DISUSED SOURCES

The Need for Proper Management and Disposition

REPORT OF THE DISUSED SOURCES WORKING GROUP

An Evaluation of the US NRC's 2015 Revision to the Branch Technical Position on Concentration Averaging and Encapsulation for the Disposal of Radioactive Sealed Sources

LLW FORUM, INC

Low-Level Radioactive Waste Forum, Inc.
May 2021

Table of Contents

An Evaluation of the US NRC's 2015 Revision to the Branch Technical Position on Concentration Averaging and Encapsulation for the Disposal of Radioactive Sealed Sources

Executive Summary

The US Nuclear Regulatory Commission (NRC) has established a classification system for low-level radioactive waste (LLRW) based on the concentration of radioactivity present in the waste. The general nature of radioactive sealed sources presents certain challenges when it comes time for their disposal because their high radioactivity and small size result in a high concentration that can easily exceed the Class C limit. In 2015, the NRC issued Revision 1 to the Branch Technical Position on Concentration Averaging and Encapsulation (BTP). The BTP provides guidance on how to properly classify low-level radioactive waste for disposal. This report prepared by the LLW Forum's Disused Sources Working Group (DSWG) evaluates the impact of the 2015 revision has on the classification of sealed sources for disposal.

The BTP allows for discrete items, like sealed sources, to be encapsulated in a non-radioactive binding matrix (typically cement) where the concentration is determined based on the volume or mass of the sealed source and encapsulation media. A process is provided in the BTP that limits the size of the container and amount of encapsulation media that can be used in classifying the waste, and considers the specific radionuclides present and the potential health impact on an inadvertent intruder.

To determine the impact of the revision, telephone interviews were conducted with LLRW disposal facility operators, brokers, and processor to determine the impact of the revision on the classification of sealed sources for disposal. The consensus was the revision improved the classification process through added clarity, allowing for the use of larger disposal containers, and providing the flexibility to apply the least restrictive classification.

While the classification process has improved with the 2015 revision, obstacles remain for disposing of sealed sources. These include the high cost of disposal, the availability and cost of Type B shipping containers, and the licensee's not adequately planning for the life cycle cost associated with sealed sources.

Introduction

The US Department of Energy's National Nuclear Security Administration (NNSA) has asked the LLW Forum's Disused Sources Working Group (DSWG) to evaluate the impact that the US Nuclear Regulatory Commission's (NRC) 2015 revision to the Branch Technical Position (BTP) on Concentration Averaging and Encapsulation has had on the disposal of radioactive sealed sources. Sealed sources are a security concern when the administrative control of the source is lost or compromised, and the source is lost, stolen, or used in a malevolent manner.

Following the end of the useful life of a sealed source, a source may be placed in storage, transferred to another licensee for reuse or recycle, returned to the manufacturer, or sent for disposal. Sealed sources sent for disposal must be properly classified. This report is intended to provide an overview of the waste classification process for sealed sources using the revised BTP and a discussion of the differences between the revised and original BTPs.

The disposal of radioactive sealed sources is problematic for a variety of reasons. First, the small size and high radioactivity content presents a significant potential hazard to the workers at the disposal facility and to an inadvertent intruder. The high radioactivity content requires shielding to protect those workers involved in the packaging, transportation, and disposal operations and to an inadvertent intruder during the post-closure period. The small size makes it easy for the intruder to relocate the source. In the process, the high activity causes an immediate exposure concern for the intruder. Second, given the small size and high radioactivity content when classifying the source for disposal it is easy for the source to exceed the Class C waste limits established in 10 CFR 61.55.

To prevent these situations from occurring, most sealed sources of concern[1] are encapsulated. Encapsulation is a process of packaging a sealed source where the source is surrounded with a non-radioactive binding matrix, typically cement or concrete. The radioactivity remains in the sealed source and is not incorporated into the encapsulation media. The encapsulation media helps prevents the release of radioactivity to the environment, provides shielding for the workers and inadvertent intruder, and provides a means to meet the structural stability requirement for Class B and C wastes (10 CFR 61.56).

When determining the waste classification, the NRC provides that activity concentration of the sealed source may include the volume/mass of the encapsulation media. To prevent an extreme situation, the NRC establishes guidance (i.e., constraints) on the volume/mass of encapsulation media that may be considered. Container size for purposes of waste classification is limited based on the waste loading in the container. Waste loading is the ratio (expressed as a percentage) of the volume of waste (sealed sources) to the overall container volume. If the waste loading is 14 percent or greater, a container size of 331 ft^3 (9.5 m^3) may be

[1] Sealed sources of concern are those sealed sources that pose a security risk, i.e., those that can be used for a malevolent purpose. These sources can be generally categorized as IAEA Category 1, 2, and 3 sealed sources.

considered.[2] For a container with waste loading less than 14 percent the container size limit for purposes of waste classification is 7.5 ft^3 (0.2 m^3) or 1100 pounds (500 kg). These size limits do not preclude the use of larger containers. Rather it limits the volume or mass that may be taken into consideration when calculating the waste class.

The NRC also establishes a minimum size, which they establish that as large enough that an inadvertent intruder would need mechanical equipment to move the container. This minimum size helps to prevent the “carry-away” scenario where the inadvertent intruder can physically remove the waste by hand.

The NRC also establishes limitation on the total radioactivity contained in a package using the classification process described below.

Process for Determining the Waste Class for Sealed Sources

Section 3.3.4 of the 2015 BTP provides the process for determining the waste class for encapsulated discrete items (sealed sources). The process for classifying encapsulated waste is shown in Figure 5[3] below. The class limits referred to in the figure are the limits from 10 CFR 61.55. 10 CFR 61.55 is reprinted in Appendix 1. The references to Tables 2 and 3 refer to those tables from the BTP and are shown below as Table 2 and 3[4].

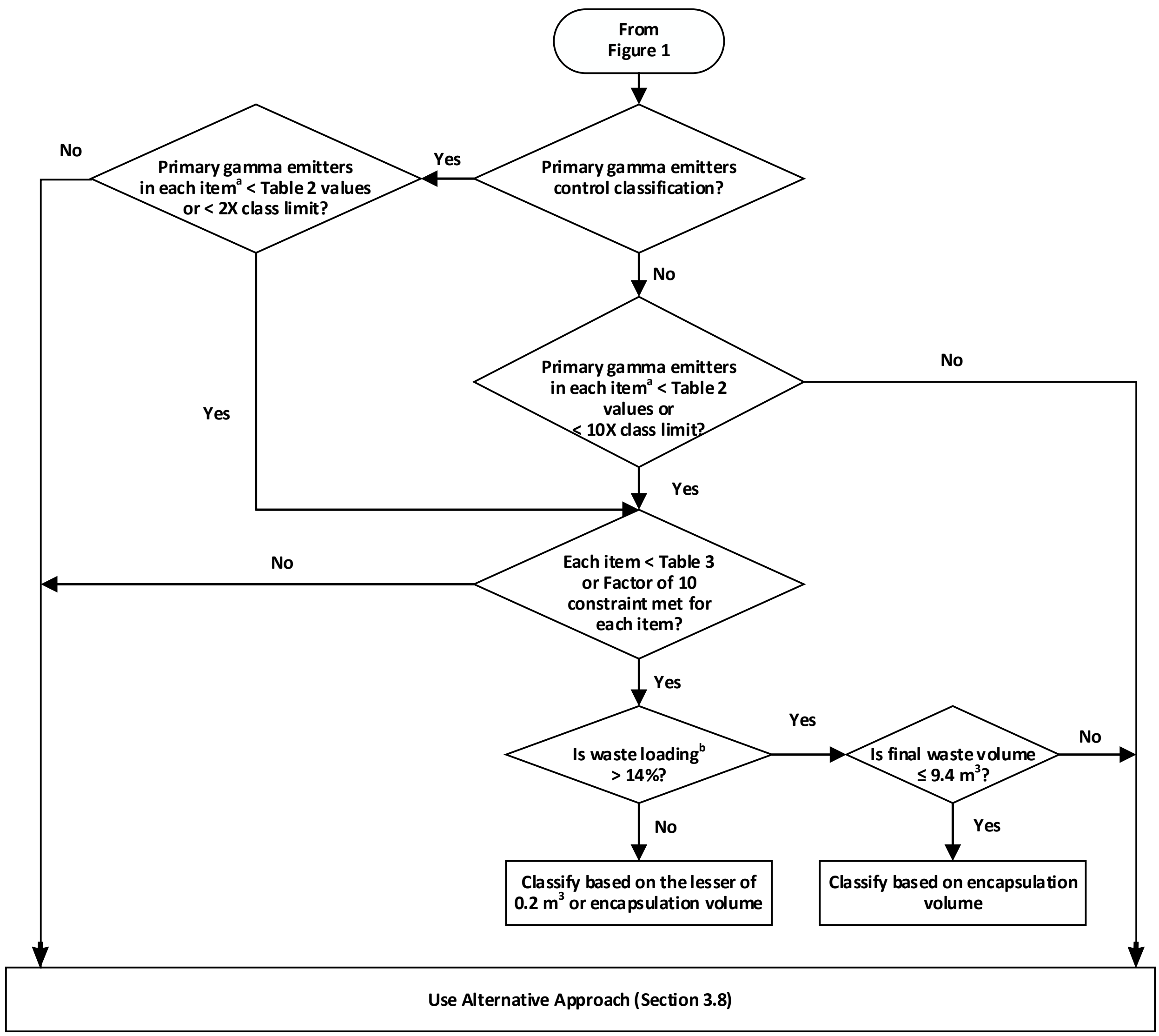
The BTP provides that when classifying a container that contains multiple sealed sources, all those sealed sources that are smaller than 0.01 ft^3 (280 cc) should be grouped together with their respective radioactivity aggregated. Sealed sources larger than 0.01 ft^3 (280 cc) may be treated individually. Given that 280 cc is equivalent to 17 cubic inches it is unlikely that a sealed source would be considered individually unless it was the only source in a container. For purposes of this report, it will be assumed that waste classification will be determined based on the aggregate radioactivity rather than specific individual items.

As shown in Figure 3, the first step in classifying the waste package is to determine whether the primary gamma emitters control classification. The primary gamma emitters, which include cobalt-60, niobium-94, and cesium-137, are a health concern for a future inadvertent intruder handling a discrete item. The non-gamma emitting radionuclides are all the radionuclides from the 10 CFR 61.55 Tables 1 and 2 except ^{60}Co, ^{94}Nb, and ^{137}Cs. More restrictive averaging constraints apply when the primary gamma-emitters control the classification.

---

[2] US NRC, Concentration Averaging and Encapsulation Branch Technical Position, Revision 1, February 2015, pg. 30.
[3] For purposes of clarity and reader comprehension, Figures and Tables are numbered based on the numbers used in the 2015 BTP. This breaks with normal writing convention but is done so that references to figures and tables in this report are the same as in the 2015 BTP.
[4] Ibid.

Figure 3. Classification of Encapsulated Items



[a] For comparison to Table 2 values, items larger than 280 cc (0.01 ft^3) may be treated individually. Items smaller than 280 cc (0.01 ft^3) should be grouped together (see Section 3.3.4)

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

The NRC provides the following explanation for determining whether primary gamma-emitters control the classification:

> "To determine whether the primary gamma emitters control the classification, the licensee should evaluate their relative significance as compared to the other radionuclides in the waste. The licensee should first determine the sums of fractions for

10 CFR 61.55 Tables 1 and 2. Then the licensee should determine which 10 CFR 61 table would result in a higher waste classification. This is the more restrictive table. If Tables 1 and 2 of 10 CFR 61.55 result in the same waste classification, the table that has the greater sum of fractions is the more restrictive table. Finally, the licensee should determine the fractional contribution that the primary gamma emitters make to the sum of fractions in the more restrictive table. If the primary gamma emitters contribute more than 50 percent of the sum of fractions in the more restrictive table, the primary gamma emitters are considered "classification controlling."

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

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

As can be seen in Table 2, the activity limit for ^{94}Nb is the same for Class A, B and C. These limits were calculated based on the intruder scenarios used for the different waste classes. The Class A intruder scenario occurs at the end of the 100-year post closure period. Class B low-level radioactive waste requires stabilization that will last a minimum of 300 years. The Class B intruder scenario occurs 300-years post closure when credit for the waste form can no longer be taken into consideration. Class C wastes requires disposal at a sufficient depth or with intruder barriers designed to last 500 years. The Class C intruder scenario occurs 500-years after closure. The half-life for ^{94}NB is approximately 20,300 years. Therefore, there is minimal radioactive decay at the time of the various intruder scenarios. This results in the same activity limit for all waste classes.[5]

[5] A more detailed explanation can be found in US Nuclear Regulatory Commission, Concentration-Averaging and Encapsulation Branch Technical Position, Revision 1, Volume 2, Responses to Stakeholder Comments and Technical Basis, Section 4.3, Gamma-Emitting Discrete Items (Table 2 and the Factor of 2). pg. 80.

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

Nuclide*	For Waste Classified as Class A or B	For Waste Classified as Class C
^{3}H	0.3 TBq (8 Ci)	No limit
^{14}C	0.04 TBq (1 Ci)	0.04 TBq (1 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.

In using the Table 2 limits for the primary gamma emitters, the sum of the fractions rule applies. When comparing to the Table 2 values, items smaller than 280 cc (0.01 ft^3) are grouped together: items larger than 280 cc (0.01 ft^3) are considered individually. The Factors of 2 and 10 are determined for each radionuclide individually, not using the sum of fractions.

For non-primary gamma emitters, the licensee may choose either the Table 3 limit or the Factor of 10 concentration limit. Licensees may choose the less restrictive limit.

The methods described above are generic and apply to all disposal sites. The revised BTP provides for alternative approaches for concentration averaging that take into consideration unique disposal site considerations and other approaches to protecting the future inadvertent intruder. These include site-specific intruder assessments, encapsulation of discrete items, and potential likelihood of intrusion.

Example:

A petrochemical plant has 13 fixed gauges all containing ^{137}Cs radioactive sealed sources. The sources are assumed to be one-half inch in diameter and two inches long. This is a volume of 1.57 cubic inches which equals 0.0000257 cubic meters. The BTP includes ^{137}Cs as a primary gamma-emitting radionuclide.

In classifying the sealed sources for disposal, the radioactivity concentration must be compared to the waste class limits specified in 10 CFR 61.55. Table 4 below provides the comparison of the source activity concentration with the waste classification limits.

Table 4 – Non-Encapsulated Waste Classification

Non-Encapsulated							
Volume: (m^3)	2.570E-05						
Isotope	Activity (Ci)	Class A limit (Ci/m^3)	Fraction of the limit	Class B limit (Ci/m^3)	Fraction of the limit	Class C Limit (Ci/m^3)	Fraction of the limit
Cs-137	0.041	1	1595.33	44	36.26	4600	0.35
Cs-137	0.041	1	1595.33	44	36.26	4600	0.35
Cs-137	0.021	1	817.12	44	18.57	4600	0.18
Cs-137	0.021	1	817.12	44	18.57	4600	0.18
Cs-137	0.041	1	1595.33	44	36.26	4600	0.35
Cs-137	0.205	1	7976.65	44	181.29	4600	1.73
Cs-137	0.028	1	1089.49	44	24.76	4600	0.24
Cs-137	0.055	1	2140.08	44	48.64	4600	0.47
Cs-137	0.055	1	2140.08	44	48.64	4600	0.47
Cs-137	0.011	1	428.02	44	9.73	4600	0.09
Cs-137	0.066	1	2568.09	44	58.37	4600	0.56
Cs-137	0.129	1	5019.46	44	114.08	4600	1.09
Cs-137	0.826	1	32140.08	44	730.46	4600	6.99
Sum of Fractions:			**59,922.18**		**1,361.87**		**13.03**

As can be seen in the table, none of the sources would be classified as Class A or B. All but 3 of the sources could be classified as Class C. This is indicated by the fraction of the limit. If the fraction is greater than 1, then the waste does not meet that waste class. Because the source activity is averaged over the extremely small volume, the concentration is high. Sources that have a fraction greater than 1 for the Class C waste class would be considered Greater Than Class C (GTCC) and are not considered suitable for near surface disposal. As indicated in the table, several sources could be combined and still be classified as Class C waste provided that the sum of the fractions does not exceed one.

The BTP allows for sealed sources to be encapsulated where the volume or mass of the encapsulation media is taken into consideration for determining waste classification. In comparison with the previous example, the radioactivity concentration is much lower since the volume is much larger.

Table 5: Encapsulated Sealed Source Waste Classification

Encapsulated							
Volume: (m^3)	0.208						
Isotope	Activity (Ci)	Class A limit (Ci/m^3)	Fraction of the limit	Class B limit (Ci/m^3)	Fraction of the limit	Class C Limit (Ci/m^3)	Fraction of the limit
Cs-137	0.041	1	0.20	44	0.00	4600	0.00
Cs-137	0.041	1	0.20	44	0.00	4600	0.00
Cs-137	0.021	1	0.10	44	0.00	4600	0.00
Cs-137	0.021	1	0.10	44	0.00	4600	0.00
Cs-137	0.041	1	0.20	44	0.00	4600	0.00
Cs-137	0.205	1	0.98	44	0.02	4600	0.00
Cs-137	0.028	1	0.13	44	0.00	4600	0.00
Cs-137	0.055	1	0.26	44	0.01	4600	0.00
Cs-137	0.055	1	0.26	44	0.01	4600	0.00
Cs-137	0.011	1	0.05	44	0.00	4600	0.00
Cs-137	0.066	1	0.32	44	0.01	4600	0.00
Cs-137	0.129	1	0.62	44	0.01	4600	0.00
Cs-137	0.826	1	3.97	44	0.09	4600	0.00
		Sum of Fractions:	**7.40**		**0.17**		**0.00**

As can be seen in the fraction of the limit column for the Class A, all but one of the sources would be considered Class A if disposed individually in an encapsulated form. Several sources could be combined into a single package and still meet the Class A limit provided the sum for the fractions does not exceed one.

Following the waste classification process depicted in Figure 5, when classifying waste where the primary gamma-emitting radionuclides control waste classification it must be determined if the aggregate radioactivity exceeds the value listed in Table 2 (7.2 mCi for Class A, 720 mCi for Class B, or 130 Ci for Class C) or if the individual sources exceed a concentration of twice the waste classification limit from 10 CFR 61.55 (1 Ci/m^3 for Class A, 44 Ci/m^3 for Class B, or 4600 Ci/m^3 for Class C).

For this specific example, the decision will likely be based on the economics of multiple encapsulated Class A waste containers versus a single encapsulated Class B waste container.

Alternative Approaches for Concentration Averaging

Section 3.8 of the revised BTP allows for alternative approaches in averaging the waste concentration from what is explicitly stated. Use of an alternative approach to concentration averaging would need to be discussed with the disposal facility operator and regulator. Alternative approaches are based on disposal facility site specific conditions, waste specific considerations and other means to protect the inadvertent intruder.

Provided that the alternative approach to concentration averaging complies with the concentration limits in 10 CFR 61.55, there is no need for the licensee to seek authorization under 10 CFR 61.58 or request an exemption. The BTP assumes that the encapsulation media will fail prior to the inadvertent intrusion, which results in either the small item or large item carry away intruder scenarios. The intruder scenarios are discussed in Volume 2, Section 4 of the BTP. Alternative approaches can propose different intruder scenarios either using a more robust case that cannot be easily opened or increased disposal depth.

The NRC identifies the following considerations when justifying the use of an alternative approach:[6]

- a detailed description of the item(s), including physical and radiological characteristics;
- a description of how the alternative approach differs from the CA BTP's position on encapsulation in Section 3.3.4;
- an overview of the proposed alternative provision (e.g., depth of burial), and how the alternative provision protects the intruder;
- a description of site characteristics pertinent to the proposal;
- a description of any source-containing devices, encapsulating media, and any additional packaging proposed for disposal;
- an analysis of the effects of degradation of packaging and engineered barriers over the period that the item remains hazardous to an intruder, as applicable; and
- an identification of the proposed limits for items to be disposed, based on the alternative inadvertent intruder analysis.

When utilizing an alternative approach to waste classification for encapsulated sealed sources, the licensee needs to work closely with the disposal facility operator and the respective regulatory agency. The alternative approach will generally focus on the potential dose an

[6] Quoted directly from the BTP page 38.

inadvertent intruder would be exposed to if the disposal container were breached and the intruder directly contacts the sealed source.

There are several factors that impact the potential for intrusion. These include a greater depth of disposal, longevity of the encapsulation media, and life of the disposal container and overpack. A greater depth of disposal will reduce the likelihood of intrusion through normal activities (resident occupant). Longer lived encapsulation media will keep the sealed source contained within the media. Robust containers and the use of modular concrete overpacks provide additional protection for the encapsulation media and sealed source.

In the BTP, the NRC states "While it is accurate to say that intrusion analyses typically result in estimates of consequences (i.e., dose) rather than risk (i.e., dose multiplied by probability), it would be inaccurate to say the staff assumes intrusion will occur."[7] Regardless of this statement, the analysis always assumes intrusion occurs. This forced failure hinders the analysis of encapsulated sealed sources by not giving credit to the inherent safety features of sealed source shielding, encapsulation media, and packaging.

<u>2015 Revision to the Concentration Averaging and Encapsulation BTP</u>

In 2015, the NRC issued the report "Concentration Averaging and Encapsulation Branch Technical Position, Revision 1". This report went through a robust public involvement process with a couple of drafts published for public comment and input. The NRC has included sealed sources in the "Discrete Items" category. Other examples of discrete items include cartridge filters, activated metals, contaminated materials, and items incorporating radioactivity into its design. Encapsulation results in a disposal container where the discrete item is surrounded with a non-radioactive binding matrix (typically cement). The radioactivity remains within the sealed source and is not dispersed in the binding matrix.

The major changes as it relates to sealed sources include:

- Consolidated the three sections that address discrete items into one section.
- For primary gamma emitters, changed the "Factor of 1.5" rule to a "Factor of 2" rule.
- Linked the Factor of 2 rule and the Factor of 10 rule to the classification limit of the mixture rather than the average concentration.
- Consolidated averaging constraints on discrete items so for primary gamma emitting radionuclides it must meet either the BTP Table 2 activity limit or the Factor of 2 or 10 concentration limit, as applicable, and for other than primary gamma-emitting radionuclides it must meet the BTP Table 3 activity limits or Factor of 10 concentration limit.
- Increased the activity limit for Cs-137 sealed sources from 30 Ci to 130 Ci.

---

[7] BTP pg. 39.

- Decreased the Class A activity limit for Co-60 from 700 Ci to 140 Ci and increased the Class B activity limit from 700 Ci to no limit.
- Added guidance for encapsulated waste that waste containers up to 331 ft^3 may be used provided they have at least 14% by volume waste loading and the factor of 2 and 10 constraints are met.
- Added an Implementation Section that provides for the use of the 1995 or 2015 version of the BTP to be used.

<u>Impact of the 2015 BTP Revision on the Disposal of Radioactive Sealed Sources</u>

In evaluating the efficacy of the 2015 revision to the BTP it is necessary to determine whether it has improved the ability to dispose of sealed sources. To do this, telephone interviews were conducted with representatives from the 4 operating LLRW disposal facilities, six LLRW brokers, one waste processor and one host state regulator. Questions of a general nature were asked with a follow-on conversation as appropriate. A summary of the conversations is provided in Appendix 2.

While not unanimous, the consensus is that the 2015 revision has improved the process for classifying sealed sources for disposal. It has done this through added clarity and reduced interpretation, has provided for the use of larger disposal containers, and provides flexibility to the generator to apply the least restrictive classification.

The 1995 BTP was brief in its explanation and established a rudimentary set of criteria for sealed source encapsulation. The revised BTP added greatly to the description of the waste classification process for encapsulating sealed source(s). A risk-informed approach was used in developing the 2015 revision with the focus on protecting not only the current day licensee staff but also the future potential inadvertent intruder. Waste classification process flowcharts detail the steps a licensee would follow for a single encapsulated sealed source or a package containing multiple sources. This additional level of detail acts to minimize the amount of interpretation a licensee would engage and reduces the level of effort for the licensee.

Under the 1995 BTP, the largest container allowed to be taken into consideration for concentration averaging was a 55-gallon drum (1100 pounds). This did not preclude the use of larger containers, just limited the volume or mass the activity could be averaged for purposes of waste classification. The 2015 revised BTP allows for the use of larger containers and the use of irregular or odd shaped containers. A container up to 331 ft3 can be used provided it has at least a 14% waste loading. Waste loading is calculated by dividing the volume of waste by the volume of the container then multiplying by 100 to get it into percentage.

The revised BTP allows for the disposal of higher activity sealed sources. The limit for Class C sources containing Cs-137 increased from 30 Ci to 130 Ci. The Class A limit for sealed source containing Co-60 decreased from 700 Ci to 140 Ci. However, the Class B limit for Co-60 sources went from 700 Ci to no limit.

Licensees can use either the 1995 or 2015 version of the BTP. This is provided in the Backfit Considerations section in the revised BTP.

So, going back to the question of whether the 2015 revision has made it easier to dispose of sealed source, the answer is yes. Approximately 95% of waste containers being disposed were classified using the 2015 version of the BTP. The next question is whether it has increased the disposal of sealed sources. The answer is no, which is explained in the section below.

Potential Obstacles to Sealed Source Disposal

While the revised BTP has improved the process for classifying sealed sources for disposal it has not resulted in a significant increase in sources being disposed. Cost and the availability of Type B shipping containers still appear to be the main hindrances to disposing of sealed sources.

The cost to dispose of sealed sources is expensive. The majority of licensee who possess sealed sources have not adequately considered and budgeted the cost to dispose of the sources. The Conference of Radiation Control Program Directors (CRCPD) has implemented a Source Collection and Threat Reduction (SCATR) program using funding from the NNSA to assist licensees financially and administratively with the proper disposal of their unwanted sealed sources. Over the years the cost share percentage has varied. Historical data indicate that the greatest number of sources disposed under the SCATR program occurred when the cost share (the percentage of cost borne by the SCATR program) was 40%. There are several possible explanations for this which should be explored to provide program insight.

The limited availability of Type B shipping containers also has a negative impact on the disposal of sealed sources. Type B shipping containers are required to transport the higher activity sealed sources. This appears to be a simple case of supply and demand. Since the supply is limited, there lacks a competitive environment that can keep costs low. The other negative impact of the limited supply of Type B shipping containers is the competitive advantage that the owner of the Type B container has. Independent waste brokers who need to rent a cask are at a competitive disadvantage when bidding on source disposal projects.

To help increase the number of Type B shipping containers, the NNSA developed a generic design and submitted it to the NRC for certification. The NNSA has made the plans available to anyone who wants to construct a Type B container. Using this approved design lowers the cost to produce and certify the container since the certification process has already been completed. To date, there has been limited use of this certified design.

Appendix 1 – 10 CFR 61.55 Waste Classification

(a) Classification of waste for near surface disposal. (1) *Considerations*. Determination of the classification of radioactive waste involves two considerations. First, consideration must be given to the concentration of long-lived radionuclides (and their shorter-lived precursors) whose potential hazard will persist long after such precautions as institutional controls, improved waste form, and deeper disposal have ceased to be effective. These precautions delay the time when long-lived radionuclides could cause exposures. In addition, the magnitude of the potential dose is limited by the concentration and availability of the radionuclide at the time of exposure. Second, consideration must be given to the concentration of shorter-lived radionuclides for which requirements on institutional controls, waste form, and disposal methods are effective.

(2) *Classes of waste*. (i) Class A waste is waste that is usually segregated from other waste classes at the disposal site. The physical form and characteristics of Class A waste must meet the minimum requirements set forth in § 61.56(a). If Class A waste also meets the stability requirements set forth in § 61.56(b), it is not necessary to segregate the waste for disposal.

(ii) Class B waste is waste that must meet more rigorous requirements on waste form to ensure stability after disposal. The physical form and characteristics of Class B waste must meet both the minimum and stability requirements set forth in § 61.56.

(iii) Class C waste is waste that not only must meet more rigorous requirements on waste form to ensure stability but also requires additional measures at the disposal facility to protect against inadvertent intrusion. The physical form and characteristics of Class C waste must meet both the minimum and stability requirements set forth in § 61.56.

(iv) Waste that is not generally acceptable for near-surface disposal is waste for which form and disposal methods must be different, and in general more stringent, than those specified for Class C waste. In the absence of specific requirements in this part, such waste must be disposed of in a geologic repository as defined in part 60 or 63 of this chapter unless proposals for disposal of such waste in a disposal site licensed pursuant to this part are approved by the Commission.

(3) Classification determined by long-lived radionuclides. If radioactive waste contains only radionuclides listed in Table 1, classification shall be determined as follows:

(i) If the concentration does not exceed 0.1 times the value in Table 1, the waste is Class A.

(ii) If the concentration exceeds 0.1 times the value in Table 1 but does not exceed the value in Table 1, the waste is Class C.

(iii) If the concentration exceeds the value in Table 1, the waste is not generally acceptable for near-surface disposal.

(iv) For wastes containing mixtures of radionuclides listed in Table 1, the total concentration shall be determined by the sum of fractions rule described in paragraph (a)(7) of this section.

Table 1

Radionuclide	Concentration curies per cubic meter
C-14	8
C-14 in activated metal	80
Ni-59 in activated metal	220
Nb-94 in activated metal	0.2
Tc-99	3
I-129	0.08
Alpha emitting transuranic nuclides with half-life greater than 5 years	[1]100
Pu-241	[1]3,500
Cm-242	[1]20,000

[1]Units are nanocuries per gram.

(4) Classification determined by short-lived radionuclides. If radioactive waste does not contain any of the radionuclides listed in Table 1, classification shall be determined based on the concentrations shown in Table 2. However, as specified in paragraph (a)(6) of this section, if radioactive waste does not contain any nuclides listed in either Table 1 or 2, it is Class A.

(i) If the concentration does not exceed the value in Column 1, the waste is Class A.

(ii) If the concentration exceeds the value in Column 1, but does not exceed the value in Column 2, the waste is Class B.

(iii) If the concentration exceeds the value in Column 2, but does not exceed the value in Column 3, the waste is Class C.

(iv) If the concentration exceeds the value in Column 3, the waste is not generally acceptable for near-surface disposal.

(v) For wastes containing mixtures of the nuclides listed in Table 2, the total concentration shall be determined by the sum of fractions rule

Table 2

Radionuclide	Concentration, curies per cubic meter		
	Col. 1	**Col. 2**	**Col. 3**
Total of all nuclides with less than 5 year half-life	700	([1])	([1])
H-3	40	([1])	([1])
Co-60	700	([1])	([1])
Ni-63	3.5	70	700
Ni-63 in activated metal	35	700	7000
Sr-90	0.04	150	7000
Cs-137	1	44	4600

[1] There are no limits established for these radionuclides in Class B or C wastes. Practical considerations such as the effects of external radiation and internal heat generation on transportation, handling, and disposal will limit the concentrations for these wastes. These wastes shall be Class B unless the concentrations of other nuclides in Table 2 determine the waste to the Class C independent of these nuclides.

(5) Classification determined by both long- and short-lived radionuclides. If radioactive waste contains a mixture of radionuclides, some of which are listed in Table 1, and some of which are listed in Table 2, classification shall be determined as follows:

(i) If the concentration of a nuclide listed in Table 1 does not exceed 0.1 times the value listed in Table 1, the class shall be that determined by the concentration of nuclides listed in Table 2.

(ii) If the concentration of a nuclide listed in Table 1 exceeds 0.1 times the value listed in Table 1 but does not exceed the value in Table 1, the waste shall be Class C, provided the concentration of nuclides listed in Table 2 does not exceed the value shown in Column 3 of Table 2.

(6) Classification of wastes with radionuclides other than those listed in Tables 1 and 2. If radioactive waste does not contain any nuclides listed in either Table 1 or 2, it is Class A.

(7) The sum of the fractions rule for mixtures of radionuclides. For determining classification for waste that contains a mixture of radionuclides, it is necessary to determine the sum of fractions by dividing each nuclide's concentration by the appropriate limit and adding the resulting

values. The appropriate limits must all be taken from the same column of the same table. The sum of the fractions for the column must be less than 1.0 if the waste class is to be determined by that column. Example: A waste contains Sr-90 in a concentration of 50 Ci/m^3. and Cs-137 in a concentration of 22 Ci/m^3. Since the concentrations both exceed the values in Column 1, Table 2, they must be compared to Column 2 values. For Sr-90 fraction 50/150=0.33; for Cs-137 fraction, 22/44=0.5; the sum of the fractions=0.83. Since the sum is less than 1.0, the waste is Class B.

(8) *Determination of concentrations in wastes*. The concentration of a radionuclide may be determined by indirect methods such as use of scaling factors which relate the inferred concentration of one radionuclide to another that is measured, or radionuclide material accountability, if there is reasonable assurance that the indirect methods can be correlated with actual measurements. The concentration of a radionuclide may be averaged over the volume of the waste, or weight of the waste if the units are expressed as nanocuries per gram.

[47 FR 57463, Dec. 27, 1982, as amended at 54 FR 22583, May 25, 1989; 66 FR 55792, Nov. 2, 2001]

Appendix 2 – Notes from Phone Conversations with Disposal Facility Operators, Brokers, and Processors

This appendix provides a summary of the phone conversations conducted with operators of the LLRW disposal facilities, brokers, and processors that were polled for their thoughts regarding the efficacy of the 2015 revision to the BTP. To protect the anonymity of the respondents, the responses are grouped together by respondent category. This may result in observations that are contradictory.

<u>Disposal Facility Operators:</u>

- The state regulator is more comfortable with the 2015 revision since the process is clearer and there is less interpretation.
- The disposal of sealed sources is tied to the availability of licensee funding.
- Most of the sealed sources in recent years are disposed through the SCATR program. There are some non-SCATR program shipments but those come from well-funded licensees.
- Has not been a noticeable increase, maybe just a few.
- There appears to be some randomness based on what a broker can fit into a package.
- Process is easier with 2015 revision.
- Receive maybe 12 or so shipments per year.
- Have one or two customers still using the 1995 version.
- In general, the revision works better for higher activity sources. Reasons include the change in the "Factor of 1.5" rule to a "Factor of 2" for primary gamma-emitters; linking the Factor of 2 and Factor of 10 rules to the classification limit of the mixture rather than the average concentration; allows for meeting the Table 2 activity limit or the Factor of 2 or 10 concentration limits for primary gamma-emitters; and either the Table 3 activity limit or the Factor of 10 for other than primary gamma-emitters. This is not as critical for lower activity sources.
- The revision has allowed shipments to be accepted that would not have been using the 1995 version.
- The process of getting a shipment done does not move fast. Higher activity shipments take a long time to plan and execute. These higher activity shipments require the coordination of removal from the originating facility, transportation in a Type B shipping cask, preparation activities at the disposal facility, possible rental of unloading equipment, staff training and regulatory oversight.

<u>Waste Brokers:</u>

- The 2015 revision has improved the process for getting sources into a disposal facility.
- Allows for the use of a larger container.
- Larger Americium sources do not have a commercial disposal option since they are classified as Greater than Class C (GTCC) waste.

- When making up a container, try to get to 90% of the Class B or C limit and then add Class A sources.
- WCS will accept multiple waste container sizes.
- Never really changed operations, the 2015 just provided more clarity.
- The 2015 results in less work on your part.
- The 2015 revision allows for odd-ball size containers and was utilized for the disposal of waste originating at the Washington state irradiator incident.
- Type B shipping cask is still a limiting factor.
- 2015 revision has helped. Provides opportunities to dispose of source that wouldn't have otherwise.
- The revision made disposal more affordable.
- Helps with Type A shipments across the board.
- Nice to have a guidance document.
- Entities who have a Type-B shipping cask have an advantage due to high rental cost.
- A few brokers commented that the revised BTP has not resulted in an increase in their sealed source disposal services.
- Did not know the system was broken.
- Only perform Type A shipments.

Processor:

- The 2015 revision has helped. 1995 version only gave option for 55-gallon container (7.5 cubic feet). The 2015 allows for larger containers.
- Achieving the 14% waste loading is doable (allows for the use of larger container).
- Actively work with other brokers.
- Some compacts are problematic with their import/export requirements.
- Operations limited to Type A quantities.
- Type B shipping cask rental fee is cost prohibitive ($40 – 50k per use).