RECEIVED

NOV 21 1995

OSTI

Greater-Than-Class C Low-Level Radioactive Waste Characterization

Appendix E-2: Mixed GTCC LLW Assessment

***Greater-Than-Class C Low-Level Waste
Management Program***

September 1994

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DOE/LLW-114E-2

Greater-Than-Class C Low-Level Radioactive Waste Characterization

Appendix E-2: Mixed GTCC LLW Assessment

Nancy P. Kirner

Published September 1994

**Ebasco Environmental
Idaho Falls, Idaho 83404**

**Prepared for EG&G Idaho, Inc.
Under Subcontract No. C90-132744
and for the
U.S. Department of Energy
Assistant Secretary for Environmental Management
Under DOE Idaho Operations Office
Contract DE-AC07-76ID01570**

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DEC

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ABSTRACT

Mixed greater-than-Class C low-level radioactive waste (mixed GTCC LLW) is waste that combines two characteristics: it is radioactive, exceeding the limits for Class C low-level radioactive waste as specified in 10 CFR 61, and it is hazardous, meeting the requirements for regulation under Subtitle C of the Resource Conservation and Recovery Act (RCRA). This report uses information compiled from *Greater-Than-Class C Low-Level Radioactive Waste Characterization: Estimated Volumes, Radionuclide Activities, and Other Characteristics* (DOE/LLW-114, Revision 1), and applies it to the question of how much and what types of mixed GTCC LLW are generated and are likely to require disposal in facilities jointly regulated by the Department of Energy and the U.S. Nuclear Regulatory Commission. The report describes how to classify a RCRA hazardous waste, and then applies that classification process to the 41 GTCC LLW waste types identified in the DOE/LLW-114 (Revision 1). Of the 41 GTCC LLW categories identified, only six were identified in this study as potentially requiring regulation as hazardous waste under RCRA. These wastes can be combined into the following three groups: fuel-in decontamination resins, organic liquids, and process waste consisting of lead scrap/shielding from a sealed source manufacturer.

The base case represents the most reasonable assumptions and estimates. For the base case, no mixed GTCC LLW is expected from nuclear utilities or sealed source licensees, whereas only 177 m³ of mixed GTCC LLW are expected to be produced by other generators through the year 2035. This relatively small volume represents approximately 40% of the base case estimate for GTCC wastes from other generators. For these other generators, volume estimates for mixed GTCC LLW ranged from less than 1 m³ to 187 m³, depending on assumptions and treatments applied to the wastes.

FOREWORD

In 1992, Nancy Kirner of Ebasco Environmental assessed the GTCC LLW reported in the August 1991 version of DOE/LLW-114, *Greater-Than-Class C Low-Level Radioactive Waste Characterization: Estimated Volumes, Radionuclide Activities, and other Characteristics*. That effort led to a September 1992 report, DOE/LLW-156, *GTCC LLW Mixed Waste Assessment*, which has been updated and is now presented as Appendix E-2 of DOE/LLW-114.

CONTENTS

ABSTRACT	iii
FORWARD	v
ACRONYMS	xi
1. BACKGROUND	1
2. MIXED GTCC LLW CLASSIFICATION	3
2.1 RCRA Waste Designation	3
2.1.1 Is the Material a Solid Waste?	3
2.1.2 Is the Waste Specifically Excluded from Regulation?	6
2.1.3 Is the Waste Listed in Subpart D of 40 CFR 261?	7
2.1.4 Does The Waste Exhibit One or More Characteristics Identified in Subpart C of 40 CFR 261?	9
2.1.5 Example of a RCRA Waste Designation	11
2.2 Designation Under 10 CFR 61	11
2.3 Treatment Requirements	13
2.4 Waste Form and Packaging Requirements	14
3. POTENTIAL FOR MIXED GTCC LLW	15
3.1 Listed Wastes	21
3.1.1 F-Listed Wastes	21
3.1.2 P- and U-Listed Wastes	22
3.2 Characteristic Wastes	23
3.2.1 Toxicity Characteristic Wastes	23
3.2.2 Radiolytic Hydrogen Generation	29
3.2.3 Other Ignitable, Reactive, and Corrosive Characteristics	29
3.3 State-only Wastes	30
3.4 Summary of Mixed GTCC LLW	31
4. ESTIMATED MIXED GTCC LLW VOLUMES	32
4.1 Fuel-in Decontamination Resins	35

4.2	Organic Liquids	36
4.3	Process Waste	37
4.4	Summary of Expected Volumes	37
5.	UNCERTAINTIES AND DATA NEEDS	38
5.1	Uncertainties in Waste Designation Criteria	38
5.2	Uncertainties and Assumptions Applicable to All Wastes	39
5.3	Uncertainties and Assumptions Used in Estimating Power Reactor Wastes	40
5.4	Uncertainties and Assumptions Used in Estimating Sealed Sources and Other Generators Wastes	40
5.5	Areas Requiring Further Research	41
6.	SUMMARY	42
7.	REFERENCES	43
	Attachment 1—Letter from M. Williams, EPA Office of Solid Waste, to Terry Husseman, Washington Department of Ecology, June 26, 1987	1-1

FIGURES

1. Logic diagram to designate a hazardous waste	4
2. Logic diagram to determine if a waste is a commercial chemical product	5
3. Logic diagram to estimate waste volume	33

TABLES

1. Threshold concentrations of contaminants for the toxicity characteristic (from 40 CFR 261)	12
2. NRC Class C limits (from 10 CFR 61.55)	13
3. Categories of GTCC LLW	16
4. Composition of reactor components likely to be classified as GTCC LLW	24
5. Chemical composition of various alloys of GTCC LLW (av. wt %) (Values are taken from the DOE/LLW-114 Revision 1 report unless otherwise noted by superscript.)	25
6. Summary of potential mixed GTCC LLW	31
7. Projected volumes of mixed GTCC LLW (m ³ packaged)	34

ACRONYMS

AEA	Atomic Energy Act
BWR	boiling water reactor
CBEC	concentration-based exemption criteria
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
ECHO	expanded characteristics option
EPA	Environmental Protection Agency
GTCC LLW	greater-than-Class C low-level radioactive waste
NRC	U.S. Nuclear Regulatory Commission
PWR	pressurized water reactor
RCRA	Resource Conservation and Recovery Act
SS-304	stainless steel 304
TC	toxicity characteristic
TCLP	toxicity characteristic leaching procedure
VR	volume reduction
WAC	waste acceptance criteria

Greater-Than-Class C Low-Level Radioactive Waste Characterization

Appendix E-2: Mixed GTCC LLW Assessment

1. BACKGROUND

Section 3(b) of the Low-Level Radioactive Waste Policy Amendments Act of 1985, Public Law 99-240, makes the Federal Government responsible for disposal of greater-than-Class C low-level radioactive waste (GTCC LLW). GTCC LLW generated by licensees of the U.S. Nuclear Regulatory Commission (NRC) and Agreement States must be disposed of in a facility licensed by the NRC. Related provisions of the Act indicate that the U.S. Department of Energy (DOE) is the Federal agency responsible for the proper management of GTCC LLW.

To carry out its responsibilities, DOE conducted several studies to obtain information concerning the types and volumes of GTCC LLW that were in storage or likely to be generated through the year 2035. The results of those studies have been published in *Greater-Than-Class C Low-Level Waste Characterization: Estimated Volumes, Radionuclide Activities, and Other Characteristics* (DOE/LLW-114, Revision 1). That report (of which this report is an appendix) evaluates the following four categories of GTCC LLW:

- Nuclear Utility
- Sealed Sources
- DOE-Held GTCC LLW
- Other Generators.

Additional information on the "Other Generators" wastes is given in Appendix D-3.

This report on mixed GTCC LLW evaluates the potential that GTCC LLW not already held by DOE is also a hazardous waste under Subtitle C of the Resource Conservation and Recovery Act (RCRA). Such GTCC LLW is referred to as mixed GTCC LLW throughout this report.

This report uses information contained in the main body of the DOE/LLW-114 Revision 1 report as its point of departure for wastes from Nuclear Utility and Sealed Sources. Consequently, the assumptions, estimations, waste categorizations, and descriptions are heavily influenced by those contained in the DOE/LLW-114 Revision 1 report. On the subject of waste from Other Generators, Appendix D-3 is the primary reference.

A brief discussion of the waste classification methodology used to determine if a waste is a mixed GTCC LLW is presented in Section 2. Each of the four categories of waste is then evaluated

against these criteria in Section 3. For those wastes having the potential to be mixed GTCC LLW, quantities and volumes of each waste category are estimated in Section 4. Whenever possible, three estimates of potential volume are made. These three estimates represent the "minimum" estimate of mixed GTCC LLW requiring disposal, a "reasonable" estimate of mixed GTCC LLW disposal volumes, and a "maximum" estimate of disposal volumes. The concept of providing a range of volumes and a reasonable estimate of volume is consistent with that used in the DOE/LLW-114 Revision 1 report. Section 5 contains a discussion of the uncertainties involved with the waste classification and volume estimates and identifies potential areas of additional research that could reduce those uncertainties. Section 6 summarizes the findings of this report.

2. MIXED GTCC LLW CLASSIFICATION

To identify GTCC LLW that is regulated under Subtitle C of RCRA, a detailed waste classification must be performed. The classification developed in this report uses U.S. Environmental Protection Agency (EPA) waste designation criteria contained in 40 CFR 261 effective April 1992. These criteria are summarized in logic diagrams in Figures 1 and 2.

Two issues should be considered when applying these designation criteria. First, EPA's waste designation criteria might be less stringent than those of an applicable State program. Because EPA can delegate its regulatory authority to States, States having an EPA-authorized mixed waste program may impose more stringent requirements. These stricter requirements would apply to any GTCC LLW treated, stored, or disposed in that State including any managed by the DOE (LEAF v. Hodel, 1974). Consequently, GTCC LLW should be evaluated against the applicable State or Federal waste designation criteria applicable to each location where GTCC LLW is treated, stored, or disposed of. Second, EPA is currently reevaluating its waste designation criteria for listed wastes and has proposed changes affecting "mixtures" of listed wastes and wastes "derived from" listed wastes (57 FR 21450). Any proposed revisions could affect the volumes of mixed GTCC LLW generated and disposed. When these criteria change, expected by April 1994, the waste designations and estimates of mixed GTCC LLW in this report will be reevaluated.

2.1 RCRA Waste Designation

Four fundamental questions must be answered to designate a candidate waste as "hazardous" under Subtitle C of RCRA:

- Is the material a solid waste?
- Is the waste specifically excluded from regulation as a hazardous waste?
- Is the waste listed in Subpart D of 40 CFR 261?
- Does the waste exhibit one or more characteristics identified in Subpart C of 40 CFR 261?

Each of these questions is discussed below.

2.1.1 Is the Material a Solid Waste?

The GTCC LLW described in DOE/LLW-114 constitutes "solid waste" as defined in 40 CFR 261.2 because such LLW constitutes a material that is a "discarded" solid, liquid, or gas. Under RCRA, a "discarded" material is any material which is "abandoned," "recycled," or "considered inherently wastelike." Under RCRA, a material can be under constant indoor surveillance and management and still be considered "abandoned." The term "abandoned" includes material that has been accumulated, stored, or treated (but not recycled) before or in lieu of being abandoned by being disposed of, burned, or incinerated [40 CFR 261.2(b)(3)]. The term also includes materials that have been disposed of, burned, or incinerated.

D93008A1

Figure 1. Logic diagram to designate a hazardous waste.

Figure 2. Logic diagram to determine if a waste is a commercial chemical product.

2.1.2 Is the Waste Specifically Excluded from Regulation?

Several exclusions exist in 40 CFR 261.4 which should be considered in making a waste determination.

The first exclusion eliminates materials subject to regulation under the Atomic Energy Act: "Source, special nuclear or byproduct material as defined by the Atomic Energy Act of 1954, as amended, 42 U.S.C. 2011 et seq." is excluded from being a solid waste [40 CFR 261(a)(4) and RCRA §1004(27)]. This exclusion, however, must also be considered within the context of the provisions of §1006(a) of RCRA, which states that RCRA would not apply to source, special nuclear, or byproduct materials as defined by the Atomic Energy Act ". . . except to the extent that such application (or regulation) is not inconsistent with the requirements of such Acts."

These provisions have been interpreted by EPA as excluding only the radioactive atoms contained in an otherwise RCRA-regulated substrate. In their joint guidance document on mixed waste identification, NRC and EPA confirmed this regulatory position: ". . . NRC and EPA consider that only the radionuclides themselves are exempt from RCRA."¹ Thus, while the radioactive atoms of a waste are not regulated under RCRA, the nonradioactive substrate is still subject to regulation as a solid waste. This holds true even if the substrate is mixed with or part of the same molecule. For example, a single molecule of ¹⁴C-labeled aldrin would be regulated as solid waste; however, the ¹⁴C atom is excluded from RCRA regulation. A similar approach was taken by the DOE in its May 1, 1987 Final Rule on the Definition of Byproduct Material (52 FR 15937).

Another exemption potentially applicable to the hazardous waste designation of GTCC LLW includes the exemption for certain laboratory samples and treatability samples from selected portions of Title 40 CFR, under specified conditions [40 CFR 261.4(d),(e), and (f)]. This exemption is important when testing any mixed waste.

The disposal of lead which is currently being used as shielding is not subject to RCRA Subtitle C regulation, according to at least one interpretive letter from EPA. A copy of one such letter is included as Attachment 1. The letter states:

"Lead containers or container liners which are used as shielding in low-level waste disposal operations pose a unique problem. Containers or container liners are not regulated by the Agency (See 40 CFR 261.7) nor would they be a waste because they are fulfilling intended uses. ((CF 40 CFR 261.2(c)(1)(ii)). In this instance, containers or liners may be analogous to commercial chemical products (e.g., pesticides) where as a product, their normal use is placement on the land. Therefore, lead whose primary use is shielding in low-level waste disposal operations is not subject to Federal hazardous waste regulations when placed on the land as part of its normal commercial use."

The lead shielding issue is specifically addressed in the question and answer portion of EPA/NRC October 4, 1989 joint guidance document (see Reference 1). This question and answer are provided below.

"6. Are lead containers whose primary use is for shielding in disposal operations, hazardous waste under RCRA?

"No. While lead containers and lead container liners may exhibit the hazardous characteristic for lead, those containers whose primary use is for shielding in low-level waste disposal operations are not considered wastes and thus, are not subject to the hazardous waste rules. These same containers and liners if disposed of or discarded would be considered wastes and if they exhibit the hazardous characteristic, would be subject to the hazardous waste rules.

"It should be noted that EPA recognizes that all lead containers and liners may be equally hazardous to human health and the environment when placed in the ground independent of its legal classification as a waste or container. Therefore, EPA recommends that all lead containers and lead liners be managed in an environmentally safe manner . . . encapsulation may be a viable mechanism to mitigate lead migration from these containers and liners."

2.1.3 Is the Waste Listed in Subpart D of 40 CFR 261?

Once the GTCC LLW material is classified as a waste having no exemption or exclusion from RCRA Subtitle C, it must be evaluated to determine if it qualifies as a hazardous waste. There are two generic types of hazardous wastes: (a) wastes identified in any of four lists contained in 40 CFR 261 Subpart D (listed wastes), and (b) wastes exhibiting hazardous characteristics described in 40 CFR 261, Subpart C.

A listed hazardous waste in Subpart D of 40 CFR 261 must either be generated from nonspecific sources (F-listed wastes), generated from specific sources (K-listed wastes), or be a discarded commercial chemical product, an off-specification species, container residue, or a spill residue thereof (P- or U- listed wastes).

Wastes designated F001 through F005 are chlorinated and nonchlorinated organic liquids used for their solvent or extraction capabilities. Wastes designated F006 through F009 are generated from electroplating, chemical etching, and chemical milling operations. Some mixed waste could fall into these categories, and although probably not GTCC LLW, are further described in Section 3 of this report. GTCC LLW are not likely to be described as waste codes F010 through F038 because these codes are not associated with processes that typically use high concentrations of radioactive materials (e.g., heat treating operations, manufacturing production of certain organic chemicals, and chemicals associated with wood preservation). F039 describes the leachate from performing the Toxicity Characteristic Leaching Procedure (TCLP) on other hazardous wastes. It is assumed that concentrations of radioactive materials in the leachate would not be sufficient to generate any GTCC LLW F039 wastes. Similarly, none of the K-list wastes are identified in the DOE/LLW-114 Revision 1 report. Thus, the K-listed wastes and the F010 through F039 wastes are not discussed further in this report.

To determine if a waste is a P- or U-listed waste as defined in 40 CFR 261.33 requires a knowledge of how the waste was generated as well as its chemical composition. EPA's waste designation process makes an important distinction between process wastes and P- or U-listed wastes [40 CFR 261.33(d)]. P- and U-listed wastes usually consist of (a) a discarded "pure" chemical that can no longer be used for its intended commercial or manufacturing use, (b) a discarded product in which the chemical is the sole active ingredient, or (c) a process intermediate from the manufacture of

a listed waste. The P- and U-listed waste designation, however, is not intended to include wastes that result from the use of listed chemicals in a chemical process. If a chemical appearing in the 40 CFR 261.33(d) lists is used in a laboratory procedure or manufacturing process, the resulting downstream wastes usually are considered process wastes, not P- or U-listed waste. The only exception to this rule occurs when the listed chemical is the sole active ingredient (e.g., a discarded chemical dissolved in water would be a P- or U-listed waste). Although the resulting waste may not be a P- or U-listed waste, it still should be evaluated for its potential to be an F-listed waste or a characteristic waste.

To prevent misinterpretation, EPA provided guidance on when a chemical listed in 40 CFR 261.33 becomes a listed waste (November 25, 1980, 45 FR 78541). In the preamble to the designation of P- and U-listed wastes, EPA provides the following guidance:

"Are manufactured articles (such as battery and mercury vapor lights) that contain any of the chemicals listed in §261.33 [i.e., P- and U-listed wastes] hazardous wastes by definition if they are discarded or intended to be discarded?

"EPA intends that the materials listed in §261.33 include only those commercial [sic] chemical products and manufacturing chemical intermediates that are known by the generic name of the chemicals listed in paragraphs (e) and (f) of that section. Manufactured articles that contain any of the chemicals listed in paragraphs (e) and (f) are rarely, if even [sic], known by the generic name of the chemical(s) they contain and, therefore, are not covered by the §261.33 listings. Should the Agency find it necessary to list any manufactured articles as hazardous wastes, it will initiate rulemaking to add these articles to §261.33."

EPA provides additional guidance on the subject in the same preamble (45 FR 78540):

"Are solid wastes that contain one or more of the chemicals listed in §261.33 hazardous wastes by virtue of containing these materials?

"Solid wastes which simply contain one of the chemicals listed in §261.33 are not thereby hazardous. Where EPA intends to list such wastes, it will do so by listing them in §261.31 and §261.32. . . . The purpose of §261.33 is to regulate only the listed chemical products and intermediates and their trade name equivalent (and certain off-specification variants, emptied containers and spill residues and debris thereof) as hazardous waste when they are discarded or intended to be discarded.

"However, when a solid waste is mixed with one of these discarded materials, the resulting mixture is a hazardous waste until delisted. . . . As set out in §261.3(b)(2), the solid waste becomes a hazardous waste when the mixing of the §261.33 chemical takes place either as an act of discarding that chemical or at the time the chemical is intended for later discard (i.e., at the time the §261.33 substance becomes a hazardous waste)."

Thus, if the mixing of the chemical occurred *before* the material was determined to be waste, it is not a listed waste; however, if the mixing occurred during the act of discarding the chemical or

after the chemical becomes destined solely for discard, then the entire mixture is a U- or P-listed waste. This aspect of waste designation is often referred to as the "mixture" rule.

Another complicating aspect of listed waste designation is the application of the "derived from" rule [40 CFR 261.3.(c)(2)(i)]. Both the "derived from" and "mixture" rules are addressed in Figure 2. The "derived from" rule, generally stated, requires any solid waste generated from the treatment, storage, or disposal of a hazardous waste to be a hazardous waste having the same waste code designation as the original waste. Thus, under the "derived from" rule, any GTCC LLW generated from the treatment of a P- or U-listed waste and all F001, F002, F004, and F005 wastes would retain the original RCRA waste code, regardless of the concentration of the RCRA-regulated component of the waste. The only exception to the "mixture" and "derived from" rules is F003 waste, which is listed solely because it exhibits the characteristic of ignitability. Once the F003 waste loses the characteristic of ignitability, this waste and its residues are no longer designated as an F003 waste according to §261.3(a)(2)(iii).

The "mixture" and "derived from" rules are being reevaluated by EPA in response to a ruling from the court that inadequate opportunity for comment was provided in 1980 when the rules were first promulgated (*Shell Oil Co. v. U.S. Environmental Protection Agency*, D.C. Cir., December 6, 1991). On May 20, 1992 EPA proposed two approaches for amending hazardous waste identification regulations under 40 CFR Parts 260, 261, 262, 264, and 268 of RCRA (57 FR 21450). One approach would establish concentration-based exemption criteria (CBEC) for listed hazardous wastes, mixtures, derivatives, and media that could be used to exit Subtitle C management requirements. The other approach is the expanded characteristics option (ECHO), which would establish "characteristic" levels for listed wastes to be used for both entering and exiting Subtitle C requirements. EPA expects that the volumes of hazardous wastes would decrease under either option. However, under the ECHO approach, americium/beryllium GTCC sources may become classified as mixed GTCC LLW. EPA is expected to finalize its rulemaking regarding these listed wastes by April 1994.

2.1.4 Does The Waste Exhibit One or More Characteristics Identified in Subpart C of 40 CFR 261?

All wastes must also be evaluated to determine if they exhibit one or more of the characteristics described in Subpart C of 40 CFR 261. All characteristic wastes are designated by waste codes with the prefix D. EPA describes the tests and criteria used to make this determination in 40 CFR 261.21 for ignitable wastes, in 40 CFR 261.22 for corrosive wastes, in 40 CFR 261.23 for reactive wastes, and in 40 CFR 261.24 for toxicity characteristic (TC) wastes. Each of these four categories is described below.

A waste is *ignitable* and is designated by waste code D001 if it meets any one of four conditions:

- It is a liquid and has a flash point less than 60°C (140°F) under specified test conditions.
- It is not a liquid and is capable under standard temperature and pressure of causing fire through friction, absorption of moisture, or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard.

- It is an ignitable compressed gas under U.S. Department of Transportation regulations (49 CFR 173.300).
- It is an oxidizer under U.S. Department of Transportation regulations (49 CFR 173.151).

A waste is *corrosive* and is designated by waste code D002 if it meets one of the following two conditions:

- It is aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5, as determined by specified tests contained in EPA publication SW-846, or an equivalent approved by the EPA.
- It is a liquid and corrodes steel (SAE 1020) at a rate greater than 6.35 mm (0.250 in.) per year at a test temperature of 55°C, as determined by EPA's specified test method.

A waste is *reactive* (Waste Code D003) if it has any of the following eight properties:

- The waste is normally unstable and readily undergoes violent change without detonating.
- The waste reacts violently with water.
- The waste forms an explosive mixture with water.
- When mixed with water, it generates toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment.
- It is a cyanide or sulfide-bearing waste which, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment.
- It is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement.
- It is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure.
- It is a forbidden explosive as defined in 49 CFR 173.51, or a Class A explosive as defined in 49 CFR 173.53, or a Class B explosive as defined in 49 CFR 173.88.

Toxicity characteristic (TC) wastes (40 CFR 261.24) are those that, when subjected to TCLP (40 CFR 261, Appendix II, Method 1311), produce a leachate that exceeds the specified concentration for any of the 40 chemicals identified in Table 1. TC wastes are assigned EPA Hazardous Waste Codes D004 to D043. Based on a general understanding of the composition of various reactor components and other GTCC LLW generating activities, the chemicals most likely to be mixed GTCC LLW were identified and appear in capitalized bold type in this table.

2.1.5 Example of a RCRA Waste Designation

Waste designation can be a complicated procedure, relying on knowledge of how the waste was generated. For example, if a hot cell contained the chemical acetone, how would the wastes containing acetone be designated? The answer depends entirely on how the acetone was or was not used. There are four possible waste classifications for such acetone wastes: U-listed, F-listed, characteristic, and not hazardous. If the acetone was discarded solely because it was chemically or radioactively contaminated to the point where it could no longer be used for its original purpose, the resulting waste would be a U-listed waste, U002. If, however, the acetone was used as a solvent or extractant in the process, the waste solvent would be designated F003. However, if the acetone was used in the chemical reaction, e.g., as the source of an acetyl group in a chemical reaction, the resulting waste might be a characteristic waste, depending on whether the waste was corrosive, reactive, ignitable, or toxic. It is also possible that the resulting waste is not a regulated hazardous waste, because process wastes that are not listed in the F- or K-lists are not regulated hazardous wastes.

2.2 Designation Under 10 CFR 61

To qualify as a mixed GTCC LLW, the waste must not only be regulated as a hazardous waste under RCRA, but it must also exceed concentration limits for Class C wastes as specified by NRC in 10 CFR 61.55. Two major differences exist between EPA's RCRA rules for waste designation and 10 CFR 61. The first is that NRC's waste designation method applies to the waste when it is finally packaged for disposal, not at the point it is generated. The second difference is that NRC's waste designation method is based *solely* on the *concentration* of regulated material in the waste. This second distinction is in sharp contrast to how EPA currently considers its listed waste under the mixture and "derived from" rules.

Table 2 presents Class C concentration limits as specified by the NRC in 10 CFR 61.55. If a radionuclide is not listed in Table 2, e.g., tritium, there is no limit on the concentration of that radionuclide in a waste. Consequently, there can be no GTCC LLW for several common radioactive wastes. Instead, practical considerations such as the effects of external radiation and internal heat generation on transportation, handling, and disposal will limit the concentrations for these short-lived radioactive wastes.

Table 1. Threshold concentrations of contaminants for the toxicity characteristic (from 40 CFR 261).

EPA hazardous waste code	Contaminant	Regulatory level (mg/L)
D004	Arsenic	5.0
D005	Barium	100
D018	BENZENE	0.5
D006	Cadmium	1.0
D019	CARBON TETRACHLORIDE	0.5
D020	Chlordane	0.03
D021	Chlorobenzene	100.0
D022	CHLOROFORM	6.0
D007	CHROMIUM	5.0
D023	O-Cresol	200
D024	M-Cresol	200
D025	P-Cresol	200
D026	Cresol (total)	200
D016	2,4-D	10
D027	1,4-Dichlorobenzene	7.5
D028	1,2-Dichloroethane	0.5
D029	1,1-Dichloroethylene	0.7
D030	2,4-Dinitrotoluene	0.13
D012	Endrin	0.02
D031	Heptachlor	0.008
D032	Hexachlorobenzene	0.13
D033	Hexachlorobutadiene	0.5
D034	Hexachloroethane	3.0
D008	LEAD	5.0
D013	Lindane	0.4
D009	MERCURY	0.2
D014	Methoxychlor	10.0
D035	Methylethyl Ketone	200.0
D036	Nitrobenzene	2.0
D037	Pentachlorophenol	100.0
D038	Pyridine	5.0
D010	Selenium	1.0
D011	SILVER	5.0
D039	TETRACHLOROETHYLENE	0.7
D015	Toxaphene	0.5
D040	TRICHLOROETHYLENE	0.5
D041	2,4,5-Trichlorophenol	400.0
D042	2,4,6-Trichlorophenol	2.0
D017	2,4,5-TT (Silvex)	1.0
D043	Vinyl chloride	0.2

Table 2. NRC Class C limits (from 10 CFR 61.55).

Long-lived radionuclides	Concentration limit (Ci/m³)
¹⁴ C	8
¹⁴ C in activated metal	80
⁵⁹ Ni in activated metal	220
⁹⁴ Nb in activated metal	0.2
⁹⁹ Tc	3
¹²⁹ I	0.08
 Short-lived radionuclides	 Concentration limit (Ci/m³)
⁶³ Ni	700
⁶³ Ni (in activated metal)	7,000
⁹⁰ Sr	7,000
¹³⁷ Cs	4,600
 Transuranic radionuclides	 Concentration limit (nCi/gm)
Alpha-emitting transuranic radio-nuclides with greater than 5-year half-life	100
²⁴¹ Pu	3,500
²⁴² Cm	20,000

2.3 Treatment Requirements

Under RCRA's land-ban provisions, most hazardous wastes are prohibited from land-based disposal unless they have been previously treated to a specified concentration or "undergone" a specified treatment technology (40 CFR 268.40). EPA developed its treatment levels (both concentration-based or technology-based treatments) by considering what technologies represented best demonstrated available treatment (BDAT) for each hazardous waste code and major waste form. Table 3 of 40 CFR 268.42 presents technology-based standards for 13 specific radioactive hazardous mixed wastes, most of which are generated by DOE facilities, not commercial generators. If a waste is not identified in 40 CFR 268.42 Table 3, the required treatment is the same as that for a nonradioactive waste having the same waste code. Waste-code-specific treatments are listed in 40 CFR 268.41 for treatment standards expressed as concentrations in waste extracts, in 40 CFR 268.42 for treatment standards expressed as specified technology, and in 40 CFR 268.43 for treatment standards expressed as concentrations of hazardous constituents in the treated waste.

If a concentration-based treatment standard cannot be met or if the treatment technology is not appropriate to the waste, the generator or treatment facility may petition EPA for a treatability variance (40 CFR 268.44). Such a variance petition may apply to only one site [40 CFR 268.44 (h)] or several sites under the control of a single generator or a treatment facility [40 CFR 268.44(a)]. In either case, the petitioner must demonstrate to the EPA that "because the physical or chemical

properties differs [sic] significantly from wastes analyzed in developing the treatment standard, the waste cannot be treated to specified levels or by the specified methods." In reviewing such a petition for a treatability variance, EPA may identify an alternative treatment concentration or technology for the waste. Hazardous mixed wastes subject to a treatability variance must be disposed of in a facility regulated under both the Atomic Energy Act (AEA) and RCRA. The land disposal facility must also meet minimum technical requirements, by having dual liners and a leachate collection system.

2.4 Waste Form and Packaging Requirements

It is assumed throughout this report that facilities receiving mixed GTCC LLW will specify waste form and packaging requirements as a condition of waste acceptance. Such waste acceptance criteria (WAC) have not yet been developed. For the purposes of this report, it is assumed that wastes offered for disposal would have been processed in a manner that meets both 10 CFR 61 minimum requirements for stability as well as 40 CFR 268 conditions for land disposal. Volumes presented in Section 4 of this report take both types of processing into account.

3. POTENTIAL FOR MIXED GTCC LLW

This study assumes that the DOE/LLW-114 Revision 1 report accurately describes the types and quantities of all GTCC LLW in the United States from Nuclear Utility and Sealed Sources and that Appendix D-3 accurately describes such waste from the Other Generators. The DOE/LLW-114 Revision 1 report identifies 35 waste types within the two broad generator categories of Nuclear Utility and Sealed Sources. Appendix D-3 identifies six waste types within the Other Generators category. These 41 types are presented in Table 3, along with (a) their areas of potential RCRA regulation, (b) the location at which they are discussed in this report, and (c) a determination of whether they are, in fact, hazardous under RCRA. A fourth broad category of GTCC LLW described in the DOE/LLW-114 Revision 1 report is DOE-held wastes; that waste category is not addressed in this report.

As discussed in Section 2, GTCC LLW wastes are regulated under Subtitle C of RCRA if they are listed wastes or if they exhibit a hazardous characteristic. In evaluating each of the 41 types of GTCC LLW identified in Table 3 against the criteria developed in Section 2, the following areas common to several of the wastes were identified:

- Listed Wastes:

The potential for *F-listed wastes* to be present in compactible trash

The potential for *P- or U-listed wastes* to be present as sealed sources or in waste from sealed source manufacturing wastes

- Characteristic Wastes:

The potential for *TC wastes*. This area includes the unlikely potential for reactor hardware, sealed sources, and other wastes composed of stainless steel to exhibit the toxicity characteristic for metals. Wastes that are also candidate TC wastes include ion exchange resins, silver-bearing wastes, metal shavings, trash, and organic liquids.

The potential for *radiolytic hydrogen generation* in GTCC LLW resins, filters, and other moist wastes to create a reactive waste

The potential for *other ignitable, reactive, and corrosive characteristic wastes*.

Section 3 discusses the potential for mixed GTCC LLW in each of these areas. In evaluating each of the wastes, a conservative approach was used. That is, a waste was considered to be a hazardous waste unless proven otherwise by data or process knowledge. Using that approach, all but six of the original 41 waste types were eliminated from consideration as mixed GTCC LLW.

Table 3. Categories of GTCC LLW.

Generator type	Waste type	Area of potential RCRA regulation	Discussed in Section		Hazardous under RCRA?
Nuclear Utility (BWR)	Control Rod Blade	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Local Power Range Monitor (LPRM) strings	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Intermediate Range Monitor (IRM)/ Source Range Monitor (SRM) Dry Tubes	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Fuel Pool/Vacuum Filters	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Control Rod Drive Filters	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
			3.2.1.5	Particulate Filters	
	Control Rod Bearings	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Poison Curtains	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Core Shroud	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Top Fuel Guide	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
Nuclear Utility (PWR-Babcock & Wilcox)	In-core Instrument Strings (In-core Detectors)	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Primary Sources	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No

Table 3. (continued).

Generator type	Waste type	Area of potential RCRA regulation	Discussed in Section		Hazardous under RCRA?
Nuclear Utility (PWR-Combustion Engineering)	Misc. Cartridge Filters-Operational	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware, Particulate Filters	No
	Crud Tank Filter	TC-metals	3.2.1.5	Crud	No
	Core Shroud (Baffle)	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Lower Core Barrel	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Lower Core Support Plate (Grid)	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Primary Sources	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	In-core Instrument Strings	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Misc. Cartridge Filters-Operational	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware, Particulate filters	No
	Core Shroud (Baffle)	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Lower Core Barrel	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
Nuclear Utility (PWR-Combustion Engineering)(cont.)	Lower Core Support Plate (Forging top plate)	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No

Table 3. (continued).

Generator type	Waste type	Area of potential RCRA regulation	Discussed in Section		Hazardous under RCRA?
Nuclear Utility (PWR-Westinghouse)	Primary Sources	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Misc. Cartridge Filters-Operational	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware,	No
			3.2.1.5	Particulate Filters	
	In-Core Instrument Strings (Thimble Tubes)	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Thimble Plug Assemblies	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware,	No
			3.2.3	Metal Scrap	
	Core Shroud (Baffle)	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Lower Core Barrel	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Upper Core Support Plate	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
	Lower Core Support Plate	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
Nuclear Utility (BWR)	Fuel-in Decon Resins	TC-metals	3.2.1.2	Resins	Probably not
Nuclear Utility (PWR-Babcock & Wilcox)	Fuel-in Decon Resins	TC-metals	3.2.1.2	Resins	Probably not
Nuclear Utility (PWR-Combustion Engineering)	Fuel-in Decon Resins	TC-metals	3.2.1.2	Resins	Probably not

Table 3. (continued).

Generator type	Waste type	Area of potential RCRA regulation	Discussed in Section		Hazardous under RCRA?
Nuclear Utility (PWR-Westinghouse)	Fuel-in Decon Resins	TC-metals	3.2.1.2	Resins	Probably not
Sealed Sources	Sealed Sources	TC-metals	3.2.1.1	Stainless Steel	No
		P- and U-listed	3.2.1.3	Sources of Silver	
		Wastes	3.1.2	P- and U- Listed Waste	
	Activated metals: Control blades, miscellaneous in-core components	TC-metals	3.2.1.1	Stainless Steel, Reactor Hardware	No
			3.2.1.3	Sources of Silver	
Other (Burnup Lab)	Contaminated Solids: Hot cell waste (fuel grinds, 25% compactible trash, glass, plastic, metal scrap, equipment)	TC-metals	3.2.3	Fuel Grinds	No
			3.2.3	Metal Scrap	
			3.2.1.4	Compactible Trash	
Other (Industrial Research and Development)	Mixed Oxide Fuel Pellets	TC-metals	3.2.3	Mixed Oxide Fuel Pellets	No
Other (¹⁴ C Users)	Organic Liquids	F-, P-, and U-listed Wastes, TC-organics	3.1 3.2.3	Listed Wastes	Yes, F-listed wastes, TC-organics, ignitable; Probably not P-listed wastes

Table 3. (continued).

Generator type	Waste type	Area of potential RCRA regulation	Discussed in Section		Hazardous under RCRA?
Other (Fuel Fabricator)	Decontamination Waste (Concrete blocks, Filters, Grit, Aqueous Liquid)	TC-metals	3.2.1.1	Stainless Steel	No
			3.2.3	Fuel Grinds, Mixed Oxide Fuel Pellets	
Other (Sealed Source Manufacturer, Non-Medical Academic Institution)	Process Waste (AmO_2 / gold foil, scrap sources, glass, absorbed liquids, compactible trash, filters, glass, lead, plastic, metal scrap, dry technetium salt)	TC-metals	3.2.1.1	Stainless Steel	Yes - lead
			3.2.1.3	Silver	
			3.2.1.4	Trash	
			3.2.3	Metal Scrap, Contaminated Equipment	

3.1 Listed Wastes

As mentioned in Section 2 of this report, mixed waste is either a listed waste or a characteristic waste. Of the four kinds of listed waste, only F-, P-, and U-listed wastes are potentially mixed GTCC LLW. The potential for a GTCC LLW to be an F-listed waste is discussed in Section 3.1.1, while the potential for a GTCC LLW to be either a P- or a U-listed waste is discussed in Section 3.1.2.

3.1.1 F-Listed Wastes

F-listed mixed wastes are typically spent solvents used in degreasing operations before welding or as solvents and chemical extractants. As such, many organic liquids would be categorized as F-listed wastes. In Appendix D-3, the only potentially F-listed wastes are 6.27 m³ of GTCC LLW organic liquids identified as mixed waste generated by ¹⁴C users, although the waste was not described by the generators using specific RCRA waste codes. For example, the one ¹⁴C user who is responsible for more than 99% of the organic liquid waste reported, described the following waste mixture (possible waste designations have been added in parentheses):

25% water

75% organic liquids:

- 15% ethanol (not regulated as hazardous)
- 15% methanol (F003 or U154)
- 10% acetone (F003 or U002)
- 10% isopropanol (not regulated as hazardous)
- 5% toluene (F005 or U220)
- 5% ethyl acetate (F003 or U112)
- 5% hexane (not regulated as hazardous)
- 5% acetonitrile (U003)
- 5% xylene (F003 or U239).

Thus, it is likely that F-listed GTCC wastes are produced.

Another potential source of F-listed waste is GTCC LLW compactible trash generated before institution of rigorous waste segregation practices (assumed to be prior to 1986). However, the updated study of Other Generators (Appendix D-3) identified no organic liquids or F-listed wastes in storage or being generated as part of compactible trash. It is therefore assumed that F-listed waste is not present in wastes designated as "trash."

Sludges and Electropolishing Wastes. The F006 and F007 waste codes are often overlooked as sources of hazardous waste. These hazardous wastes can be generated through various operations related to electroplating, electropolishing, and chemical milling operations. The F006 waste code applies to wastewater treatment sludges generated not only from conventional electroplating operations, but also from cleaning/stripping operations on metals other than tin-, zinc-, and aluminum-plated carbon steel, and chemical etching and milling of all metals except aluminum. Thus, sludges generated from treatment of electropolishing wastes would be designated as an F006 mixed

waste. The F006 designation also applies to chemical etching or cleaning operations even in the absence of an electrical current if the intent is to remove the base metal. However, chemically removing only surface contamination, scale, or crud in the absence of an electrical current would not constitute a potential F006 waste. Because the radioactive concentrations of these wastes are generally low and can be administratively controlled, they are not GTCC LLW as defined in 10 CFR 61.

The F007 waste code is applied to spent cyanide plating bath solutions from electroplating operations. Such wastes could be generated as a result of fabricating plated "sealed" sources. However, because no sealed source manufacturer specifically identified such wastes in the surveys of GTCC LLW reported in the DOE/LLW-114 Revision 1 report, it is likely that either the concentrations of radioactive materials in the plating baths are not sufficiently high to qualify such spent materials as GTCC LLW, or the plating baths may not contain cyanide compounds. Therefore, this study assumes that such wastes do not exist as mixed GTCC LLW.

F008 wastes result from residues in the bottom of plating baths containing cyanides, and F009 wastes result from spent electroplating cleaning and stripping baths where cyanides are used. Cyanides must be used in the process of making plated sealed sources to qualify as an F008 or F009 waste. These plating wastes were not identified in the DOE/LLW-114 Revision 1 report or in Appendix D-3 as GTCC LLW and, therefore, are not considered as mixed GTCC LLW. As explained in section 2.1.3, GTCC LLW is not likely to be described as waste codes F010 through F039 because these codes are not associated with processes that typically use high concentrations of radioactive materials.

3.1.2 P- and U-Listed Wastes

Mixed GTCC LLW composed of discarded commercial chemical products (P- and U-listed wastes) can fall into two general categories: (a) solutions or chemicals which become contaminated and are discarded along with GTCC LLW, and (b) discarded commercial chemical products which are themselves GTCC LLW. Currently, the designation of a P- and U-listed waste is independent of concentration.

As discussed in the previous section, U-listed GTCC LLW is likely; however, information on how the chemicals are used is not available. Nonetheless, from the responses to the updated survey contained in Appendix D-3, the possibility of U-listed wastes generated by ^{14}C users cannot be ruled out.

Other candidate GTCC LLW P-listed mixed wastes are beryllium contained in unwanted sealed sources and beryllium-contaminated wastes generated as a result of the manufacture of such sources. These wastes illustrate the important distinction that was introduced in Section 2.1.3 of this report between a listed waste and a process waste. The process of making an americium/beryllium sealed source involves the deliberate mixture of americium with beryllium. Thus, wastes generated from mixing beryllium with americium during manufacturing are likely to be process wastes, not P015 listed wastes. Examples of such process wastes include ductwork leading from a hot cell where the mixing occurred; equipment used to mix, form, and weld the sealed sources during their fabrication; and any unwanted or off-specification sealed sources.² While it is likely that some off-specification beryllium waste may be generated in the process of making sealed sources, such wastes are not likely to be mixed GTCC LLW. To qualify as a mixed GTCC LLW, the waste would have to be generated

before entering into the manufacturing process *and* contain sufficient radioactivity to also be a GTCC LLW. These relatively high radioactivity concentrations (e.g., at least 100 nCi/g of americium or up to 50 mCi of americium in a container of concentration averaged waste) are usually associated with process wastes (therefore, not RCRA-regulated hazardous wastes), not off-specification commercial chemical products (e.g., P015 listed waste with inadvertent contamination). Thus, it is assumed that the highly radioactive nature of GTCC LLW precludes generation of listed mixed GTCC LLW as a result of manufacturing sealed sources. This assumption is confirmed by the updated survey of Other Generators' waste.

Another example of the difference between a process and a listed waste is the past use of hydrazine as a corrosion inhibitor in power reactor systems. Hydrazine is a U-listed chemical in 40 CFR 262.33 (U133). In normal operations, it is added to the system as a process chemical; thus any wastes generated from the use of hydrazine are not regulated hazardous wastes. However, any unusable hydrazine residues remaining in the bottom of "empty" containers must be managed as hazardous waste. But since the concentrations of radioactivity associated with the disposal of these hydrazine residues would not approach GTCC LLW levels, hydrazine is not expected to be mixed GTCC LLW.

3.2 Characteristic Wastes

If a waste is not a listed waste it may still be a regulated hazardous waste because of its characteristics. This section evaluates whether each of the 41 GTCC LLW types identified in References 1 and 2 exhibits the characteristics of toxicity, ignitability, reactivity, or corrosivity.

3.2.1 Toxicity Characteristic Wastes

As shown in Table 3, TC was identified as an area of potential RCRA regulation for each of the 41 types of GTCC LLW. However, upon further evaluation, all but one can be ruled out for the toxicity characteristic using process knowledge and generator confirmation. This section first groups the 41 waste types into 6 general categories, then discusses each category and its potential to be a mixed GTCC LLW for TC.

The 41 waste types can be combined into the following general groups:

- Stainless steel and reactor hardware (e.g., reactor components, particulate or cartridge filters, metal shavings, and sealed source containers)
- Ion exchange resins
- Sources of silver (e.g., reactor hardware, sealed source containers and manufacturers)
- Compactible and noncompactible trash (e.g., lead shielding, fuel grinds, glass, metal scrap, and equipment)

- Crud and particulate wastes
- Organics.

The potential for each of these waste groups to be a regulated TC hazardous waste is discussed below.

3.2.1.1 Stainless Steel and Reactor Hardware. Stainless steel and other corrosion-resistant alloys are used in reactor hardware, reactor fuel cladding, and sealed sources. The chemical composition of several reactor components identified as GTCC LLW are listed in Table 4. This table indicates that stainless steel 304 (SS-304) is the dominant alloy used in conventional light-water reactors in the United States. The chemical composition of SS-304 and other alloys used as fuel cladding and in the manufacture of sealed sources is presented in Table 5.

Of all the metals noted in Table 5, only chromium is also identified in Table 1 as a constituent in determining TC. Therefore, an evaluation of the solubility of chromium from SS-304 is provided in this report to confirm the intuitive conclusion that stainless steel and other corrosion-resistant metals are not hazardous waste.

Such an evaluation was attempted in EPA's evaluation of spent fuel as a mixed waste.³ According to that report, "corrosion data tables for the metals of interest (aluminum, stainless steel, Zircaloy, etc.) all show excellent resistance to acetic acid in tests ranging from 5% to 95%. Unfortunately, the data are not presented in a way useful for quantitatively predicting TCLP performance." That report tentatively concluded that reactor fuel cladding materials including stainless steels did not constitute a TC waste.

Table 4. Composition of reactor components likely to be classified as GTCC LLW. (Information taken from DOE/LLW-114 Revision 1, and from Reference 4.

Reactor component	Principal materials
BWR - Control rod blades	SS-304, Boron carbide pellets
BWR - LPRM instrument strings	SS-304, Uranium
BWR - IRM/SRM dry tubes	SS-304, Uranium
BWR - Poison curtains	Borated SS-304
BWR - Core shroud	SS-304
BWR - Top fuel guide	SS-304
PWR/W - Thimble plug assemblies	SS-304 and Inconel
PWR - Instrument strings	SS, Inconel, and Rhodium
PWR - Core shroud (baffle)	SS-304
PWR - Lower Core barrel	SS-304
PWR/W - Upper Core Support Plate	SS-304
PWR - Lower Core Support Plate	SS-304

Table 5. Chemical composition of various alloys of GTCC LLW (av. wt %) (Values are taken from the DOE/LLW-114 Revision 1 report unless otherwise noted by superscript.)

ALLOY	Cr	Fe	Ni	Co	Nb	Mo	C	Zr	Sn	Mn	Si
SS-304L	18-20 ⁵	remainder ⁷	8-12 ⁷				0.03 ⁷			2 ⁷	1
SS-316L	16-18 ⁷	remainder ⁷	10-14 ⁷			2-3 ⁷	0.03 ⁷			2 ⁷	1
SS-317	18-20 ⁷	remainder ⁷	11-15 ⁷			3-4 ⁷	0.08 ⁷			2	1
Zircaloy-4	0.05-0.15 ⁵	0.05-0.15 ⁵	0.05-0.15 ⁵					93.9	2.7		
Inconel-718	17-21	remainder	50-55	0.087	4.4	2.79					
Hastelloy C-22	22 ⁶	3 ⁸	55.5 ⁸	2.5 ⁸		13 ⁸					
Hastelloy G-30	28-31.5 ⁷	13-17 ⁹	30.2-44.8 ⁹	5 ⁹		4-6 ⁹					

To definitively answer the question of whether SS-304 qualifies as TC hazardous waste, additional research was conducted on a 50-mg sample of 304 stainless steel. Series 304 stainless steel was chosen because this material is frequently used in nuclear reactors and has a relatively high chromium content of 18-20%.⁵ A TCLP extraction was performed with subsequent analysis using an inductively coupled Plasma Atomic Emission Spectrometer. A very low concentration of chromium was detected in the stainless steel sample (125 µg/L or 2.5% of the regulatory limit).⁸ Data validation for these laboratory results confirmed that the chromium value for the sample of stainless steel did not exceed the TCLP regulatory limits specified in 40 CFR 261.24. This assessment confirms that stainless steel is not a RCRA hazardous waste.

Similarly, Zircaloy and Inconel wastes are determined to be nonhazardous wastes. Zircaloy, another corrosion-resistant metal used in reactor components, has a chromium content of only 0.05 to .15% (two orders of magnitude less chromium than SS-304). Therefore, if uniform corrosion rates and mechanisms are similar to SS-304, Zircaloy components would also not be expected to exhibit the toxicity characteristic by TCLP. Similarly, Inconel, another corrosion-resistant metal used in reactor components with a chromium content similar to SS-304, should not be a characteristic waste for chromium. This last assumption is highly conservative since nickel is lower in the galvanic series than iron or stainless steels.⁹ Thus, a nickel-based metal would be expected to corrode even less than SS-304.

Since stainless steels are not a hazardous waste, components fabricated from stainless steel cannot be mixed GTCC LLW. This conclusion pertains to such wastes as reactor hardware; particulate (e.g., cartridge) filters; miscellaneous metals used in reactor or other systems having similar corrosion resistance; and metal shavings from sealed source manufacturers and fuel fabricators using stainless steels.

3.2.1.2 Ion-Exchange Resin Wastes. Appendix D-3 of DOE/LLW-114, Revision 1 does not list resin wastes as GTCC LLW from Other Generators. However, the DOE/LLW-114 report identified GTCC LLW resin wastes as originating from boiling water reactor (BWR) and pressurized water reactor (PWR) fuel-in decontamination systems. The resins become radioactive by concentrating the dissolved radioactive ions contained in circulating water in reactor systems and in

fuel pools. The dissolved radioactive ions originate when fuel cladding and reactor hardware directly contact water and from fission products resulting from tramp uranium on the outside of the fuel or any leaks in the fuel.

Radioactively contaminated resins have the potential to be mixed waste by three mechanisms: incorporation of chromates for corrosion control, an organic TC waste from the resin itself, and concentration of chromium leached from stainless steel hardware. Before 1986, chromates were often used as corrosion inhibitors in the PWR secondary coolant or BWR component coolant, leading to RCRA-regulated concentrations of chromium on resins.¹⁰ However, these coolants are not in direct contact with the fuel. Therefore, concentrations of radioactivity on these mixed waste resins are too low to qualify as GTCC LLW, eliminating these wastes from further consideration as mixed GTCC LLW.

Before testing of the resin media, there was concern that the resins contained regulated concentrations of TC organics. Power reactor generators have begun testing the resins and preliminary results to date indicate that the resins themselves are not TC wastes.^a

Nonetheless, the potential exists for resins to concentrate the small quantities of dissolved ions in primary coolant to qualify as a toxicity characteristic waste for chromium. This potential is shown by resins containing ⁶³Ni, an activation product from irradiation of stainless steel reactor hardware that is leached from the stainless steel and concentrated in the resin bed. While the potential may exist for some degree of chromium concentration on the resins, data are lacking on whether those chromium concentrations would be sufficiently high to constitute a hazardous waste.

Although it may be *theoretically* possible to generate RCRA-regulated hazardous wastes, such waste generation is not inevitable. Resins can be changed out at a more rapid rate to avoid generating both TC chromium wastes and GTCC LLW. Currently, nuclear utilities are actively avoiding the generation of mixed waste of all classes. GTCC LLW generation is also being avoided.^b

If, despite efforts to the contrary, toxicity characteristic resin wastes are generated, must they be *disposed of* as mixed GTCC LLW? The answer depends on how effectively they can be treated. According to 40 CFR 268.40, wastes designated as D007 (chromium TC wastes) must be treated before disposal so that they no longer exhibit a toxicity characteristic. Some solidification technologies have been tested and appear to meet this treatment requirement.^c Assuming that treatment for these wastes would be effective, the actual volume of PWR and BWR resin mixed GTCC LLW requiring disposal would be zero. If treatment were not effective, however, a treatability variance may need to be obtained from EPA. This variance could allow a less effective

---

a. Unpublished report, *Addendum to Mixed Waste Management Options Study: Mixed Waste Survey for NRC-Licensed Shut Down Nuclear Power Reactors*, by Ebasco Environmental for National Low-Level Radioactive Waste Program, EG&G Idaho, Idaho Falls, Idaho.

b. Personal communication with David Duke, Pacific Gas and Electric Company, San Francisco, California, April 9, 1992.

c. Personal communications with John Carlson, Chem Nuclear Systems, Columbia, South Carolina, and John Hass, SEG, Oak Ridge, Tennessee, May 20, 1992.

treatment, provided disposal occurred in a RCRA-permitted facility meeting minimum technical requirements.

Because of all the above factors, ion-exchange resin waste will probably not be mixed GTCC LLW. Such waste, however, was retained for further consideration in this report because data and systems are lacking to preclude its generation.

3.2.1.3 Sources of Silver. The DOE/LLW-114 Revision 1 report and Appendix D-3 identify sealed source licensees, sealed source distributors, and a university research and test reactor as generating GTCC LLW in the form of activated metals and process waste. In addition to stainless steel and other corrosion resistant metals discussed in Section 3.2.1.1 of this report, these generators occasionally encounter silver as a solder and plating material. Thus, there is some potential that these heterogeneous metal wastes could be TC hazardous wastes (D011 wastes) if their concentrations of silver are sufficiently high.

The use of silver solder would not likely result in a TC hazardous waste. A 50-mg sample of silver solder (85% silver and 15% manganese as specified by Amersham for model AMCL source) was subjected to a TCLP extraction with subsequent analysis using an inductively coupled Plasma Atomic Emission Spectrometer (Reference 10). A very low concentration of silver was reported in the silver solder extract ($3.5 \mu\text{g/L}$, $< 1\%$ of the regulatory limit). Data validation for these laboratory results confirmed that the silver value for the sample of silver solder did not exceed the TCLP regulatory limits specified in 40 CFR 261.24.

This TCLP result was from a sample that consisted entirely of silver solder. Any fabricated sealed source or reactor component would have only a small percentage of its weight comprised of solder materials. Therefore, a TCLP test of the actual GTCC LLW would yield even lower concentrations of silver in the leachate.

While silver solder and, most likely, resins can be ruled out as sources of D011 wastes, some sealed sources use silver as a plating material and were therefore evaluated for the potential of D011 wastes. One typical source is the Amersham Model AMM 1001 H smoke detector foil.^d A calculation of percent composition for this source indicates only 1% of the source is silver. Such a low percentage of silver is insufficient to cause an aggregation of these typical smoke detector sources to show the toxicity characteristic of silver.

This report, therefore, concludes that identified sources of GTCC LLW (sealed sources, activated metal, and process wastes) do not contain enough silver to be regulated as D011 wastes.

3.2.1.4 Compactible and Noncompactible Trash. Appendix D-3 identified process wastes and contaminated solids as GTCC LLW containing compactible trash and equipment (noncompactible trash). The most likely TC waste contaminants in compactible and noncompactible trash are lead (a

---

d. When an individual AMM 1001 H source is installed in a smoke detector, disposal of the intact smoke detector is exempt from regulation as a radioactive waste. This discussion applies only to accumulations of these sources as waste. Sealed source distributors can have such accumulations, but none were reported in Reference 2.

potential D008 waste), mercury (a potential D009 waste), organic liquids (several DXXX and F00X waste codes), and other components already discussed as potential TC waste. Of these potential TC wastes, the updated survey of Other Generators confirms the presence of only lead as a GTCC LLW waste from a sealed source manufacturer.

Lead. Potential lead wastes include shielding, contaminated lead, and activated lead. As mentioned in Section 2, if a lead container is used as shielding, it is not regulated by EPA under RCRA since empty containers or container liners are exempt under 40 CFR 261.7. Also, such lead shielding would not be solid waste because it would be fulfilling its intended use [40 CFR 261.2(c)(1)(ii)]. These arguments are confirmed in the EPA/NRC joint guidance on mixed waste identification and characterization (Reference 3). Care should be taken in applying this guidance, as at least one State, Washington, does not recognize the distinction between lead shielding and lead waste.

If the lead were disposed of because it was contaminated or no longer useful, it would qualify as a D008 waste. It is likely that the radioactivity on most contaminated lead can be averaged over the entire volume of a waste container to classify the entire contents of the container as Class A, B, or C waste, not GTCC LLW. This common practice is described in the DOE/LLW-114 Revision 1 report. However, if the contaminated lead waste cannot be concentration averaged and remains GTCC LLW, it must be disposed of as mixed GTCC LLW following treatment with macroencapsulation.

Appendix D-3 indicated that 5% of the total volume of 9.4 m³ of GTCC LLW generated by one sealed source manufacturer consisted of "lead scrap/shielding, etc." This generator confirmed the generation of TC wastes, and it is assumed that these TC wastes belong only to the lead scrap/shielding category. From the description of the waste that was provided, it did not appear that the hazardous components of the waste were segregated from the other components of the waste. For the maximum estimate, it will be assumed that the waste cannot be segregated and the entire volume of 9.4 m³ is hazardous waste.

Treatment and packaging requirements for TC wastes can affect the volume of mixed GTCC LLW disposed of. Elemental lead as a mixed waste is required to be treated by macroencapsulation, which could increase the original volume of waste generated by a factor of 1.2.¹⁰ This treatment/packaging factor is considered in estimating volumes of lead scrap or shielding requiring disposal.

3.2.1.5 Crud and Particulate Wastes. Other potential TC wastes include crud and particulate from filters. The only credible source of GTCC LLW crud and particulate filter waste is from the primary coolant, as secondary coolant is not sufficiently radioactive to generate GTCC LLW. Primary coolant crud filters would be expected to accumulate particulates from any fuel failure, stainless steel moving parts, and cladding sources.^e None of these materials are characteristic wastes. Therefore, crud and particulate from filters are not considered to be a potential mixed GTCC LLW. Section 3.2.1.1 contains additional information on these typical reactor metals.

---

e. Personal communication with Dennis Turner, Babcock & Wilcox, Lynchburg, Virginia, June 12, 1992.

3.2.1.6 Organics. Several TC organic compounds are listed in Table 1 as having the potential to be mixed GTCC LLW. TC organic compounds identified in Class A wastes include benzene, carbon tetrachloride, chloroform, tetrachloroethylene and trichloroethylene. Appendix D-3 confirms that no generator produces mixed GTCC LLW containing these TC chemicals, although other organic liquid wastes (F- or U-listed wastes) were identified. Therefore, it is reasonable to conclude that no GTCC LLW is mixed waste due to the presence of TC-organics.

3.2.2 Radiolytic Hydrogen Generation

High intensity radiation can cause radiolysis of water molecules generating potentially explosive concentrations of hydrogen in closed containers. Such radiolytic generation of hydrogen has been observed in Class C resin wastes and other highly radioactive moist wastes. But, because of the definition of reactivity (40 CFR 261.23) and the exemption for source, special nuclear, and byproduct material [40 CFR 261.(a)(4)], radiolytic generation of hydrogen gas does not constitute a reactive waste.

A waste is reactive if it has any of the properties listed in 40 CFR 261.23, including:

- It is capable of detonation or explosive reaction if it is subjected to a strong initiating source, or if heated under confinement, or
- The waste forms an explosive mixture with water.

While moist GTCC LLW has been known to generate hydrogen, it is the exempt radioactive component of the waste that causes the hydrogen generation, not the waste substrate. In addition, the radiolysis is not an immediate reaction, but a relatively slow buildup of hydrogen gas.

The characteristic of reactivity was intended to be applied to the RCRA-regulated chemical constituent of the waste. In the case of radiolytic hydrogen generation, electromagnetic or particle radiation combines with water to generate hydrogen. Water is not a reactive waste, and the radiation emanates from a material that is exempt from RCRA regulation. Consequently, although radiolytic hydrogen generation represents a safety hazard for some GTCC LLW, its presence does not constitute a RCRA-regulated hazardous waste. Radiolytic hydrogen generation is similarly not an ignitable waste, since the radiolysis is not rapid enough to cause the waste to be ignitable. Additionally, high integrity containers are vented and standard 55-gal drums are not leaktight, further controlling the safety hazard of this waste.

3.2.3 Other Ignitable, Reactive, and Corrosive Characteristics

Because of the treatment requirements of 40 CFR 268, it is unlikely that any GTCC wastes will be ignitable, reactive, or corrosive by the time the wastes are offered for *disposal*. Yet, an evaluation of these other characteristic wastes is warranted. Such wastes might include organic liquids, metal scrap, filter media, fuel grinds, mixed oxide fuel pellets, and contaminated equipment.

Organic Liquids. Four of the identified compounds in organic liquid GTCC wastes have the potential to be ignitable wastes, if present in concentrations having a flash point less than 140°F under specified test conditions. These compounds (methanol, acetone, ethyl acetate, and xylene) compose

approximately 35% of the volume of reported GTCC organic liquids and are also potentially designated as F003 wastes. F-listed waste is described in Section 3.1.1 of this report. RCRA-mandated treatment of these wastes should render them nonignitable and nonhazardous under RCRA following successful treatment. Because F003-listed wastes are designated as listed wastes solely due to the characteristic of ignitability, such treated waste mixtures should also lose any F003 designation following successful treatment.

Metal Scrap. While metal scrap from fuel burnup laboratories could be considered a reactive waste, uranium and other pyrophoric radioactive metals are source material, and therefore exempt from regulation under RCRA. Shavings of Zircaloy, a frequently used fuel cladding material, have been tested by EPA at Research Triangle Park, North Carolina, and have been determined *not* to be a hazardous waste.^f

Filter Media. This media, generated by sealed source manufacturers, is assumed to be air filter media, not resins or cartridge filters. The only sealed sources which are likely to have a hazardous waste component are the alpha-emitter/beryllium sources (e.g., americium/beryllium and plutonium/beryllium sealed sources). As previously discussed, such wastes result from the deliberate mixing of process chemicals. The waste is therefore a process waste, not a listed waste. It is unlikely that air filter media themselves would constitute a characteristic waste, as the filter media usually consist of paper or glass fibers. Sometimes these fibers have charcoal impregnated into them. These materials are not ignitable, corrosive, reactive, or toxicity characteristic wastes.

Fuel Grinds and Mixed Oxide Fuel Pellets. Reference 3 determined that mixed oxide fuel pellets of the type used for the Hanford Fast Flux Test Facility were *not* a RCRA hazardous waste. In fact, Reference 3 concludes that all light water commercial fuel is *not* regulated as a RCRA hazardous waste.

Contaminated Equipment. To the extent that waste equipment from sealed source manufacturers is contaminated with beryllium powders resulting from the manufacture of sealed sources, the equipment would *not* be RCRA-regulated because it is a process waste. The nature of beryllium is not ignitable, reactive, or corrosive. It is unlikely that lubricating oils or hazardous organic liquids would remain in the equipment. Thus, it is unlikely that contaminated waste equipment from sealed source manufacturers would represent a mixed GTCC LLW.

3.3 State-only Wastes

Because State hazardous waste programs may be more stringent than the Federal RCRA program, the possibility exists that some wastes are classified as hazardous waste in one State, but not in another. For example, the State of California regulates waste oil as a hazardous waste, and Washington State regulates lead used as shielding as a hazardous waste. To the extent the data would allow, these differences in State hazardous waste regulations were accommodated in this assessment of mixed GTCC LLW.

---

f. Personal communication with Thomas Nelson, Teledyne Wah Chang, Albany, Oregon, June 11, 1992.

3.4 Summary of Mixed GTCC LLW

Of the 41 categories of waste identified in Table 3, all but six have been eliminated from consideration as mixed GTCC LLW by process knowledge or through confirmation by individual generators. Table 6 provides a brief summary of these six remaining wastes, describes the potential area of regulation under RCRA, and provides a brief discussion of the likelihood that these wastes will require disposal as mixed GTCC LLW.

Table 6. Summary of potential mixed GTCC LLW.

	Waste type	Reason	Certainty
1 - 4.	Four types of fuel-in decontamination resins generated by Nuclear Utilities (BWR, PWR-Babcock and Wilcox, PWR-Combustion Engineering, and PWR-Westinghouse).	TC levels of chromium may concentrate on these resins during this decontamination procedure.	Highly unlikely this waste will be generated. Fuel-in decontamination will probably not be done. If it is performed, generators will most likely avoid producing this discretionary waste. Effective treatment of any waste generated further reduces the likelihood that <i>any</i> of this waste will require disposal as a mixed waste.
5.	Organic liquids produced by Other Generators (¹⁴ C users).	Many discarded organic liquids are F- or U-listed solvents or exhibit the characteristic of ignitability or toxicity.	Confirmed that organic liquid mixed GTCC wastes are generated. There is uncertainty about their specific hazardous waste classification (e.g., F00X or D001 or UXXX).
6.	Process Waste produced by Other Generators (sealed source manufacturer).	Potential for contaminated lead.	Confirmed that lead scrap/shielding were generated in the past and exist in current GTCC LLW inventories.

4. ESTIMATED MIXED GTCC LLW VOLUMES

Of the 41 categories of waste identified in Table 3, all but six have been eliminated from consideration as mixed GTCC LLW by process knowledge or through confirmation by individual generator. These remaining six wastes are listed in Table 6. A comparison was made between the GTCC LLW identified in the DOE/LLW-114 Revision 1 report and those wastes identified in the National Profile.¹¹ The description of wastes in the DOE/LLW-114 Revision 1 report, although broad, appears to encompass all the waste types identified in the comprehensive survey reported in Reference 11.

Three estimates of volume for each of these remaining six wastes are made. The three estimates represent a minimum, expected, and maximum assessment of the volume requiring disposal as mixed GTCC LLW. For conservatism, the concentration averaged volumes in the DOE/LLW-114 Revision 1 report were not factored into these estimates. According to the DOE/LLW-114 Revision 1 report, concentration averaging can virtually eliminate *all* mixed GTCC LLW volumes generated by nuclear utilities. Current waste management activities demonstrate that by using a combination of waste segregation, concentration averaging, and more precise waste characterization, inventories of potential GTCC LLW at most reactor facilities are thought to have been near zero by January 1, 1993. Consequently, estimates of the quantities of GTCC LLW in the DOE/LLW-114 Revision 1 report are conservative.

The methodology identified in Figure 3 describes how mixed GTCC LLW volumes are estimated. The first consideration involves how the wastes are generated. Is this type of waste avoidable? For example, current waste generation practices actively avoid the generation of both GTCC LLW and hazardous waste. Fuel-in decontamination resin is an example of a mixed GTCC LLW that is theoretically possible, but from a practical perspective, this waste would probably not be generated.

Because hazardous waste must be treated using the best available technology before being acceptable for land disposal, it was assumed that the waste would be treated as prescribed in 40 CFR 268. Some prescribed treatments would virtually eliminate the hazardous characteristic of the waste, allowing disposal of this waste as only GTCC LLW. For such characteristic wastes, the minimum and expected disposal volumes are assumed to be zero. However, for the maximum estimate, it is assumed that treatment either was not effective or could not be accomplished because of the highly radioactive nature of the waste. For the maximum estimate, the unpackaged base case estimate of the DOE/LLW-114 Revision 1 report is modified by volume reduction (VR) factors appropriate to the required 40 CFR 268 treatment and a packaging factor appropriate to the waste type. VR factors from Reference 10 are used for hazardous waste treatment; packaging factors from Appendix E-4, *Packaging Factors for GTCC LLW*, of DOE/LLW-114 Revision 1 are also used.

For the maximum estimate, the mixed GTCC LLW would be required to be disposed of in a facility regulated by both NRC and EPA or an authorized State program. Any waste that could not meet 40 CFR 268 treatment standards would be disposed of under a treatability variance, and the disposal facility would be required to meet minimum technical requirements or have a no-migration variance.

D93 00311

Figure 3. Logic diagram to estimate waste volume.

For those listed wastes or wastes that had specified treatment technologies, VR factors appropriate to the required treatment were applied. As for the characteristic wastes, the minimum and expected estimates assumed the treatment was effective. For the maximum estimate, the unpackaged base-case volume was multiplied by an appropriate VR for the EPA-preferred treatment and a packaging factor per the DOE/LLW-114 Revision 1 report, Appendix E-4.

For those wastes from Other Generators, data from Appendix D-3 was used to predict current inventory and future generation of waste. Appropriate VR factors for the EPA-preferred treatment and packaging factors were also applied.

A brief explanation for each of the six mixed GTCC LLW categories is provided below. The data from the DOE/LLW-114 Revision 1 report for Nuclear Utilities and from Appendix D-3 for Other Generators concerning the base case unpackaged and packaged GTCC LLW for each waste type are presented in an introductory table for each waste type. Unless otherwise noted, the data refer to waste projections through the year 2035. All values have been rounded to the nearest m³. For conservatism, no concentration averaging has been included beyond that incorporated in the DOE/LLW-114 Revision 1 report estimates. The results of this assessment are also summarized and presented in Table 7. The text explains how the estimates were made.

Table 7. Projected volumes of mixed GTCC LLW (m³ packaged).

Generator category	Waste type	Minimum volume	Expected volume	Maximum volume
Nuclear Utility	Fuel-in decontamination resins ^a	0	0	309-618 ^a
Other Generators	Organic liquids ^b	< 1	176	176
Other Generators	Process waste ^b	0	< 1	11
	Total	< 1	< 177	496-805
Total Nuclear Utility		0	0	309-618 ^a
Total Other Generators		< 1	< 177	187
Total Sealed Sources		0	0	0

a. It is highly speculative that these mixed GTCC LLWs will ever be generated. If the Nuclear Utility industry never utilizes this decontamination technique, then the maximum mixed GTCC LLW estimate for Nuclear Utilities becomes zero. The quantities listed are through the year 2055.

b. Other Generators mixed GTCC LLW estimates are through the year 2035.

4.1 Fuel-in Decontamination Resins

Generator type	GTCC LLW volume (m ³)		Mixed GTCC LLW estimates (m ³)		
	Unpackaged	Packaged	Minimum	Expected	Maximum
Nuclear Utility (BWR)	71	71	0	0	71-142
Nuclear Utility (PWR-B&W)	30	30	0	0	30-60
Nuclear Utility (PWR-CE)	51	51	0	0	51-102
Nuclear Utility (PWR-W)	157	157	0	0	157-314
Total	309	309	0	0	309-618

Note: Volumes represent all Nuclear Utility GTCC LLW resins through the year 2055 to account for the possibility of license extension by some plants.

Generators can avoid producing GTCC LLW fuel-in decontamination resins by taking the resins out of service before they become GTCC LLW. Scaling factors can also be used to control the concentration of a TC metal waste. For example, it should be possible to relate an activation product, such as ⁶⁰Co, to a hazardous waste constituent, such as chromium. In this way plant operations can administratively monitor and control the build up of both radioactive and chemically hazardous species on the resins. As described in the DOE/LLW-114 Revision 1 report, a full system fuel-in decontamination procedure has not yet been employed in the industry. Therefore, there is no 1993 inventory for these reactor wastes.

For the purposes of discussion, however, this study assumes that these wastes eventually will be generated. A total volume of 309 m³ has been estimated for these fuel-in decontamination resins through the year 2055. Because the waste is hazardous from TC metals, 40 CFR 268 treatment standards require treatment to levels at or below the concentration that defines a hazardous waste. Therefore, if these wastes are successfully treated, they may be disposed of as solely GTCC LLW, and the minimum and expected volume estimates are zero. If, however, treatment is not effective, or could not be performed due to the unique nature of the wastes (e.g., high dose rates), the waste will remain mixed GTCC LLW and will be required to have a treatability variance before disposal in a jointly regulated facility under both the AEA and RCRA. Assuming treatment of the resins by solidification, waste volumes could increase by at least a factor of two. Thus, a maximum disposal volume of 309 to 618 m³ may be required for this waste, depending on whether treatment was attempted or not. It is assumed that in the case of unsolidified resins, disposal would be in a high-integrity container having a packaging factor of 1. Solidified resins may also require a high integrity container, depending on the performance of the solidification/stabilization media.

4.2 Organic Liquids

Generator type	GTCC LLW volume (m ³)		Mixed GTCC LLW estimates (m ³)		
	Unpackaged	Packaged	Minimum	Expected	Maximum
Other Generators (¹⁴ C users)	88 (estimated)	176	0.5	176	176

Mixed GTCC LLW organic liquids were produced by three generators, according to Appendix D-3. Those generators are ¹⁴C Users. Appendix D-3 indicates that 7.0 m³ of packaged mixed GTCC LLW organic liquid was in storage in 1993, 3.32 m³ of mixed GTCC LLW organic liquid was expected to be generated in 1993, and 3.92 m³ of mixed GTCC LLW organic liquid was expected to be produced for each of the next 5 years. Assuming near-term generation patterns continue through the year 2035, a total of 176 m³ of packaged mixed GTCC LLW organic liquid is assumed to be generated. 40 CFR 268 recommended that treatment for most of these hazardous constituents is incineration; however, the high concentrations of ¹⁴C present in this waste are likely to preclude these standard treatment techniques due to environmental releases of ¹⁴C. Appendix D-3 describes a packaging factor of 2 for these wastes, with 30-gal drums of liquid overpacked in 55-gal drums and annular spaces filled with absorbent. Based on the packaging factor of 2, the unpackaged volume of mixed GTCC LLW through the year 2035 is estimated to be 88 m³.

Following the methodology in Figure 3, the minimum volume estimate is based on treating the waste by incineration, as this treatment is recommended by EPA for most organic liquids. Appendix E-4 identifies a VR factor of 0.003 for incineration. Applying this factor to the unpackaged volume results in an estimate of 0.26 m³ of ash residue. It is assumed that the ash remains a mixed GTCC LLW, and must be stabilized through solidification. A packaging factor of 2 is assumed for solidification/stabilization/packaging, yielding a minimum estimate of 0.5 m³ of this type of mixed GTCC LLW requiring disposal.

If incineration of the organic liquids is not performed due to concerns about stack effluents, a treatability variance will likely be needed. If the waste is disposed of as packaged waste without further treatment, a total of 176 m³ is assumed. If nonincineration treatment is applied, e.g., biological treatment with capture of any ¹⁴C that may be released from the bioreactor or supercritical water oxidation, it is assumed that the resulting wastes will be neither greater nor less than the original packaged waste volume. Whenever a treatability variance is granted, disposal must be in a facility meeting minimum technical requirements of 40 CFR 264.301.

The maximum estimate is also 176 m³. If solidification/stabilization of the wastes is the final treatment, this technology can usually be applied within an overall volume increase of only 2. Applying an overall volume increase of 2 to the unpackaged waste volume of 88 m³ results in a maximum volume estimate of 176 m³. Consequently, the expected and maximum volume estimates are the same, 176 m³. These estimates assume that the inner container remains substantially intact. Any contaminated absorbent resulting from a breach of the inner container is assumed to not be a GTCC LLW.

4.3 Process Waste

Generator type	GTCC LLW volume (m ³)		Mixed GTCC LLW estimates (m ³)		
	Unpackaged	Packaged	Minimum	Expected	Maximum
Other Generators (Sealed Source manufacturers)	Not reported	9.4	0	0.56	11.3

Metals from operations include lead-laden metals that are regulated as toxicity characteristic wastes under RCRA. Contaminated lead solids are required to be treated by macroencapsulation (designated by the 5-letter treatment code: MACRO). It is assumed that MACRO increases original volume by a factor of 1.2, and that the treated waste could be disposed of in a high integrity container with a packaging factor of 1.

Of the 9.4 m³ of waste reported by a sealed source/device manufacturer, 5% was estimated to be lead scrap/shielding, etc. Assuming this waste can be decontaminated or treated so that it is no longer considered to be TC hazardous GTCC LLW, the minimum estimate would be 0 m³. If the TC waste could be segregated and were treated with macro-encapsulation, a packaging/treatment factor of 1.2 would be appropriate. Under this expected scenario, 0.56 m³ of mixed GTCC LLW would result. Under the maximum estimate, it is assumed that waste segregation is not possible due to radiation protection concerns and the entire 9.4 m³ of waste is considered RCRA-regulated with treatment/packaging by macroencapsulation followed by a high integrity container. The maximum estimate is, therefore, 11.3 m³. No continuing generation of this waste is expected.

4.4 Summary of Expected Volumes

Estimated volumes for all suspect mixed waste range from a minimum estimate of 0.5 m³, to an expected estimate of <177 m³, and a maximum estimate ranging from 496 to 805 m³. The only mixed waste identified from Nuclear Utilities is resins generated as a result of the fuel-in decontamination procedure. Generation of these wastes is discretionary since the resins can be changed more frequently to avoid generation of this waste. It is also highly questionable whether this procedure will even be conducted, as the nuclear industry is still evaluating its application. Nonetheless, these wastes were retained in this estimate because of their large volumes, should they ever be generated in a manner requiring disposal as a mixed GTCC LLW. The more realistic estimate of mixed GTCC LLW from fuel-in decontamination resins is represented by the expected volume estimate of zero.

The estimate of 176 m³ for organic liquid wastes also bears some explanation. If the recommended treatment of incineration is applied to these wastes, less than one cubic meter should result. However, it is likely that ¹⁴CO₂ treatment will be required to contain releases to the environment or some other technology will need to be applied to this waste to control both the radiological and chemical hazard. In that case, it is expected that whatever technology is applied may result in an overall volume increase of a factor of two over the estimated unpackaged volume.

5. UNCERTAINTIES AND DATA NEEDS

Hazardous waste evaluations based on process knowledge depend on first-hand knowledge about generating processes and resultant wastes. Consequently, EPA places the responsibility for waste characterization on the generator of the waste because that person is most familiar with the waste (40 CFR 262.11). Because this report addresses mixed GTCC LLW from an industry or generic perspective, it cannot replace the detailed assessment and characterization required of a generator.

In assessing the types and volumes of mixed GTCC LLW, a conservative approach was used. That is, a waste was considered to be a hazardous waste unless proven otherwise by data or process knowledge. This report also relies on information derived from radiological, not chemical, evaluations of GTCC LLW waste generation practices (the DOE/LLW-114 Revision 1 report). Consequently, there are considerable uncertainties in this report. This section identifies these uncertainties in waste designation criteria; volume estimates and waste designation for power reactor wastes; and volume estimates and waste designation for other generators. This section also identifies where additional research is needed to identify and quantify mixed GTCC LLW with greater certainty.

5.1 Uncertainties in Waste Designation Criteria

Three areas of uncertainty affect the waste designation process. First, mixed waste designation procedures and criteria are not uniform throughout the United States. Because EPA can delegate its regulatory authority to a State with a regulatory program that is as stringent as that of EPA, each authorized State may impose its own set of criteria. Some States have more stringent requirements; others have requirements identical to EPA. In States having authorized mixed waste programs (29 States as of March 1992) it is the State designation criteria, not the Federal criteria, that would apply to the GTCC LLW. This position has been tested and upheld in at least one court decision, *LEAF vs. Hodel*, 1974. Consequently, GTCC LLW would need to be evaluated against the applicable waste designation criteria at each location where the GTCC LLW is treated, stored, or disposed of.

The second area of uncertainty exists with EPA's waste designation criteria. In response to a court order (*Shell Oil v. EPA*, No. 80-1532, D.C. Cir. December 6, 1991), EPA is currently reevaluating its waste designation criteria for listed waste mixtures and residues. It is anticipated that after EPA revises the criteria, the types and amounts of listed wastes would be reduced. However, because the lawsuit between Shell and EPA dealt with procedural aspects of the "mixture" and "derived from" rules, authorized States would not be obligated to implement the same changes. That is, States would retain the authority to impose stricter requirements than those of the Federal government. Nonetheless, if EPA's criteria change, the waste designations and estimates of mixed GTCC LLW in this report should be reevaluated.

The third area of uncertainty relates to the difficulty of applying the EPA's waste designation criteria to such highly radioactive material as GTCC LLW. Actual testing of the GTCC LLW might not be required, depending on the level of process knowledge about the waste. NRC and EPA have issued draft guidance on how to meet RCRA hazardous waste testing requirements for mixed waste, stressing the need to maintain radiation exposures as low as reasonably achievable.¹² As concentrations of radioactivity in the waste increase, avoiding unnecessary radiation exposures

assumes greater importance. The degree of waste characterization for mixed GTCC LLW will need to be negotiated as part of the permitting process under RCRA. Some waste testing is also required to verify that treatment standards of 40 CFR 268, subpart D have been met. Treatability variances may also be used to avoid radiation dose associated with actual testing of this highly radioactive mixed waste. This is particularly true of organic liquid wastes with high concentrations of ^{14}C .

5.2 Uncertainties and Assumptions Applicable to All Wastes

There are two general sources of error when evaluating mixed GTCC LLW: the quality of the data describing the GTCC LLW component, and the quality of the data describing the hazardous waste component. The overriding assumption throughout this report is that the DOE/LLW-114 Revision 1 report accurately estimates all the GTCC LLW in the United States, excluding that currently held at DOE facilities. Comparisons to the National Profile of mixed waste generation (Reference 11) confirm that all types of mixed GTCC LLW appear to be identified in the DOE/LLW-114 Revision 1 report. For conventional power reactors, the radiological and physical data on the types and volumes of the GTCC LLW components are quantitative and well defined as a result of the detailed analyses performed in support of the DOE/LLW-114 Revision 1 report. Data on the radiological component of sealed sources is of high quality due to NRC's regulatory controls over these sources. However, data on the GTCC LLW component of Other Generators wastes described in the DOE/LLW-114 Revision 1 report are more "order of magnitude" estimates than reliable quantitative information. Consequently, a separate updated survey of Other Generators wastes was conducted (see Appendix D-3). This study assumes that Appendix D-3 accurately represents all of the GTCC LLW produced by Other Generators.

While the radiological component of some wastes are well characterized, the regulatory distinctions among the chemical characteristics of all the wastes are not well characterized in the DOE/LLW-114 Revision 1 report, Appendix D-3, or elsewhere. Nonetheless, the chemical characteristics of the reactor wastes are more predictable because they are more standardized than many types of Other Generators wastes. The large numbers of sealed sources and their multiple manufacturers and manufacturing techniques make estimating volumes of mixed GTCC LLW less reliable. The updated questionnaire and scope of the updated information on Other Generators' waste in Appendix D-3 provides greater assurance that GTCC LLW, and in particular mixed GTCC LLW, was not overlooked.

Thus, conclusions reached on mixed GTCC LLW volumes generated from conventional power reactors are more reliable than those for Sealed Sources. In comparison, conclusions reached on Other Generators mixed GTCC LLW have the highest degree of uncertainty, primarily because of the difficulty in assigning specific RCRA waste codes to these wastes and because treatment technology has yet to be developed for many of these wastes.

Some general assumptions that were applied to all GTCC LLW in this report are:

- Treatment by solidification is assumed to increase volume by a factor of two.
- Heterogeneous wastes generated after 1986 are assumed to have been generated under strict waste segregation programs that eliminated the mixing of any non-GTCC LLW mixed or hazardous wastes from other GTCC LLW. The year 1986 was chosen for three

reasons. In 1985, the last of the commercial disposal sites ceased acceptance of mixed waste. Early in 1987, NRC and EPA issued their first joint guidance on the characterization and identification of mixed waste,¹³ bringing further attention to the issue of mixed waste. Lastly, by 1986 the high cost of disposal made waste minimization and segregation programs commonplace at generators' facilities.

- The DOE will require, as a condition of acceptance of any GTCC LLW, a full waste characterization in accordance with recent NRC guidance (Reference 12) and generator requirements found in 40 CFR 262.11 and 40 CFR 268.
- The DOE will require, as a condition of acceptance of any mixed GTCC LLW for disposal, that the waste is acceptable for land disposal under 40 CFR 268 and that it meets stability requirements of 10 CFR 61.
- Packaging factors developed for GTCC LLW do not change for mixed GTCC LLW. Similarly, volume reduction factors developed for LLW mixed waste do not change when applied to mixed GTCC LLW.

5.3 Uncertainties and Assumptions Used in Estimating Power Reactor Wastes

In spite of the high quality data and standardized manufacturing processes for the conventional power reactor, the chemical components of many common reactor wastes are not well characterized. Since data from directly applicable tests are limited, extrapolations from less relevant testing protocols were used for this assessment. In all cases, the less relevant testing conditions are conservative compared to the prescribed RCRA tests. The following assumptions were used for reactor wastes:

- Current management of resins and reactor coolant wastes would eliminate routine generation of GTCC LLW and mixed waste resins.
- Because of the uncertainty involved with management and disposal of resins resulting from fuel-in decontamination operations, power reactor operations personnel would actively avoid the generation of GTCC LLW and mixed GTCC LLW from these operations.
- Stainless steels and other reactor hardware are not hazardous waste.
- Fuel particles from all Nuclear Utilities are not a hazardous waste.

5.4 Uncertainties and Assumptions Used in Estimating Sealed Sources and Other Generators Wastes

Estimates of resulting treated wastes from Other Generators are considered the least reliable estimates, and therefore, represent the least reliable data in this report. Although wastes generated in this category have been better described with the updated survey information in Appendix D-3, uncertainty exists on the specific RCRA waste code designation and the treatment technology to be employed for these wastes.

It was assumed that if sealed sources contained less than 5% by weight of silver, they could not become mixed GTCC LLW. No sealed source evaluated was found to contain more than 5% by weight of silver. Therefore, no sealed sources were identified as being mixed GTCC LLW.

5.5 Areas Requiring Further Research

Conventional Power Reactors. Additional research on the potential for conventional power reactors to generate mixed waste is currently being sponsored by Electric Power Research Institute (EPRI). This research is intended to characterize all routinely and most non-routinely generated LLW on an industry-wide basis. Therefore, by evaluating all potential mixed wastes from the power reactors on a generic, but limited basis, EPRI intends to conduct detailed waste characterization in a manner that satisfies EPA requirements under 40 CFR 262.11 while maintaining exposures to radiation as low as reasonably achievable. EPRI's study is also evaluating the effectiveness of several treatment techniques for meeting 40 CFR 268 specified treatments. Initial results from the EPRI work do not identify any mixed GTCC LLW; the final report of this work is expected in late 1994.^g

Other. The Other Generators category has the potential to comprise up to 100% of all mixed GTCC LLW estimated in this report. The uncertainties associated with these estimates are related to the need to better characterize the wastes from a regulatory perspective and the need to develop appropriate treatment technologies for these high-activity wastes. The range of estimates depends on whether incineration, no treatment, or solidification technologies are employed. Biological treatment or supercritical water oxidation may also be possible; resulting increases/decreases in volume need to be confirmed.

---

g. Personal communication with Carol Hornibrook, Electric Power Research Institute, Palo Alto, California, June 1994.

6. SUMMARY

The volumes and types of mixed GTCC LLW are difficult to estimate with certainty. This report has identified that the only potential mixed GTCC LLW from nuclear utilities are resins from a fuel-in decontamination procedure. It must be noted that the fuel-in decontamination process is not currently conducted at any nuclear plant, and the plants are aggressively avoiding the generation of GTCC LLW and any mixed waste. Thus, it is reasonable to expect that no mixed GTCC LLW will be generated by Nuclear Utilities. Recent research conducted by EPRI identifies no routinely generated mixed GTCC LLW.

Aside from fuel-in decontamination resins, the overwhelmingly large volume of mixed GTCC LLW was identified as organic liquids generated by two ¹⁴C Users in the Other Generators category. While these Other Generators did not contribute a large percentage to the total volume of nonmixed GTCC LLW compared to power reactors, they generate essentially all the mixed GTCC LLW that can reasonably be expected to be generated in the future. One Other Generator also produced mixed GTCC LLW as metals from sealed source manufacturing operations, but no future generation is expected. Waste from Other Generators could represent up to 100% of the estimated 177 m³ of mixed GTCC LLW reasonably expected to be generated through the year 2035. There is a two order of magnitude difference, however, between minimum (< 1 m³) and maximum (187 m³) estimates of Other Generators' mixed GTCC LLW in this report. Uncertainties regarding these estimates are mainly related to which technologies will be used to treat these wastes. Currently, no commercial treatment facility is available to provide the treatment required under 40 CFR 268. DOE treatment facilities are also not currently available for these high-activity organic wastes. A treatability variance may also be required. One consequence of a treatability variance is that disposal must occur in a RCRA-regulated facility meeting minimum technical requirements or having a no-migration variance.

7. REFERENCES

1. U.S. Environmental Protection Agency and U.S. Nuclear Regulatory Commission, *Guidance on the Definition and Identification of Commercial Mixed Low-level Radioactive and Hazardous Waste*, October 4, 1989.
2. Nancy P. Kirner, *Greater-Than-Class C Low-Level Radioactive Waste Characterization: RCRA Designation of Discarded Americium/Beryllium Sealed Sources*, DOE/LLW-195, Idaho Falls, Idaho, September 1994.
3. S. Cohen and Associates, Inc. for U.S. Environmental Protection Agency, Office of Radiation Programs, *Evaluation of Spent Nuclear Fuel as Mixed Waste*, June 1990.
4. M. Benedict, T. H. Pigford, and H. W. Levi, *Nuclear Chemical Engineering*, Second Edition, McGraw-Hill Book Company, New York, 1981.
5. R. H. Perry, D. W. Green, and J. O. Maloney, *Chemical Engineers' Handbook*, 6th Edition, McGraw Hill, Inc., 1984.
6. Haynes International, Inc., *Hastelloy Alloy C-22*, Kokomo, Indiana, 1988.
7. Haynes International, Inc., *Hastelloy Alloy G-30*, Kokomo, Indiana, 1989.
8. EG&G Idaho, Inc., *Toxicity Characteristic Leachability Procedure Findings for a Silver-Manganese Solder Sample and a 304 Stainless Steel Sample*, DOE/LLW-177, National Low-Level Waste Program, Idaho Falls, Idaho, May 1993.
9. K. Othmer, *Encyclopedia of Chemical Technology*, Third Edition, Volume 7, John Wiley and Sons, New York, 1979.
10. N. Kirner, G. Faison, and C. Owens, *Mixed Waste Management Options*, DOE/LLW-134, December 1991.
11. Klein, J. A., J. E. Mrochek, R. L., Jolley, I. N. Osborne-Lee, A. A. Francis, T. Wright, *National Profile on Commercially Generated Low-Level Radioactive Mixed Waste*, NUREG/DR-5938, ORNL-6734, U.S. Nuclear Regulatory Commission, Washington, D.C., 1992.
12. U.S. Nuclear Regulatory Commission, *Clarification of RCRA Hazardous Waste Testing Requirements for Mixed Waste, Draft Guidance*, March 1992.
13. U.S. Nuclear Regulatory Commission and U.S. Environmental Protection Agency, *Guidance on the Definition and Identification of Commercial Mixed Low-Level Radioactive and Hazardous Waste*, January 5, 1987.

Attachment 1

**Letter from M. Williams,
EPA Office of Solid Waste,
to Terry Husseman,
Washington Department of Ecology,
June 26, 1987**

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JUN 26 1987

Received for the Waste Program
Dept. of Ecology JUL 06 1987
OFFICE OF
SOLID WASTE AND EMERGENCY RESPONSE

Mr. Terry Russeman
Chair, Northwest Interstate
Compact Committee
Washington Department of Ecology
PV-11
Olympia, Washington 98504

Dear Mr. Russeman:

Thank you for your letter of May 23 in which you requested guidance on treatment and disposal methods for low-level waste that contains uncontaminated lead used as shielding, surface contaminated lead and activated lead.

First, I would like to address activated or radioactive lead. As you know, lead is not a naturally occurring radionuclide. Lead may become radioactive or activated as a result of neutron bombardment while being used as shielding in nuclear power plants, for example. Such activated lead, if short-lived, may be stored to allow radioactive decay prior to disposal. The resultant non-activated or elemental lead may be disposed of as hazardous waste in a hazardous waste disposal facility. If storage for decay is impractical, the activated lead must be managed as mixed waste. You should note, however, that in States authorized to administer the Federal mixed waste program or in States with Federally administered hazardous waste programs, any storage of mixed waste in excess of ninety days for generators and ten days for transfer facilities would require a Resource Conservation and Recovery Act (RCRA) permit. Similarly, designated storage facilities must obtain a RCRA permit.

Lead which is contaminated on the surface may be decontaminated by a number of commercially available processes. However, because lead is malleable and easily gouged or pitted, radioactive contamination is often not limited to the surface and may be imbedded in the lead itself. Where decontamination is incomplete or contraindicated because of occupational health considerations, the lead must be managed as a mixed waste. Also, EPA's Office of Radiation Programs is developing a standard which will delineate levels of radiation which are below regulatory concern (BRC). Once BRC levels have been established, it may be possible to dispose of lead which exhibits BRC levels of radioactive contamination as a hazardous waste.

Lead containers or container liners which are used as shielding in low-level waste disposal operations pose a unique problem. Containers or container liners are not regulated by the Agency (See 40 CFR 261.7) nor would they be a waste because they are fulfilling intended uses. ((CF 40 CFR 261.2(c)(1)(ii))). In this instance, containers or liners may be analogous to commercial chemical products (e.g., pesticides) where as a product, their normal use is placement on the land. Therefore, lead whose primary use is shielding in low-level waste disposal operations is not subject to Federal hazardous waste regulations when placed on the land as part of its normal commercial use.

Encapsulation represents a viable mechanism for mitigating the hazardous waste characteristic lead may exhibit upon EP toxicity testing only in specific circumstances. The EP toxicity test procedure requires grinding the waste into pieces not greater than one square centimeter in size prior to extraction. Therefore, encapsulation would result in a non-hazardous waste only in those instances where it could be demonstrated that the encapsulation process results in a product that would not degrade after disposal, (i.e., is resistant to degradation or fracturing when placed in the land disposal environment). In such instances, you could petition the Agency to waive the EP toxicity test requirement. Additionally, the Agency is revising existing EP toxicity test procedures. Work is underway to develop procedures for evaluating a waste's long term physical stability. These procedures may then be used demonstrate that the encapsulated material will not degrade and allow testing of an intact lead brick or the like, for example.

The Agency has not evaluated specific technologies for encapsulation of lead or other wastes, nor has the Agency performed specific laboratory analyses of materials to determine their resistance to the EP toxicity test. However, a polymer or some other material which maintains its integrity under environmental stress would seem to be suitable.

In view of the urgency of the lead issue, it may be prudent to explore the feasibility of obtaining both a Nuclear Regulatory Commission license and an EPA permit to provide for the disposal of mixed waste.

If I can be of further assistance, do not hesitate to contact me.

Sincerely yours,

Marice E. Williams, Director
Office of Solid Waste

cc: Alan Corson
Floyd Galpin
Ken Shuster