of the effort to revise the BTP. Subsequently, the NRC issued Revision 1 to the BTP in February of 2015 (BTP 2015) directly addressing concentration averaging issues. [4]

The BTP 2015 is a significant improvement over the 1995 BTP (BTP 1995). [5] [6] The NRC has altered many of its positions in the interest of clarification and recognized many of the processes that have developed over the years. It also reiterates past NRC positions on related topics and provides a perspective on what was originally intended by the BTP 1995.

This guide for applying the BTP 2015 to industry-specific waste streams is intended to ensure consistent application of the BTP 2015 during waste generation, processing and disposal activities allowing for clear and consistent determination of waste classification. This guide has been vetted and supported by industry participants (including utilities, disposal sites, and industry experts). Representatives of regulatory entities (NRC and Agreement States) also assisted in the preparation of this document.

The BTP 2015 provides guidance to determine appropriate volumes and masses to use for calculating concentrations to determine waste classification in accordance with 10 CFR 61.55 ("Waste classification"). The primary purpose of the waste classification system is to manage the risk to an individual who could hypothetically intrude into Low Level Radioactive Waste (LLRW) in a disposal facility and inadvertently come into contact with the waste disposed there. [7] [4]

The BTP provides further clarification and addresses specific hypothetical intruder scenarios that serve to constrain potential pockets of higher radioactivity or 'hot spots' in the waste. [4] The BTP provides generic provisions that are meant to apply to any situation. As such, they do not necessarily represent any particular situation or disposal site. [4] Guidance for the development of alternative approaches is also provided so that conditions more applicable to specific disposal sites or waste types can be addressed. [4]

The BTP 2015 introduces two broad categories of waste for the purposes of concentration averaging; blendable and discrete. Blendable wastes can be brought together in a mixture that results in a relatively uniform distribution of activity and is generally not expected to contain hot spots that could pose a hazard to an inadvertent intruder. Discrete wastes are items that will retain their form and an activity concentration of concern throughout the disposal process and may pose a 'carry-away' hazard to the inadvertent intruder. These concepts are explained in more detail in the following sections. A schematic overview of the BTP 2015 process is shown in Figure 1 of the BTP 2015 and is reproduced here.

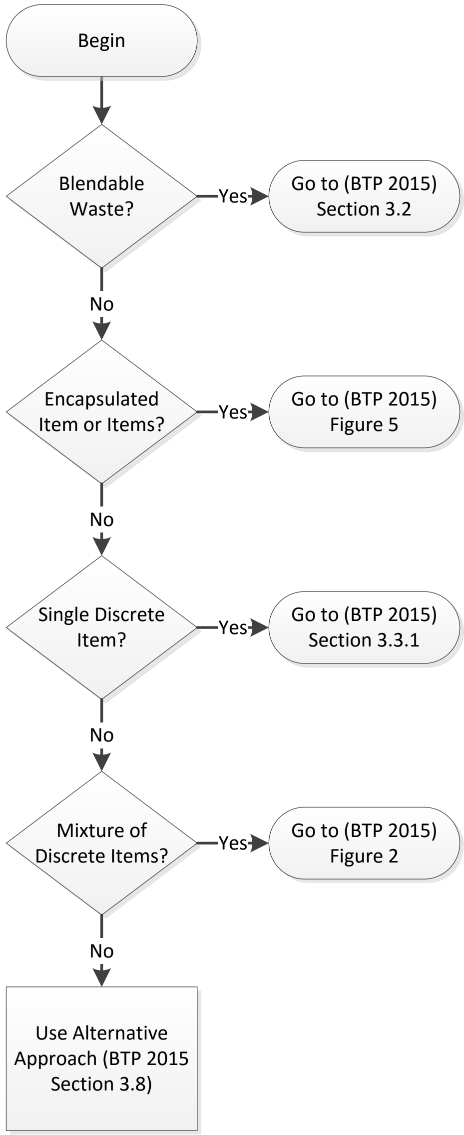


Figure 1-1
BTP 2015 Figure 1 – Overview [4]

The guidance in this document is intended to supplement and explain the concepts in the BTP 2015 with real-life examples of utility waste. It is not a replacement for the actual NRC guidance, nor is it intended to conflict with the BTP 2015. In the course of developing implementation examples in this document, preliminary waste classifications are provided as a means for demonstrating the results of averaging calculations. These preliminary classifications, like shipments to radioactive waste processors, have no meaning with regard to the actual waste classification which is based on the final waste form as presented for disposal consistent with NRC guidance. [8] In some examples, isotopic activities, weights, volumes, and types and volumes of binding agents were adjusted to specifically demonstrate aspects of the averaging guidelines and may not represent true utility waste conditions. This document also does not specifically address any restrictions or requirements from Agreement States or site-specific waste acceptance criteria. It remains the responsibility of the generator to evaluate such restrictions prior to sending waste for disposal to a particular site.

The BTP 2015 is guidance from the NRC and therefore the strongest word used in the BTP 2015 is 'should'. In this EPRI document, the words must, shall or required may be used in discussing the application of the BTP 2015. In these cases, the words must, shall or required mean that the action should be performed or the action will not be in accordance with the BTP 2015 guidance. If a licensee chooses not to implement the guidance as discussed in the BTP 2015 or the BTP 1995 as authorized by the appropriate Agreement State Regulator, then the licensee would need to consider the methodology under BTP 2015 Section 3.8, 'Alternative Approaches for Averaging'.

Section 2: Waste Characterization

The first technical section of the BTP 2015 addresses waste characterization. This is the process of identifying the physical and radiological characteristics of the waste. The BTP 2015 broadly categorizes LLRW into two groups; blendable waste or discrete items. [4] The BTP 2015 also uses the terms 'waste streams' and 'waste types' in a manner that is slightly different from the BTP 1995. It is important to recognize the distinction and apply the terms as they are used in the BTP 2015. It is also important to recognize that 'waste streams' and 'waste types', as used in the BTP 2015 may be different than the waste streams defined by each site to develop sampling programs and the establishment of isotopic distributions. The definitions as used in the BTP 2015 are meant to be applied only to concentration averaging.

Identifying Waste Streams

Guidance

The BTP 2015 describes a waste stream as having "…relatively uniform radiological and physical characteristics". [4] The term 'relatively uniform' is described in footnote 24 as concentrations where "…an intruder who encounters the waste is unlikely to encounter waste more concentrated than the class limit by a factor of 10 or more." [4] Relative uniformity for blendable waste types can therefore only be defined in terms of the context of the process of generating the final waste form and within the constraints defined in the BTP 2015. EPRI documents define a waste stream as any waste product or mixture of products where the Difficult-to-Measure (DTM) radionuclide concentrations can be inferred by the use of a single set of scaling factors. [9] In practical terms, the waste stream is used to define the radiological characteristics of the waste while the physical characteristics are defined by the waste type. Mixed-ion exchange bead resin is a waste type (physical properties) that may be used in different systems and have different radiological properties (waste streams). Some systems may use different waste types (resin and charcoal) in the same or different vessels to process the same fluid. For the purpose of sampling programs, the radiological properties may be similar enough for the different types to be considered the same waste stream; however, as used in the BTP 2015 they would be considered separate waste streams.

The use of the terms waste streams and waste types in the BTP 2015 is slightly different than current industry understanding and may lead to some confusion. NRC Staff published answers to questions raised by stakeholders related to the use of the terms ‘waste streams’ and ‘waste types’. [10] The following excerpt describes the NRC’s view:

> ‘As defined in the [BTP 2015], a waste type has a “unique physical description” and a waste stream has both “relatively uniform radiological and physical characteristics.” Under the [BTP 2015], waste streams are subsets of waste types. That is, a waste type could contain separate waste streams, but a single waste stream would not include more than one waste type. Stakeholders have noted that there appears to be a different standard for physical uniformity applied to waste types as compared to waste streams, noting “a unique physical description” could be interpreted to be a more stringent standard than “relatively uniform” physical characteristics. Under the [BTP 2015], there is no distinction between these two phases. The term “unique physical description” was used for consistency with the definition of waste type in 10 CFR Part 20. For the purposes of the [BTP 2015] waste types are not more physically uniform than waste streams.’
>
> ‘Other stakeholders asked specifically if mixed-bed resins represented a single waste stream that contains more than one waste type. For the purposes of the [BTP 2015], the purpose of distinguishing blendable waste types from one another is to determine when physical and chemical compatibility should be documented. In this case, because the different physical materials in a mixed bed resin are used in contact with one another, the physical and chemical compatibility are generally apparent, and the mixed bed resin can generally be treated as a single waste type for the purposes of the [BTP 2015].’

It is clear from this response that the specificity of these terms as used in the BTP 2015 is meant to ensure that waste presented for disposal is physically and chemically compatible. The definition of waste stream may be different when evaluating other aspects of the characterization program such as establishing sample points or determining the applicability of scaling factors.

Implementation Examples

The BTP 2015 refers to NRC Information Notice 86-20, “Low Level Radioactive Waste Scaling Factors, 10CFR Part 61” to provide examples of basic waste streams from nuclear power plants divided by Pressurized Water Reactors (PWR) and Boiling Water Reactors (BWR). [4] These are: [11]

- Primary Purification Filters (PWR)
- Primary Purification Resins (PWR)
- CVCS Evaporator Bottoms (PWR) (CVCS = Chemical and Volume Control System)
- Radwaste Polishing Resins (PWR)
- Secondary System Wastes (filters and resins) (PWR)

- Dry Active Waste (PWR)
- Cleanup filters/Resins (BWR)
- Condensate Polishing Resins (BWR)
- Evaporator Bottoms (BWR)
- Radwaste Ion Exchange Resins (BWR)
- Dry Active Waste (BWR)

This list is not meant to be proscriptive or comprehensive and other waste stream names can be used. Such as:

- Contaminated oils
- Silt
- Contaminated metal
- Sludge
- Charcoal
- Zeolite
- Irradiated concrete
- Debris/rubble
- High Rad Trash

Many power plants continue to use these basic waste stream designations although some use different names based on site-specific nomenclature. The development of alternate filtration or cleanup liquid processing technologies such as charcoal filtration and reverse osmosis has introduced waste stream names not identified in earlier guidance documents. Not noted in the list but discussed specifically as separate waste types are activated metals, sealed sources and soil. [4] It is important to note that for the purposes of the BTP 2015, the waste stream is a subset of waste types and is to be defined based on characteristics, not an arbitrary list of names. The BTP 2015 use of the term 'waste streams' is not meant to supersede waste characterization program definitions used to establish sampling or analysis requirements. An analysis of radiological characteristics from different named waste streams may show that they can be combined for the purposes of establishing sample requirements. The use of process knowledge to evaluate data obtained from samples to ensure a waste stream is adequately described is central to the characterization process as described in the BTP 1983 "Low-Level Waste Licensing Branch Technical Position on Radioactive Waste Classification".

Comparison to Previous Guidance

The BTP 1995 did not specifically mention waste stream definitions outside of the broad based descriptions used in the actual guidance. The importance of waste streams is expanded and more important to the issues of blending discussed in the BTP 2015. The distinction is necessary to differentiate waste streams with respect to the treatment of Blendable Waste. As discussed below, blendable waste streams must still be defined in terms of the initial concentrations to determine the need for demonstrations of adequate blending (see Section 3.2 and Table 1 of the BTP 2015).

Identifying Waste Types

Guidance

The BTP 2015 describes a waste type as waste having "…relatively uniform physical characteristics." [4] This description is slightly different than in the glossary section of the BTP 2015 which states that a 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." [4] As used in the BTP 2015, the waste type is used to establish physical and chemical compatibility of the waste as packaged for disposal.

Implementation Examples

Primary and secondary resins are examples of the same waste type even though they may be different waste streams. Soil would be a different waste type from resin. [4] A mixture of resin and charcoal from a system that uses both materials during operation could also be considered a single waste type if the resin and charcoal are used in a way that makes their physical and chemical compatibility generally apparent (e.g., in a mixed bed). Alternately they can be considered separate waste types and can be disposed of together if their physical and chemical compatibility is documented. [10]

Comparison to Previous Guidance

The BTP 1995 did not specifically mention waste type definitions outside of the broad based descriptions used in the actual guidance. In practical terms, the waste type is used to define the physical characteristics of the waste while the radiological characteristics are used to define the waste stream. The importance of waste types is essential to the issues of blending discussed in the BTP 2015. The distinction is necessary to differentiate waste types with respect to the treatment of Blendable Waste or Discrete Items. As discussed below, blendable waste types must be demonstrated to be physically and chemically compatible when mixed to ensure there are no adverse reactions during disposal (see Section 3.2.2 and Section 3.4 of the BTP 2015).

Physical Characterization

Guidance

The BTP 2015 describes physical characterization specifically in the context of the guidance for the purposes of concentration averaging. LLRW is either 'blendable' or discrete. [4]

Blendable waste is any waste that can be mixed or blended where the constituents, especially radiological constituents, are distributed throughout the mixture. Resins, filter media and soils are the clearest examples, but the guidance also includes compactible and non-compactible trash in this category because the trash typically does not include "…discrete, durable items that would be a hazard to an inadvertent intruder". [4] A durable item that does not contain a high concentration of radioactivity does not pose a hazard to the inadvertent intruder and is included in the definition of blendable waste. It is not intended that durability is to be determined as part of field evaluations.

Discrete items are items that are expected to be durable beyond the period of institutional control AND have relatively high concentrations of radioactivity. They are specifically identified as the following waste types: [4]

1. Activated metals
2. Sealed sources
3. Cartridge filters (with exceptions)
4. Contaminated materials
5. Components incorporating radioactive material in their design (e.g. radium-dial watches)

Comparison to Previous Guidance

The term 'blendable waste' is different and distinct from the BTP 1995 which used the term 'homogeneous' to describe these kinds of waste types. Part of the BTP 2015 objective was to more clearly define homogeneity in blendable waste due to concerns that 'pockets' of higher concentration waste may persist in a blended product package. [12] This concept recognizes that true homogeneity is not only impractical but also not necessary. Homogeneous wastes are wastes where the radionuclide concentrations are likely to approach uniformity in the context of the intruder scenarios. [6]

The constraints on mixing 'blendable' waste are essentially removed. The BTP 1995 limited the concentration of blended waste streams to within a factor of 10 of the package average. The BTP 2015 establishes volumes of waste in Table 1 with concentrations relative to the waste class limit beyond which a demonstration of mixing is required but not otherwise constraining the ability to blend. The BTP 2015 maintains the position of the BTP 1995 that a collection of wastes within a licensee's facility combined for operational efficiency, occupational safety, or occupational dose reduction is not subject to averaging constraints. This reasoning is based in part on NRC experience with these wastes and the staff determination that potential hot spots in these wastes are unlikely to present significant hazards to an inadvertent intruder." [12] Blending at a processing facility is expected to be readily controlled as part of a demonstrable process to prevent 'hot spots'. The end result is recognition that the radionuclide concentration in the final package is the important aspect for waste classification.

The distinction between dry active waste (DAW) (as a blendable waste type) and 'durable' contaminated material with 'significant activity' (discrete item) is not entirely clear. The description of contaminated materials (as discrete items) exists in the BTP 1995 and was included in BTP 2015 so as not to disrupt current practices.[1] The BTP 2015 does not address how to make this distinction and does not suggest that a formal evaluation or field test is necessary. An approach that seems reasonable is to consider durable contaminated materials that should be considered discrete items as having activity commensurate with BTP 2015 Table 2 and 3 values. Licensees may be able to demonstrate that a DAW waste stream does not contain (discrete) contaminated materials through a documented evaluation rather than assessments of individual items.

The use of the term discrete items is subtly different than that found in the BTP 1995. The BTP 2015 clearly includes activated metal objects as discrete items. High activity contaminated items such as valve components or cartridge filters from primary systems that are 'durable' in the disposal environment could represent an exposure risk in one of the carry-away scenarios and are therefore treated as discrete items. The treatment of these types of items for concentration averaging is consistent with the BTP 1995 with the exceptions that (1) the factors of 1.5 and 10 are now factors of 2 and 10 and are applied at the classification level rather than the package average, (2) the licensee has the option of applying BTP 2015 Tables 2 and 3 instead of the Factors of 2 and 10. While the BTP 2015 and the BTP 1995 treat these items similarly, the labeling of them is different. The BTP 1995 labeled these items as 'components' and reserved the term 'discrete' for a subset of these items. The BTP 2015 more broadly applies the definition of a discrete item. The terminology is different but the intended treatment remains similar.

Sealed sources are not defined in either the BTP 1995 or the BTP 2015 except in terms of activity. The NRC defines a sealed source as "…any byproduct material that is encased in a capsule designed to prevent leakage or escape of the byproduct material". [13] The International Atomic Energy Agency (IAEA) defines a sealed radioactive source as "…radioactive material that is permanently sealed in a capsule or closely bonded and in a solid form. The source is designed to contain the radioactive material under normal operating conditions and usually has high concentration of radioactive material in a small volume." [14] The

[1] NRC acknowledged in the Notice of Availability for the BTP that "Neither the 1995 CA BTP nor draft revisions published for public comment provided guidance for categorizing items as either contaminated materials or radioactive trash. In addition, the staff received no comments from stakeholders on this issue. The staff will consider whether additional guidance, such as a Regulatory Issue Summary (RIS), is warranted for distinguishing contaminated materials from radioactive trash."

characterization guidance for sealed sources in both versions of the BTP is equivalent (differences in averaging guidance applicable to sealed sources are discussed in subsequent sections).

Radiological Characterization

Guidance

The BTP 2015 refers to Sections C.1 and C.2 in the BTP 1983 as currently applicable to identifying and quantifying radionuclide activities in LLRW. [4] There are four basic methods for radiological characterization of waste. [15] [4] The BTP 1983 and the BTP 2015 use slightly different words to mean the same thing.

- Materials accountability (1983 & 2015)[2],
- Classification by source (1983 & 2015)
- Gross radioactivity measurements (1983 & 2015)
- Direct measurement of individual radionuclides (1983) / Measurement of specific radionuclides (2015)

The level of complexity of any particular radiological characterization program depends on the nature of the method of waste generation and the ability of the licensee to effectively implement the characterization method. Any or all of the characterization methods can be used in conjunction for particularly complex generation processes and nuclear power facilities are expected to employ a combination of methods. [15]

Quantification of activity for radioisotopes identified in 10 CFR 61.55 is required in order to determine concentrations for waste classification. [7] The lower limit of detection (LLD) for a measurement of a particular radionuclide should be no more than 0.01 times the concentration for that radionuclide listed in 10 CFR 61.55 Table 1 and 0.01 times the smallest concentration for that radionuclide listed in 10 CFR 61.55 Table 2. [15]

The total activity of the radionuclides ^{3}H, ^{14}C, ^{99}Tc and ^{129}I as well as the total masses of ^{233}U, ^{235}U and isotopes of plutonium are required to be reported in waste manifests for shipment. [16] Where the isotopic quantities of ^{3}H, ^{14}C, ^{99}Tc and ^{129}I are based on LLD values, the quantities are to be expressed as the sum of the LLD-based quantities. [17] In lieu of using LLD values for DTM radionuclides, indirect methods such as scaling factors, materials accountability or computer codes that estimate the activity of radionuclides may be used to report the concentration of radionuclides. [18] Indirect methods may also be used for other radionuclides. [18]

[2] Section 3.1.4 of the BTP 2015 states "compliance through materials compatibility". NRC acknowledges this is a typographical error and was intended to mean "materials accountability" consistent with the BTP 1983. [10]

There are different interpretations of NRC guidance as to the inclusion of concentrations for the radionuclides ^{3}H, ^{14}C, ^{99}Tc and ^{129}I in waste classification calculations if they are based on LLD values. One interpretation is that these four radionuclides should be included in waste classification even when they are based on LLD values. The examples in this document contain radionuclide quantifications and waste classifications that in some cases are based on LLD measurements from sample data (these are identified in the classification tables with '<' symbols.) Another interpretation is that they do not need to be included when they are based on LLD values. Neither interpretation is expected to have a large impact on the waste classification or concentration averaging if the LLD values are consistent with the NRC guidance on LLD values in the 1983 BTP on Waste Classification[3]. This issue is broader than this implementation guide for the NRC BTP on concentration averaging and is relevant to all issues related to waste classification. NRC Staff has been asked to clarify the guidance on this issue and may provide clarification in future guidance. Until such time as the NRC provides further clarification on this issue, EPRI has no position on which approach is used.

Blendable items generally require less specific methods of characterization while discrete items should be individually characterized to account for averaging constraints. [4] The radioactivity content of contaminated items may be determined from representative swipes.

Implementation Examples

Compliance through materials accountability is a program where a quantity (and resulting concentration) of radioactive material may be known or inferred in a given waste quantity by determining the difference between the quantity of radioactive material entering and exiting a given process. [15] The radioactive material quantity can be measured or inferred through calculation (such as activation analysis) and distribution determined through knowledge of the process or measurements of influent and effluent waste streams. [15] Specific examples include: [15]

- Biomedical research facility where a known quantity of a known radioisotope is distributed in a specific manner to items that later become radioactive waste.
- Research facility (or nuclear power plant) performing activation analysis on known quantities of specific metals exposed to a known neutron flux.
- Nuclear power plant determining radioactive material content in a resin bed by measuring the influent and effluent of the resin vessel.

Classification by source is similar to materials accountability where the radioactivity content and concentration of the waste is determined through

[3] The 1983 BTP indicates that the LLDs for radionuclides identified in 10 CFR 61.55 should be 0.01 times the 10 CFR 61.55 Table 1 value or 0.01 times the lowest § 61.55 Table 2 value for the appropriate radionuclide. It uses these same thresholds to identify radionuclides that are "significant for the purposes of waste classification".

knowledge and control of the process that is the source of the waste. [15] Specific examples include: [15]

- Byproduct licensee with physically separate areas using specific radioisotopes where facility operations are conducted such that the transfer of a radioisotope from one area to another cannot occur.

Gross radioactivity measurements, (also known as Dose-to-Activity) is a method where gross radioactivity measurements (dose rates) are correlated in a consistent basis with the distribution of radionuclides in a particular waste stream. The process must take into account the geometry of the measurement process (size, shape and density of the waste along with the relative position of the detector), type of instrumentation used, energies of the isotopes involved and properties of the source material and any intervening material with respect to attenuation and buildup of incident photons. This process usually involves the use of point-kernel or Monte Carlo modeling programs to translate the dose rate measurement to a photon (or gamma) activity distribution specific to the waste stream, container and geometry of the measurement scenario. The photon activity estimated from this process is expanded through the use of scaling factors or by merging to a reference spectrum including difficult to measure isotopes. Radionuclide distributions are determined through periodic, direct measurement techniques. [15] [18]

Measurement of specific radionuclides is a process where radionuclide concentrations in waste are determined through direct measurement. Direct measurement techniques may include measurements of samples of the waste in either its final form or at any intermediary part of the process as long as concentrations are determined based on the final waste form. Direct measurement techniques may also use scaling factors for difficult-to-measure radionuclides based on ratios to more easily detected radionuclides. [15] Scaling factors developed in this manner should be based on correlations from a history of facility waste streams to ensure accuracy to within a factor of ten of the actual values. [11] Scaling factors based on a single set of detailed sample analysis results are acceptable provided there is reasonable assurance that the sample is representative of the waste. [11] Various statistical methods for establishing scaling factors are discussed in EPRI technical documents. [9] [20] [21]

Comparison to Previous Guidance

The guidance in the BTP 2015 is consistent with the guidance in the BTP 1995 and the historical record of NRC guidance in this subject area.

Section 3: Blendable Waste

Overview

Blendable waste is any waste type that can be physically mixed to create a relatively uniform radionuclide concentration(s) or waste that is not expected to contain durable items with significant activity. [4] The waste can meet either condition to qualify. The BTP 2015 makes a distinction between waste types and waste streams. Waste types are physically different as in resin versus soil. Waste streams may have similar physical properties but different radiological properties such as primary and secondary system resins. As used in the BTP 2015, waste streams are a subset of waste types.

Blendable waste would typically be applied to the following Uniform Manifest Waste Descriptor Codes (BTP 2015 waste type):

- 20, Charcoal
- 21, Incinerator Ash
- 22, Soil
- 26, Filter Media
- 30, Cation Ion Exchange Media
- 31, Anion Ion Exchange Media
- 32, Mixed Bed Ion Exchange Media
- 35, Glassware or Lab-ware
- 38, Evaporator Bottoms/Sludges/Concentrates
- 39, Compactible Trash
- 40, Non-compactible Trash

Aqueous liquids (Codes 24, 25, 34) and gases (Code 23) are also considered blendable waste types although liquids and gases are not typically accepted directly for disposal. Mechanical (Cartridge) Filters (Code 27) may be considered as blendable waste when other constraints have been met. Care should be taken to ensure discrete items are not mixed with trash. See Alternative Treatment of Certain Cartridge Filters in Section 4.

DAW is considered blendable because it is not expected to contain durable items with significant activity. [4] This description is consistent with the BTP 1995 and should not be either a departure from current practices or establish a field test for activity. An approach that seems reasonable is to consider durable contaminated materials that should be considered discrete items as having activity commensurate with BTP 2015 Table 2 and 3 values. Radioactive contamination in typical waste is unlikely to have activities sufficient to meet these nuclide limits in items typically considered DAW (i.e., significant neutron activation of metals would typically be required).[4]

A licensee can use process knowledge to demonstrate that durable DAW items would not meet the BTP 2015 Table 2 or Table 3 limits based on their specific isotopic mixture if it was deemed necessary or prudent. Such a demonstration is not required. One possible approach to such a demonstration would be to model typical durable objects using the isotopic mixture established for this waste stream and calculate the dose rate at which the object may contain BTP 2015 Table 2 or Table 3 quantities of activity. The resulting dose rate or utility established administrative fraction of that dose rate can be used as a screening level for bags of trash that should be more carefully evaluated prior to packaging as DAW.

Cartridge filters may be considered a blendable waste subject to constraints and demonstrations discussed in Alternative Treatment of Certain Cartridge Filters in Section 4.

There are few constraints on combining multiple blendable waste streams and / or waste types. Physical and chemical compatibility must be evaluated and documented for different waste types. The BTP 2015 makes a distinction between wastes that are 'blendable' meaning they can be combined to create a relatively uniform activity distribution versus wastes that are 'blended', meaning they have been physically mixed. It is not always necessary to physically mix blendable waste streams. Combining large volumes of waste with significant differences in activity concentration may trigger the need to demonstrate that the resulting combination is adequately mixed to avoid the creation of 'pockets' of high activity. The volumes and activity characteristics needing such a demonstration are identified in Table 1 of the BTP 2015. [4] The demonstration of blending is only needed where at least one of the constituents in the combination is more than a factor of 10 higher than the waste class of the combination and the volume of the high activity constituent represents a potential to create a 'hot spot'. [4] Demonstrations of adequate blending where multiple waste streams of a single waste type are combined for the purposes of operational efficiency, occupational safety or occupational dose reduction are specifically excluded and Table 1 of the BTP 2015 does not apply. However, this exclusion does not apply to wastes if they have already been packaged separately for shipping; as from a generator to a processor. [4] The basic process flow for blendable waste is shown in Figure 3-1.

[4] The NRC requested comments from stakeholders on this issue via Federal Register Notice (81FR3166, dated January 20, 2016, Docket ID NRC NRC-2011-0022). A resolution has not been issued at the time of this report's publication.

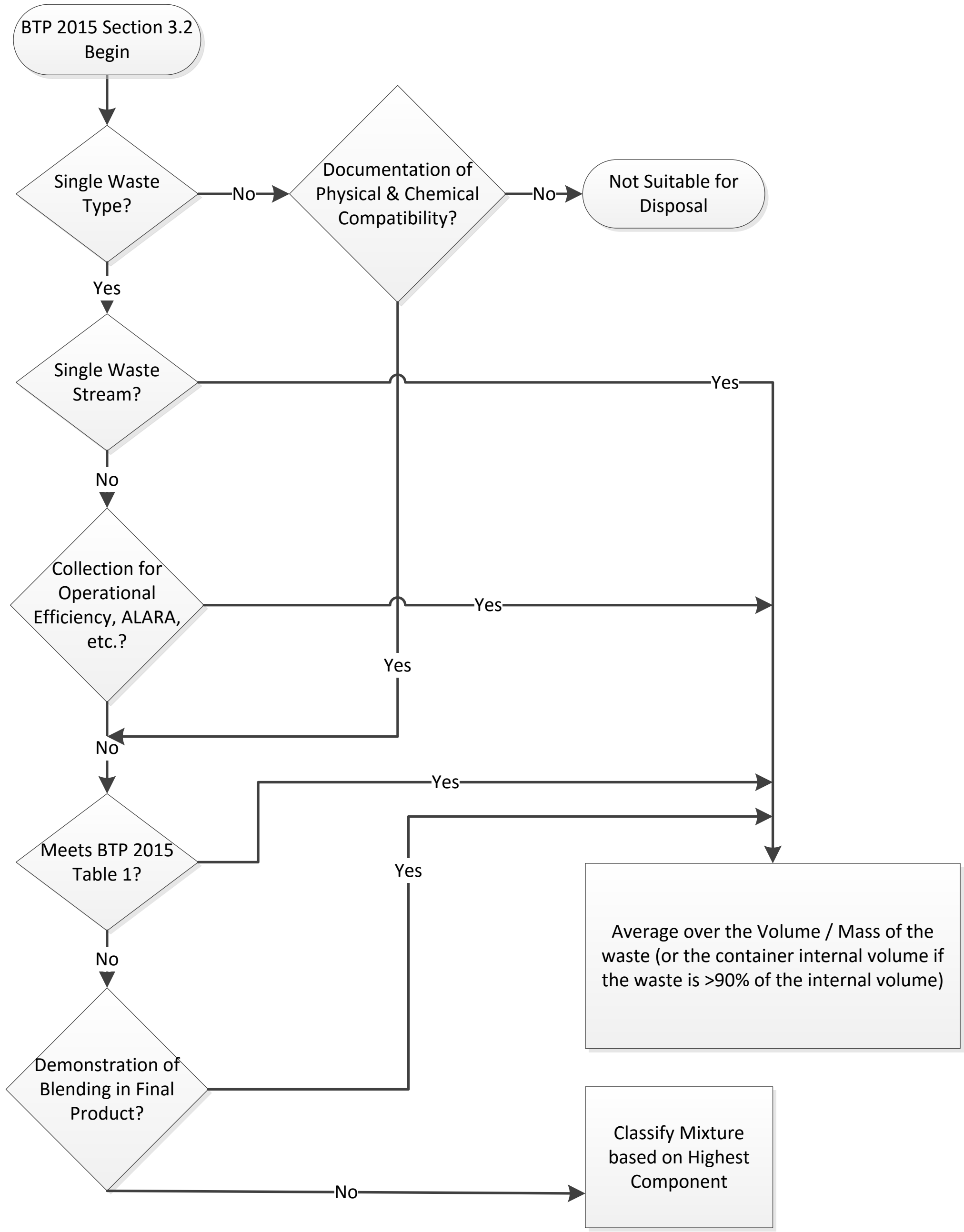


Figure 3-1
BTP 2015 Section 3.2 *Flow Chart [4]*

Solidified waste is waste that is mixed with a binding agent to create a physically uniform waste form in accordance with accepted industry standards (e.g. ANSI/ANS 55.1 "Solid Radioactive Waste Processing System for Light-Water-Cooled Reactor Plants"). As such, it is also considered to be relatively uniform in the context of the BTP 2015. [4] NRC guidance and industry standards specify solidified waste be adequately mixed to ensure uniformity of the final product. This mixing would eliminate radiological hot-spots. Therefore, the mass and volume of the solidified mixture would be the basis for waste classification. This does not include encapsulated materials where the waste remains distinct from the binder. Solidification binding agents should have some purpose other than solely to affect concentrations for waste classification; for example, improving the waste form for stability or thermal process control. As in the BTP 1995, there are no numerical constraints in the BTP 2015 on the amount of binding agent compared to the original radioactive constituent that would define an 'extreme measure' to reduce waste classification. [6] [4] [10] NRC Staff has chosen to allow the State regulators the flexibility to make this determination. [10]

The BTP 2015 is applicable to waste generators and waste processors. It is expected however, that waste processors who are likely to accept larger volumes of blendable waste from multiple generators will have a greater need to demonstrate adequate blending. This could be done as part of the initial process development.

Additional guidance is presented for specific situations and is discussed separately in the sections below.

Comparison to Previous Guidance

The BTP 1995 was inconsistent when describing the issue of blending. The term 'blending' was not used at all. Instead, the concept of homogeneity was discussed. The BTP 1995 did not specifically address waste streams. There was no clear definition for when a waste was homogeneous although the same basic waste types were discussed as examples. [6] Section 3.1 of the BTP 1995 identified collections of homogeneous waste types from sources within a facility to not be considered as mixing when they are done for operational efficiency or as low as reasonably achievable (ALARA) reasons. [6] However, the next sentence identified concentrations at a factor of 10 of the mixture average as a limitation on a 'mixture' of waste types. [6] Since the constraints were based on the average concentration of the mixture rather than the waste classification limits, situations resulted where a mixture of two components could meet the concentration limits and constraints for a particular waste class but the addition of lower activity material in the same waste class would seem to require a higher waste classification. The guidance in the BTP 2015 is based on the waste classification limits and is more technically defendable and consistent with the risk assessment inherent in the waste classification system.

Concentration Averaging for a Single Blendable Waste Stream

Guidance

Section 3.2.1 of the BTP 2015 states that a single blendable waste stream may be averaged over the total volume and weight of the waste in the package or, if the waste fills 90 percent or more of the package, then averaged over the interior volume of the container. [4]

Absorbed liquids may only be averaged over the volume or mass of the liquid prior to absorption (i.e., should not include the absorbent medium). [4]

Sources or gauges with less than 3.7 Megabequerel (MBq) [100 microcurie (μCi)] may be mixed with contaminated trash and averaged over the trash volume (subject to the restrictions of the individual disposal sites). [4]

Implementation Examples

In the following examples, waste constituents will be introduced and the key parameters necessary for waste classification and implementation of the concentration averaging guidance specified. These include the waste weight, waste volume, radionuclide activity and waste type(s). Where necessary, container information may also be identified along with the uniform waste manifest code (UM Code) of the waste type(s) being evaluated. Following the identification of the constituent and characterization, the BTP 2015 concentration averaging position will be demonstrated and the resulting waste classification presented in a table. Preliminary waste classifications of the original constituents may be calculated as part of the demonstration and to illustrate various points. These preliminary waste classifications are not meant to represent an actual waste classification as would be presented for disposal.

Example #1 – Single Blendable Waste Stream / Single Waste Type

Table 3-1
Example #1 - Single Blendable Waste Stream/Type Characterization

Container Model:	EL-142
Waste Volume (ft^3)	96
Waste Weight (lbs)	4745
Total Activity (mCi)	2.46E+04
Waste Stream:	Primary Resin
UM Code	32
Nuclide	**Activity (mCi)**
^{3}H	3.76E-03
^{14}C	6.51E+00
^{51}Cr	1.08E+03
^{54}Mn	3.49E+02
^{55}Fe	2.53E+03
^{59}Fe	2.19E+02
^{58}Co	1.13E+03
^{60}Co	1.04E+04
^{63}Ni	8.30E+03
^{89}Sr	2.43E+01
^{90}Sr	3.70E+00
^{95}Zr	1.42E+03
^{95}Nb	1.47E+03
^{99}Tc	2.70E+01
^{129}I	9.38E-01
^{134}Cs	1.91E+02
^{137}Cs	4.73E+02
^{238}Pu	6.62E-02
^{239}Pu	6.11E-02
^{241}Pu	2.08E+01
^{241}Am	1.95E-02
^{242}Cm	1.99E+00
^{243}Cm	3.35E-02
Total	2.76E+04

Activity concentrations are developed based on the waste volume. The results are shown in Table 3-2 and the waste is Class B.

Table 3-2
Example #1 Classification Based on Waste Volume

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m^3) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	<2.4E-03	0.8	0.003	—	—	8	0.0003
^{99}Tc	<9.93E-03	0.3	0.0331	—	—	3	0.0033
^{129}I	<3.45E-04	0.008	0.0431	—	—	0.08	0.0043
^{241}Pu *	9.67E+00	350	0.0276	—	—	3500	0.0028
^{242}Cm *	9.23E-01	2000	0.0005	—	—	20000	0
Other TRU*	8.37E-02	10	0.0084	—	—	100	0.0008
Sum-of-fractions			0.1157	—	—		0.0116
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m^3)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	1.38E-06	40	0	—	—	—	—
^{60}Co	3.82E+00	700	0.0055	—	—	—	—
^{63}Ni	3.06E+00	3.5	0.8732	70	0.0437	700	0.0044
^{90}Sr	1.36E-03	0.04	0.034	150	0	7000	0
^{137}Cs	1.74E-01	1	0.1736	44	0.0039	4600	0
Half-life ($t_{1/2}$) <5 yrs	3.10E+00	700	0.0044	—	—	—	—
Sum-of-fractions			1.0907		0.0476		0.0044

The next example will consider how using the internal volume of the container might affect the waste classification. The EL-142 liner used in this example has an internal volume of 105 ft^3 (2.97 m^3). The waste volume is 96 ft^3 (2.72 m^3) which represents a fill percentage of 91.4%. Therefore, the volume of the waste exceeds the 90% threshold and the internal container volume can be used to calculate the concentration of the waste as shown in Table 3-3. The waste is now Class A.

Table 3-3
Example #1 Waste Classification Based on Container Internal Volume

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m^3) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	<2.19E-03	0.8	0.0027	—	—	8	0.0003
^{99}Tc	<9.08E-03	0.3	0.0303	—	—	3	0.003
^{129}I	<3.15E-04	0.008	0.0394	—	—	0.08	0.0039
^{241}Pu *	9.67E+00	350	0.0276	—	—	3500	0.0028
^{242}Cm *	9.23E-01	2000	0.0005	—	—	20000	0
Other TRU*	8.37E-02	10	0.0084	—	—	100	0.0008
Sum-of-fractions			0.1089	—	—		0.0109
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m^3)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	1.26E-06	40	0	—	—	—	—
^{60}Co	3.49E+00	700	0.005	—	—	—	—
^{63}Ni	2.79E+00	3.5	0.7984	70	0.0399	700	0.004
^{90}Sr	1.24E-03	0.04	0.0311	150	0	7000	0
^{137}Cs	1.59E-01	1	0.1587	44	0.0036	4600	0
$t_{1/2}$<5 yrs	2.83E+00	700	0.004	—	—	—	—
Sum-of-fractions			0.9972		0.0435		0.004

Comparison to Previous Guidance

This guidance is similar to previous guidance in the BTP 1995. The BTP 1995 only discussed the use of the container volume as the basis for determining concentration where the waste is ≥90% of the internal volume for contaminated trash and contaminated soil. [6] The BTP 2015 specifically discusses this same allowance in this section on a single blendable waste stream. [4] However, NRC Staff clarified that this provision is permissible to be used for any combination of blendable waste that meets the applicable constraints for combining multiple waste streams and types. [10]

Concentration Averaging for Multiple Blendable Waste Streams

Guidance

Section 3.2.2 of the BTP 2015 states that it is permissible to combine blendable waste streams of the same waste type in a single container without a physical mixing process provided the waste class sum-of-fractions thresholds in Table 1 of the BTP 2015 are not exceeded (See Table 3-4). [4]. In such a case, the total activity in the container can be divided by the total mass or volume in the container to determine the waste class of the container (or the internal volume of the container if ≥90%). The combination of waste streams exceeding the threshold values requires a demonstration of blending to show that the waste is mixed well enough to avoid the creation of persistent hot spots. [4] The constraints for the demonstration of adequate blending apply to the original generator and waste processors equally with the exception that the aggregation of multiple waste streams of a single waste type at a generator's facility for the purposes of operational efficiency, occupational safety or occupational dose reduction can be performed without the need to address hot spots in the mixture. [4] An example of such an aggregation would be a single waste collection tank with similar waste type inputs (e.g., Resin) from different process systems (e.g., Primary System and Fuel Pool System in some PWR's and Condensate and Spent Fuel Pool Resin in some BWR's). This provision does not apply to waste aggregated at a processor's facility. [4]

The combination of multiple, blendable waste types with each other or with waste types identified as 'discrete' requires additional documentation. This would include a demonstration of the physical and chemical compatibility of the wastes in the container. Wastes that could interact to cause undesirable chemical reactions (e.g., unacceptable amounts of hydrogen generation) should not be combined. Additional constraints may be necessary to meet the Waste Acceptance Criteria of a specific disposal facility. [4] Sections 3.2.2 and 3.4 of the BTP 2015 taken together mean that it is permissible to combine multiple, waste streams consisting of different, blendable waste types as long as the provisions of both BTP 2015 Table 1 (or a demonstration of adequate blending) and the evaluations for physical and chemical compatibility are fulfilled. [10] The combination of blendable and discrete waste types is also permitted but the waste types must be evaluated separately in accordance with the direction in the BTP 2015 Section 3.2 (Blendable Waste) and Section 3.3 (Discrete Items). [4]

Table 3-4
BTP 2015 Table 1 - Thresholds for Demonstrating Adequate Blending [4]

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 Environmental Impact Statement (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).

Example #2 - Multiple Waste Streams / Single Waste Type

In this example, two waste streams consisting of Powdered Resins with different radiological characteristics are mixed in a single container (one from the primary system and the other from fuel pool system). The characterization of the two constituents is shown in Table 3-5.

Table 3-5
Example #2 - Multiple Waste Streams / Single Waste Type - Characterization

	Constituent #1	Constituent #2	
Waste Type	Ion Exchange Resin	Ion Exchange Resin	
UM Code	32	32	
Waste Stream	Primary Resin	Fuel Pool Resin	Total
Waste Volume (ft^3)	45	55	100
Waste Weight (lbs)	2248	2747	4995
Nuclide	**Activity (mCi)**	**Activity (mCi)**	**Total Activity (mCi)**
^{3}H	1.77E-03	2.17E-03	3.94E-03
^{14}C	<3.19E+00	<1.38E+00	<4.57E+00
^{51}Cr	5.32E+02		5.32E+02
^{54}Mn	1.72E+02	2.26E-02	1.72E+02
^{55}Fe	1.24E+03	4.11E+01	1.28E+03
^{59}Fe	1.08E+02		1.08E+02
^{58}Co	5.57E+02		5.57E+02
^{60}Co	5.11E+03	5.92E+02	5.70E+03
^{63}Ni	4.08E+03	1.64E+03	5.72E+03
^{89}Sr	1.19E+01		1.19E+01
^{90}Sr	1.82E+00	6.16E-01	2.43E+00
^{95}Zr	6.97E+02		6.97E+02
^{95}Nb	7.22E+02		7.22E+02
^{99}Tc	<1.32E+01	<5.73E+00	<1.90E+01
^{129}I	<4.59E-01	<1.99E-01	<6.58E-01
^{134}Cs	9.35E+01	1.40E+00	9.49E+01
^{137}Cs	2.32E+02	7.51E+01	3.07E+02
^{238}Pu	3.24E-02	1.49E-02	4.74E-02
^{239}Pu	3.00E-02	1.29E-02	4.29E-02
^{241}Pu	1.02E+01	2.73E+00	1.29E+01
^{241}Am	9.59E-03	5.97E-02	6.93E-02
^{242}Cm	9.76E-01		9.76E-01
^{243}Cm	1.65E-02	5.57E-03	2.20E-02
Total	1.36E+04	2.37E+03	1.59E+04

Each waste stream constituent, if evaluated separately would have the preliminary waste classifications as shown in Table 3-6 and Table 3-7. The Primary System resin is Class B and the Fuel Pool System resin is Class A.

Table 3-6
Example #2 Constituent #1 Preliminary Waste Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m³) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	<2.51E-03	0.8	0.0031	—	—	8	0.0003
^{99}Tc	<1.04E-02	0.3	0.0347	—	—	3	0.0035
^{129}I	<3.61E-04	0.008	0.0451	—	—	0.08	0.0045
^{241}Pu *	1.00E+01	350	0.0286	—	—	3500	0.0029
^{242}Cm *	9.56E-01	2000	0.0005	—	—	20000	0
Other TRU*	8.67E-02	10	0.0087	—	—	100	0.0009
Sum-of-fractions			0.1207	—	—		0.0121
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m³)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	1.39E-06	40	0	—	—	—	—
^{60}Co	4.00E+00	700	0.0057	—	—	—	—
^{63}Ni	3.20E+00	3.5	0.9143	70	0.0457	700	0.0046
^{90}Sr	1.43E-03	0.04	0.0356	150	0	7000	0
^{137}Cs	1.82E-01	1	0.1817	44	0.0041	4600	0
$t_{1/2}$<5 yrs	3.24E+00	700	0.0046	—	—	—	—
Sum-of-fractions			1.142		0.0499		0.0046

Table 3-7
Example #2 Constituent#2 Preliminary Waste Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m³) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	<8.87E-04	0.8	0.0011	—	—	8	0.0001
^{99}Tc	<3.68E-03	0.3	0.0123	—	—	3	0.0012
^{129}I	1.28E-04	0.008	0.016	—	—	0.08	0.0016
^{241}Pu *	2.19E+00	350	0.0063	—	—	3500	0.0006
^{242}Cm *	0.00E+00	2000	0	—	—	20000	0
Other TRU*	7.47E-02	10	0.0075	—	—	100	0.0007
Sum-of-fractions			0.043	—	—		0.0043
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m³)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	1.39E-06	40	0	—	—	—	—
^{60}Co	3.81E-01	700	0.0005	—	—	—	—
^{63}Ni	1.06E+00	3.5	0.3016	70	0.0151	700	0.0015
^{90}Sr	3.96E-04	0.04	0.0099	150	0	7000	0
^{137}Cs	4.82E-02	1	0.0482	44	0.0011	4600	0
$t_{1/2}$<5 yrs	2.73E-02	700	0	—	—	—	—
Sum-of-fractions			0.3603		0.0162		0.0015

The combination of the two constituents results in 100 ft^3 (2.83 m^3) and 4,995 lbs (2266 kg) of waste. The resulting combination has activity concentrations and waste class fractions as shown in Table 3-8. The combination is Class A.

Table 3-8
Example #2 Combination Waste Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m^3) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	<1.62E-03	0.8	0.002	—	—	8	0.0002
^{99}Tc	<6.7E-03	0.3	0.0223	—	—	3	0.0022
^{129}I	<2.33E-04	0.008	0.0291	—	—	0.08	0.0029
^{241}Pu *	5.71E+00	350	0.0163	—	—	3500	0.0016
^{242}Cm *	4.30E-01	2000	0.0002	—	—	20000	0
Other TRU*	8.01E-02	10	0.008	—	—	100	0.0008
Sum-of-fractions			0.078	—	—		0.0078
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m^3)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	1.39E-06	40	0	—	—	—	—
^{60}Co	2.01E+00	700	0.0029	—	—	—	—
^{63}Ni	2.02E+00	3.5	0.5773	70	0.0289	700	0.0029
^{90}Sr	8.59E-04	0.04	0.0215	150	0	7000	0
^{137}Cs	1.08E-01	1	0.1083	44	0.0025	4600	0
$t_{1/2}$<5 yrs	1.47E+00	700	0.0021	—	—	—	—
Sum-of-fractions			0.7121		0.0313		0.0029

The sum-of-fractions for each constituent in the mixture is less than 10 times the Class A limit, therefore there is no volume threshold and no demonstration of adequate blending required. This would also be true if the constituents had been mixed in a tank or in the container at the generator's facility for operational efficiency or ALARA reasons.

Example #3- Multiple Waste Streams / Single Waste Type with Volumes and/or Concentrations that Exceed Table 1 Conditions

In this example, two waste streams consisting of Powdered Resins with different radiological characteristics are mixed to produce a Class A final product. It must be noted that the typical isotopic relationships in utility waste had to be adjusted by more than 3 orders of magnitude in some cases in order to create a situation where BTP 2015 Table 1 conditions would be exceeded. This illustrates the point that BTP 2015 Table 1 should not ordinarily be a constraint during normal nuclear power plant operations. The characterization of the two constituents is shown in Table 3-9.

Table 3-9
Example #3 Characterization

	Constituent #1	**Constituent #2**	
Waste Type	Ion Exchange Resin	Ion Exchange Resin	
UM Code	32	32	
Waste Stream	Secondary Resin	Primary Resin	Total
Waste Volume (ft^3)	1000	15	1015
Waste Weight (lbs)	49,944	749.16	50,693.16
Nuclide	**Activity (mCi)**	**Activity (mCi)**	**Total Activity (mCi)**
^{3}H	5.09E-02	3.64E+03	3.64E+03
^{14}C	1.99E-01	1.32E+03	1.32E+03
^{54}Mn	1.78E+01	3.18E+04	3.18E+04
^{55}Fe	1.46E+02	2.18E+04	2.19E+04
^{59}Fe		1.13E+03	1.13E+03
^{58}Co	5.35E+02	3.41E+05	3.41E+05
^{60}Co	4.32E+02	1.80E+05	1.80E+05
^{59}Ni	6.20E-01	1.69E+02	1.70E+02
^{63}Ni	6.41E+01	1.51E+04	1.52E+04
^{90}Sr	1.55E-02	4.58E+00	4.60E+00
^{95}Zr		2.47E+03	2.47E+03
^{134}Cs		2.00E+04	2.00E+04
^{137}Cs		2.20E+04	2.20E+04
^{238}Pu	2.92E-06	1.26E-03	1.26E-03
^{239}Pu	1.59E-06	6.76E-04	6.77E-04
^{241}Pu	1.65E-04	5.50E-02	5.52E-02
^{241}Am	3.70E-06	3.35E-04	3.39E-04
^{242}Cm	5.55E-06	1.21E-02	1.21E-02
^{244}Cm	3.24E-06	9.20E-04	9.24E-04
Total	1.20E+03	6.40E+05	6.41E+05

Constituent #1 has the following isotopic concentrations and preliminary waste classification as shown in Table 3-10. The waste is Class A.

Table 3-10
Example #3 Constituent 1 Preliminary Waste Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m³) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	7.01E-06	0.8	0.00	—	—	8	0.00
^{99}Tc	4.08E-08	0.3	0.00	—	—	3	0.00
^{129}I	0.00E+00	0.008	0.00	—	—	0.08	0.00
^{241}Pu *	7.27E-03	350	0.00	—	—	3500	0.00
^{242}Cm *	2.45E-04	2000	0.00	—	—	20000	0.00
Other TRU*	5.05E-04	10	0.00	—	—	100	0.00
Sum-of-fractions			0.00				0.00
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m³)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	1.80E-06	40	0.00	—	—	—	—
^{60}Co	1.53E-02	700	0.00	—	—	—	—
^{63}Ni	2.26E-03	3.5	0.00	70	0.00	700	0.00
^{90}Sr	5.49E-07	0.04	0.00	150	0.00	7000	0.00
^{137}Cs	0.00E+00	1	0.00	44	0.00	4600	0.00
$t_{1/2}$<5 yrs	1.95E-02	700	0.00	—	—	—	—
Sum-of-fractions			0.00		0.00		0.00

Constituent #2 has the following isotopic concentrations and preliminary waste classification as shown in Table 3-11. The waste is Class C.

Table 3-11
Example #3 Constituent 2 Preliminary Waste Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m^3) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	3.11E+00	0.8	3.88	—	—	8	0.39
^{99}Tc	0.00E+00	0.3	0.00	—	—	3	0.00
^{129}I	0.00E+00	0.008	0.00	—	—	0.08	0.00
^{241}Pu *	1.62E+02	350	0.46	—	—	3500	0.05
^{242}Cm *	3.54E+01	2000	0.02	—	—	20000	0.00
Other TRU*	9.38E+00	10	0.94	—	—	100	0.09
Sum-of-fractions			5.30				0.53
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m^3)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	8.56E+00	40	0.21	—	—	—	—
^{60}Co	4.23E+02	700	0.60	—	—	—	—
^{63}Ni	3.56E+01	3.5	10.18	70	0.51	700	0.05
^{90}Sr	1.08E-02	0.04	0.27	150	0.00	7000	0.00
^{137}Cs	5.19E+01	1	51.85	44	1.18	4600	0.01
$t_{1/2}$<5 yrs	9.29E+02	700	1.33	—	—	—	—
Sum-of-fractions			64.45		1.69		0.06

The mixture of the two resin constituents has the following isotopic concentrations as shown in Table 3-12. The waste is Class A. However, the total volume of waste used to obtain Class A is 1,015 ft^3 (28.7 m^3) and the 10 CFR 61.55 Table 2 Class A sum-of-fractions of the most limiting waste constituent (Constituent #2) is 64.45. These values exceed the BTP 2015 Table 1 threshold value of 210 ft^3 (5.95 m^3) for a Class A end product where the most concentrated constituent sum-of-fractions is between 50 and 100 of the Class A limit. Therefore, a demonstration of adequate blending of the final product is required before the mixture can be disposed as Class A waste. If the mixture is classified as Class B waste, no demonstration of adequate blending would be required.

Table 3-12
Example #3 Mixture Waste Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m^3) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	4.59E-02	0.8	0.06	—	—	8	0.01
^{99}Tc	4.02E-08	0.3	0.00	—	—	3	0.00
^{129}I	0.00E+00	0.008	0.00	—	—	0.08	0.00
^{241}Pu *	2.40E+00	350	0.01	—	—	3500	0.00
^{242}Cm *	5.24E-01	2000	0.00	—	—	20000	0.00
Other TRU*	1.39E-01	10	0.01	—	—	100	0.00
Sum-of-fractions			0.08				0.01
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m^3)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	1.26E-01	40	0.00	—	—	—	—
^{60}Co	6.27E+00	700	0.01	—	—	—	—
^{63}Ni	5.29E-01	3.5	0.15	70	0.01	700	0.00
^{90}Sr	1.60E-04	0.04	0.00	150	0.00	7000	0.00
^{137}Cs	7.66E-01	1	0.77	44	0.02	4600	0.00
$t_{1/2}$<5 yrs	1.38E+01	700	0.02	—	—	—	—
Sum-of-fractions			0.95		0.02		0.00

Comparison to Previous Guidance

The BTP 1995 was inconsistent when describing the issue of blending. The term 'blending' was not used at all. Instead, the concept of homogeneity was discussed. The BTP 1995 did not specifically address waste streams. There was no clear definition for when waste was homogeneous although the same basic waste types were discussed as examples. [6] Section 3.1 of the BTP 1995 identified collections of homogeneous waste types from sources within a facility to not be considered as mixing when they are done for operational efficiency or ALARA reasons. [6] However, the next sentence identified concentrations at a factor of 10 of the mixture average as a limitation on a 'mixture' of waste types. [6] The constraints were also based on the average concentration of the mixture rather than the waste class resulting in situations where a mixture of two components could meet the concentration limits and constraints for a particular waste class but the addition of lower activity material in the same waste class would seem to require a higher waste classification. The guidance in the BTP 2015 is based on the waste classification limits and is more technically defendable and consistent with the risk assessment inherent in the waste classification system.

Classification of Solidified Waste

Guidance

Section 3.2.3 of the BTP 2015 identifies solidification as the incorporation of radioactive waste into a binding matrix to create a solid, physically and radiologically uniform waste form. [4] Examples include solidified liquids, solidified ion-exchange resins and solidified shredded cartridge filters. [4] The mixing required to implement the solidification process is expected to eliminate radiological hot spots. Therefore, the mass and volume (as applicable) of the solidified product is to be used to determine the activity concentration of the waste.

Solidification constitutes a qualitative improvement in the waste form, even when waste is already physically and radiologically uniform and would be acceptable for disposal prior to solidification. Generators and processors may solidify waste even in the absence of any regulatory or disposal site requirement to do so, because the addition of a non-radioactive binder to waste for solidification may be said to satisfy the BTP by achieving a purpose (qualitative improvement) other than changing waste classification. The BTP 2015 is consistent with the BTP 1995 in stating that 'extreme measures' should not be taken and that the binder should have some purpose other than lowering the waste classification. The BTP 2015 does not specify any particular numerical constraints on the amount of binder that would be considered extreme leaving that decision to the State regulators. [10]

Implementation Examples

Example #4 – Solidification of Liquids

In this example, liquid evaporator concentrates are solidified with cement to form a solid monolith. The characterization of the constituent is shown in Table 3-13.

Table 3-13
Example #4 - Solidified Evaporator Concentrates - Characterization

	Constituent #1
Waste Type	Evaporator Bottoms
UM Code	38
Waste Stream	Evaporator Concentrates
Waste Volume (ft^3)	80
Waste Weight (lbs)	5,462

Nuclide	**Activity (mCi)**
^{3}H	9.70E-04
^{14}C	1.07E+02
^{54}Mn	2.11E+02
^{55}Fe	1.36E+04
^{59}Fe	4.03E+01
^{58}Co	2.09E+03
^{60}Co	1.06E+04
^{63}Ni	1.19E+04
^{90}Sr	3.57E-01
^{95}Zr	4.11E+01
^{95}Nb	5.19E+00
^{99}Tc	<2.49E-03
^{129}I	<2.03E-07
^{137}Cs	1.90E+01
^{238}Pu	2.51E-02
^{239}Pu	1.98E-02
^{240}Pu	1.98E-02
^{241}Pu	4.27E+00
^{241}Am	2.28E-02
^{242}Cm	1.02E-01
^{244}Cm	2.11E-02
Total	3.87E+04

The preliminary classification of the liquid waste is Class B as shown in Table 3-14.

Table 3-14
Example #4 - Evaporator Concentrates Preliminary Waste Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m^3) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	4.73E-02	0.8	0.0591	—	—	8	0.0059
^{99}Tc	<1.1E-06	0.3	0	—	—	3	0
^{129}I	<8.97E-11	0.008	0	—	—	0.08	0
^{241}Pu *	1.73E+00	350	0.0049	—	—	3500	0.0005
^{242}Cm *	4.11E-02	2000	0	—	—	20000	0
Other TRU*	4.38E-02	10	0.0044	—	—	100	0.0004
Sum-of-fractions			0.0685	—	—		0.0068
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m^3)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	4.29E-07	40	0	—	—	—	—
^{60}Co	4.71E+00	700	0.0067	—	—	—	—
^{63}Ni	5.25E+00	3.5	1.4993	70	0.075	700	0.0075
^{90}Sr	1.57E-04	0.04	0.0039	150	0	7000	0
^{137}Cs	8.40E-03	1	0.0084	44	0.0002	4600	0
$t_{1/2}$<5 yrs	7.06E+00	700	0.0101	—	—	—	—
Sum-of-fractions			1.5284		0.0752		0.0075

The concentrates are solidified in a liner using 73.9 ft^3 (2.09 m^3) and 12,918 lbs (5860 kg) of cement (Uniform Manifest Code 90) to make a final product with a volume of 154 ft^3 (4.36 m^3) and a weight of 19,740 lbs (8954 kg). The activity is averaged over the total weight and volume of the mixture with the result that the waste is Class A as shown in Table 3-15.

Table 3-15
Example #4 - Solidified Evaporator Concentrates Waste Classification

Part 61.55 Table 1 Radionuclide	**Concentration (Ci/m^3) (*nCi/g)**	**Class A Limit**	**Class A Fraction**			**Class C Limit**	**Class C Fraction**
^{14}C	2.46E-02	0.8	0.0307	—	—	8	0.0031
^{99}Tc	<5.72E-07	0.3	0	—	—	3	0
^{129}I	<4.66E-11	0.008	0	—	—	0.08	0
^{241}Pu *	5.13E-01	350	0.0015	—	—	3500	0.0001
^{242}Cm *	1.22E-02	2000	0	—	—	20000	0
Other TRU*	1.30E-02	10	0.0013	—	—	100	0.0001
Sum-of-fractions			0.0335	—	—		0.0034
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m^3)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	2.23E-07	40	0	—	—	—	—
^{60}Co	2.45E+00	700	0.0035	—	—	—	—
^{63}Ni	2.73E+00	3.5	0.7794	70	0.039	700	0.0039
^{90}Sr	8.18E-05	0.04	0.002	150	0	7000	0
^{137}Cs	4.36E-03	1	0.0044	44	0.0001	4600	0
$t_{1/2}$<5 yrs	3.67E+00	700	0.0052	—	—	—	—
Sum-of-fractions			0.7945		0.0391		0.0039

Example #5 – Solidification of Resin

In this example, primary resins are solidified with vinyl ester styrene (VES) to form a solid monolith. The characterization of the constituent is shown in Table 3-16.

Table 3-16: Example #5 – Solidification of Resin – Characterization

	Constituent #1
Waste Type	Ion Exchange Resin
UM Code	32
Waste Stream	Primary Resin
Waste Volume (ft^3)	100
Waste Weight (lbs)	4,994

Nuclide	Activity (mCi)
^{3}H	3.95E-03
^{14}C	6.03E+01
^{51}Cr	1.00E+04
^{54}Mn	3.24E+03
^{55}Fe	2.34E+04
^{59}Fe	2.03E+03
^{58}Co	1.05E+04
^{60}Co	9.62E+04
^{63}Ni	7.68E+04
^{89}Sr	2.25E+02
^{90}Sr	3.43E+01
^{95}Zr	1.31E+04
^{95}Nb	1.36E+04
^{99}Tc	2.50E+02
^{129}I	8.68E+00
^{134}Cs	1.76E+03
^{137}Cs	4.38E+03
^{238}Pu	6.11E-01
^{239}Pu	5.65E-01
^{241}Pu	1.92E+02
^{241}Am	1.81E-01
^{242}Cm	1.84E+01
^{243}Cm	3.11E-01
Total	2.56E+05

The preliminary classification of the bulk resin waste is Class C as shown in Table 3-17.

Table 3-17
Example #5 - Solidification of Resin - Preliminary Waste Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m^3) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	<2.13E-02	0.8	0.0266	—	—	8	0.0027
^{99}Tc	<8.82E-02	0.3	0.2941	—	—	3	0.0294
^{129}I	<3.06E-03	0.008	0.3828	—	—	0.08	0.0383
^{241}Pu *	8.50E+01	350	0.2428	—	—	3500	0.0243
^{242}Cm *	8.11E+00	2000	0.0041	—	—	20000	0.0004
Other TRU*	7.36E-01	10	0.0736	—	—	100	0.0074
Sum-of-fractions			1.024	—	—		0.1024
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m^3)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	1.39E-06	40	0	—	—	—	—
^{60}Co	3.39E+01	700	0.0485	—	—	—	—
^{63}Ni	2.71E+01	3.5	7.7557	70	0.3878	700	0.0388
^{90}Sr	1.21E-02	0.04	0.3023	150	0.0001	7000	0
^{137}Cs	1.54E+00	1	1.5415	44	0.035	4600	0.0003
$t_{1/2}<5$ yrs	2.75E+01	700	0.0393	—	—	—	—
Sum-of-fractions			9.6873		0.4229		0.0391

The resin is solidified in a liner using 37 ft³ (1.05 m³) and 3490 lbs (1583 kg) of VES (Uniform Manifest Code 94) to make a final product with a volume of 110 ft³ (3.11 m³) and a weight of 8,484 lbs (3848 kg). The activity is averaged over the total weight and volume of the mixture with the result that the waste is Class B as shown in Table 3-18.

Table 3-18
Example #5 - Solidified Resin Waste Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m³) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	<1.93E-02	0.8	0.0242	—	—	8	0.0024
^{99}Tc	<8.02E-02	0.3	0.2674	—	—	3	0.0267
^{129}I	<2.78E-03	0.008	0.348	—	—	0.08	0.0348
^{241}Pu *	5.00E+01	350	0.1429	—	—	3500	0.0143
^{242}Cm *	4.77E+00	2000	0.0024	—	—	20000	0.0002
Other TRU*	4.33E-01	10	0.0433	—	—	100	0.0043
Sum-of-fractions			0.8282	—	—		0.0828
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m³)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	1.27E-06	40	0	—	—	—	—
^{60}Co	3.09E+01	700	0.0441	—	—	—	—
^{63}Ni	2.47E+01	3.5	7.0506	70	0.3525	700	0.0353
^{90}Sr	1.10E-02	0.04	0.2748	150	0.0001	7000	0
^{137}Cs	1.40E+00	1	1.4014	44	0.0318	4600	0.0003
$t_{1/2}$<5 yrs	2.50E+01	700	0.0357	—	—	—	—
Sum-of-fractions			8.8066		0.3845		0.0356

Example #6 – Solidification of Shredded Cartridge Filters

In this example, 60 cartridge filters are generated as a result of work in the spent fuel pool. For simplicity, all but one of the cartridge filters have the same activity. The characterization of the filters is shown in Table 3-19.

Table 3-19
Example #6 - Solidification of Shredded Cartridge Filters - Characterization

	Single Filter	60 Filters
Waste Type	Cartridge Filters	Cartridge Filters
UM Code	27	27
Waste Stream	Fuel Pool	Fuel Pool
Waste Volume (ft^3)	0.49	29.4
Waste Weight (lbs)	6.75	405

Nuclide	Activity (mCi)	Activity (mCi)
^{3}H	5.32E-06	3.19E-04
^{14}C	6.70E-02	4.02E+00
^{54}Mn	1.10E-03	6.58E-02
^{55}Fe	2.00E+00	1.20E+02
^{60}Co	2.89E+01	1.74E+03
^{63}Ni	8.00E+01	4.80E+03
^{90}Sr	3.00E-02	1.80E+00
^{99}Tc	2.78E-01	1.67E+01
^{129}I	9.68E-03	5.81E-01
^{134}Cs	6.81E-02	4.09E+00
^{137}Cs	3.65E+00	2.19E+02
^{238}Pu	7.27E-04	4.36E-02
^{239}Pu	6.30E-04	3.78E-02
^{241}Pu	1.33E-01	7.96E+00
^{241}Am	2.89E-03	1.74E-01
^{243}Cm	2.70E-04	1.62E-02
Total	1.15E+02	6.91E+03

The preliminary waste classification of the filters is Class B as shown in Table 3-20.

Table 3-20
Example #6 - Solidification of Shredded Cartridge Filters Preliminary Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m³) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	<4.84E-03	0.8	0.006	—	—	8	0.0006
^{99}Tc	<2.01E-02	0.3	0.0669	—	—	3	0.0067
^{129}I	6.96E-04	0.008	0.0871	—	—	0.08	0.0087
^{241}Pu *	4.33E+01	350	0.1238	—	—	3500	0.0124
^{242}Cm *	0.00E+00	2000	0	—	—	20000	0
Other TRU*	1.48E+00	10	0.1478	—	—	100	0.0148
Sum-of-fractions			0.4316	—	—		0.0432
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m³)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	3.84E-07	40	0	—	—	—	—
^{60}Co	2.08E+00	700	0.003	—	—	—	—
^{63}Ni	5.76E+00	3.5	1.6458	70	0.0823	700	0.0082
^{90}Sr	2.16E-03	0.04	0.054	150	0	7000	0
^{137}Cs	2.63E-01	1	0.2632	44	0.006	4600	0.0001
$t_{1/2}$<5 yrs	1.49E-01	700	0.0002	—	—	—	—
Sum-of-fractions			1.9662		0.0883		0.0083

The cartridge filters are shredded and mixed with cement to form a uniform matrix with a total volume of 100 ft^3 (2.83 m^3) and a weight of 10,990 lbs (4985 kg). The BTP 2015 does not specify any particular numerical constraints on the amount of binder that would be considered extreme leaving that decision to the State regulators. [10] The waste to binder ratio in this example is 0.294 (pre-processed waste volume / final product waste volume). The final waste classification is based on the total volume and weight of the mixture and is shown in Table 3-21. The waste is Class A.

Table 3-21
Example #6 - Solidification of Shredded Cartridge Filters - Final Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m^3) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	<1.42E-03	0.8	0.0018	—	—	8	0.0002
^{99}Tc	<5.9E-03	0.3	0.0197	—	—	3	0.002
^{129}I	<2.05E-04	0.008	0.0256	—	—	0.08	0.0026
^{241}Pu *	1.60E+00	350	0.0046	—	—	3500	0.0005
^{242}Cm *	0.00E+00	2000	0	—	—	20000	0
Other TRU*	5.45E-02	10	0.0054	—	—	100	0.0005
Sum-of-fractions			0.0571	—	—		0.0057
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m^3)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	1.13E-07	40	0	—	—	—	—
^{60}Co	6.14E-01	700	0.0009	—	—	—	—
^{63}Ni	1.70E+00	3.5	0.4843	70	0.0242	700	0.0024
^{90}Sr	6.36E-04	0.04	0.0159	150	0	7000	0
^{137}Cs	7.73E-02	1	0.0773	44	0.0018	4600	0
$t_{1/2}$<5 yrs	4.38E-02	700	0.0001	—	—	—	—
Sum-of-fractions			0.5785		0.026		0.0024

Comparison to Previous Guidance

The guidance in the BTP 2015 is the same as the BTP 1995 with two notable exceptions. The first is that a specific standard is provided as an example in the BTP 2015 (ANSI/ANS 55.1) and recognition that the degree of mixing required to create a physically uniform product would also eliminate radiological hot spots. This is the same standard that was available at the time of the BTP 1995 however the BTP 1995 seemed to leave this issue open to additional demonstration. The second notable exception is the specific discussion of shredded, solidified cartridge filters as an acceptable waste form. This specific mention recognizes and accepts a practice that was implemented in the industry subsequent to the BTP 1995.

Section 4: Discrete Items

Overview

The BTP 2015 states that discrete items require specific guidance for waste classification as they are expected to remain intact at the time of the intruder scenarios and are expected to contain relatively high amounts or concentrations of radioactivity. [4] The discrete item rules apply even when classifying a container of discrete items of a single waste type and are intended to maintain the safety of the inadvertent intruder. [4] The specific concern regarding hazards from discrete items is based on a number of well-publicized accidents that occurred after 10 CFR Part 61 became final that involved the loss of control over small, highly radioactive sealed sources. [12] These became the basis of the 'carry-away' scenarios on which the discrete item restrictions are based.

The concept of discrete items in the BTP 2015 is similar to that in the BTP 1995. Discrete items are evaluated on an individual basis and concentration averaging among mixtures of discrete items is allowed within factors of 2 (primary gamma radionuclides) and 10 (non-gamma radionuclides) of the classification limit. [4] Concentration averaging is also allowed if the discrete item contains less than specified activities of certain radioisotopes regardless of the concentration. [4] The implementation of the limits will be specifically discussed in subsequent sections of this document.

Guidance

Discrete items are evaluated on an individual basis with concentration determined based on the weight or volume of the item. Concentrations of isotopic activity in mixtures of discrete items may be averaged over the total volume or weight of the mixture or collection if the individual items meet the criteria (factor of 2 and 10 or BTP 2015 Table 2 or Table 3 values). Otherwise, the mixture or collection must be classified based on the highest classification item. Alternately, the item(s) that do not meet the criteria may be removed from the mixture. Refer back to Figure 1-1 for the entry to the BTP 2015 Discrete Item decision points.

Waste is either discrete or blendable. If the waste is not blendable, then the next step is to determine if the item(s) is encapsulated or not.

For a single, discrete item that is not encapsulated, the activity concentrations are based on the activity of its 10 CFR 61.55 radionuclides divided by the volume or weight of the item as applicable. [4] For a single discrete item that is encapsulated, the activity concentrations are based on the activity of its 10 CFR 61.55 radionuclides divided by the volume or weight of the final waste form, including the encapsulating material subject to the restrictions in BTP 2015 Section 3.3.4 (which will be illustrated in detail in subsequent implementation examples). [4]

Mixtures of discrete items that were individually evaluated as the same waste class may be packaged and classified together at that waste class. The BTP 2015 provides a set of simplified screening criteria for mixtures of discrete items of the same waste type to determine if activities can be averaged over the volume or weight of the mixture. The process is shown in Figure 4-1.

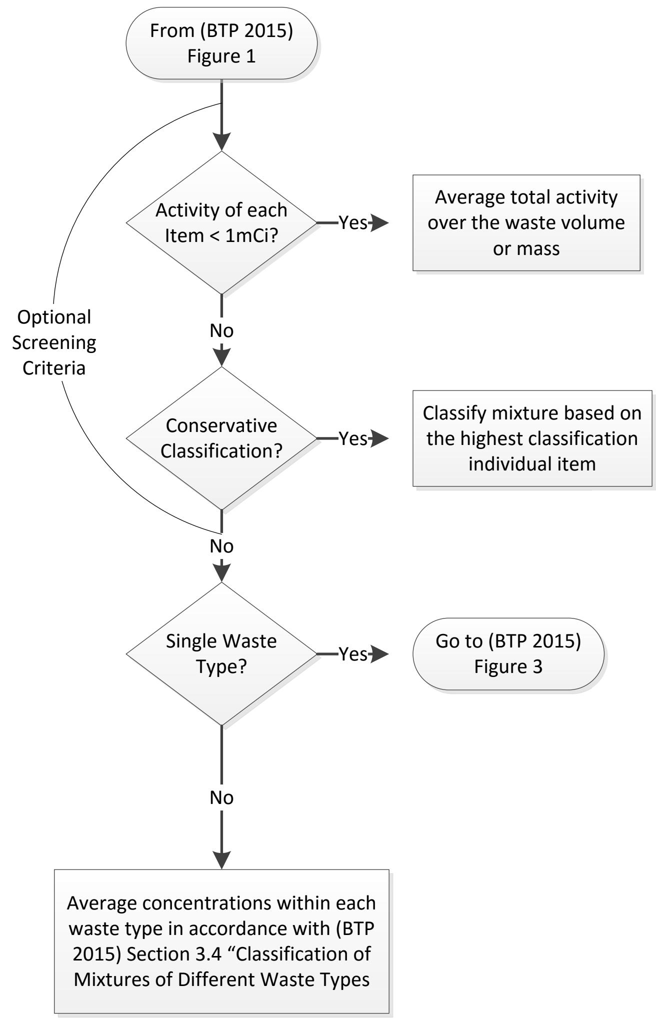


Figure 4-1
BTP 2015 Figure 2 – *Discrete Item Simplified Screening [4]*

If the simplified screening criteria are used and if each discrete item has a total activity less than 1 mCi (37 MBq) then the concentrations for classification are derived from the total activity divided by the total volume or weight of the mixture. If the simplified screening criteria are used and any or all items have an activity 1 mCi (37 MBq) or greater, then the classification of the mixture is based on the discrete item with the highest individual waste classification. If the mixture contains different waste types (e.g. Activated metal and cartridge filters), then each waste type must be evaluated separately and the classification of the package based on the highest waste type classification.

If the simplified screening criteria are not used, then the concentration averaging constraints must be evaluated. This process is shown graphically in Figure 4-2 which is a reproduction of the BTP 2015 Figure 3.

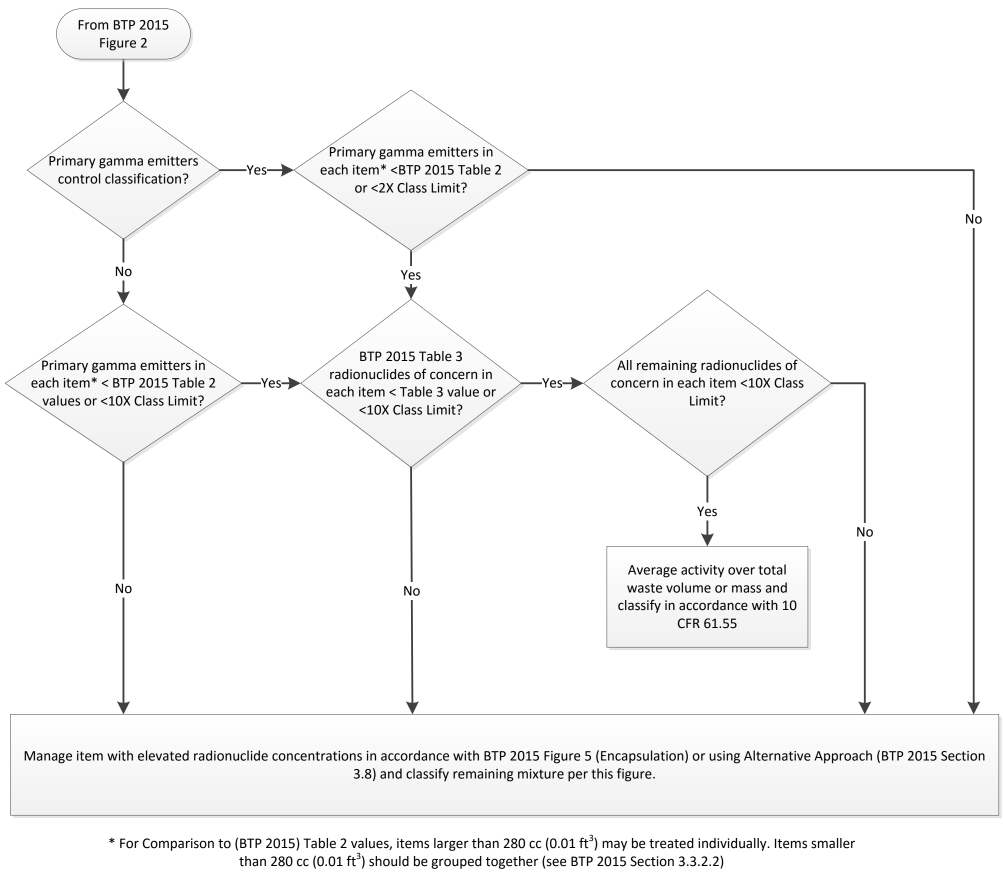


Figure 4-2
BTP 2015 Figure 3 – *Discrete Item Concentration Averaging [4]*

The first step is to determine if the primary gamma radionuclides (^{60}Co, ^{94}Nb and ^{137}Cs) control classification. Primary gamma radionuclides control classification if the class-fraction of the isotope(s) accounts for more than 50% of the more restrictive §61.55 Table 1 or 2 fraction of the item. If so, then the primary gamma radionuclides in each item must be less than the BTP 2015 Table 2 values *or* less than two times the applicable class limit to be eligible for averaging. If the primary gamma radionuclides do not control classification, they must be less than the BTP 2015 Table 2 values *or* less than ten times the applicable class limit to be eligible for averaging. For comparison to BTP 2015 Table 2 values, items larger than 280 cm^3 (0.01 ft^3) may be treated individually.

However, items smaller than 280 cm^3 (0.01 ft^3) should be grouped together. In both cases, non-gamma radionuclides listed in the BTP 2015 Table 3 (^{3}H, ^{14}C, ^{59}Ni, ^{63}Ni, TRU) must be less than the BTP 2015 Table 3 limits *or* less than ten times the applicable class limit. It is important to note that either an activity limit or a concentration limit may be applied to averaging, whichever is least restrictive. The BTP 2015 Table 2 limits should be applied using a sum of fractions. The BTP 2015 Table 3 limits and the Factors of 2 and 10 are applied separately to each radionuclide (i.e., a sum of fractions is not applied). If the activities of the discrete items in the mixture are within the averaging parameters, then the classification of the mixture is based on the volumetric or weight average of all items in the mixture. If the discrete item is not within the averaging parameters, then there are two options:

- The package can be classified according to the highest discrete item,
- The non-averagable items may be removed.

In addition, the non-averageable items that were removed may be encapsulated and re-evaluated based on the rules for encapsulated items.

Implementation Examples

The following Uniform Manifest Waste Stream Codes are applied to discrete items:

- 27, Cartridge Filters (with specific exceptions)
- 36, Sealed Sources
- 40, Contaminated materials
- 43, Activated Metals
- 59, Components incorporating radioactive material into their design

Comparison to Previous Guidance

The BTP 2015 and the BTP 1995 implement averaging constraints on discrete items for the same purpose and, since either version may be used for compliance, the end result is similar. However, the BTP 2015 describes methods that require a conceptual change over the BTP 1995. The term "discrete" as used in the BTP 1995 was commonly interpreted as a subset of activated metals or sources including size and activity specifications. [6] Discrete items in the BTP 2015 are specifically defined by the waste type (i.e., activated metals, etc.) and the size and activity specifications are used to determine the ability to perform concentration averaging for classification. The treatment of items is essentially the same although the BTP 2015 gives the added flexibility to use either the concentration limits or limits on isotopic activity (as shown in Tables 2 and 3 of the BTP 2015) to determine if items are averageable.

Another significant change is the replacement of the Factor of 1.5 and the Factor of 10 above the **package average** (for gamma and non-gamma radionuclides respectively) with a Factor of 2 and a Factor of 10 above the **Class limit** for limiting the concentrations of discrete items that can be averaged in a package. Since the BTP 1995 constraints were based on the average concentration of the mixture rather than the waste classification limits, situations resulted where a mixture of two components could meet the concentration limits and constraints for a particular waste class but the addition of lower activity material in the same waste class would seem to require a higher waste classification. The use of 'top-down' averaging methods to ensure a verifiable population of averageable items to meet the waste class of the package was necessary to demonstrate compliance. The guidance in the BTP 2015 is based on the waste classification limits and is more technically defendable and consistent with the risk assessment inherent in the waste classification system. The BTP 2015 also allows averaging based on the use of an activity limit or concentration limits whichever is least restrictive to the application. In general, the BTP 2015 Table 2 or Table 3 limits are less restrictive for small items and the Factor of 2 and Factor of 10 are less restrictive for large items. The technical bases for the two limits are described in the BTP 2015 Volume 2. [12]

Another important distinction between the BTP 1995 and the BTP 2015 is how the terms Radionuclides of Concern and Classification Controlling Radionuclides are defined and used. The distinction becomes important when determining if the primary gamma radionuclides control classification and how the Factor of 2 and Factor of 10 are applied. In the BTP 1995, Classification Controlling Radionuclides were defined as a nuclide contained in the waste in concentrations greater than 0.01 times the concentration of that nuclide listed in §61.55 Table 1 or 0.01 times the applicable class-dependent concentration of that nuclide in §61.55 Table 2, Column 2 or 3. [6] This is the same definition used for Radionuclides of Concern in the BTP 2015. [4] In the BTP 1995, the phrase 'dictate classification' was used as well as 'classification controlling' leaving some room for additional interpretation with the result that the primary gamma emitters were seldom considered as dictating classification and therefore the factor of 1.5 was not frequently implemented as a constraint in averaging. [6] The BTP 2015 does not define 'classification controlling' radionuclides but is specific in how to determine if primary gamma radionuclides control classification. In the BTP 2015, this determination is made first based on which §61.55 Table has the highest fraction and then the relative proportion of primary gamma contribution to that Table's fraction determines the application of the Factor of 2. NRC Staff comments in the BTP 2015 and NRC's BTP Implementation Q&A indicate that this method is intended to be consistent with the BTP 1995 and so, the common practice application of the Factor of 1.5 in the BTP 1995 may need to be re-evaluated. [10] Regardless, the BTP 2015 method increases the relative importance of ^{94}Nb in the classification analysis which may restrict the disposal of some component types. Since the concentration of ^{94}Nb is often inferred from material specification trace element limits and not actual measured values, the impact of this constraint may be reduced by improving knowledge of base metal constituents. [2]

The BTP 2015 and the BTP 1995 treat 'contaminated materials' (Uniform Manifest code 40) as items to be evaluated individually. The BTP 2015 more clearly categorizes them as discrete items by defining them as such. There is no introduction of new recommendations or field evaluations of contaminated items in the BTP 2015 than were already implied in the BTP 1995. An item must be durable and have significant activity to be considered a contaminated material (which is discrete) instead of DAW (which is blendable). [4]An approach that seems reasonable is to consider durable contaminated materials that should be considered discrete items as having activity commensurate with BTP 2015 Table 2 and 3 values. Therefore, contaminated material with activity less than the indicated values should be treated as DAW for waste classification purposes. A simple documented justification based on site isotopic mixtures of contaminated materials should be adequate to bound the practice if one has not already been performed.[5]

Concentration Averaging and Classification of Single Discrete Items- Section 3.3.1 of the BTP 2015

Guidance

The BTP 2015 states, "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 final waste form, including the encapsulating material, subject to the constraints in Section 3.3.4."

Implementation Examples

Example # 7 – Single Discrete Item

In this example, a single Control Rod Blade (CRB) is evaluated. The CRB consists of stainless steel and small amounts of other types of metal that have been irradiated for several cycles in a reactor. The item also has a layer of contamination (thin corrosion layer) typical of reactor vessel internal components. The isotopes and activities from both activation and contamination sources are included in the analysis. The characterization of the component is shown in Table 4-1.

[5] The NRC requested comments from stakeholders on this issue via Federal Register Notice (81FR3166, dated January 20, 2016, Docket ID NRC NRC-2011-0022). A resolution has not been issued at the time of this report's publication.

Table 4-1
Example #7 - Single Discrete Item - Characterization

	BTP CRB1
Waste Type	Activated Material
UM Code	43
Waste Stream	Activated Metal
Waste Volume (ft^3)	0.28
Waste Weight (lbs)	128

Nuclide	Activity (mCi)
^{3}H	3.00E-01
^{14}C	3.51E+01
^{51}Cr	2.25E+01
^{54}Mn	1.02E+03
^{55}Fe	8.16E+04
^{59}Fe	9.49E+00
^{58}Co	1.16E+01
^{60}Co	1.00E+05
^{59}Ni	2.10E+02
^{63}Ni	2.55E+04
^{65}Zn	1.46E+01
^{90}Sr	1.46E-02
^{94}Nb	6.89E-01
^{95}Zr	2.14E-13
^{99}Tc	7.59E-03
^{129}I	1.45E-03
^{137}Cs	2.92E-01
^{238}Pu	1.70E-03
^{239}Pu	5.73E-04
^{241}Pu	3.38E-02
^{241}Am	3.38E-03
^{242}Cm	4.22E-03
^{243}Cm	2.12E-03
Total	2.08E+05

The classification of the item is based on the total volume and weight of the item. The results are shown in Table 4-2. The waste is Class C.

Table 4-2
Example #7 - Single Discrete Item - Waste Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m³) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	4.44E+00	8	0.5549	—	—	80	0.0555
^{59}Ni	2.65E+01	22	1.2039	—	—	220	0.1204
^{94}Nb	8.70E-02	0.02	4.3513	—	—	0.2	0.4351
^{99}Tc	9.57E-04	0.3	0.0032	—	—	3	0.0003
^{129}I	1.83E-04	0.008	0.0229	—	—	0.08	0.0023
^{241}Pu *	5.85E-01	350	0.0017	—	—	3500	0.0002
^{242}Cm *	7.26E-02	2000	0	—	—	20000	0
Other TRU*	1.34E-01	10	0.0134	—	—	100	0.0013
Sum-of-fractions			6.1513	—	—		0.6151
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m³)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	3.80E-02	40	0.0009	—	—	—	—
^{60}Co	1.26E+04	700	18.0177	—	—	—	—
^{63}Ni	3.22E+03	35	91.8902	700	4.5945	7000	0.4595
^{90}Sr	1.84E-03	0.04	0.046	150	0	7000	0
^{137}Cs	3.68E-02	1	0.0368	44	0.0008	4600	0
$t_{1/2}$<5 yrs	1.04E+04	700	14.8967	—	—	—	—
Sum-of-fractions			124.8884		4.5954		0.4595

Example #8 – Sealed Source

In this example, a single radioactive source is evaluated on its own weight and volume. This example does not present the typical method for disposal of this type of material but is instead meant to illustrate the difficulty with sealed source disposal. A sealed source disposal option will be discussed in Example #12. The source consists of 10 Curies (Ci) (370 Gigabequerel or GBq) of ^{137}Cs. The characterization of the component is shown in Table 4-3.

Table 4-3
Example #8 - Sealed Source - Characterization

Waste Type	**Sealed Source**
UM Code	36
Waste Stream	Sealed Source
Waste Volume (ft^3)	0.003
Waste Weight (lbs)	0.1
Nuclide	Activity (mCi)
^{137}Cs	1.00E+04

The classification of the item is based on the total volume and weight of the item. The results are shown in Table 4-4. The waste is greater than Class C.

Table 4-4
Example #8 - Sealed Source Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m³) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	0.00E+00	8	0	—	—	80	0
^{99}Tc	0.00E+00	22	0	—	—	220	0
^{129}I	0.00E+00	0.02	0	—	—	0.2	0
^{241}Pu *	0.00E+00	0.3	0	—	—	3	0
^{242}Cm *	0.00E+00	0.008	0	—	—	0.08	0
Other TRU*	0.00E+00	350	0	—	—	3500	0
Sum-of-fractions			0	—	—		0
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m³)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	0.00E+00	40	0	—	—	—	—
^{60}Co	0.00E+00	700	0	—	—	—	—
^{63}Ni	0.00E+00	35	0	700	0	7000	0
^{90}Sr	0.00E+00	0.04	0	150	0	7000	0
^{137}Cs	1.18E+05	1	117715.55	44	2675.354	4600	25.5903
$t_{1/2}$<5 yrs	0.00E+00	700	0	—	—	—	—
Sum-of-fractions			117715.55		2675.354		25.5903

Comparison to Previous Guidance

This guidance is equivalent to the BTP 1995 with regards to the handling of discrete items. The BTP 2015 Table 2 Class C value for discrete items containing ^{137}Cs was increased to 4.8 Terabequerels (TBq)(130 Ci) and other values were changed. The process for evaluating if gamma radionuclides control classification is more explicit in the BTP 2015.

Concentration Averaging and Classification of Mixtures of Discrete Items – Section 3.3.2.2. of the BTP 2015

Guidance

The BTP 2015 describes two methods for performing concentration averaging to classify mixtures of discrete items of the same waste type.

The first method employs a screening criterion and is illustrated in Figure 4-1. If the items are less than 37 MBq (1 mCi) total activity on an individual basis, then the isotopic concentration for waste classification can be based on the volume or weight of the collection of items. If any single item is greater than or equal to 37 MBq (1 mCi), the collection can be classified based on the single item with the highest classification. [4]

A second method can be implemented if the 37 MBq (1 mCi) screening criterion is not met and the licensee chooses not to classify the waste based on the item with the highest classification. Section 3.3.2.2 and Figure 3 of the BTP 2015 describe the process. [4] The general process is summarized as follows and is shown in Figure 4-2 of this report.

1. Determine if the primary gamma radionuclides (^{94}Nb, ^{60}Co, ^{137}Cs) control classification.
    a. Determine which §61.55 Table classification is highest. If both tables result in the same waste Class, then determine which table has the highest fraction. This is the most restrictive table.
    b. Determine if the Primary Gamma Radionuclides in the most restrictive table contribute more than 50 percent of the sum-of-fractions in that table. If so, then the primary gamma radionuclide is 'classification controlling'.
2. If primary gamma radionuclides control classification then:
    a. The limits in Table 2 of the BTP 2015 Revision (See Table 4-5) apply (using a sum-of-fractions approach and grouping items smaller than 0.01 ft^3 (280 cm^3)) or:
    b. The concentration of each primary gamma radionuclide must be within a factor of 2 of the applicable classification limit.
3. If the primary gamma radionuclides are not 'classification controlling' but are 'radionuclides of concern', then the concentration of each radionuclide (listed

in the BTP 2015 Table 2 or Table 3) must be within a factor of 10 of the applicable classification limit for that radionuclide or less than the BTP 2015 Table 2 values (using a sum-of-fractions approach and grouping items smaller than 0.01 ft^3 (280 cm^3)) or Table 3 values (See Table 4-6).

4. The Factor of 10 applies to all radionuclides of concern not present in Table 2 or Table 3 of the BTP 2015.

Table 4-5
BTP 2015 Table 2 - *Recommended Activity Limits of Primary Gamma Emitters Potentially Requiring Piecemeal Consideration in Classification Determinations [4]*

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)

Table 4-6
BTP 2015 Table 3 - Recommended Activity Limits of Radionuclides Other Than Primary Gamma Emitters Potentially Requiring Piecemeal Consideration in Classification Determinations [4]

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.		

If a component is sectioned for packaging, as is typically performed for CRB's from Boiling Water Reactors (BWR's), then some additional evaluation of the individual sections is needed to ensure that the classification basis of the original component is maintained. The sections should all be packaged together. Sections smaller than 0.01 ft^3 (280 cm^3) should have isotopic activity within the BTP 2015 Table 2 criteria and all pieces of any size should meet the BTP 2015 Table 3 criteria. If any of these constraints are not met, then the sections should be evaluated individually. If these constraints are met, then the sections can be classified based on the classification of the original item (i.e., as if the item had not been sectioned). [4] Items that are smaller than 0.01 ft^3 (280 cm^3) should be grouped together for comparison to the BTP 2015 Table 2 limits.

The Factor of 2 and Factor of 10 are applied to each item individually, irrespective of size. [4] 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 in accordance with the BTP 2015 Section 3.3.1. If items smaller than 280 cm^3 (0.01 ft^3) **collectively** exceed the BTP 2015 Table 2 limits, using a sum-of-fractions, and they do not individually meet the Factor of 2 or Factor of 10 (as applicable), their concentrations should not be averaged to meet the Factor of 2 or Factor of 10. Smaller groups can be made but should be placed in separate packages. The classification of the remaining mixture may be based on the volumetrically averaged or weight-averaged concentrations of the mixture. [4] See Figure 4-3 for a graphical representation of the process.

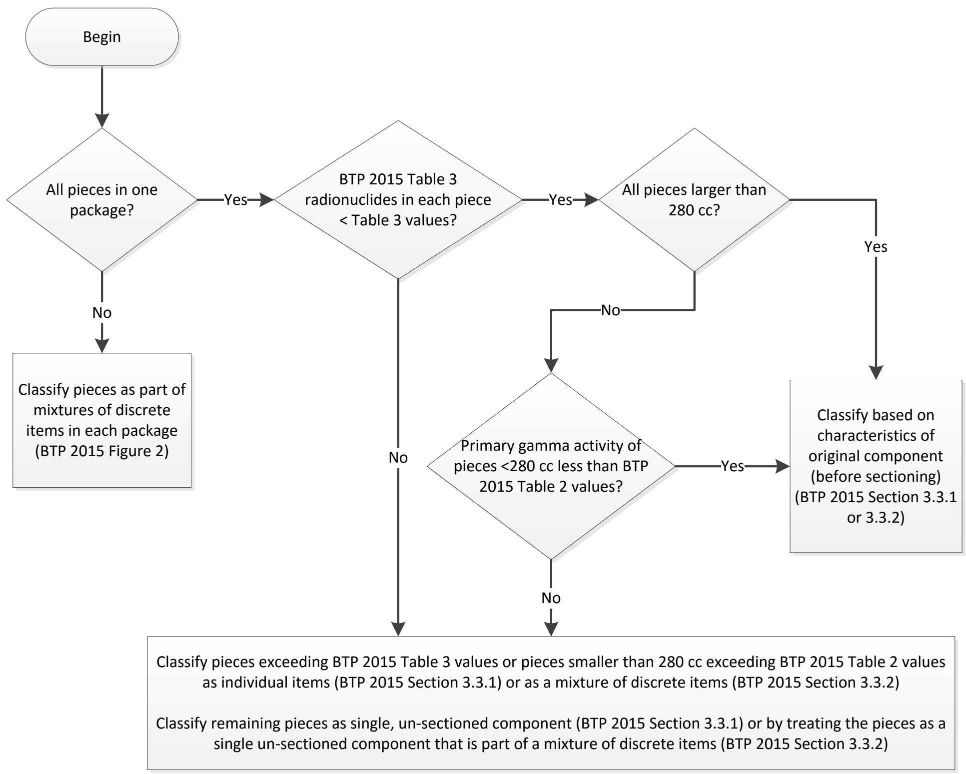


Figure 4-3
BTP 2015 Figure 4 - *Classification of Sectioned Components (from Section 3.3.2.3) [4]*

Items that do not meet the constraints should be removed from the mixture or the classification of the package should be based on the most restrictive item. [4]

Implementation Examples

Example # 9 – Simplified Screening Criteria – Collection of Multiple Discrete Items

In this example, a collection of 100 activated metal bolts is evaluated. The characterization of the components is shown in Table 4-7.

Table 4-7
Example #9 - Simplified Screening Criteria - Characterization

	Highest Activity Bolt	Representative of 99 Single Bolts	Total of 100 Bolts
Waste Type	Activated Material	Activated Material	Activated Material
UM Code	43	43	43
Waste Stream	Activated Metal	Activated Metal	Activated Metal
Waste Volume (ft^3)	.008	.008	0.8
Waste Weight (lbs)	.0625	.0625	6.25
Nuclide	**Activity (mCi)**	**Activity (mCi)**	**Activity (mCi)**
^{3}H	1.70E-11	4.24E-12	4.38E-10
^{14}C	1.36E-04	3.41E-05	3.51E-03
^{51}Cr	1.55E-13	3.86E-14	3.97E-12
^{54}Mn	3.81E-03	9.51E-04	9.81E-02
^{55}Fe	3.11E-02	7.81E-02	7.76E+00
^{59}Fe	2.70E-10	6.76E-11	6.97E-09
^{59}Ni	8.08E-04	2.02E-04	2.08E-02
^{58}Co	8.73E-07	2.18E-07	2.25E-05
^{60}Co	3.86E-01	9.65E-02	9.95E+00
^{63}Ni	9.84E-02	2.46E-02	2.53E+00
^{65}Zn	5.62E-05	1.41E-05	1.45E-03
^{95}Zr	8.24E-19	2.06E-19	2.12E-17
^{94}Nb	2.66E-01	6.65E-07	2.66E-01
^{99}Tc	8.00E-21	2.00E-21	2.06E-19
Total	7.86E-01	2.00E-01	2.06E+01

The highest activity bolt, if evaluated on its own, would have activity concentrations that would evaluate to greater than Class C. However, each bolt, including the one with the highest activity is less than 1 mCi (37 MBq) in total activity. Therefore, the classification of the collection is based on the total volume and weight of the collection. The results are shown in Table 4-8. The waste is Class A.

Table 4-8
Example #9 - Simplified Screening Criteria - Waste Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m^3) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	1.55E-04	8	0	—	—	80	0
^{59}Ni	9.18E-04	22	0	—	—	220	0
^{94}Nb	1.17E-02	0.02	0.5871	—	—	0.2	0.0587
^{99}Tc	9.09E-21	0.3	0	—	—	3	0
^{129}I	0.00E+00	0.008	0	—	—	0.08	0
^{241}Pu *	0.00E+00	350	0	—	—	3500	0
^{242}Cm *	0.00E+00	2000	0	—	—	20000	0
Other TRU*	0.00E+00	10	0	—	—	100	0
Sum-of-fractions			0.5872	—	—		0.0587
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m^3)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	1.93E-11	40	0	—	—	—	—
^{60}Co	4.39E-01	700	0.0006	—	—	—	—
^{63}Ni	1.12E-01	35	0.0032	700	0.0002	7000	0
^{90}Sr	0.00E+00	0.04	0	150	0	7000	0
^{137}Cs	0.00E+00	1	0	44	0	4600	0
$t_{1/2}$<5 yrs	1.93E-11	40	0	—	—	—	—
Sum-of-fractions			0.0043		0.0002		0

Example #10 – Collection of Multiple Discrete Items Meeting Table 2 and Table 3 Criteria

In this example, two discrete items, both activated CRBs, are evaluated. The characterization of the components is shown in Table 4-9.

Table 4-9
Example #10 - Collection of Multiple Discrete Items Meeting Table 2 and Table 3 Criteria Characterization

	CRB#1	CRB#2	Total
Waste Type	Activated Material	Activated Material	Activated Material
UM Code	43	43	43
Waste Stream	Activated Metal	Activated Metal	Activated Metal
Waste Volume (ft^3)	0.28	0.28	0.56
Waste Weight (lbs)	127.85	127.85	255.7
Nuclide	**Activity (mCi)**	**Activity (mCi)**	**Activity (mCi)**
^{3}H	3.01E-01	3.01E-01	6.02E-01
^{14}C	4.58E+01	3.52E+01	8.10E+01
^{51}Cr	2.25E+01	2.25E+01	4.50E+01
^{54}Mn	1.31E+03	1.02E+03	2.33E+03
^{55}Fe	1.06E+05	8.16E+04	1.88E+05
^{59}Fe	9.48E+00	9.48E+00	1.90E+01
^{58}Co	1.17E+01	1.16E+01	2.33E+01
^{60}Co	1.30E+05	1.00E+05	2.30E+05
^{59}Ni	2.73E+02	2.10E+02	4.82E+02
^{63}Ni	6.62E+04	2.55E+04	9.17E+04
^{65}Zn	1.90E+01	1.46E+01	3.36E+01
^{90}Sr	1.46E-02	1.46E-02	2.92E-02
^{94}Nb	8.97E-01	6.90E-01	1.59E+00
^{95}Zr	2.78E-13	2.14E-13	4.92E-13
^{99}Tc	7.59E-03	7.59E-03	1.52E-02
^{129}I	1.45E-03	1.45E-03	2.90E-03
^{125}Sb	0.00E+00	0.00E+00	0.00E+00
^{137}Cs	2.92E-01	2.92E-01	5.83E-01
^{238}Pu	1.70E-03	1.70E-03	3.41E-03
^{239}Pu	5.73E-04	5.73E-04	1.15E-03
^{241}Pu	3.39E-02	3.39E-02	6.78E-02
^{241}Am	3.38E-03	3.38E-03	6.77E-03

Table 4-9 (continued)
Example #10 - Collection of Multiple Discrete Items Meeting Table 2 and Table 3 Criteria Characterization

Nuclide	Activity (mCi)	Activity (mCi)	Activity (mCi)
^{242}Cm	4.21E-03	4.21E-03	8.42E-03
^{243}Cm	2.12E-03	2.12E-03	4.25E-03
Total	3.04E+05	2.09E+05	5.13E+05
Table 1 C SOF*	7.98E-01	6.15E-01	
Table 2 C SOF*	1.19E+00	4.59E-01	

* Sum-of-fractions

The preliminary waste classification of CRB#1 is greater than Class C. The §61.55 Table 2 fraction is the higher table and since the only gamma radionuclide in §61.55 Table 2 applicable to classification at this level is ^{137}Cs and the fraction for ^{137}Cs is less than 50% of the total (^{137}Cs fraction is 8E-06), primary gammas do not control classification for this component. In addition, all isotopes are less than their respective BTP 2015 Table 2 or Table 3 values.

The preliminary waste classification of CRB#2 is C. The §61.55 Table 1 fraction is the higher and the ^{94}Nb fraction of 0.435 is more than 50% of the total, therefore primary gammas do control classification for this component. However, all isotopes, including ^{94}Nb, are less than their respective BTP 2015 Table 2 or Table 3 values and all other radionuclides of concern are less than the Class limit.

Therefore, the classification of the collection can be based on the total volume and weight of the collection. The results are shown in Table 4-10. The waste is Class C.

Table 4-10
Example #10 - Collection of Multiple Discrete Items Meeting Table 2 and Table 3 Criteria Waste Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m³) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	5.11E+00	8	0.6385	—	—	80	0.0639
^{59}Ni	3.05E+01	22	1.3845	—	—	220	0.1384
^{94}Nb	1.00E-01	0.02	5.004	—	—	0.2	0.5004
^{99}Tc	9.57E-04	0.3	0.0032	—	—	3	0.0003
^{129}I	1.83E-04	0.008	0.0229	—	—	0.08	0.0023
^{241}Pu *	5.85E-01	350	0.0017	—	—	3500	0.0002
^{242}Cm *	7.42E-02	2000	0	—	—	20000	0
Other TRU*	<1.34E-01	10	0.0134	—	—	100	0.0013
Sum-of-fractions			7.0681	—	—		0.7068
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m³)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	3.80E-02	40	0.0009	—	—	—	—
^{60}Co	1.45E+04	700	20.7577	—	—	—	—
^{63}Ni	5.78E+03	35	165.2379	700	8.2619	7000	0.8262
^{90}Sr	1.84E-03	0.04	0.0461	150	0	7000	0
^{137}Cs	3.68E-02	1	0.0368	44	0.0008	4600	0
$t_{1/2}$<5 yrs	1.20E+04	700	17.184	—	—	—	—
Sum-of-fractions			203.2634		8.2627		0.8262

Example #11 – Collection of Multiple Discrete Items with Factor of 2 and 10 Averaging

In this example, three discrete items consisting of activated Fuel Channels (FC) are evaluated. The characterization of the components is shown in Table 4-11.

Table 4-11
Example #11 - Collection of Multiple Discrete Items with Factor of 2 and 10 Averaging Characterization

	FC#1	FC#2	FC#3	Total
Waste Type	Activated Material	Activated Material	Activated Material	Activated Material
UM Code	43	43	43	43
Waste Stream	Activated Metal	Activated Metal	Activated Metal	Activated Metal
Waste Volume (ft^3)	0.14	0.14	0.14	0.42
Waste Weight (lbs)	58	58	58	174
Nuclide	**Activity (mCi)**	**Activity (mCi)**	**Activity (mCi)**	**Activity (mCi)**
^{3}H	4.00E-01	4.75E-01	3.85E-01	1.26E+00
^{14}C	1.75E+01	7.85E+01	5.26E+00	1.01E+02
^{51}Cr	2.83E+01	2.83E+01	2.83E+01	8.50E+01
^{54}Mn	6.34E+01	1.51E+02	4.59E+01	2.60E+02
^{55}Fe	9.47E+03	3.94E+04	3.49E+03	5.24E+04
^{59}Fe	1.19E+01	1.19E+01	1.19E+01	3.58E+01
^{58}Co	1.43E+01	1.43E+01	1.43E+01	4.30E+01
^{60}Co	1.02E+04	4.52E+04	3.22E+03	5.87E+04
^{59}Ni	1.55E+00	6.96E+00	4.64E-01	8.98E+00
^{63}Ni	1.01E+02	4.29E+02	3.55E+01	5.66E+02
^{65}Zn	1.40E-02	6.31E-02	4.21E-03	8.13E-02
^{90}Sr	1.84E-02	1.84E-02	1.84E-02	5.52E-02
^{94}Nb	3.17E-01	1.43E+00	9.52E-02	1.84E+00
^{95}Zr	2.92E-05	1.31E-04	8.75E-06	1.69E-04
^{99}Tc	1.08E-02	1.50E-02	9.91E-03	3.56E-02
^{129}I	1.82E-03	1.82E-03	1.82E-03	5.47E-03
^{125}Sb	5.48E+04	2.46E+05	1.64E+04	3.18E+05
^{137}Cs	3.67E-01	3.67E-01	3.67E-01	1.10E+00
^{238}Pu	2.14E-03	2.14E-03	2.14E-03	6.43E-03
^{239}Pu	7.21E-04	7.21E-04	7.21E-04	2.16E-03

Table 4-11 (continued)
Example #11 - Collection of Multiple Discrete Items with Factor of 2 and 10 Averaging Characterization

Nuclide	Activity (mCi)	Activity (mCi)	Activity (mCi)	Activity (mCi)
^{241}Pu	4.27E-02	4.27E-02	4.27E-02	1.28E-01
^{241}Am	4.26E-03	4.26E-03	4.26E-03	1.28E-02
^{242}Cm	5.30E-03	5.30E-03	5.30E-03	1.59E-02
^{243}Cm	2.67E-03	2.67E-03	2.67E-03	8.02E-03
Total	7.47E+04	3.32E+05	2.33E+04	4.30E+05

The preliminary waste classification of FC#1 is Class C. The §61.55 Table 1 fraction is the higher table and the ^{94}Nb fraction of 0.401 is more than 50% of the §61.55 Table 1 total, therefore primary gammas control classification for this component. All isotopes are less than their respective BTP 2015 Table 2 or Table 3 values and all other radionuclides of concern are less than the Class limit.

The preliminary waste classification of FC#2 is greater than Class C. The §61.55 Table 1 fraction is the higher table and the ^{94}Nb fraction of 1.8 is more than 50% of the total, therefore primary gammas control classification for this component. The activity for ^{94}Nb is greater than the BTP 2015 Table 2 value but less than 2 times the Class C limit. All other isotopes are less than their respective BTP 2015 Table 2 or Table 3 values and all other radionuclides of concern are less than the Class limit.

The preliminary waste classification of FC#3 is Class C. The §61.55 Table 1 fraction is the higher table and the ^{94}Nb fraction of 0.12 is more than 50% of the total, therefore primary gammas control classification for this component. However, all isotopes, including ^{94}Nb, are less than their respective BTP 2015 Table 2 or Table 3 values and all other radionuclides of concern are less than the Class limit.

Therefore, the classification of the collection can be based on the total volume and weight of the collection of all three Fuel Channels. The results are shown in Table 4-12. The waste is Class C.

Table 4-12
Example #11 - Collection of Multiple Discrete Items with Factor of 2 and 10 Averaging Waste Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m^3) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	8.52E+00	8	1.0645	—	—	80	0.1065
^{59}Ni	7.56E-01	22	0.0343	—	—	220	0.0034
^{94}Nb	1.55E-01	0.02	7.7485	—	—	0.2	0.7748
^{99}Tc	3.00E-03	0.3	0.0100	—	—	3	0.0010
^{129}I	4.61E-04	0.008	0.0576	—	—	0.08	0.0058
^{241}Pu *	1.62E+00	350	0.0046	—	—	3500	0.0005
^{242}Cm *	2.01E-01	2000	0.0001	—	—	20000	0.0000
Other TRU*	3.72E-01	10	0.0372	—	—	100	0.0037
Sum-of-fractions			8.9569	—	—		0.8957
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m^3)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	1.06E-01	40	0.0027	—	—	—	—
^{60}Co	4.94E+03	700	7.0527	—	—	—	—
^{63}Ni	4.77E+01	35	1.3615	700	0.0681	7000	0.0068
^{90}Sr	4.64E-03	0.04	0.1161	150	0.0000	7000	0.0000
^{137}Cs	9.27E-02	1	0.0927	44	0.0021	4600	0.0000
$t_{1/2}$<5 yrs	3.12E+04	700	44.5464	—	—	—	—
Sum-of-fractions			53.1720		0.0702		0.0068

Comparison to Previous Guidance

As discussed in the overview to this Section, the BTP 2015 methods for averaging discrete items represent an expansion of the range of what may be included in the averaging calculation over the BTP 1995. While the end result of each methodology is reasonably equivalent, the application process is quite different. Either method may be used to comply with 10 CFR Part 61.55.

Alternative Treatment of Certain Cartridge Filters

Guidance

The BTP 2015 provides for alternate methods to classify cartridge filters. By definition, they are discrete items and should be evaluated as discussed above. [4] However, an evaluation can be performed and documented to show that the type of cartridge filter or the manner in which activity is contained in or on it will not remain durable in the disposal environment or the filter will otherwise not exhibit the same characteristics of a discrete item. In this case, the cartridge filter may be treated as a blendable waste form. [4] The evaluation would be specific for each system or filter type and must show that: [4]

- The historic activity levels of primary gamma radionuclides are within the Table 2 values in the BTP 2015 and that the concentrations of the remaining radionuclides of concern do not exceed Class C limits and,
- The design of the filter would preclude retention of radioactivity contained within the filter itself during an intrusion event, and;
- The filter medium itself is non-metallic and expected to degrade in the disposal environment before the anticipated intrusion can occur.

Filters treated in this manner would still need to be treated as a separate waste stream with reporting on manifests for disposal in accordance with 10 CFR Part 20 Appendix G. [4] [16]

Implementation Examples

There are a number of operating experience examples of cartridge filters that can be shown to be non-durable in certain conditions. Some types of underwater vacuum filters have a documented history of degradation after storage in water over a period of time. [21] [22] Filters from other manufacturers composed of similar materials should be expected to have similar characteristics and not be durable in the disposal environment given similar conditions of use and storage. Once the alternative treatment option is documented, the classification of those filters would proceed as with blendable waste per the BTP 2015 Section 3.2.

Comparison to Previous Guidance

The BTP 1995 did not contain any similar guidance. Cartridge filters are treated as discrete items subject to individual averaging constraints. [6] The BTP 1995 did not specifically prohibit changing the form of cartridge filters by shredding and mixing with a binding agent to then treat the resulting form as solidified waste. The BTP 2015 explicitly recognizes this process as a legitimate option for processing cartridge filters. [4] The BTP 2015 also provides specific criteria that can be used to identify certain filters as not discrete.

Encapsulation of Discrete Items

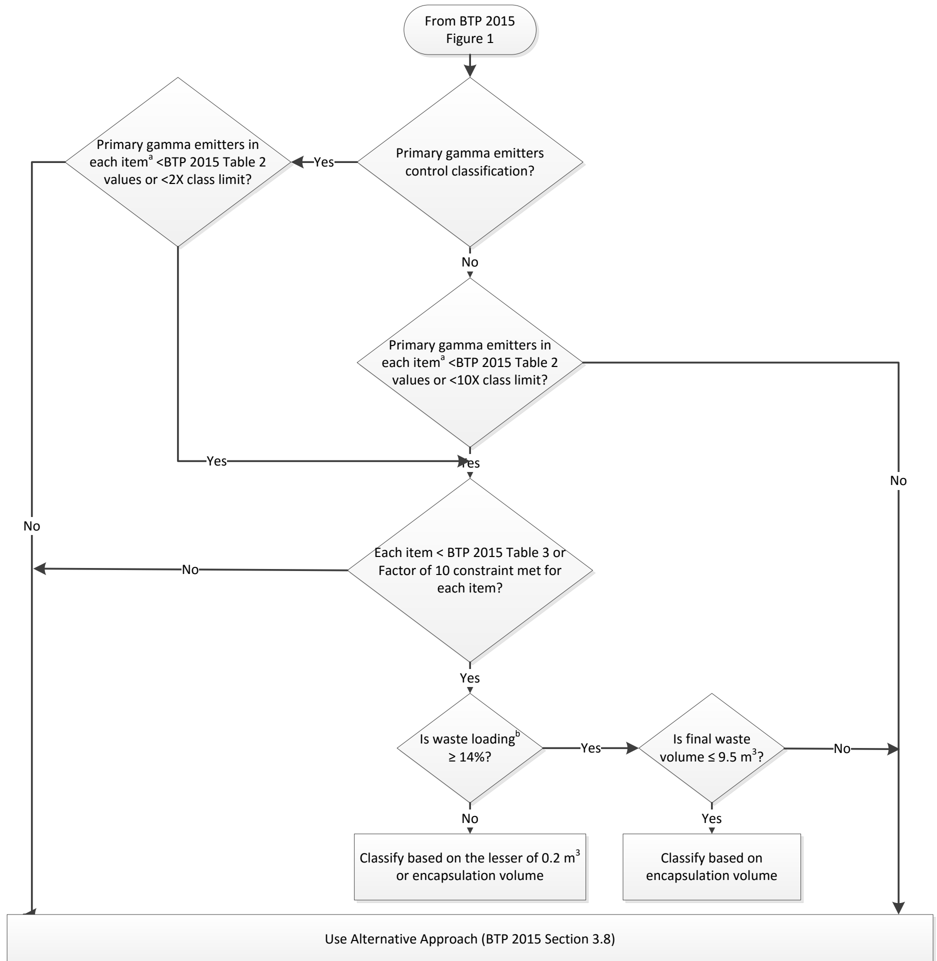
Guidance

The BTP 2015 defines encapsulation as the process of surrounding a discrete (radioactive) item in a non-radioactive binding matrix as opposed to mixing the radioactive material into and within the matrix. [4] 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 volume and mass of the binding matrix may be used to determine the concentration of radioisotopes for waste classification subject to the following limitations: [4]

- The volume of waste divided by the total volume of the waste and binder is at least 14% to take credit for volumes more than 0.2 m^3 (55 gallons).
- If the waste loading is less than 14%, then the maximum volume / mass that can be included in the calculation of concentration is 0.2 m^3 (55 gallons) / 500 kg (1,100 lbs).
- Containers up to and including 9.5 m^3 (331 ft^3) in volume are allowed.
- The minimum solid volume or weight should be large enough to inhibit movement of the item without the use of large equipment
- The amount of radioactivity or concentrations of individual encapsulated items are subject to the discrete item activity limits (Section 3.3.2 and Tables 2 and 3 of the BTP 2015). [4]

Larger container volumes or higher activity amounts, such as the encapsulation of activated metals inside a reactor vessel may be acceptable but are to be evaluated on a case by case basis as discussed in Section 3.8.4 of the BTP 2015. [4] The process is shown graphically in Figure 4-4.



[a] For comparison to Table 2 values, items larger than 280 cc (010. ft³) may be treated individually. Items smaller than 280 cc (0.01 ft³) should be grouped together (see Section 3.3.4)

[b] Waste loading = (vol waste / total vol) x 100

Figure 4-4

BTP 2015 Figure 5 - *Classification of Encapsulated Items*[6] *[4]*

Implementation Examples

Example #12 – Encapsulated Sealed Source

The source from Example #8 is encapsulated with concrete in a 55-gallon drum. The isotope is ^{137}Cs with no other isotopes; therefore, primary gamma isotopes control classification. The quantity of ^{137}Cs (10 Ci or 370 GBq) is less than the BTP 2015 Table 2 limit of 130 Ci (4.81 TBq) for Class C waste. The source is encapsulated in a single 55-gallon drum (0.2 m^3) with a final weight of 1,285 lbs (583 kg). Therefore, the classification of the package can be based on the weight and volume of the source and concrete in the drum. The results are shown in Table 4-13. The waste is Class C.

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[6] Section 3.3.4 of the BTP 2015 identifies the final waste volume limit as ≤9.5m^3 while BTP 2015 Figure 5 and the more accurate conversion of 331 ft^3 is 9.4 m^3. The NRC acknowledges the discrepancy and identified 9.5m^3 as the correct value to use. This table has been modified to correct the error in the original document. [10]

Table 4-13
Example #12 – Encapsulated Sealed Source - Final Waste Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m³) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	0.00E+00	8	0	—	—	80	0
^{99}Tc	0.00E+00	22	0	—	—	220	0
^{129}I	0.00E+00	0.02	0	—	—	0.2	0
^{241}Pu *	0.00E+00	0.3	0	—	—	3	0
^{242}Cm *	0.00E+00	0.008	0	—	—	0.08	0
Other TRU*	0.00E+00	350	0	—	—	3500	0
Sum-of-fractions			0	—	—		0
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m³)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	0.00E+00	40	0	—	—	—	—
^{60}Co	0.00E+00	700	0	—	—	—	—
^{63}Ni	0.00E+00	35	0	700	0	7000	0
^{90}Sr	0.00E+00	0.04	0	150	0	7000	0
^{137}Cs	4.80E+01	1	47.9623	44	1.0901	4600	0.0104
$t_{1/2}$<5 yrs	0.00E+00	700	0	—	—	—	—
Sum-of-fractions			47.9623		1.0901		0.0104

Example #13 – Encapsulated Cartridge Filters

In this example, a collection of 87 cartridge filters is evaluated. The preliminary waste classifications of the individual filters range from Class A to greater than Class C. Table 4-14 shows the characterization of the highest, lowest and collection totals and the preliminary waste classification of the highest and lowest filters.

Table 4-14
Example #13 – Encapsulated Cartridge Filters - Characterization

	09-K-039	**12-K-058**	**Total of 87 Filters**
Waste Type	Cartridge Filter	Cartridge Filter	Cartridge Filter
UM Code	27	27	27
Waste Stream	Primary System	Primary System	Primary System
Waste Volume (ft^3)	0.29	0.19	17.77
Waste Weight (lbs)	4.5	4.5	395.25

Nuclide	**Activity (mCi)**	**Activity (mCi)**	**Activity (mCi)**
^{3}H	3.00E+00	1.82E+00	1.35E+02
^{14}C	2.59E+02	7.14E-01	1.81E+03
^{51}Cr	4.41E-14	4.49E-02	1.57E+00
^{54}Mn	4.62E+00	4.11E-01	2.04E+02
^{55}Fe	6.65E+03	1.29E+01	2.21E+04
^{59}Fe	4.54E-08	0.00E+00	1.46E+00
^{57}Co	5.59E-01	3.19E-02	1.53E+01
^{58}Co	1.84E-03	8.00E-01	1.81E+02
^{60}Co	5.11E+02	5.49E+00	5.57E+03
^{59}Ni	3.86E+00	2.37E-02	3.11E+01
^{63}Ni	5.76E+02	1.29E+00	2.38E+03
^{65}Zn	7.27E+00	4.05E-01	1.33E+02
^{89}Sr	3.54E-11	7.51E-05	4.03E-02
^{90}Sr	7.14E-02	3.65E-05	2.26E-01
^{95}Zr	1.84E-05	4.81E-02	1.78E+01
^{95}Nb	4.05E-05	1.15E-01	3.84E+01
^{99}Tc	7.46E-04	4.59E-06	6.03E-03
^{124}Sb	0.00E+00	1.96E-02	4.78E+00
^{125}Sb	0.00E+00	0.00E+00	3.16E-05

Table 4-14 (continued)
Example #13 – Encapsulated Cartridge Filters - Characterization

Nuclide	Activity (mCi)	Activity (mCi)	Activity (mCi)
^{129}I	0.00E+00	7.95E-02	1.07E+02
^{134}Cs	1.75E-07	1.08E-09	1.41E-06
^{137}Cs	0.00E+00	4.05E-03	1.24E+00
^{124}Sb	0.00E+00	2.86E-02	2.33E+01
^{237}Np	2.27E-05	1.92E-08	5.51E-05
^{238}Pu	2.39E-02	2.04E-05	5.84E-02
^{239}Pu	2.04E-02	1.73E-05	4.97E-02
^{240}Pu	2.04E-02	1.73E-05	4.97E-02
^{241}Pu	3.11E+00	3.24E-03	7.92E+00
^{242}Pu	2.48E-04	2.11E-07	6.05E-04
^{241}Am	4.27E-02	1.65E-05	9.22E-02
^{242}Cm	1.82E-04	1.14E-04	1.21E-02
^{243}Cm	1.64E-02	1.54E-05	4.05E-02
^{244}Cm	1.54E-02	1.54E-05	3.89E-02
Total	8.02E+03	2.42E+01	3.28E+04
§61.55 Table 1	**Class C Fractions**	**Class A Fractions**	
^{14}C	3.9374	0.166	
^{99}Tc	0	0	
^{129}I	0	0	
^{241}Pu *	0.4349	0.0045	
^{242}Cm *	0	0	
Other TRU*	0.6838	0.005	
Sum-of-fractions	5.0562	0.1756	
§61.55 Table 2	**Class C Fractions**	**Class A Fractions**	
^{3}H	—	0.0085	
^{60}Co	—	0.0015	
^{63}Ni	0.1003	0.0686	
^{90}Sr	0	0.0002	
^{137}Cs	0	0.0053	
$t_{1/2}$<5 yrs	—	0.004	
Sum-of-fractions	0.1003	0.088	

The most restrictive filter (09-K-039) is evaluated to establish the boundary of the analysis. Classification of this filter is not controlled by primary gamma radionuclides and the concentrations of all other radionuclides of concern are within a factor of 10 of the Class C limit. Additionally, the filter contains less than the BTP 2015 Table 2 and Table 3 radionuclide activities at the Class A level with a sum-of-fractions for BTP 2015 Table 2 and each nuclide in BTP 2015 Table 3 less than 1 as shown in Table 4-15. Each of the other filters also meet the BTP 2015 Table 2 and Table 3 limits.

Table 4-15
Filter 09-K-039 BTP 2015 Table 2 and Table 3 Evaluation

Nuclide	Class A Limit (mCi)	09-K-039 Activity (mCi)	Fraction
^{60}Co	1.40E+05	5.11E+02	0.004
^{94}Nb	1.00E+00	0.00E+00	0.000
^{137}Cs	7.20E+00	0.00E+00	0.000
Table 2 Total			0.004
^{3}H	8.00E+03	3.00E+00	0.000
^{14}C	1.00E+03	2.59E+02	0.259
^{59}Ni	4.00E+03	3.86E+00	0.001
^{64}Ni	7.00E+03	5.76E+02	0.082
TRU	3.00E+00	1.39E-01	0.046

The collection of filters is placed in a single container which is filled with a vinyl ester styrene encapsulation agent to form a monolith with a total volume of 77 ft^3 (2.18 m^3) and a weight of 6,255 lbs (2824 kg). resulting in a waste loading of 23% which exceeds the minimum waste loading of 14%. Since the final waste volume is less than 9.5 m^3 (331 ft^3) and all other constraints have been met, the classification of the container can be based on the encapsulation volume and weight.[7] The results are shown in Table 4-16 . The waste is Class C.

Table 4-16
Example #13 – Encapsulated Cartridge Filters - Waste Classification

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m³) (*nCi/g)	Class A Limit	Class A Fraction			Class C Limit	Class C Fraction
^{14}C	8.28E-01	0.8	1.0349	—	—	8	0.1035
^{99}Tc	2.76E-06	0.3	0.0000	—	—	3	0.0000
^{129}I	6.48E-10	0.008	0.0000	—	—	0.08	0.0000
^{241}Pu *	2.79E+00	350	0.0080	—	—	3500	0.0008
^{242}Cm *	4.26E-03	2000	0.0000	—	—	20000	0.0000
Other TRU*	1.16E-01	10	0.0116	—	—	100	0.0012
Sum-of-fractions			1.0545	—	—		0.1055
Part 61.55 Table 2 Radionuclide	**Concentration (Ci/m³)**	**Class A Limit**	**Class A Fraction**	**Class B Limit**	**Class B Fraction**	**Class C Limit**	**Class C Fraction**
^{3}H	6.21E-02	40	0.0016	—	—	—	—
^{60}Co	2.55E+00	700	0.0036	—	—	—	—
^{63}Ni	1.09E+00	3.5	0.3116	70	0.0156	700	0.0016
^{90}Sr	1.04E-04	0.04	0.0026	150	0.0000	7000	0.0000
^{137}Cs	1.07E-02	1	0.0107	44	0.0002	4600	0.0000
$t_{1/2}$<5 yrs	1.26E+02	700	0.1798	—	—	—	—
Sum-of-fractions			0.5099		0.0158		0.0016

[7] Section 3.3.4 of the BTP 2015 identifies the final waste volume limit as ≤9.5m^3 while BTP 2015 Figure 5 and the more accurate conversion of 331 ft^3 is 9.4 m^3. The NRC acknowledges the discrepancy and identified 9.5m^3 as the correct value to use. [10]

Comparison to Previous Guidance

The guidance in the BTP 2015 is very similar to Appendix C in the BTP 1995 with the notable exception that the container size limitation has been increased. The requirement for a waste loading to be at least 14% to take advantage of more than 0.2 m^3 (7.5 ft^3) binding volume during concentration averaging maintains the technical consistency with the BTP 1995 for encapsulated items. The BTP 2015 also explicitly recognizes encapsulation binders with topical report approval which includes binders approved by the Conference of Radiation Control Program Directors (CRCPD). [4]

Section 5: Additional Considerations

Classification of Mixtures of Different Waste Types

Guidance

The BTP 2015 permits the mixture of different blendable waste types (such as resin and soil) as long as the physical and chemical compatibility of the mixture is documented and available for inspection. [4] The classification is based on the total activity divided by the total mass and volume as applicable and subject to the constraints of mixing multiple blendable waste streams as discussed in Section 3 of the BTP 2015.

A mixture of discrete items of different waste types is also permitted but the waste classification is based on the highest classification of any of the individual waste types. [4]

Implementation Examples

Example #14 – Multiple Blendable Waste Types

Refer back to Example #2 - Multiple Waste Streams / Single Waste Type. If component #2 was composed of charcoal (Uniform Manifest Code 20) instead of resin, then the only difference in the classification analysis would be to document the physical compatibility of a mixture of resin and charcoal.

Example #15 – Multiple Discrete Waste Types

In this example, the two activated metal components from Example #10 – Collection of Multiple Discrete Items Meeting Table 2 and Table 3 Criteria are combined in a container with the filters in Example #13 – Encapsulated Cartridge Filters. The classification of the container would be based on the higher classification of either the activated metal or the filters. No combinations or averaging across the different waste types is permitted. The container would still be Class C. (If the filters were justified as blendable waste, then the physical and chemical compatibility of the activated metal and encapsulated filters would need to be evaluated and documented).

Comparison to Previous Guidance

The guidance of the BTP 2015 provides more specific direction than the BTP 1995. The BTP 2015 specifies conditions under which different waste types may be combined and the demonstrations necessary to show safety. The BTP 1995 provided less guidance and implied that combinations may need to be addressed under 10 CFR 61.58 "Alternative requirements for waste classification and characteristics".

Determining the Volume or Mass of Waste – Section 3.5 of the BTP 2015

Guidance

The volume of waste may be calculated from the mass of the waste divided by a representative density. [4] For blendable and solidified waste types, this is fundamentally the same as the filled volume of the container. For activated metal components and surface contaminated objects, this is the material volume less the major void spaces. Table 4 in the BTP 2015, reproduced below in Table 5-1, provides a summary of the routine waste types and expected method for determining waste volume. [4] The volume and mass (as applicable) of solidification media may be used in the overall calculation of waste classification if the solidification media has some purpose other than to reduce waste classification (such as stabilization or process control). [4] The guidance provides for the determination of alternate volumes or masses for determining waste classification under the 'Alternative Approaches' section. [4]

Table 5-1
BTP 2015 Table 4 - *Volume and Mass for Determination of Concentration [4]*

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	(BTP 2015) Table 1 volumes.
Blended waste (i.e., two or more blendable waste streams that have been physically mixed together)	(BTP 2015) Table 1 volumes, or larger volumes if adequate blending is demonstrated.

Table 5-1 (continued)
BTP 2015 Table 4 - *Volume and Mass for Determination of Concentration [4]*

Waste	Allowable Classification Volume or Mass
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 (BTP 2015) 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.

Implementation Examples

For purposes of waste classification and often commercial pricing arrangements it is relatively straight forward to determine the waste weight and volume for a waste drum, box, liner, or cargo container with a fixed volume and tare weight.

For an item such as a reactor coolant pump, which may be considered to be contaminated material, the overall displaced volume would be required to be determined with major void volumes subtracted from the envelope volume. For the reactor coolant pump this involves subtracting the interior volume of volute region, suction and discharge nozzles from the envelope volume which includes the casing, shaft and impeller. Since the weight of the pump is known the waste volume can also be conservatively determined by dividing the weight by the density of steel.

Comparison to Previous Guidance

The guidance in the BTP 2015 is similar to the BTP 1995 with the exception that waste volumes and masses are subject to the other constraints for the different waste types.

Quality Assurance Program

Guidance

The BTP 2015 identifies that Appendix G to 10 CFR Part 20 requires the licensee to classify waste in accordance with a quality assurance program designed to ensure compliance with 10 CFR Part 61.55. [4] [16]Documentation of the waste classification analysis along with the shipping manifest must be maintained and available for inspection. [4]

Comparison to Previous Guidance

The guidance in the BTP 2015 is similar to the BTP 1995.

Alternative Requirements for Waste Classification (10 CFR 61.58)

10 CFR 61.58 establishes a regulatory alternative to the waste classification process. This is a distinct and completely separate process from the methods described in the BTP 1995 or the BTP 2015. To date, there are not clear guidelines on how to implement an alternative assessment under this part of the regulations. NRC is currently working on establishing implementation guidance for alternative provisions as part of a revision to 10 CFR 61. [23]

Alternative Approaches for Averaging

The BTP 2015 recognizes that not all situations can be identified in advance and that there may be other approaches to averaging that would be acceptable under the regulations in 10 CFR 61.55(a)(8). Such an alternative would not necessarily require the use of the exemption under 10 CFR 61.58. [4] These alternative approaches would be reviewed by the regulator for the disposal facility and potentially authorized under that authority. The statements in this section, like all of the averaging guidance in the BTP 2015, are not rules or requirements but merely suggestions to licensees that could be used to develop a site-specific alternative approach to averaging for review and approval by the appropriate regulator.

Although conducted before the Alternative Approaches guidance in the BTP 2015 was developed, the disposal of the Trojan reactor vessel detailed in the Technical Evaluation Report of the Washington State Department of Health could serve as a model for such an evaluation. [25]

Site-Specific Intruder Assessments

Site-specific concentration averaging approaches that are different from those in the averaging guidance in the BTP 2015 Sections 3.2 through 3.5 could be based on specific intruder scenarios. These scenarios should be based on a set of assumptions that are considered to be 'reasonably foreseeable' yet conservative and specific to the disposal site. [12] The BTP 2015 identifies a number of specific issues or factors that should be addressed in the submittal to ensure a thorough evaluation. Consideration should also be given to the disposal site's waste acceptance criteria and previous intruder assessments conducted in support of the facility's disposal license.

Encapsulation of Discrete Items, Including Sealed Sources

The encapsulation guidance in Section 3.3.4 of the BTP 2015 is based on specific assumptions regarding the longevity of the encapsulating material and the nature of intrusion events expected within the hazardous time frame of the discrete item. [4] Full details of the assumptions are included in Volume 2 of the BTP 2015. [12] An analysis that identifies site specific criteria that can be shown to be different from the analyses used could justify a different volume or mass for determining the waste classification of the encapsulated item. The differences could include a more robust container or a deeper disposal depth. The analysis would need to be specific with regard to the nature of the encapsulating material or container and the site conditions. [4]

Likelihood of Intrusion

The BTP 2015 includes the position that an intrusion event must be evaluated as it is unlikely but possible at some time in the future. The low probability of such an event is considered in the use of higher dose limitations. [4] [12] The circumstances under which the likelihood of intrusion can be used in an alternative approach are extremely limited. The provable existence of non-potable groundwater under the disposal site or long-term control of the disposal site by the U.S. Department of Energy are examples given where a change to this parameter may be considered in preparing a proposal. [4]

Large Components

The evaluation of large components has always been a special consideration for implementation of the BTP. A prime example is the evaluation of the Trojan reactor vessel with internal components grouted into the vessel and averaged over the total volume. [4] These evaluations are subject to review and approval by the appropriate regulator on a case-by-case basis.

Time of Intrusion into Blendable Waste

The intruder scenarios used in the development of blendable waste constraints in the BTP 2015 are based on specific assumptions on when the intrusion will occur. The times for intrusion for Class A and Class B wastes do not assume the use of intruder barriers. [12] A site specific evaluation that includes the use of robust barriers for Class A and Class B waste could justify a basis for changing these constraints. In practice, this would only be useful where classification is controlled by the §61.55 Table 2 radionuclides because changing the model's time frame for intrusion for the §61.55 Table 1 radionuclides does not appreciably change the dose. [4]

Legacy Wastes

The BTP 2015 recognizes legacy wastes as waste generated by past activities for which the characterization basis may be incomplete or limited with regards to the information needed to implement the current requirements. [4] An alternative evaluation could be prepared to minimize the risk to current workers from opening waste containers and obtaining more direct measurements of packaged items. The guidance in this part is consistent with the BTP 1983 on Waste Classification in that process knowledge can be used to supplement or as a substitute for direct waste samples. [15] The evaluation of legacy wastes may not always require a departure from the concentration averaging provisions of the BTP 2015. Where an alternative approach is considered necessary, then documentation and discussion of the approach is likely to be required by the applicable disposal facility regulator.

Comparison to Previous Guidance

The Alternative Approaches Section of the BTP 2015 is a significant departure from the BTP 1995 which stated that 10 CFR 61.58 exemptions were needed to depart from the guidance. [6] The BTP 2015 clarifies that §61.58 is only needed for exemptions from the rule and provides several examples of Alternative Approaches that can be accomplished without such an exemption. Approval of alternative approaches is left to the competent regulatory authority of the disposal site.

Section 6: Implementation and Back Fit Considerations

The BTP 2015 is intended to clarify and enhance previous guidance. The methods described in the BTP 1995 are still acceptable and both positions can be used to develop waste classifications for compliance with 10CFR 61.55(a)(8). [4] Where the BTP 2015 differs from a disposal facility license condition, the license takes precedence. [4]

Section 7: 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 Concentration Averaging (CA) BTP, a waste type is "blendable" if: (1) the waste can be physically mixed to create relatively uniform radionuclide concentrations or (2) the waste is not expected to contain durable items with significant activity. 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.
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, 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. As described in Section 3.3.3, cartridge filters may be treated as blendable waste in some cases.

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-Emitting Radionuclides	Cobalt-60 (^{60}Co), Niobium-94 (^{94}Nb), and Cesium-137 (^{137}Cs).
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.
Source (Discrete source and Sealed Source) [13]	*Discrete source* means a radionuclide that has been processed so that its concentration within a material has been purposely increased for use for commercial, medical, or research activities. *Sealed source* means any byproduct material that is encased in a capsule designed to prevent leakage or escape of the byproduct 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.

All definitions are from the BTP 2015 [4] except where otherwise noted.

Program:

Radiation Safety Program

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