EPRI Research Results: The EPRI Implementation Guide for the NRC BTP on Concentration Averaging and Encapsulation - 17488

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ABSTRACT

The Nuclear Regulatory Commission published Revision 1 of the Branch Technical Position (BTP) on “Concentration Averaging and Encapsulation” (BTP 2015.) [6] PRI developed an Implementation Guide for applying BTP 2015 to nuclear power plant specific waste streams. This Implementation Guide has been vetted and supported by an EPRI organized working group consisting of industry participants (including utilities subject matter experts, disposal sites, NRC and Agreement State representatives and industry experts) will ensure compliant and consistent application during waste generation, packaging, processing and disposal activities.

The Implementation Guide provides for a comparison to previous BTP guidance and provides clarification and common understanding of the key concepts contained within the revised BTP. These include averaging constraints, hot spots, waste streams, waste types, discrete items, blending, solidification, encapsulation and alternative approaches.

EPRI published the *Implementation Guidance for the Nuclear Regulatory Commission Branch Technical Position on “Concentration Averaging and Encapsulation, Revision 1”* (EPRI Report 3002008189) [12] in the September 2016 and it was made available to the public.

INTRODUCTION

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. The primary purpose of the BTP 2015 is to manage the risk to an individual who could hypothetically intrude on Low Level Radioactive Waste (LLRW) in a disposal facility. [4]

The BTP 2015 introduces two broad categories of waste for the purposes of concentration averaging; blendable or 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 activity concentration (not accounting for radioactive decay) after disposal and may pose a hazard to the inadvertent intruder.

WASTE CHARACTERIZATION

The first technical section of the BTP 2015 deals with waste characterization. This is the process of identifying the physical and radiological characteristics of the waste. 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.

Waste Streams

The BTP 2015 defines a waste stream as having "…relatively uniform radiological and physical characteristics". [4] The term 'relatively uniform' is described 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 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. [7] 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. The radiological properties may be similar enough for the different types to be considered the same waste stream. [4] Common waste streams include: [8]

- 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)

Waste Types

The BTP 2015 defines a waste type as waste having "…relatively uniform physical characteristics." [4] 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] 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 defined by the waste stream. The importance of waste types is important 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 transportation or disposal (see Section 3.2.2 and Section 3.4 of the BTP 2015).

Physical Characterization

The BTP 2015 defines physical characterization specifically. 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 most clear examples but NRC 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. It is not intended that durability is to be determined as part of field evaluations).

Discrete items are expected to be durable during and beyond the period of institutional control AND have relatively high concentrations of radioactivity. They are specifically defined 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

Radiological Characterization

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. [9] [4] he BTP 1983 and BTP 2015 use slightly different words to mean the same thing.

- Materials accountability (1983) / Compliance through materials compatibility (2015),
- Classification by source (1983 & 2015)
- Gross radioactivity measurements (1983 & 2015)
- Direct measurement of individual radionuclides (1983) / Measurement of specific radionuclides (2015)

BLENDABLE WASTE

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. Blendable waste would typically be applied to the following Uniform Manifest Waste Stream Codes:

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

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. DAW is considered blendable because it is not expected to contain durable items with significant activity. [4] This definition is consistent with the BTP 1995 and is not intended to be either a departure from current practices or establish a field test for activity. Significant activity is expressed by the nuclide limits in Table 2 and Table 3 of the BTP 2015 and are highly unlikely based on contamination activity alone (i.e. significant neutron activation of metals would typically be required). A licensee could use process knowledge to show that DAW items would not meet the Table 2 or Table 3 limits based on their specific isotopic mixture if it was deemed necessary or prudent.

Cartridge filters may be considered a blendable waste subject to constraints and demonstrations discussed in Alternative Treatment of Certain Cartridge Filters in Section 3.3.3 of the BTP 2015.

There are few constraints on the mixing of 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 mixed to create a relatively uniform activity distribution versus wastes that are ‘blended’, meaning they have been mixed. It is not always necessary to mix blendable waste streams. Intentional blending of large volumes of waste with significant differences in activity concentration may trigger the need to demonstrate that the resulting mixture is adequately blended to avoid the creation of ‘pockets’ of high activity. The volumes requiring such a demonstration are identified in Table 1 of the BTP 2015. [4] The constraints are intended to apply where at least one of the components in the mixture is more than a factor of 10 higher than the waste class of the mixture and the volume of the high activity component represents a potential to create a ‘hot spot’. [4] Constraints on averaging blendable waste are not applicable if the process utilized can be demonstrated to result in a relatively uniform distribution of radioactivity. [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 after they have already been packaged separately for shipping; as from a generator to a processor. [4].

Comparison to Previous Guidance

The BTP 1995 on Concentration Averaging was internally inconsistent when describing this issue. 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 ALARA. [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. The constraints were also based on the average concentration of the mixture rather than the waste class. This resulted 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

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 non-radioactive materials to waste for solidification may be said to satisfy the BTP by achieving a purpose (qualitative improvement) other than lowering the waste classification. The addition of any quantity of non-radioactive material to a waste form is not prohibited as an extreme measure, provided the generator or processor can demonstrate that the non-radioactive material addition fulfills some purpose. It is not required to demonstrate that the addition of non-radioactive material fulfills a purpose or is in a quantity that is *necessary* to facilitate compliant waste disposal, regardless of whether the addition of non-radioactive material has the effect of lowering the waste class.

DISCRETE ITEMS

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 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 fulfill the scenario objectives and 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. [10] This led NRC to the development of the 'carry-away' scenarios on which the discrete item restrictions are based.

The concept of discrete items in the BTP 2015 is intended to be similar to the BTP 1995. Discrete items are intended to be 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] Previous allowable factors were 1.5 (primary gamma radionuclides) and 10 (non-gamma radionuclides) and were applied to the container average. [6] Concentration averaging is also allowed if the discrete item contains less than specified quantities of certain radioisotopes regardless of the concentration. [4]

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 or multiples of a type of discrete item may be averaged over the total volume or weight of the mixture or collection if the individual items meet the criteria. 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. The process of evaluating discrete items begins with the determination whether the waste is blendable or not. If the waste is not blendable, then it must be determined if the item(s) will be encapsulated or not. The activity concentrations for a single, discrete item *that is not encapsulated* are based on the activity of their 10 CFR 61.55 radionuclides divided by the volume or weight of the item as applicable. [4] The activity concentrations for a single, discrete item *that is encapsulated* are based on the activity of their 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. [4]

Mixtures of discrete items that individually evaluate to the same waste class may be packaged and classified together as 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.

If each discrete item has a total activity < 37 MBq (1 mCi) then the concentrations for classification can be derived from the total activity divided by the total volume or weight of the mixture. If any or all items have an activity 37 MBq or greater, then the classification of the mixture may be based on the discrete item with the highest individual waste classification. If the mixture contains different waste types (ex. 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. 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 class-fraction of the isotope(s) accounts for more than 50% of the respective §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 (Table 1 of this report) 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 (Table 1 of this report) values or less than ten times the applicable class limit to be eligible for averaging. In both cases, non-gamma radionuclides listed in BTP 2015 Table 3 (^{3}H, ^{14}C, ^{59}Ni, ^{63}Ni, TRU) must be less than the BTP 2015 Table 3 (Table 2 in this report) 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. 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 the package can be classified according to the highest discrete item, the non-averageable items may be removed or the non-averageable items may be encapsulated and re-evaluated based on the rules for encapsulated items.

Table 1 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 2 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 241Pu and 242Cm)	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 Control Rod Blades (CRB's) from Boiling Water Reactors (BWR's), then some additional evaluation of the individual sections is required to ensure that the classification basis of the original component is maintained. The sections must all be packaged together. Sections smaller than 280 cm^3 (0.01 ft^3) should have isotopic activity within the Table 2 criteria and all pieces of any size should meet the Table 3 criteria of the BTP 2015. If any of these constraints are not met, then the sections should be evaluated individually. [4] Items that are smaller than 280 cm^3 (0.01 ft^3) should be grouped together. That is, for comparison to Table 2, the sum of fractions should be based on the total inventory of each primary gamma-emitting radionuclide in the items smaller than 280 cm^3 (0.01 ft^3). The Factors of 2 and 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 BTP 2015 Section 3.3.1. If items smaller than 280 cm^3 (0.01 ft^3) collectively exceed the Table 2 limits, using a sum of fractions, and they do not individually meet the Factor of 2 or 10 (as applicable), their concentrations should not be averaged to meet the Factor of 2 or 10. The classification of the remaining mixture may be based on the volumetrically averaged or weight-averaged concentrations of the mixture. 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]

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/on it will not remain as 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.
- The design of the filter would enable radioactivity contained in it to not remain within the filter itself during an intrusion event, or;
- 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] [11]

Encapsulation of Discrete Items

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 for storage or 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 is 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 stable binder is at least 14%.
- 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).

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]

ADDITIONAL CONSIDERATIONS

Classification of Mixtures of Different Waste Types

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]

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

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, 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]

IMPLEMENTATION EXAMPLES [12]

The following are two implementation examples provided in the EPRI BTP Implementation Guide.

Example #2 - Multiple Waste Streams / Single Waste Type

Two waste streams of Powdered Resins with different radiological characteristics (one from the primary system and the other from fuel pool system) are combined in a single container. The characterization of the two constituents is shown in Table 3.

Table 3 Example #2 - Multiple Waste Streams / Single Waste Type – Characterization [12]

	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, m^3 (ft^3)	1.3 (45)	1.6 (55)	2.83 (100)
Waste Weight, kg (lbs)	1020 (2248)	1246 (2747)	2266 (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

If evaluated separately, each waste constituent would have the preliminary waste classifications as shown in Table 4 and Table 5. The Primary System resin is Class B and the Fuel Pool System resin is Class A. [12]

Table 4 Example #2 Constituent #1 Preliminary Waste Classification [12]

Part 61.55 Table 1 Radionuclide	Concentration (Ci/m^3) (*nCi/g)	Class A Limit	Class A Frac-tion			Class C Limit	Class C Frac-tion
^{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/m^3)	Class A Limit	Class A Frac-tion	Class B Limit	Class B Frac-tion	Class C Limit	Class C Frac-tion
^{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 5 Example #2 Constituent #2 Preliminary Waste Classification [12]

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	<8.87E-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/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	3.81E-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 activity concentrations and waste class fractions of the resulting combination is shown in Table 6. The waste classification of the combination is Class A. [12]

Table 6 Example #2 Combination Waste Classification [12]

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 combination is less than 10 times the Class A limit. As such, there is no volume threshold and demonstration of adequate blending is not required.

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

Three discrete items consisting of activated Fuel Channels (FC) are evaluated. The characterization of each of the components is shown in Table 7.

Table 7 Example #11 – Characterization of Fuel Channels [12]

	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, m^3 (ft^3)	3.4E-03 (0.14)	3.4E-03 (0.14)	3.4E-03 (0.14)	1.2E-02 (0.42)
Waste Weight, kg (lbs)	26 (58)	26 (58)	26 (58)	79 (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
^{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. As such, the classification for this component is controlled by primary gammas. 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. As such, the classification for this component is controlled by primary gammas. 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. As such, the classification for this component is controlled by primary gammas., 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 8. The waste is Class C. [12]

Table 8 Example #11 - Waste Classification of the Combination of Fuel Channels [12]

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

CONCLUSIONS

The objective of this work was to create a BTP 2015 Implementation Guide for nuclear power plant generated waste. EPRI sponsored a working group consisting of waste generators (utilities), disposal sites, NRC and Agreement State representatives to develop the guide. The guide incorporates explanations of key concepts and provides guidance, flowcharts and examples for

- Blending of resins and other wastes
- Solidification of shredded filters
- Justification for Treatment of Cartridge Filters as Blendable
- Concentration Averaging of Discrete Items
- Encapsulation

Constraints on mixing blendable wastes are significantly reduced, based on the average concentration of the mixture and can facilitate disposal of more waste as Class A waste. Constraints on averaging of discrete items are now based on the classification limits rather than the package average. Discrete items can be averaged over the mixture of discrete items if they're within factors of 2 for primary gamma radionuclides and 10 for non-gamma radionuclides of the applicable waste classification limit. In the BTP 1995 the factors were 1.5 for primary gamma radionuclides and 10 for non-gamma radionuclides and the factors were applied to the container average. In addition, concentration averaging of discrete items is also allowed if the discrete item contains less than specified quantities of certain radioisotopes regardless of the concentration. Again, this approach can facilitate disposal of more waste as Class A waste. In all cases, the averaging constraints are consistent with clear technical evaluations and meet the NRC's objective of becoming more risk-informed.

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