REMOTE-HANDLED TRU WASTE CHARACTERIZATION PROGRAM IMPLEMENTATION PLAN

Revision 0D

(Subject to Approval)

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U.S. Department of Energy
Carlsbad Field Office

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Acronyms and Abbreviations

AK	Acceptable knowledge
ALARA	As low as reasonably achievable
ANSI	American National Standards Institute
ASTM	American Society of Mechanical Engineers
CBFO	Carlsbad Field Office
CCA	Compliance Certification Application
CFR	Code of Federal Regulations
CPR	Cellulose, plastic, and rubber
DA	Destructive assay
DOE	U.S. Department of Energy
DQO	Data Quality Objective
DTC	Dose-to-curie
EPA	U.S. Environmental Protection Agency
ICP-MS	Inductively coupled plasma-mass spectrometry
LLD	Lower limit of detection
LWA	Land Withdrawal Act
NDA	Nondestructive assay
NMHWA	New Mexico Hazardous Waste Act
NRC	Nuclear Regulatory Commission
OJT	On-the-job training
PA	Performance Assessment
PAVT	Performance Assessment Verification Test
PK	Process knowledge
QA	Quality Assurance
QC	Quality Control
QAO	Quality Assurance Objectives
QAPD	Quality Assurance Program Document
RH	Remote-handled
RPD	Relative percent difference
RSD	Relative standard deviation
SCG	Summary Category Group
SOPs	Standard Operating Procedures
SPQAO	Site Project QA Officer
SPM	Site Project Manager
TMU	Total measurement uncertainty
TRU	Transuranic
VE	Visual examination
WCPIP	Waste Characterization Program Implementation Plan
WIPP	Waste Isolation Pilot Plant
WMPs	Waste Material Parameter(s)
WSPF	Waste Stream Profile Form
WWIS	WIPP Waste Information System

1.0 Introduction

Remote-handled (**RH**) transuranic (**TRU**) waste characterization, which involves obtaining chemical, radiological, and physical data, is a primary component of ensuring compliance of the Waste Isolation Pilot Plant (**WIPP**) with regulatory requirements. This RH TRU Waste Characterization Program Implementation Plan (**WCPIP**) identifies waste characterization requirements and methods to satisfy requirements in Title 40 Code of Federal Regulations (**CFR**) Part 191 (Subparts B and C) and Part 194 (EPA, 1993; EPA, 1996), the Environmental Protection Agency (**EPA**) final certification decision (EPA, 1998), and the WIPP Land Withdrawal Act (**LWA**) (Public Law 102-579).

Other important aspects of the overall RH TRU waste characterization program that are not covered in this document are:

- New Mexico Hazardous Waste Act (**NMHWA**) requirements in the WIPP Hazardous Waste Facility Permit (NMED, 1999)
- Transportation requirements specified in the shipping package Safety Analysis Reports for Packaging and associated Certificates of Compliance
- WIPP operations and safety requirements

Implementation of the requirements and methods in this WCPIP will result in a system of controls sufficient to meet the EPA waste characterization requirements for RH TRU waste.

2.0 Overview of the RH TRU Waste Characterization Program

The RH TRU waste characterization program consists of characterization requirements and objectives that must be met by the generator site waste programs prior to the shipment of RH TRU waste to the WIPP facility. The following sections provide a summary of the data quality objectives (**DQOs**) and quality assurance objectives (**QAOs**), a general description of the overall RH TRU waste characterization process, and a description of the applicable criteria.

2.1 RH TRU Waste Characterization Overview

The requirements for the characterization of RH TRU waste that are relevant to the EPA's oversight of the WIPP come from two sources: those established by EPA's certification of the repository and those established by the LWA. The primary purpose of the characterization requirements based on the LWA is to ensure that the U.S. Department of Energy/Carlsbad Field Office (**DOE/CBFO**) operates the repository in accordance with the statutory limits and mission established by the Congress.

In demonstrating compliance with the requirements of 40 CFR §194.24, EPA has specified that DOE quantify the following parameters and the uncertainty associated with their quantification:

- Cellulose, plastics, and rubber (**CPR**)
- Radionuclide content
- Residual liquids
- Ferrous metals
- Non-ferrous metals

To this end, the RH TRU characterization program presented in this document describes the technical processes necessary to quantify these waste parameters.

2.2 Data Quality Objectives (DQOs) and Quality Assurance Objectives (QAOs)

DQOs and QAOs serve two separate functions. First, DQOs support decision-making and are developed in order to satisfy the requirements that significant waste components must be tracked and controlled to assure that the inventory-related assumptions in the Performance Assessment (**PA**) and Performance Assessment Verification Test (**PAVT**) remain valid. These objectives ensure compliance with legal and regulatory requirements (i.e., they are the bases for decisions on whether compliance is achieved). Second, QAOs are data characteristics used to determine that the quality of data is acceptable. They also support decision-making by assessing the integrity of the data used. In the strictest sense, QAOs are used to assess the quality of analytical data and therefore are quantitative. However, in order to maintain regulatory and programmatic consistency, QAOs may be used with qualitative information. In this case, all of the QAOs (precision, accuracy, representativeness, comparability, and completeness) may not be applicable.

For purposes of implementation of the waste characterization program, DQOs have been developed and are derived directly from a regulatory requirement. Subsequently, QAOs have been developed and are derived from methods used to collect data to satisfy the DQOs. Many times, the regulatory requirement provides a quantitative limit that the total waste inventory must meet. In some cases, the requirement also specifies acceptable methods for assessing compliance with the limit and the amount and nature of documentation needed to demonstrate compliance.

2.2.1 DQO for Defense Waste Determination

The following is the DQO for meeting regulatory requirements that only waste generated by atomic energy defense activities can be sent to the WIPP.

Purpose for collecting the data:

To determine whether waste was generated by atomic energy defense activities (Regulatory basis: LWA).

Type of data to collect:

Information about the processes used to generate the waste and the purposes for which any materials produced in the processes were used.

Tolerable decision error:

This is a qualitative DQO with no specified decision error tolerance since the generator site must make the decision based on available information. The generator site must have documented objective evidence in their acceptable knowledge (**AK**) record that the waste was generated by atomic energy defense activities.

2.2.2 DQOs for Radioactive Properties

The following three DQOs were established for meeting regulatory requirements concerning radioactive properties of the waste.

2.2.2.1 TRU Waste Determination

Purpose for collecting the data:

To determine whether the waste contains 100 nanocuries (nCi) or more of TRU isotopes per gram of waste (Regulatory basis: LWA).

Type of data to collect:

Data on the TRU activity for each waste container shipped to the WIPP.

Tolerable decision error:

The definition of TRU waste does not specify a margin of error or uncertainty. Generator sites must demonstrate that their methods for determining the TRU isotopes per gram of waste are capable of distinguishing TRU waste from low-level waste for those wastes near 100 nCi per gram (nCi/g). Instruments performing TRU/low-level waste

discrimination measurements must have an lower limit of detection **(LLD)** of 100 nCi/g or less.

2.2.2.2 RH Waste Determination

Purpose for collecting the data:

To determine surface dose rate to ensure that it is equal to or greater than 200 millirems per hour (mrem/hr) and less than 1000 rem/hr (Regulatory basis: LWA).

Type of data to collect:

Surface dose rate data for each container of waste.

Tolerable decision error:

The surface dose rate minimum and maximum limits for RH TRU waste are not established with an associated error or uncertainty. The generator sites must make these measurements with instruments having calibrations meeting the requirements of the DOE/CBFO Quality Assurance Program Document (**QAPD**).

2.2.2.3 Activity Determination

Purpose for collecting the data:

To confirm the total activity for compliance with LWA limits concerning the total waste inventory (i.e., no more than 5.1 million curies of RH TRU waste disposed; 23 curies per liter limit per canister) and to track radionuclides that are important to the calculation of releases (Regulatory bases: LWA, EPA Certification of the WIPP).

Type of data to collect:

Data on the activity of the waste in each container.

Tolerable decision error:

The activity requirements for RH TRU waste are not specified with associated precision or accuracy limits. There may be uncertainties associated with the methods for obtaining the data needed. The generator sites must determine and document the total uncertainty associated with the determination of the activity of the radionuclides in waste to be shipped to the WIPP. For each payload container, the total activity plus two times the associated total measurement uncertainty (**TMU**), expressed in terms of one standard deviation, shall not exceed 23 curies per liter averaged over the volume of the payload container.

2.2.3 DQOs for Physical and Chemical Properties

The DOE has identified two DQOs necessary to meet LWA and EPA requirements on reporting, tracking, and controlling physical and chemical properties of the waste:

- Residual liquids DQO
- EPA physical and chemical properties DQO

The development of these DQOs is discussed below.

2.2.3.1 DQO for Residual Liquids[1]

Purpose for collecting the data:

To confirm the absence of residual liquids in excess of one percent (Regulatory basis: EPA Certification of the WIPP).

Type of data to collect:

Information on the processes and materials that produced the waste, and information about the specific items in the waste stream.

Tolerable decision error:

The limit on residual liquids was not specified with an associated error.

2.2.3.2 DQO for Physical Form

Purpose for collecting the data:

To determine the physical form of the waste (i.e., CPR, ferrous metals) as required by the final certification rule (Regulatory basis: EPA Certification of the WIPP).

Type of data to collect:

Information on the type and number of containers, waste forms, processes and materials that produced the waste.

Tolerable decision error:

This DQO provides information that allows the WIPP to track material parameter weights and compare the quantity disposed of to the limits established for the total waste inventory. As such, no errors are specified. Generator sites must determine the uncertainty in the estimate of the weight of the waste.

2.2.4 Quality Assurance Objectives

The following QAOs are used in the RH TRU characterization program:

- Data precision – A measure of the mutual agreement between comparable data gathered or developed under similar conditions.
- Data accuracy – The degree to which data agree with an accepted reference or true value.
- Data representativeness – The degree to which data accurately and precisely represent a characteristic of a population, a parameter, variations at a sampling point, or environmental conditions.

[1] For the Compliance Certification Application, the DOE assumed that residual liquid occurred as free water which was available to participate in gas generation activities (e.g., corrosion, microbial degradation).

- Data completeness – A measure of the amount of valid data obtained compared to the amount that was expected.
- Data comparability – A measure of the confidence with which one data set can be compared to another.

QAOs are associated with each method and are method-specific. Section 4.0 discusses specific methods identified by the DOE for use in the RH TRU waste characterization program. Methods are associated with each DQO and QAOs are associated with each method. The QAOs for each method are summarized in Table 2-1.

2.3 RH TRU Waste Characterization Process

The RH TRU waste characterization program consists of characterization requirements and objectives that must be met by the DOE and participating TRU waste generator sites before RH TRU waste may be shipped to the WIPP facility.

A waste stream is defined as waste material generated from a single process or activity, or as waste with similar physical, chemical, and radiological properties. Only those individual containers that can be related to a particular waste stream will be contained in that waste stream.[2]

The term AK process refers to the process of determining the characteristics of a waste by gathering and examining existing knowledge of the waste. The AK process uses information concerning materials or processes used to generate the waste, and analyses and results from prior testing activities. This information may include records; administrative, procurement, and quality control records associated with the processes that generated the waste; past sampling and analytical data; material inputs to the process that generated the waste; and the time period during which the waste was generated. The waste characterization process for RH TRU waste is shown in Figure 1.

Acceptable knowledge information, qualified by one or more of the processes described in Section 4.3, will be used to characterize RH TRU waste. AK information will continue to be collected, evaluated, and qualified until all AK DQOs have been met.

[2] For purposes of these discussions, the term "related" means that information must exist showing that each container belongs in a particular waste stream.

Table 2.1 RH TRU Waste Characterization Method Quality Assurance Objectives

METHOD	PRECISION	ACCURACY	REPRESENTATIVENESS	COMPLETENESS	COMPARABILITY
Visual Examination (VE)	Precision is maintained by reconciling any discrepancies between two operators (or between the operator and the independent technical reviewer) with regard to the identification of important waste characteristics (i.e., physical form of the waste and absence of residual liquid in excess of 1% by volume) within a single container. Any container with unreconciled discrepancies cannot be shipped to the WIPP.	Accuracy is maintained by requiring operators to pass a comprehensive examination with a score of 80% and demonstrate satisfactory performance in the presence of the VE expert during their initial qualification and subsequent requalification.	The contents placed in a container selected for VE will be described.	The relevant waste information must be assembled. This information must be documented on audio/videotape, photograph, or other unalterable media.	Comparability is ensured through sites meeting the training requirements and complying with the minimum standards outlined for guidance used to implement this characterization process.
Radiography	Precision is maintained by reconciling any discrepancies between two operators with regard to the identification of important waste characteristics (i.e., physical form of the waste and absence of residual liquid in excess of one percent by volume) within a single container. Any container with unreconciled discrepancies cannot be shipped to the WIPP.	Accuracy is obtained by using a target to tune the image for maximum sharpness and by requiring operators to successfully identify 100 percent of the items in a training container during their initial qualification and subsequent requalification.	All of the relevant contents in a container selected for radiography will be described.	All of the relevant waste information must be assembled and must show that each of the containers in the waste stream belongs to the waste stream. This information must be documented on videotape or other equivalent media and data form.	Comparability is ensured through a site meeting the training requirements and complying with the minimum standards used to implement the radiography process.
AK	The qualitative determinations, such as compiling and assessing AK documentation, do not lend themselves to statistical evaluations of precision, therefore, precision requirements are not established for AK.	Accuracy is the degree of agreement between an observed sample result and the true value. The percentage of waste containers which require reassignment to a new SCG or new waste stream based on the reevaluation of AK or on obtaining testing, sampling and/or analysis data, will be reported as a measure of AK accuracy. The sites shall, in addition, develop a methodology to compare radionuclide information from	Representativeness is a qualitative parameter that will be satisfied by ensuring that the process of obtaining, evaluating, and documenting AK information is performed in accordance with the minimum standards established in the WCPIP.	The AK record shall contain 100% of the information specified in the WCPIP. The usability of the AK information will be assessed for completeness during audits.	Comparability is ensured through sites meeting the training requirements and complying with the minimum standards outlined for guidance used to implement the AK process.

METHOD	PRECISION	ACCURACY	REPRESENTATIVENESS	COMPLETENESS	COMPARABILITY
		confirmation with the information in the AK record and address significant discrepancies. What constitutes a significant discrepancy will depend on site- and waste stream-specific considerations. If AK accuracy falls below 90%, the site shall document this as a significant condition adverse to quality as defined by the CBFO QAPD. The site shall notify the CBFO of this condition and implement appropriate corrective actions before proceeding with further characterization activities on the affected waste stream(s). The DOE and EPA will examine these documents for adequacy during audits and inspections.			
NDA	Precision is reported as %RSD. The %RSD shall not exceed the values listed in Table 4.1	Accuracy is reported as %R. Accuracy will not exceed ±30% on a non-interfering matrix.	Representativeness is ensured through assay of each waste container when NDA is used to satisfy DQOs.	Required completeness is 100%. All NDA data used to satisfy a DQO must be valid and usable.	Comparability is ensured through a site meeting the training requirements and complying with the minimum standards used to implement the NDA process.
DA	Precision is reported as relative percent difference (**RPD**). The RPD is derived from analysis of laboratory duplicates as listed in Table 4.3.	Accuracy is reported as %R. The %R is derived from analysis of laboratory control samples and matrix spikes as listed in Table 4.3.	Representativeness of DA data shall be achieved by the collection of unbiased samples.	Completeness of DA data shall be expressed as the ratio of the number of samples that are analyzed with valid results to the total number of samples that are submitted for analysis, expressed as a percent. Acceptable DA data shall be obtained for 90% of the samples acquired for waste characterization. Valid results for radioassay data are those that were obtained when the laboratory or testing facility demonstrated that the instrumentation and method were in	Comparability is ensured through a site meeting the training requirements and complying with the minimum standards used to implement the DA process.

METHOD	PRECISION	ACCURACY	REPRESENTATIVENESS	COMPLETENESS	COMPARABILITY
				control	
Sampling	Sampling precision is established by comparing the RPD between duplicate samples. A nonconformance report shall be issued for any duplicate samples with RPDs greater than 25%. Nonconformance reports shall be dispositioned in accordance with section 3.5.2.2 of this WCPIP.	Sampling accuracy through the use of standard reference materials shall not be measured. Because waste containers containing RH TRU waste with known quantities of radionuclides are not available, sampling accuracy cannot be determined. Sampling accuracy as a function of sampling cross-contamination will be measured. Sampling equipment will be verified as clean by the use of standard radiological control survey methods.	A sampling plan must be developed by the RH TRU generator site that describes the sampling strategy for obtaining representative samples. This sampling plan must be approved by CBFO and EPA.	Sampling completeness shall be expressed as the number of valid samples collected as a percent of the total number of samples collected for each waste stream. The participating sampling facilities are required to achieve a minimum 90 percent completeness.	Compliance with the requirements of this section of the WCPIP will ensure comparability between RH TRU waste generator sites.
DTC	Precision shall be established and maintained within the recommendations of the manufacturer of the dose-rate instrument used. The precision of the instrument shall be documented and factored into the TMU determined for the overall method.	Calibration shall be established and maintained within the recommendations of the manufacturer of the dose-rate instrument. The accuracy of the instrument shall be documented and factored into the TMU determined for the overall method.	Representativeness of the isotopic distributions will be confirmed by sampling in accordance with an approved sampling plan (see Section 4.1.8). The representativeness of the sampling shall be documented and factored into the TMU determined for the overall method.	This will be ensured by measuring the dose rate for every container. The sites must verify that the measured dose rate is at least 10 times greater than background.	Standardized instructions must be used in designing and implementing the measurement program.
Dose Rate	Precision established and maintained within the recommendations of the manufacturer of the instrument used to measure dose.	Calibration established and maintained within the recommendations of the manufacturer of the dose measurement instrument used.	The measurement applied to the entire waste container.	100% of the measurements needed to determine surface dose rate are performed and useable.	Dose rate measurements are performed by site health physics personnel in accordance with the DOE Orders governing radiological control.

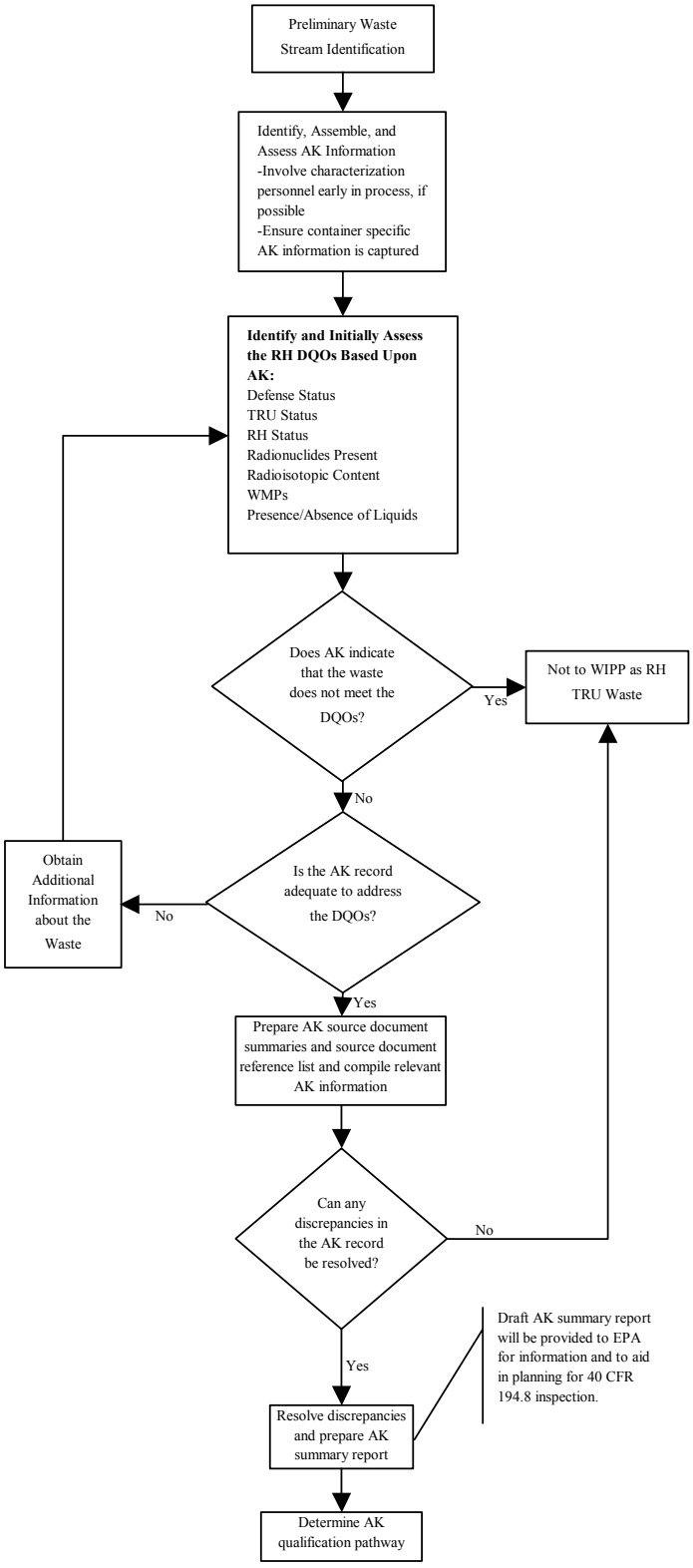

Figure 1. RH TRU Waste Acceptable Knowledge Process

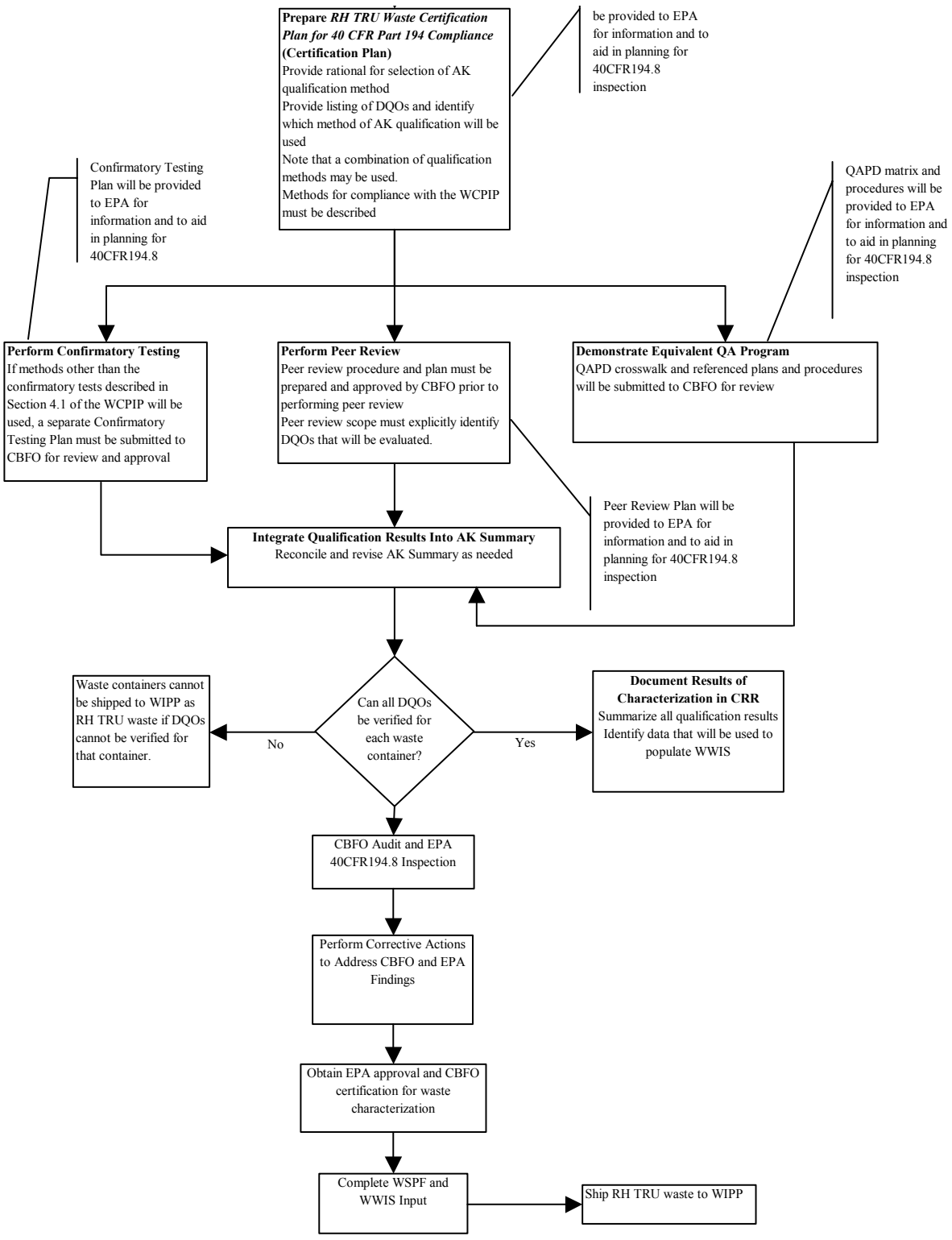

Figure 1. RH TRU Waste Acceptable Knowledge Process (continued)

Generator sites may use information that is contained in the AK record and was obtained prior to implementation and approval of a quality assurance (**QA**) program at the generator site that meets the requirements of the CBFO QAPD. The CBFO QAPD contains the requirements for a QA program that implements American Society of Mechanical Engineers (ASME) NQA-1-1989 edition, ASME NQA-2a-1990 addenda, part 2.7, of ASME NQA-2-1989 edition, and ASME NQA-3-1989 edition (excluding Section 2.1 (b) and (c), and Section 17.1).

When characterization relies on information that was not generated under a QAPD-compliant program (e.g., previous visual examination (**VE**) data, VE audio/videotapes, radiography data, audio/videotapes, radiological characterization data), that information shall be qualified using one or more of the methods allowed by 40 CFR §194.22(b). These methods are:

1. Peer review in accordance with NUREG 1297, *Peer Review for High-Level Nuclear Waste Repositories*, February 1988
2. Corroborating data
3. Confirmatory testing
4. Demonstrating that the QA program that was applied to the data was equivalent in effect to ASME NQA-1-1989 edition, ASME NQA-2a-1990 addenda, part 2.7, of ASME NQA-2-1989 edition, and ASME NQA-3-1989 edition (excluding Section 2.1 (b) and (c) and Section 17.1).

2.4 RH TRU Waste Acceptance Criteria

These criteria serve to ensure that RH TRU waste is managed and disposed of in a manner that protects human health, safety, and the environment. The specific criterion are listed in the following sections. The requirements on which each criterion is based are also listed and originate either from the EPA Certification or the LWA.

2.4.1 Payload Container Acceptance Criteria

Compliance Certification Requirement. Generator sites will report to the WIPP Waste Information System (**WWIS**) the number and types of payload containers shipped to the WIPP (DOE, 1996, Appendix WCL).

Acceptance Criterion. The limits for metals are a minimum of 2×10^7 kilograms (kg) for ferrous metals and 2×10^3 kg for nonferrous metals. The limits for ferrous and nonferrous metals will be met by disposed payload container count and average container material of construction weights. This parameter will be tracked by the WIPP as reported in the WWIS.

Note: The only approved payload containers for shipment of RH TRU waste to the WIPP are 55-gallon drums and RH-72B canisters. Approved payload containers and their properties are listed below:

Table 2.2 Approved RH TRU Payload Containers and Nominal Properties

Container Type	Container Weight (kg)	Gross Weight Limit (kg)	Volume (m^3)
55-Gallon Drum	29	453.59	0.21
RH Canister, Direct Loaded	514	2318	.89
RH Canister Containing 55-Gallon Drums	514	2712	.89
RH Canister Containing 30-Gallon Drums	514	2712	.89

Generator sites may request to use alternate payload containers, but the use of such containers requires prior approval from CBFO and EPA.

2.4.2 Physical Properties Acceptance Criteria

Compliance Certification Requirement. The total residual liquid in any payload container shall not exceed one percent by volume of that payload container (DOE, 1996, Appendix WCL).

Acceptance Criterion. Liquid waste is prohibited at the WIPP. Waste shall contain as little residual liquid as is reasonably achievable. The total residual liquid in any payload container shall not exceed one percent by volume of that payload container. If VE methods are used, the detection of any liquids in non-transparent internal containers will be addressed by using the total volume of the internal container when determining the total volume of liquids within the payload container.

2.4.3 Physical Form

Compliance Certification Requirement. The repository limit for CPR is a maximum of 2×10^7 kg (DOE, 1996, Appendix WCL).

Acceptance Criterion. The amount of CPR for debris waste (S5000) will be determined by multiplying the volume of the waste container by the maximum loading density of plastic (620 kg/m^3). Weights up to the net weight of the waste will be assigned using this method. The derived weight will be entered into WWIS with a waste material parameter type of "plastic." For soils and gravel (S4000), the net weight of the waste will be entered into the WWIS with a waste material parameter type of "soil." For homogeneous solids (S3000), the net weight of the waste will be entered into the WWIS with the waste material parameter type appropriate to the waste (e.g., solidified inorganic material, solidified organic material, cement). For S3000 and S4000 wastes that also contain debris, the generator sites will estimate the weight of debris in each payload container of waste. The debris in S3000 and S4000 wastes will be entered into WWIS with a waste material parameter type of "plastic." For all summary category groups, weights for

plastics in packaging (e.g., drum liners) will be entered into the WWIS. The total CPR mass in RH TRU waste will be tracked and controlled through the WWIS such that the repository limit on CPR is not exceeded.

2.4.4 Radiation Surface Dose Rate

Land Withdrawal Act Requirement. The LWA defines "remote-handled transuranic waste" as TRU waste with a surface dose rate of 200 mrem/hr or greater. The LWA prohibits the receipt of TRU waste with a surface dose rate in excess of 1000 rem/hr, and no more than five percent by volume of the RH TRU waste received at the WIPP may have a surface dose rate in excess of 100 rem/hr (LWA).

Acceptance Criterion. The external radiation dose equivalent rate of individual payload containers shall be greater than or equal to 200 mrem/hr and less than or equal to 1000 rem/hr at the surface of the payload container. The total dose equivalent rate and the neutron contribution and associated uncertainty shall be reported in the WWIS for each payload container. The WIPP will track the dose rates and volumes of containers, using WWIS, to ensure that no more than five percent by volume of the RH TRU waste received at the WIPP has a surface dose rate in excess of 100 rem/hr.

2.4.5 TRU Alpha Activity Concentration

Land Withdrawal Act Requirement. The LWA defines "transuranic waste" as waste containing more than 100 nCi of alpha-emitting TRU isotopes per gram of waste, with half-lives greater than 20 years.

Acceptance Criterion. Payload containers shall contain more than 100 nCi/g of alpha-emitting TRU isotopes with half-lives greater than 20 years. The TRU alpha activity concentration for a payload container is determined by dividing the TRU alpha activity of the waste by the weight of the waste. The weight of the waste is the weight of the material placed into the payload container (i.e., the net weight of the container). The weight of the waste is typically determined by subtracting the tare weight of the payload container (including the weight of the rigid liner and any shielding external from the waste, if applicable) from the gross weight of the payload container. In the event waste containers (e.g., 55-gallon drums) are overpacked in a payload container (e.g., in a canister), sites shall sum the individual TRU alpha activity values of the individual waste containers and divide by the sum of the individual net waste weights (i.e., less container, shielding, and liner weights, as appropriate) to determine the activity per gram for the payload container. The TRU alpha activity concentration and its associated uncertainty shall determined for any radiological characterization method used (i.e., DTC, DA, or NDA) and be reported to the WWIS.

2.4.6 Radionuclide Activity

Compliance Certification Requirement. The activity of emplaced radionuclides shall be quantified (DOE, 1996, Section 4).

Land Withdrawal Act Requirement. RH TRU waste received at the WIPP shall not exceed 23 curies per liter maximum activity level (averaged over the volume of the canister). The total curies of the RH TRU waste received at the WIPP shall not exceed 5,100,000 curies (LWA).

Acceptance Criterion. The activities and masses of ^{241}Am, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{233}U, ^{234}U, ^{238}U, ^{90}Sr, and ^{137}Cs shall be established on a payload container basis for purposes of tracking their contributions to the total WIPP radionuclide inventory. The activities and masses for these 10 radionuclides, including their associated uncertainties expressed in terms of one standard deviation, shall be reported to the WWIS on a payload container basis. For any of these 10 radionuclides whose presence can be substantiated from AK information, direct measurement, computations, or a combination thereof, and for which any measured data are determined to be below the LLD for that radionuclide, the site shall report the character string "< LLD" to the WWIS for the activity and mass of that radionuclide; otherwise a value of zero shall be reported. The total activity and its associated uncertainty shall also be reported and tracked on a per container basis.

2.4.7 Waste Origin

Land Withdrawal Act Requirement. The LWA limits the WIPP mission to the disposal of radioactive waste materials generated by atomic energy defense activities.

Acceptance Criterion. The waste must be generated by atomic energy defense activities.

3.0 RH TRU Waste Characterization Program

The following sections identify the general programmatic requirements for characterizing RH TRU waste.

3.1 General Program Requirements

This WCPIP identifies the characterization objectives, DQOs, methods of meeting the objectives, and implementing requirements that must be met by generator sites before they can ship RH TRU waste to the WIPP. This document prescribes the process and characterization methods that must be implemented to meet characterization program objectives.

Before characterizing waste for shipment to the WIPP, generator sites must establish a QA program governing waste characterization activities that meet the requirements of the DOE/CBFO QAPD. This QA program must be reviewed and approved by CBFO. The QAPD is the quality management document that identifies federal, state, and industry quality requirements applicable to CBFO programs. The QAPD specifically establishes the QA program requirements applicable to this RH TRU waste characterization program, as specified in 40 CFR §194.22.

3.2 Program Documents

The RH TRU waste characterization program includes a hierarchy of documents that will guide and control characterization activities and QA activities. Figure 2 shows the hierarchy and relationship of program QA documents.

3.2.1 Waste Characterization Program Implementation Plan

This WCPIP describes the activities to be undertaken by the program and by participating sites to characterize RH TRU waste in compliance with the criteria in 40 CFR Part 194. The QA criteria of 40 CFR §194.22 are met by compliance with the QAPD. This WCPIP includes both management and technical aspects of program implementation as well as data requirements and characterization requirements that each TRU waste site must meet in characterizing RH TRU waste intended for disposal at the WIPP.

3.2.2 TRU Waste Site Program Documentation

Each participating TRU waste site shall develop and implement program documentation that addresses the requirements specified in this WCPIP. This documentation shall include or reference the appropriate management and technical criteria of the program, as well as qualitative or quantitative criteria for determining that program activities are being satisfactorily performed. The documentation shall also include a QA plan that addresses the applicable requirements of the QAPD.

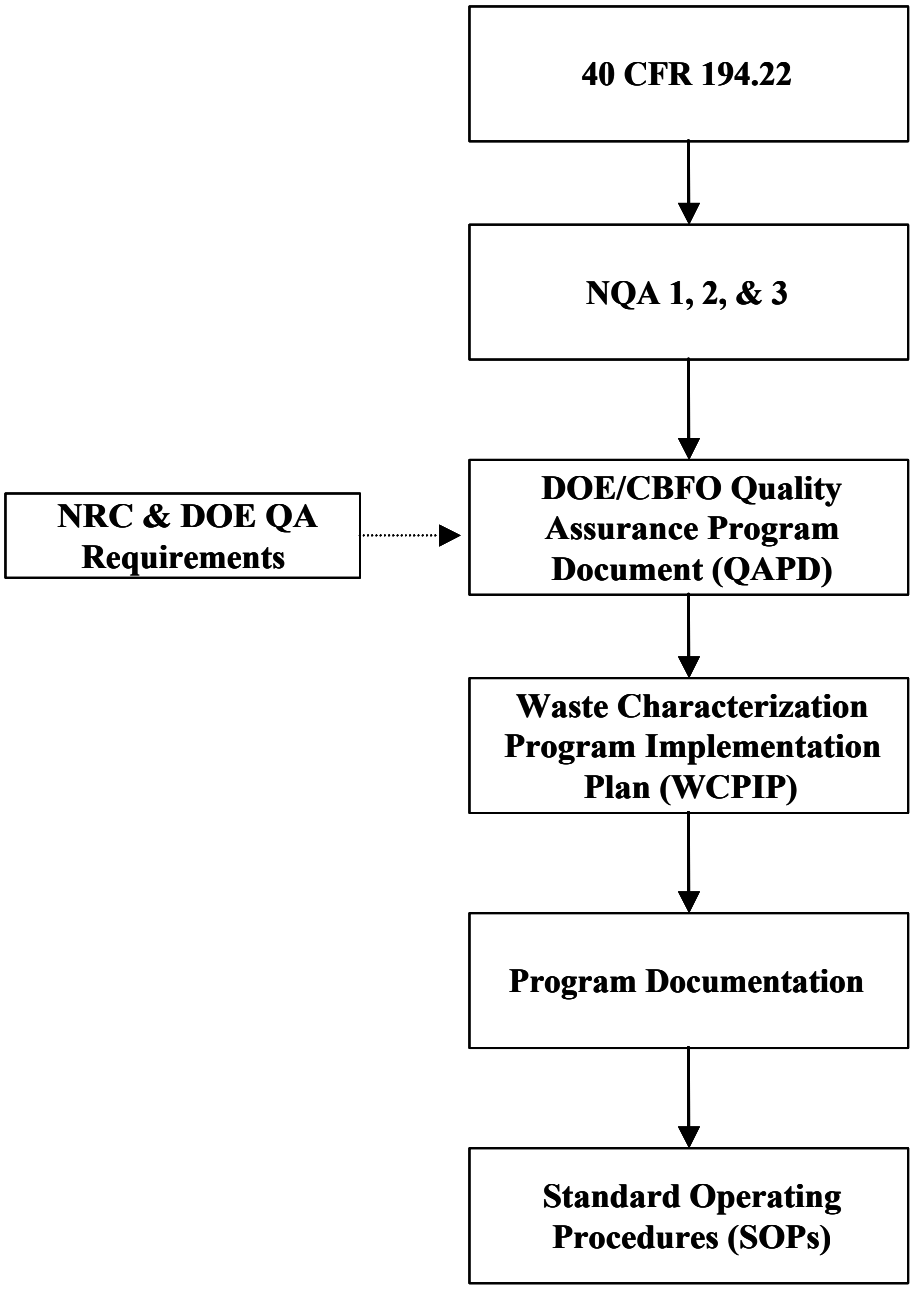

Figure 2. Program QA Document Hierarchy

Each site's program documentation shall identify the organizations and positions responsible for their implementation and reference site-specific documentation that details how each of the required elements of the program will be performed. The TRU waste site program shall be described in an RH TRU Waste Certification Plan for 40 CFR Part 194 Compliance that shall be approved by the CBFO prior to the certification of any RH TRU waste from the TRU waste site. The required QA plan shall be approved by the CBFO and may be incorporated into the Certification Plan. Likewise, either or both plans may be incorporated as separate and distinct sections in existing TRU Waste Certification Plans and QA plans if deemed appropriate by the participating TRU waste site.

At a minimum, the TRU Waste Certification Plan shall contain the following:

- A description of the rationale for attaining each DQO, including the selection of peer review, equivalent QA program, or confirmatory testing as methods of qualifying AK information for each DQO

- A listing of the DQOs, and identification of which methods will be used to assess compliance with the DQOs, and the rational for the selection of the method(s), including specific methods of AK qualification.

Prior to the implementation of program activities, standard operating procedures (**SOPs**) will be developed for activities affecting program quality. For purposes of the program, the term SOP refers to any site-specific implementing document. Compliance with SOPs will ensure that tasks are performed in a consistent manner that results in required information being obtained with the quality required by the program. The organization, format, content, and designation of SOPs must be described in the program documentation.

Additional program documents are required for implementation of specific waste characterization methods. These documents may include:

- Sampling Plans (Section 4.1.5.2)

- Peer Review Plans (Section 4.3.1)

- Confirmatory Testing Plans (Section 4.3.3)

- QAPD Matrices (Section 4.3.4)

- DTC Technical Reports (Section 4.1.3.1)

The applicable program documents must be submitted to the CBFO for review and approval. The CBFO will also submit the program documents to the EPA for review and approval. Any waste characterization activities performed prior to approval of the generator site's program documents by both CBFO and EPA is "at risk" and may have to be repeated.

3.3 Assessment and Oversight

Specific assessment actions will be taken during the program to ensure all parties are adhering to the requirements of this WCPIP. These actions include periodic audits as well as management and independent assessments conducted in accordance with the QAPD, the details of which shall be specified in the program documentation. Corrective actions shall be taken when conditions adverse to quality are identified. The results of these actions will be summarized in semiannual reports, nonconformance reports, and audit reports. Through this system of assessment and response, overall quality improvement of the program will be realized.

Audits shall include management and technical aspects of the program outlined in this WCPIP and in site program documentation. In addition to audits, management and independent assessments shall be regularly performed. The goal of these assessments is to improve overall program quality by focusing on management systems and work processes.

Corrective actions shall be taken if any condition adverse to quality is detected during an audit or assessment. The cause of any adverse condition, identified by any means, that affects compliance with the Quality Assurance/Quality Control (**QA/QC**) requirements specified in this WCPIP shall be promptly determined and action taken to preclude its recurrence. The identification, cause, and corrective actions for conditions not complying with the quality requirements for the program must be documented and reported to appropriate levels of management.

In addition to approval of this site-specific documentation, generator and storage sites must pass an initial site certification audit where adequate and effective implementation of these programs is assessed.

Each TRU waste generator and storage site that is characterizing RH TRU waste to the requirements of the WCPIP is recertified by the CBFO annually. A recertification consists of reviewing (if applicable):

- site-specific program documents that are written and approved to the latest WCPIP
- program implementation as determined by a site certification audit
- reports from surveillances conducted during the past year
- performance in shipping RH TRU waste to the WIPP

To ensure that the generator and storage sites comply with the WIPP RH TRU waste certification program, audits are conducted by the CBFO. An initial audit is conducted at each generator site performing waste characterization activities prior to the formal acceptance of the waste-stream profile forms and/or any waste characterization data supplied by site personnel. This formal acceptance is referred to as site certification. Audits are performed at least annually thereafter, including the possibility of unannounced (not regularly scheduled) audits. These audits verify that the generator site has implemented a QA program for all certification activities. After approval of the generator site's program documents, the EPA will perform an audit or an inspection of a CBFO audit of the generator site to verify a QA program and a waste characterization program have been properly implemented. These activities are performed in

accordance with the requirements of 40 CFR 194.8. The EPA may perform additional audits of the generator sites, under the authority of 40 CFR 194.8, 194.22 and 194.24, to verify continued compliance with the QA and technical requirements for waste characterization.

3.4 Waste Characterization Tracking and Control

40 CFR §194.24 specifies requirements concerning the tracking and control of waste components that significantly influence the performance of the repository. Sites will enter required RH TRU waste characterization information into the WWIS. WIPP Operations will review and track this information and administratively control the repository inventory to stay within compliance and performance limits.

3.5 Data Management

This section contains the data management requirements applicable to waste characterization data.

3.5.1 Data Review and Validation

The generator sites will implement the data generation and management processes described in this section. All measurement data must be reviewed and approved by qualified personnel prior to being reported. At a minimum, the data must be reviewed by a technical reviewer and approved by the Site Project Manager (**SPM**) or designee.

3.5.1.1 Acceptable Knowledge Process

The SPM or designee reviews the documents generated through the AK process to determine if the AK documentation is complete and if the information contained therein is adequate to characterize the waste stream. The SPM or designee reconciles AK characterization with the required DQOs and documents the reconciliation. This reconciliation ensures that AK characterization has provided documented evidence that the waste stream meets the DQOs. Specifics of the AK process and the required reconciliation steps are established in the Acceptable Knowledge Procedure for Remote-Handled TRU Waste (Attachment A).

3.5.1.2 Measurement Methods and Data Validation Requirements

A testing batch data report for data validation and QA purposes is required when radiography, radioassay (excluding radiochemistry), dose-to-curie (**DTC**), sampling or VE are used to characterize waste. A testing batch data report (or equivalent) includes data pertaining to radiography, radioassay (excluding radiochemistry), DTC, or VE for up to 20 waste containers or samples.

An analytical batch data report for data validation and QA purposes is required when radiochemistry is used. An analytical batch data report (or equivalent) includes data pertaining to analysis for up to 20 samples, excluding QC samples.

A sampling batch report for data validation and QA purposes is required when sampling is performed. A sampling batch data report (or equivalent) includes sampling data for no more

than 20 samples that were collected for analysis by radiochemistry, excluding QC samples. Analytical and sampling data may be combined into one batch report for reporting purposes.

All measurement data must be reviewed and approved by qualified personnel prior to being reported. At a minimum, the data must be reviewed by an independent technical reviewer. This review shall be performed by an individual other than the data generator who is qualified to have performed the initial work. The independent technical reviewer shall verify, at a minimum, the following information:

- Data generation and reduction were conducted in a technically correct manner in accordance with the methods used (procedure with revision).
- Data were reported in the proper units and correct number of significant figures.
- Calculations have been verified by a valid calculation program, a spot check of verified calculation programs, and/or 100 percent check of all hand calculations.
- Values that are not verifiable to within rounding or significant difference discrepancies must be rectified prior to completion of independent technical review.
- The data have been reviewed for transcription errors.
- The testing, sampling, or analytical data QA documentation for batch data reports is complete and includes, as applicable, raw data, calculation records, chain-of-custody (**COC**) forms, calibration records (or references to an available calibration package), and QC sample results. Corrective action will be taken to ensure that all batch data reports are complete and include all necessary raw data prior to completion of the independent technical review.
- QC sample results are within established control limits and, if not, the data have been appropriately dispositioned using the nonconformance process described in Section 3.4.2.2.
- Radiography tapes have been reviewed (independent observation) on a waste container basis at a minimum of once per testing batch or once per day of operation, whichever is less frequent.
- Field sampling records are complete. Incomplete or incorrect field sampling records will be subject to resubmittal prior to completion of the independent technical review.
- The appropriate QAOs have been met.

All data must be approved by the SPM or designee. The SPM shall verify, at a minimum, the following information:

- Data generation-level independent technical review, validation, and verification have been performed as evidenced by the completed review checklists and appropriate signature release. Batch data review checklists are complete.
- Batch data reports are complete and data are properly reported (e.g., data are reported in the correct units and with the correct number of significant figures)
- Data meet all applicable QAOs.

To ensure that data of known and documented quality are generated, each participating measurement facility shall implement a documented facility QA program. Any measurement technique used for RH TRU waste must be performed in accordance with calibration and operating procedures that have been written, approved, and controlled by the site or testing

facility. Laboratory procedures must contain applicable quality controls. Facility QA programs shall specify qualitative and quantitative acceptance criteria for the QC checks of this program, and corrective actions to be taken when these criteria are not satisfied. Only appropriately trained and qualified personnel shall be allowed to perform data validation/review.

3.5.2 Reconciliation with Data Quality Objectives and Quality Assurance Objectives

Reconciling the results of waste characterization to the DQOs and QAOs provides a way to ensure that data support the waste acceptance criteria. Reconciliation with the DQOs and QAOs will be completed and approved by the SPM or designee.

3.5.2.1 Reconciliation by the Site

The reconciliation process involves a review of each DQO, including a listing of the compliance methods used to meet that DQO and a decision/determination documenting that the information is sufficient to meet the QAOs associated with the characterization objective. As part of this decision/determination, a discussion shall be included that satisfies all aspects of the QAO. If the QAO does not have any criteria for determination of sufficiency, that shall also be stated. If any nonconformances are identified during this process, they shall be identified and documented.

Reconciliation must be completed prior to submittal of the Waste Stream Profile Form (**WSPF**) except for the surface dose rate measurements used to establish the dose rate for the payload container. This measurement must be taken and entered into WWIS prior to the waste being accepted for transportation to the WIPP.

Each SPM or designee will ensure that all data generated and used in decision-making meet the DQOs provided in Section 2.2.1 and the QAOs identified in Section 4.0 for the specific method being employed.

For each waste stream or waste stream lot characterized, the SPM or designee shall determine if data have been collected on a waste stream or container basis, as required. If the SPM or designee determines that sufficient data have not been collected to make the determinations described above, additional data collection efforts must be undertaken. The reconciliation of a waste stream shall be performed prior to submittal of the WSPF to the DOE/CBFO for the waste stream. Once a waste stream is fully characterized, the SPM will submit the completed WSPF and characterization reconciliation report (**CRR**) for the waste stream to the CBFO for approval. Written approval of the WSPF must be obtained prior to shipment of the waste stream to the WIPP. For each WSPF submitted for approval, the CBFO will verify that each submittal (i.e., WSPF and CRR) is complete and will notify the originating generator site in writing of the WSPF approval.

3.5.2.2 Nonconformances

The status of work and the WCPIP activities at participating TRU waste sites shall be monitored and controlled by the SPM and Site Project QA Officer (**SPQAO**). This monitoring and control shall include nonconformance identification, documentation, and reporting.

Nonconformances are uncontrolled and unapproved deviations from an approved plan or procedure. Nonconforming items and activities are those that do not meet the WCPIP

requirements, procurement document criteria, or approved work procedures. Nonconforming items shall be identified by marking, tagging, or segregating. Participating TRU waste sites shall reconcile and correct nonconforming items as appropriate in accordance with the CBFO QAPD. Disposition of nonconforming items shall be identified and documented. The TRU waste site SOPs shall identify the person(s) responsible for evaluating and dispositioning nonconforming items.

Management at all levels shall foster a "no-fault" attitude to encourage the identification of nonconforming items and processes. Nonconformances may be detected and identified by anyone performing WCPIP activities, including:

- Project staff – during field operations, supervision of subcontractors, data validation and verification, and self-assessment
- Laboratory staff – during the preparation for and performance of laboratory testing; calibration of equipment; QC activities; laboratory data review, validation and verification; and self-assessment
- QA personnel – during oversight activities or audits

A nonconformance report shall be prepared for each nonconformance identified. Each nonconformance report shall be initiated by the individual(s) identifying the nonconformance. The nonconformance report shall then be processed by knowledgeable and appropriate personnel. For this purpose, a nonconformance report shall be prepared including or referencing, as appropriate, results of laboratory analysis, QC tests, audit reports, internal memoranda, or letters.

The nonconformance report must provide the following information:

- Identification of the individual(s) identifying or originating the nonconformance
- Description of the nonconformance
- Method(s) or suggestions for correcting the nonconformance (corrective action)
- Schedule for completing the corrective action
- An indication of the potential ramifications and overall usability of the data, if applicable
- Any approval signatures specified in the site nonconformance procedures

The SPQAO shall oversee the nonconformance report process and be responsible for developing a plan to identify and track all nonconformances and report this information to the CBFO. Documentation of nonconformances shall be made available to the SPM, who in turn is responsible for notifying project personnel of the nonconformance. Completion of the corrective action for nonconformances must be verified by the SPQAO.

For any non-administrative nonconformance related to applicable requirements specified in this WCPIP that is first identified during reconciliation of DQOs and QAOs at the site project level, the CBFO shall receive written notification within five calendar days of identification and shall also receive a nonconformance report within 30 calendar days of identification. The site must

implement a corrective action to remedy the nonconformance prior to management, storage, or disposal of the affected waste at the WIPP.

3.5.3 Data Reporting

The following are the minimum requirements for raw data collection and management of testing, sampling, and analytical data:

- All raw data shall be signed and dated in reproducible ink by the person generating them. Alternately, unalterable electronic signatures may be used.
- All data must be recorded clearly, legibly, and accurately in field and laboratory records (bench sheets, logbooks), and include applicable sample identification numbers (for sampling and analytical labs).
- All changes to original data must be lined out, initialed, and dated by the individual making the change. A justification for changing the original data may also be included. Original data must not be obliterated or otherwise disfigured so as not to be readable. Data changes shall only be made by the individual who originally collected the data or an individual authorized to change the data.
- All data must be transferred and reduced from field and laboratory records completely and accurately.
- All field and laboratory records must be maintained as QA records
- Data must be organized into a standard format for reporting purposes, as specified in sampling, testing, and analytical procedures.
- All electronic and video data must be stored appropriately to ensure that waste container, sample, and associated QC data are readily retrievable.

Data must be reported on a batch basis. A batch is defined, for the purpose of the program, as a suite of waste containers or samples undergoing measurement or sampling using the same testing, analytical, or sampling equipment, with a maximum of 20 containers or samples. Each measurement/testing facility is required to submit batch data reports for each batch to the site project office on standard forms (either hard copy or electronic equivalent), as provided in approved site-specific documentation.

Batch data reports shall consist of the following:

- testing facility name, testing batch number, batch report date, container or sample numbers included in that testing batch, technical reviewer signature, and signature release by the SPM or designee
- background and performance data or control charts for the relevant time period (if applicable)
- separate testing report sheet for each container in the testing batch that includes:
  - method used for measurement (i.e., procedure identification)
  - date of measurement

  - for a radioassay or DTC batch data reports, activities and/or masses of individual radioisotopes present and their associated uncertainties (curies and/or grams), as appropriate for the measurement/testing
  - if for radiography or VE batch data report, parameters of interest (such as summary category group (**SCG**), absence of residual liquids in excess of one percent)
- QC documentation
- references to or copies of associated nonconformance reports, if any
- data review checklists
- operator signature/date
- independent technical reviewer signature/date

Associated uncertainty shall be included in the measurement/testing batch data report or other QA record or database. When associated uncertainty is reported differently on the testing report sheet than in the WWIS, the method of expressing associated uncertainty shall be specified on the testing report sheet or associated procedures.

Analytical data must be reported on a batch basis. A batches is defined, for the purpose of the program, as a suite of samples undergoing analysis or radiochemistry, with a maximum of 20 samples (excluding QC samples). Each measurement/testing facility is required to submit analytical batch data reports for each analytical batch to the site project office on standard forms (either hard copy or electronic equivalent), as provided in approved site-specific documentation.

Analytical batch data reports shall consist of the following:

- analytical facility name, analytical batch number, batch report date, sample numbers included in that analytical batch, technical reviewer signature, and signature release by the SPM or designee.
- table of contents
- background and performance data or control charts for the relevant time period
- separate testing report sheet for each sample in the batch that includes:
  - method used for measurement (i.e., procedure identification)
  - date of measurement
- QA documentation, including, as applicable, raw data calculation records, chain-of-custody forms, calibration records (or references to an available calibration package)
- reference to or copy of associated nonconformance reports, if any
- data review checklists
- operator signature/date
- independent technical reviewer signature/date

Sampling batch data reports shall contain the following:

- sampling facility name, sampling batch number, batch report date, sample numbers included in that sampling batch, technical reviewer signature, and signature release by the SPM or designee.
- table of contents
- identification of the sample matrix (e.g., sludge, swipe, salt, plastic, metal)
- sample type (e.g., duplicate, blank)
- method used for measurement (i.e., procedure identification)
- waste container identification number (if applicable)
- date of sampling
- analysis requested and laboratory
- sample number
- sample size
- sample location
- sampling personnel identification
- chain-of-custody record
- sampling equipment numbers
- cross reference of sampling equipment numbers and cleanliness survey records
- sampling data sheets
- reference to or copy of associated nonconformance reports, if any
- data review checklists
- operator signature/date
- independent technical reviewer signature/date

Sampling and analytical batch reports may be combined, but all required information must be contained in the combined report.

3.5.4 Data and Records Retention

The following nonpermanent records shall be maintained at the measurement facilities or shall be forwarded to the site project office for maintenance, and shall be documented and retrievable by batch number, in accordance with the QAPD:

- batch data reports
- raw data, including instrument readouts, calculation records, and QC results
- applicable instrument calibration reports

3.5.5 Data Reporting to WWIS

Sites shall transmit required characterization, certification, and shipping data to WIPP using the WWIS. The WWIS is an electronic database equipped with edit/limit checks to ensure that the data representing the waste payload containers are in compliance with this WCPIP. Before shipping RH TRU waste payload containers from a WIPP-accepted waste stream, the site shall transmit the required waste characterization, certification, and shipping data via WWIS to WIPP. WIPP will not accept any waste shipments for disposal if the waste payload container information has not been correctly submitted and approved for shipment by the WWIS Data Administrator. The WWIS User's Manual provides the information needed by TRU waste sites to perform tasks associated with transmittal of the payload container's characterization, certification, and shipment information to WIPP. The reporting requirements for waste components to WWIS are contained in Section 2.4 of this WCPIP.

4.0 RH TRU Waste Program Characterization Methods

The following sections describe the methods available to the RH TRU waste generator sites for characterizing RH TRU waste, as well as direction regarding the methods that may be used to obtain particular information. In addition, QAOs for characterization methods are provided.

4.1 Characterization Methods

The DOE/CBFO has identified characterization methods to collect the data needed to support the RH TRU waste characterization program DQOs. The primary method is the compilation and qualification of AK information. The process for qualifying AK data is described in Section 4.3.

4.1.1 Acceptable Knowledge

AK consists of information about the materials and processes that generated a waste and the procedures and policies that were used to package and manage the waste. AK includes, but is not limited to, information about the physical form of the waste, the base materials composing the waste, the radiological characteristics of the waste, and the process that generated the waste. Implementation of the AK process, which involves the compilation and qualification of AK information, forms the foundation for the characterization of a RH TRU waste stream. The following sections describe the AK process as it applies to the RH TRU waste characterization program.

4.1.1.1 Acceptable Knowledge Process

Any AK information used to define waste streams, assign summary categories, or demonstrate compliance with other requirements of this WCPIP must be collected in accordance with the RH TRU AK procedure (see Attachment A). AK information may include process knowledge (**PK**) or previous examinations and measurements (e.g., radiography, VE, or radioassay). Of particular importance is AK information that documents the management of residual liquids and serves to confirm that such items are not in the waste stream in excess of program limits. Generator sites will compile, summarize, and qualify AK in accordance with this WCPIP for any waste streams for which approval is sought for disposal at the WIPP.

The result of the AK process is an auditable record and an AK Summary Report. The auditable record consists of the documents that contain the source material used to make decisions regarding waste characterization. This can include documents that establish a parameter that addresses the DQOs, demonstrate limitations of AK information, or demonstrate the absence of a parameter. The AK Summary Report is a narrative that describes, in detail, the characteristics of the waste stream and how each of the DQO and QAO requirements is satisfied by the available documentation. The AK Summary Report will be annotated so that it is possible to identify the source document for each requirement covered in the AK Summary Report.

The AK Summary Report describes the physical form of the waste. This description will identify the waste as debris, soil/gravel, or homogeneous solid. The waste stream description will be sufficiently detailed to allow the reader to understand the types of items that are expected in the waste stream. The description need not be exhaustive; it only needs to be sufficient to allow distinction between similar waste streams.

The AK Summary Report must include radiological information about the waste stream. This may include the results of measurements (field or laboratory), radionuclide inventory records, safeguards information, modeling studies, and other assessments used to determine the radionuclide characteristics of the waste stream.

The AK Summary Report must also specifically address residual liquids and describe the policies or procedures that were used to exclude or remove residual liquids. Based on the source documents summarized in the AK Summary Report, a site must be able to document that the waste stream contains no residual liquids in excess of one percent and includes only waste from a single process or waste with similar physical, chemical, and radiological constituents. For the designation of waste streams based on physical and chemical similarity and common process, the AK Summary Report should address the expected variability in radionuclide concentrations among the containers in the waste stream. This variability will be important to understand when trying to use AK information to relate waste stream characteristics to individual containers for reporting and tracking.

AK information that is relied upon to satisfy DQOs (except for the defense waste determination) must be qualified in accordance with Section 4.3. This may include qualification confirmatory testing using the characterization methods described in Section 4.1.

Confirmation alternatives for radiological properties are:

- 100% nondestructive assay (**NDA**) or DTC of waste containers
- Destructive assay (**DA**) used to establish activity per unit volume or mass for homogeneous waste
- Analysis of a representative number of samples to confirm isotopic ratios derived from modeling
- Modeling (e.g., ORIGEN) used to confirm isotopic ratios derived from sampling and analysis

Confirmation alternatives for physical/chemical properties are:

- 100% VE of waste requiring packaging or repackaging
- VE or radiography of a sub-population of waste that is already packaged in payload containers (10-10-All)

4.1.1.2 Quality Assurance Objectives

To ensure the consistent application of the AK process, sites must comply with the following data quality requirements for AK documentation. These data quality requirements, expressed as QAOs, are applied to the AK process, not necessarily to the data being collected in the process.

Precision – Precision is the agreement among a set of replicate measurements without assumption of the knowledge of a true value. The qualitative determinations, such as compiling and assessing AK documentation, do not lend themselves to statistical evaluations of precision. Therefore, precision requirements are not established for AK.

Accuracy – Accuracy is the degree of agreement between an observed sample result and the true value. The percentage of waste containers which require reassignment to a new SCG or new waste stream based on the reevaluation of AK or on obtaining testing, sampling and/or analysis data, will be reported as a measure of AK accuracy. The sites shall, in addition, develop a methodology to compare radionuclide information from confirmation with the information in the AK record and address significant discrepancies. What constitutes a significant discrepancy will depend on site- and waste stream-specific considerations. If AK accuracy falls below 90%, the site shall document this as a significant condition adverse to quality as defined by the CBFO QAPD. The site shall notify the CBFO of this condition and implement appropriate corrective actions before proceeding with further characterization activities on the affected waste stream(s). The DOE and EPA will examine these documents for adequacy during audits and inspections.

Completeness – Completeness is an assessment of the number of waste streams or number of samples collected compared to the number of samples determined to be useable through the data validation process. The AK record shall contain 100 percent of the information specified in Attachment A. The usability of the AK information will be assessed for completeness during audits.

Comparability – Data are considered comparable when one set of data can be compared to another set of data. Comparability is ensured through sites meeting the training requirements and complying with the minimum standards outlined for procedures that are used to implement the AK process.

Representativeness – The degree to which sample data accurately and precisely represent characteristics of a population. Representativeness is a qualitative parameter that will be satisfied by ensuring that the process of obtaining, evaluating, and documenting AK information is performed in accordance with the minimum standards established in Attachment A.

4.1.2 Visual Examination

VE is used to identify or confirm waste parameters, including physical form and the absence of residual liquids in excess of one percent. Detail regarding implementation of this method is provided below.

4.1.2.1 VE Method

VE involves operators looking at every item that goes into a payload container. The examination will be recorded on a signed data form accompanied by visual evidence such as video/ audiotapes, photographs, or some other form of unalterable media. In lieu of a video/audiotape or other unalterable media, two trained operators may look at every item and document their examination on a signed data form. It may not be possible to see through inner containers because of discoloration, dust, or because inner containers are sealed. In these instances, documented AK may be used to identify the SCG and verify the absence of residual liquids in excess of one percent. During packaging, only materials from the same waste stream, with similar radiological properties may be packaged in the same waste container.

At a minimum, the VE data to be entered on the VE data form must include:

- container number
- container's waste stream designation
- operator(s) performing the VE
- description of the container contents including waste material parameters that are present
- determination of whether the waste matches the waste stream description in the AK summary report
- determination of whether residual liquids exceed one percent by volume of the waste container
- description of packaging including any liners used
- fill percentage range of the container: 0-25%, 26-66%, 67-90%, or 91-100% (required to implement DTC)
- determination of whether the container contents are primarily concrete, primarily steel, or primarily organic materials (required to implement DTC)
- Other information regarding waste matrix properties, if required by the TRU waste site program, to implement DTC or NDA
- date of VE
- videotape or equivalent media identification number (if applicable)
- videotape or equivalent media start and stop time (if applicable)
- title and revision number of the VE procedure used
- signature of first trained operator
- signature of second trained operator (if not using videotape)

4.1.2.2 VE Training

The site must have a training program that provides VE operators with both on-the-job training (**OJT**) and formal training. VE operators must be instructed in the site-specific waste generating practices and expected packaging configurations of RH TRU waste. The OJT must be conducted by an experienced and qualified VE operator. The training programs will be site-specific due to differences in equipment and waste configurations. For example, the particular physical forms and packaging configurations at each site will vary, so operators must be trained on types of RH TRU waste that are generated, stored, and/or characterized using VE at that site. VE personnel must be requalified every two years.

Although the site-specific training programs will vary, the sites that use VE must have a training program containing the following required formal training elements:

- project requirements
- container identification and labeling

- applicable state and federal regulations
- site-specific instruction

The site must have a site-specific training program, including OJT, addressing the following aspects of waste characterization with VE, as applicable to the waste characterization being conducted using VE:

- identification of summary category groups
- identification of waste material parameters
- identification of packaging configurations
- identification of residual liquids

Each VE facility must designate a VE expert. The VE expert must be familiar with the RH TRU waste-generating processes that have taken place at the site, all the types of RH TRU waste being characterized at that site using VE, and the data that are collected from VE operations. The VE expert must be responsible for the overall direction and implementation of VE at that facility. The site must specify in the certification plan the selection, qualification, and training requirements of the VE expert.

To become qualified, VE operators must, at a minimum:

- Successfully pass a comprehensive exam based on training enabling objectives. The exam will address the VE training and implementation requirements. A minimum score of 80 percent is required to pass the comprehensive exam.
- Demonstrate capability in the presence of the site VE expert during OJT.

Operators must be qualified at least every two years, based on evidence of continued satisfactory performance. Unsatisfactory performance is defined as the failure to identify a prohibited item during OJT or a score of less than 80 percent on the comprehensive exam. Retraining and demonstration of satisfactory performance are required before an operator is again allowed to perform VE for the WIPP program.

4.1.2.3 Quality Assurance Objectives

The following QAOs apply to the VE method:

Precision QAO – Precision is maintained by reconciling any discrepancies between two operators (or between the operator and the independent technical reviewer) with regard to the identification of important waste characteristics (i.e., physical form of the waste and absence of residual liquid in excess of one percent by volume) within a single container. Any container with unreconciled discrepancies cannot be shipped to the WIPP.

Accuracy QAO – Accuracy is maintained by requiring operators to pass a comprehensive examination with a score of 80% and demonstrate satisfactory performance in the presence of the VE expert during their initial qualification and subsequent requalification.

Representativeness QAO – The contents placed in a container will be described on the data forms.

Completeness QAO – The relevant waste information must be collected. This information must be documented on a videotape and/or data form, or other unalterable media.

Comparability QAO – Comparability is ensured by a site meeting the training requirements and complying with the minimum standards used to implement this characterization process. In some instances, waste will be contained in opaque containers and not all items will be visible to the operator (e.g., sealed paint cans or 5-gallon buckets). If these containers are not opened during VE, source documents must be available in the AK record that allow the operator to identify the contents of the closed containers.

If a site intends to use records of visual examination performed prior to implementation of this WCPIP to demonstrate compliance with a DQO, it must demonstrate that the information collected regarding the waste stream and individual containers is sufficient to meet the QAOs and the programmatic DQOs that can be satisfied using VE. Site plans for qualification of VE data require CBFO approval to assure consistency with RH TRU waste characterization program objectives. The plan must demonstrate compliance with the requirements of Section 4.3.

4.1.3 Dose-to-Curie Conversion

The curie content of RH TRU waste containers can be derived, based on a dose rate measurement taken with calibrated instrumentation. This process, referred to as dose-to-curie (DTC), can be used to establish isotopic activity, total activity, and activity per canister, when used in conjunction with adequate AK information.

4.1.3.1 Dose-to-Curie Conversion Method

The DTC method uses a standard profile of the waste to relate the quantity of gamma-emitting radionuclides to the activities in the waste. DTC conversions are based on a dose rate measurement taken with calibrated instrumentation. The measurement is associated with documented isotopic distributions within the waste through the use of empirically developed conversion factors. The external dose rate can be correlated to the activity in the container, such as ^{137}Cs, by taking into account such factors as matrix and container geometry. The calculated ^{137}Cs activity is then correlated to other radionuclides by scaling or conversion factors. The radionuclide conversion factor derivation shall be documented. For some RH TRU wastes, the distribution can be calculated based on fuel characteristics, sampling, and computer modeling (from a program such as ORIGEN). Sites will confirm AK information related to radionuclide distribution derived from modeling, by sampling and analysis (see the Representativeness QAO). Acceptable knowledge information that was obtained by previous sampling and analysis may be qualified in accordance with the requirements of Section 4.3 of the WCPIP.

When smears, swipes, or material samples are used for determining radionuclide distribution, the generator site must demonstrate that sampling does not bias the results (i.e., removable contamination has similar radionuclide distribution when compared to fixed contamination). The assumption will be that the radioactive source material is the same for each waste stream or waste stream lot. This assumption is expected to be valid for most sites where the processes that

generate RH TRU waste involved studies of reactor fuel specimens. At sites where the sources varied, the assumption may not be valid and, as a result, greater sampling may be needed to represent the waste stream. When sites designate waste streams, they will be required to determine the applicability of the DTC method and the sampling and analysis required to determine conversion factors.

The use of this technique is well-established in the commercial power industry to characterize and classify wastes that are difficult to measure, such as dry active waste. In this application, surrogate samples such as floor smears are used.[3] Typically, two relationships must be established to use the DTC method: the radionuclide distribution anticipated within the waste and the relationship between the measured radionuclide (usually ^{137}Cs) and its concentration within the container. Obtaining these relationships (also referred to as scaling factors or conversion factors) can be problematic if it requires extensive sampling and analysis of radionuclides. Fortunately, the limited nature of RH TRU waste, in terms of its sources, facilitates the calculation of radionuclide distributions based on the characteristics of the waste, the reactor operation, and the waste-generating process. Such modeling calculations, when coupled with sampling programs, can establish the conversion factors. Modeling used to implement DTC method shall be documented in a technical report by the generator site. The technical report shall be reviewed and approved as a controlled document under the generator site QA program. The technical report will contain a quantitative description of the compliance of the model(s) with the QAOs listed in Section 2.2.4. The guidance in EPA QA/G-5M, *Guidance for Quality Assurance Project Plans for Modeling*, shall be used in developing the models used to implement DTC. All software used to implement DTC models will be managed in accordance with the software QA requirements described in the CBFO QAPD.

Generator sites must use Attachment B, *Dose-to-Curie Survey Procedure for Remote Handled TRU Waste,* to perform dose measurements and conversions for RH TRU wastes. The sites must also use Attachment C, *General Procedure for Dose-to-Curie Estimation For Remotely Handled Transuranic (RH TRU) Radioactive Waste,* to develop the standard isotopic mixes and models used for DTC.

4.1.3.2 Quality Assurance Objectives

The conversion method is used in conjunction with AK and involves the use of computer modeling or sampling to establish the isotopic distribution and appropriate scaling factors. QAOs for radioassay methods are discussed in Section 4.1.5. The following QAOs are applied for the DTC method:

> Precision QAO – Precision shall be established and maintained within the recommendations of the manufacturer of the dose-rate instrument used. This will be demonstrated by a satisfactory source check of the instrument prior to obtaining dose rate measurements. The precision of the instrument shall be documented and factored into the TMU determined for the overall method.

[3] See for example EPRI Report TR-107201, "Low Level Waste Characterization Guidelines." A description of this report is available at the EPRI Website at www.epri.com.

Accuracy QAO – Calibration shall be established and maintained within the recommendations of the manufacturer of the dose-rate instrument used. The accuracy of the instrument shall be documented and factored into the TMU determined for the overall method.

Representativeness QAO – Representativeness of the isotopic distributions will be confirmed by sampling in accordance with an approved sampling plan (see Section 4.1.8). The representativeness of the sampling shall be documented and factored into the TMU determined for the overall method.

Completeness QAO – This will be ensured by measuring the dose rate for every container. The sites must verify that the measured dose rate is at least 10 times greater than background.

Comparability QAO – Standardized instructions must be used in designing and implementing the measurement program.

In addition, measurement facilities must document the following attributes:

Lower Limit of Detection (**LLD**)–The LLD for the DTC method shall be determined for all measured radionuclides. When used for TRU/low-level waste discrimination, measurements must have an LLD of 100 nCi/g or less. Site-specific environmental background and container-specific interferences must be factored into LLD determinations. The LLD is that level of radioactivity which, if present, yields a measured value greater than the critical level with a 95% probability, where the critical level is defined as that value which measurements of the background will exceed with 5% probability. Because the LLD is a measurement-based parameter, it is not feasible to calculate LLDs for radionuclides that are not determined primarily by measurement (e.g., ^{90}Sr). In such cases, the site shall derive the equivalent of an LLD (i.e., a reporting threshold for a radionuclide) when it is technically justified. This value may be based on decay kinetics, scaling factors, or other scientifically based relationships and must be adequately documented in site records. For purposes of reporting radionuclide data in the WWIS, this value will be the equivalent of an LLD.

Total Measurement Uncertainty (**TMU**) – The TMU must be determined for the DTC method.

4.1.4 Radiography

Radiography may be used to establish a number of waste characteristics including the physical form of the waste and the absence of residual liquids in excess of one percent.

4.1.4.1 Radiography Method

Radiography involves the use of penetrating radiation to examine the contents of containers. The examination will be recorded on a signed data form accompanied by visual evidence such as videotape or other unalterable media.

Radiography shall consist of a qualitative evaluation of the waste container contents and shall be recorded on videotape (or another equivalent unalterable medium). A radiography data form

shall be used to document the data that are collected by a trained radiography operator. Sites that use radiography must use controlled procedures that identify all data that must be collected during radiography and entered on the radiography data form. At a minimum, the radiography data to be entered on the radiography data form must include:

- container number
- container waste stream designation
- operator(s) performing the radiography
- description of container contents including waste material parameters that are present
- determination of whether the waste matches the waste stream description in the AK summary report
- determination of whether residual liquids exceed one percent by volume of the waste container
- description of packaging, including any liners used
- fill percentage range of the container: 0-25%, 26-66%, 67-90%, or 91-100% (required to implement DTC)
- determination of whether the container contents are primarily concrete, primarily steel, or primarily organic materials (required to implement DTC)
- Other information regarding waste matrix properties, if required by the TRU waste site program, to implement DTC or NDA
- date of radiography
- videotape or equivalent media identification number
- videotape or equivalent media start and stop time
- title and revision number of the radiography procedure used
- signature of trained operator

At the beginning of each day, prior to performing radiography on any waste containers, the radiography equipment must be checked by observing a known test target to verify image quality. A videotape recording (or a recording on an equivalently unalterable media) shall be made of the test target and each waste container scan. Independent replicate scans shall be performed on one waste container per day or once per testing batch, whichever is less frequent. Independent observations of one scan (not the replicate scan) shall also be made once per day or once per testing batch, whichever is less frequent, by a qualified radiography operator other than the individual who performed the first examination. A testing batch is a suite of waste containers undergoing radiography using the same testing equipment. A testing batch can be up to 20 waste containers. The radiography data form shall be used to document the data that are collected. Sites that use radiography must have trained radiography operators who can scan the waste container, generate the recorded image, interpret the image, and complete the radiography data form. A second trained operator is necessary for the independent observation.

4.1.4.2 Radiography Training

The site shall have a training program that provides radiography operators with both OJT and formal training. Radiography operators shall be instructed in the specific RH TRU waste-generating practices and typical packaging configurations. The OJT shall be conducted by an experienced, qualified radiography operator prior to qualification of the training candidate. Because of differences in equipment, waste configurations, and the types of data being collected during radiography, the training programs will be site-specific. For example, certain sites use digital radiography equipment, which is operated differently than real-time radiography equipment. In addition, the waste and packaging configurations at each site will vary; therefore, radiography operators shall be trained on the types of RH TRU waste that are representative at that site.

Although the site-specific training programs will vary based on the data that are being collected using radiography, sites that use radiography shall have a training program including the following required formal training elements:

- project requirements
- applicable state and federal regulations
- basic principles of radiography
- radiographic image quality and calibration
- radiographic scanning techniques
- radiography of waste forms
- standards, codes, and procedures for radiography
- site-specific instruction

Each site that uses radiography must have a site-specific training program that addresses the following aspects of waste characterization using radiography:

- system operation
- identification of packaging configurations
- identification of summary category groups
- identification of waste material parameters
- identification of residual liquids

A radiography test container shall be examined as part of the radiographer qualification. The radiography test container shall include items representative of the physical properties of the waste streams at the site and must include prohibited items (i.e., liquid in excess of one percent). The test container contents shall be successfully identified by the operator as part of the qualification process. Qualified radiography operators shall, at a minimum:

- Successfully pass a comprehensive exam based on training enabling objectives. The comprehensive exam will address radiography operation, documentation, characterization, and procedural elements stipulated in this WCPIP. A minimum score of 80 percent is required to pass the comprehensive exam.
- Perform practical capability demonstration in the presence of the appointed site radiography subject matter expert (this person is an experienced radiography operator who is qualified as an OJT trainer).

Operators shall be qualified at least every two years, based on evidence of continued satisfactory performance (primarily audio/videotape reviews). Unsatisfactory performance is defined as the failure to identify a prohibited item in a test container or a score of less than 80 percent on the comprehensive exam. Retraining and demonstration of satisfactory performance are required before an operator is again allowed to operate the radiography system for the purposes of this WCPIP.

4.1.4.3 Quality Assurance Objectives

The following QAOs shall apply to the radiography method:

Precision QAO – Precision is maintained by reconciling any discrepancies between two operators with regard to the identification of important waste characteristics (i.e., physical form of the waste and absence of residual liquid in excess of one percent by volume) within a single container. Any container with unreconciled discrepancies cannot be shipped to the WIPP.

Accuracy QAO – Accuracy is obtained by using a target to tune the image for maximum sharpness and by requiring operators to successfully identify 100 percent of the items in a training container during their initial qualification and subsequent requalification.

Representativeness QAO – All of the relevant contents in a container selected for radiography will be described.

Completeness QAO – All of the relevant waste information must be assembled and must show that each of the containers in the waste stream belongs to the waste stream. This information must be documented on videotape or other equivalent media and data form.

Comparability QAO – Comparability is ensured through a site meeting the training requirements and complying with the minimum standards used to implement the radiography process.

If a site chooses to use records of radiography performed prior to implementation of this WCPIP to demonstrate compliance with a DQO, it must demonstrate that the information collected regarding the waste stream and individual containers is sufficient to meet the QAOs and the overall programmatic DQOs that can be satisfied using radiography.

Sites are required to have their plan to qualify radiography data approved by the DOE/CBFO to assure consistency with RH TRU waste characterization program objectives. The plan must demonstrate compliance with the requirements of Section 4.3.

4.1.5 Radioassay

This section describes the requirements for obtaining characterization data for RH TRU wastes using measurement techniques referred to as radioassay. Radioassay is a term used to define methods for determining the radionuclide content of waste, and includes both NDA and DA (i.e., radiochemistry). Radiochemistry is a subset of radioassay and typically involves collecting a representative sample of a waste that is subjected to physical and/or chemical processing for subsequent analysis by standard radioactivity counting methods.

RH TRU waste typically contains higher concentrations of gamma-emitting radionuclides such as ^{137}Cs and ^{60}Co. The corresponding external radiation fields (dose equivalent rates or dose rates) present measurement challenges for performing NDA. Assay systems that provide data for the characterization of RH TRU waste must be controlled under formal measurement control programs, as required by the QAPD.

4.1.5.1 Nondestructive Assay

NDA, in conjunction with adequate AK, can be used to establish TRU activity, total activity, isotopic activity, and activity per canister. NDA is used in conjunction with AK information or a documented study that provides the needed relationship between NDA and the isotopic characteristics of the waste.

At a minimum, NDA programs must be capable of identifying, measuring, and reporting the presence or absence of the ten radionuclides identified in Section 2.4.6 for tracking of the WIPP radionuclide inventory.

In support of the above requirements, each site must evaluate, document, and technically justify the following determinations.

Lower Limit of Detection – The LLD for each NDA system must be determined. Instruments performing TRU/low-level waste discrimination measurements must have an LLD of 100 nCi/g or less. Site-specific environmental background and container-specific interferences must be factored into LLD determinations. The LLD is that level of radioactivity which, if present, yields a measured value greater than the critical level with a 95% probability, where the critical level is defined as that value which measurements of the background will exceed with 5% probability. Because the LLD is a measurement-based parameter, it is not feasible to calculate LLDs for radionuclides that are not determined primarily by measurement (e.g., ^{90}Sr). In such cases, the site shall derive the equivalent of an LLD (i.e., a reporting threshold for a radionuclide) when it is technically justified. This value may be based on decay kinetics, scaling factors or other scientifically based relationships and must be adequately documented in site records. For purposes of reporting radionuclide data in the WWIS, this value will be the equivalent of an LLD.

Total Measurement Uncertainty (TMU) – The method used to calculate the TMU for the quantities in Section 2.4.5 (TRU Alpha Activity Concentration) and 2.4.6 (Radionuclide Activity) must be documented and technically justified for each CBFO-certified NDA system. Compliance with this requirement will be evaluated by CBFO in reviews of the TMU documentation package for each assay system.

Calibration Procedures and Frequencies – Each NDA measurement system shall be calibrated before initial use. During calibration or recalibration, system correction factors shall be established and algorithms adjusted such that the value of %R is set equal to 100% (i.e., the system is calibrated to 100%R). The range of applicability of system calibrations must be specified in site procedures. The matrix/source surrogate waste combinations used for calibration shall be representative of the:

- activity range or gram loading
- relevant waste matrix characteristics (e.g., densities, moderator content, container size) planned for measurement by the system

Calibration shall be performed in accordance with consensus standards, when such standards exist. If consensus standards are not used, full documentation of the calibration technique must be provided to and approved by CBFO prior to performing WIPP-related assays. Primary calibration standards shall be obtained from suppliers maintaining a nationally accredited measurement program. When primary standards are not available, the standards used shall be correlated with primary standards obtained from a nationally accredited measurement program.

Calibration Verification – Notwithstanding the need to calibrate individual components for replacement, changes, or adjustments (e.g., energy calibration of a detector), verification of NDA measurement system calibration shall be performed after any one of the following occurs:

- major system repairs and/or modifications
- replacement of the measurement system's components (e.g., detector, neutron generator or supporting electronic components that have the capacity to affect data)
- significant changes to system software
- relocation of the system

Calibration verification shall consist of demonstrating that the system is within the range of acceptable operation. Secondary standards can be used for the calibration verification if their performance has been correlated with the calibration standard. If a verification of the measurement system's calibration or other test demonstrates that the system's response has significantly changed, recalibration of the system shall be performed.

Calibration Confirmation – In order to confirm that the calibration of the NDA system was correctly established, the accuracy and precision of the system are determined after each calibration or recalibration by performing replicate measurements of a non-interfering matrix. Calibration confirmation replicate measurements shall be performed on containers of the same nominal size as those in which actual waste is assayed and according to approved waste assay procedures. The number of replicate measurements to be performed shall be documented and technically justified. The replicate measurements shall be performed using nationally recognized standards, or certified standards derived from nationally recognized standards that span the range of use. The standards used to calculate accuracy shall not be the same as those used for the system calibration. Accuracy is reported as percent recovery

(%R). The applicable range for accuracy shall not exceed ± 30% on a non-interfering matrix. Precision is reported as percent relative standard deviation (**% RSD**). The %RSD shall not exceed the values listed in Table 4.1 for the corresponding number of replicate measurements in a non-interfering matrix. Measurement facilities may develop alternate limits for accuracy and precision subject to approval by CBFO prior to certification of waste.

Table 4.1. Upper Limits for %RSD vs. Number of Replicates

Number of Replicates	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Max %RSD	1.8	6.6	10.0	12.3	14.0	15.2	16.2	17.1	17.7	18.3	18.8	19.3	19.7	20.0

The values listed are derived from the measured standard deviation of the replicate measurements using $\frac{s}{\mu} \bullet 100\% < \sqrt{\frac{(0.292) \bullet \chi^2_{0.05,n-1}}{n-1}} \bullet 100\%$ where s is the measured standard deviation, n is the number of replicates, μ is the true value, $\chi^2_{0.05,n-1}$ is the critical value for the upper 5% tail of a one sided chi-squared distribution with n-1 degrees of freedom, and 0.292 corresponds to a 95% upper confidence bound on the true system precision limit of 29.2%.

Quality Control

To ensure that data of known and documented quality are generated, each participating measurement facility shall implement a documented facility QA program. Any NDA technique used for TRU waste must be performed in accordance with calibration and operating procedures that have been written, approved, and controlled by the site or testing facility. Laboratory procedures must contain applicable quality controls. Facility QA programs shall specify qualitative and quantitative acceptance criteria for the QC checks of this program and corrective action measures to be taken when these criteria are not satisfied.

General Requirements

Nondestructive Assay Training – Only appropriately trained and qualified personnel shall be allowed to perform NDA and data validation/review. Standardized training requirements for NDA personnel shall be based upon existing industry standardized training requirements (e.g., ASTM C1490, *Standard Guide for Selection, Training and Qualification of Nondestructive Assay (NDA) Personne*l ANSI N15.54, *Radiometric Calorimeters – Measurement Control Program*) and shall meet the specifications in the QAPD. Requalification of NDA personnel shall be based upon evidence of continued satisfactory performance and must be performed at least every two years.

Software QC Requirements – All computer programs and revisions thereof used for NDA shall meet the applicable requirements in the QAPD.

NDA QC Requirements

The assay procedures cited in various American Society for Testing and Materials (**ASTM**) and American National Standards Institute (**ANSI**) standards and Nuclear Regulatory Commission (**NRC**) standard practices and guidelines are recommended for use at all testing facilities.

Background Measurements – Background measurements must be performed and recorded daily, unless otherwise approved by CBFO. Contributions to background due to radiation from nearby radiation-producing equipment, standards, or wastes must be carefully controlled or more frequent background checks must be performed.

Instrument Performance Measurements – Performance checks on calibrated and operable gamma and neutron NDA instruments must be performed and recorded once per operational day. Performance checks shall include efficiency checks (when applicable), matrix correction checks and, for spectrometric instruments, peak position and resolution checks.

Both radioactive sources and surrogate waste matrix containers (both non-interfering and interfering) are used. At least once per operational week an interfering matrix must be used to assess the long-term stability of the NDA instrument's matrix correction. Surrogate waste containers must reflect the type of waste (e.g., debris, sludge) currently being assayed. To verify calibration, radioactivity standards must be selected such that, over a six-month period, the operating range of the assay system is tested in each applicable surrogate waste matrix. The use of interfering and non-interfering matrices provides a realistic assessment of the assay system's performance over time, and will assist measurement personnel in detecting potential problems relative to the matrices currently assayed by the measurement system.

Interfering surrogate matrix containers must be constructed in such a way that the waste characteristics do not change over time.

Radioactive sources should be long-lived, easy to position relative to the detector, and of sufficient radioactivity to obtain good results with relatively short count times.

Data Checks

Background and performance measurements shall be reviewed and evaluated at least weekly to determine continued acceptability of the assay system and to monitor performance trends. If daily performance checks result in data that are outside the acceptable range, the required responses in Table 4.2 shall be followed.

NDA QAOs

The following QAOs apply to the NDA method:

Precision QAO – Precision is reported as %RSD. The %RSD shall not exceed the values listed in Table 4.1.

Accuracy QAO – Accuracy is reported as %R. Accuracy will not exceed ±30% on a non-interfering matrix.

Representativeness QAO – Representativeness is ensured through assay of each waste container when NDA is used to satisfy DQOs.

Completeness QAO – Required completeness is 100%. All NDA data used to satisfy a DQO must be valid and usable.

Comparability QAO – Comparability is ensured through a site meeting the training requirements and complying with the minimum standards used to implement the NDA process.

Table 4.2. Range of Applicability

	Acceptability Range	Required Response
Acceptable Range	Data[b] $2\sigma^a$	No action required.
Warning Range	$2\sigma^a$ < Data $3\sigma^a$	The performance check standard shall be run no more than twice. If the rerun performance check results in data within ± 2σ, then the additional performance checks shall be documented and work may continue. If the system does not fall within ± 2σ after two performance checks, then the required response for the Action Range shall be followed.
Action Range	Data> $3\sigma^a$	Work shall stop and the occurrence shall be documented and appropriately dispositioned (e.g., initiating a nonconformance report). The NDA system shall be removed from service pending successful resolution of all necessary actions, and all assays performed since the last acceptable performance check are suspect, pending satisfactory resolution. Recalibration or calibration verification is required prior to returning the system back to service.

[a]σ - The standard deviation is only based on the reproducibility of the data check measurements themselves. This is not TMU.

[b]Absolute Value

4.1.5.2 Destructive Assay (Radiochemistry)

Representative samples of RH TRU waste may be analyzed by NDA or DA techniques. The decisions regarding the use of such techniques shall be made by the waste measurement facility and will be technically justified and documented by each facility. If a waste characterization facility chooses to collect and analyze representative samples of the TRU waste material, the site must technically justify and document that the samples collected are representative of the waste material with respect to nuclear properties/radiological characteristics and physical or chemical aspects that significantly affect the measurement process. While it is anticipated that analysis of these samples will be used mainly to determine or confirm a sample's isotopic composition, in some cases it may be possible for a site to use this type of data to directly quantify WIPP-required radionuclides. TRU waste sites that plan to use DA to characterize waste for disposal at WIPP must develop a sampling plan. The requirements for sampling plans are described in Section 4.1.8.

The analyses of samples may produce isotopic distribution values, radionuclide- or element-specific mass values, or both. These data may stand alone or be used in conjunction with other techniques (i.e., as model inputs) to derive values for other wastes with similar origins. The measurement facility will document their measurement capabilities and technically justify the applications of data collected on those systems. Sample collection and analysis will be controlled by the use of written procedures in accordance with the CBFO QAPD.

Depending on the medium and target analyte, the sample preparation can involve considerable processing (e.g., the use of strong acids and solvents for sample digestion and separation). Following separation, purification and appropriate preparation, the sample is assayed for alpha, beta, or gamma radiations, and the instrument outputs are converted to meaningful data by applying calibration and sample-specific correction factors. Radiochemistry techniques can provide isotopic distributions, gross activities, and radionuclide-specific concentrations.

Each laboratory used for TRU waste assay by DA shall demonstrate that the analytical methods are appropriate to assay the specific wastes for which they are proposed. These methods must contain the following general provisions:

- Assay standards must be prepared and used as indicated in the standard test methods.
- The sample taken from the waste must be representative and traceable to its specific waste batch or waste container.
- The test result for each sample must be associated with a specific lot, batch number, or container.
- Lower Limit of Detection – The LLD for each DA method must be determined. Site-specific environmental background and sample-specific interferences must be factored into LLD determinations. The LLD is that level of radioactivity which, if present, yields a measured value greater than the critical level with a 95% probability, where the critical level is defined as that value which measurements of the background will exceed with 5% probability. Because the LLD is a measurement-based parameter, it is not feasible to calculate LLDs for radionuclides that are not determined primarily by measurement. In such cases, the site shall derive the equivalent of an LLD (i.e., a reporting threshold for a radionuclide) when it is technically justified. This value may be based on decay kinetics, scaling factors, or other scientifically based relationships, and must be adequately documented in site records.

All methods will be preceded by radiochemical separation and/or preparation for measurement. Table 4.3 presents a list of laboratory control procedures that must be performed by laboratories involved in the TRU waste DA process.

The following QAOs apply to the DA method:

Precision QAO – Precision is reported as relative percent difference (**RPD**). The RPD is derived from analysis of laboratory duplicates as listed in Table 4.3. The RPD shall not exceed the values listed in Table 4.3.

Accuracy QAO – Accuracy is reported as %R. The %R is derived from analysis of laboratory control samples and matrix spikes as listed in Table 4.3. The %R shall not exceed the values listed in Table 4.3.

Representativeness QAO – Representativeness of DA data shall be achieved by the collection of unbiased samples.

Completeness QAO – Completeness of DA data shall be expressed as the ratio of the number of samples that are analyzed with valid results to the total number of samples that are submitted for analysis, expressed as a percent. Acceptable DA data shall be obtained for 90 percent of the samples acquired for waste characterization. Valid results for radioassay data are those that were obtained when the laboratory or testing facility demonstrated that the instrumentation and method were in control.

Comparability QAO – Comparability is ensured through a site meeting the training requirements and complying with the minimum standards used to implement the DA process.

Table 4.3. Quality Control Requirements for Radiochemistry

QC Sample	Minimum Frequency	Acceptance Criteria	Corrective Action
Laboratory control samples (LCS)	One per analytical batch	75% to 125%R	See Laboratory Control Sample[a]
Method blank	One per analytical batch	Site-specific statistical control limits	See Method Blanks[b]
Laboratory duplicate	One per analytical batch	RPD 40	See Laboratory Duplicate[c]
Matrix spike (MS)	One per analytical batch for ICP-MS, as required by the test performed	50 to 150%R	See Matrix Spike and Matrix Spike Duplicate[d]
Matrix spike duplicate (MSD)	One per analytical batch, as required by the test performed	50 to 150%R RPD 40	See Matrix Spike and Matrix Spike Duplicate[d]
Radioisotopic tracers	Every sample	Site-specific statistical control limits	See Radioisotopic Tracer[e]

[a]**Laboratory Control Sample (LCS)**: An LCS is analyzed at least once per analytical batch. If a solid matrix with established control limits is used as the LCS, the established limits may be used for the acceptance criteria. The control limits will meet the criteria in Table 4.4.

[b]**Method Blanks**: A method blank is analyzed at least once per analytical batch. It contains all reagents in proportions equal to those in the samples and is carried through the analytical procedure to identify if contamination is present. Each site establishes the acceptance criteria for method blanks; if they are expressed as statistical control limits they shall meet the requirements in Table 4.4. Criteria may be absolute values, multiples of background variation, fractions of activity concentrations observed in samples, or other appropriate units.

[c]**Laboratory Duplicate**. A laboratory duplicate is analyzed at least once per analytical batch. A laboratory duplicate is a separate aliquot from the same field sample carried through the entire analytical procedure. The RPD between duplicate results is compared with the criteria.

[d]**Matrix Spike and Matrix Spike Duplicate:** Duplicate MSs on individual field samples are performed for inductively coupled plasma-mass spectrometry (ICP-MS) analysis at a minimum frequency of one pair (MS plus MSD) per analytical batch. The MSDs are preferred for any analytical procedure not using radioactive tracers. The MS and MSD results are acceptable if the criteria given above for percent recovery and RPD are met.

[e]**Radioisotopic Tracer**: Some methods require that all samples, blanks, LCSs, and laboratory duplicates be spiked with radioisotopic tracers to determine chemical recoveries, counting efficiencies, or a combination thereof. Each site establishes the acceptance criteria for method blanks; if they are expressed as statistical control limits they shall meet the requirements in Table 4.4.

Table 4.4 Statistical Control Limits

	Acceptability Range	Required Response
Acceptable Range	Data[b] $2\sigma^a$	No action required.
Warning Range	$2\sigma^a$ < Data $3\sigma^a$	The QC measurement shall be run no more than twice. If the rerun QC measurement results in data within ± 2σ, then the QC measurements shall be documented and work may continue. If the system does not fall within ± 2σ after two QC measurements, then the required response for the Action Range shall be followed.
Action Range	Data> $3\sigma^a$	Work shall stop and the occurrence shall be documented and appropriately dispositioned (e.g., initiating a nonconformance report). The measurement system shall be removed from service pending successful resolution of all necessary actions, and all assays performed since the last acceptable QC measurement are suspect, pending satisfactory resolution.

[a]σ - The standard deviation is only based on the reproducibility of the data check measurements themselves. This is not TMU.

[b]Absolute Value

4.1.6 Surface Dose Rate

Surface dose rate measurements consist of radiation surveys to determine compliance with some of the requirements listed in this WCPIP.

4.1.6.1 Method

Measurements must be conducted to determine surface dose rates of RH TRU waste containers. Dose rate surveys will be performed only by trained and qualified personnel using properly calibrated instruments appropriate for the types, levels, and energies of the radiation encountered, and appropriate for the existing conditions in which the instruments will be used. Surveys for radiation must be performed as specified by the Radiological Control Organization, Radiological Work Permits, or other technical documents. The Radiological Control Organization should review the adequacy of dose rate measurement systems when facility or operational changes occur. Records must be maintained to document changes in monitoring equipment, techniques, and procedures. Generator sites shall determine the uncertainty associated with dose rate measurements.

Assessment of container surface dose rates shall include a sufficient number of measurements to characterize the radiation present and to determine compliance with the surface dose rate DQO. Surface dose rate measurement results shall be reviewed by the cognizant radiological supervisor. The review shall ensure that all required measurements have been performed and that the documentation is accurate and complete. Surface dose rate measurements shall be recorded on appropriate standard forms and include the following common elements:

- Date, time, and purpose of the measurement
- General and specific location of the measurement

- Name of the person performing the measurement
- Pertinent special information needed to interpret measurement results (e.g., unusual background levels, special survey distances)
- Survey maps illustrating where measurements were performed and the results

For RH TRU wastes, the SPM or designee shall review the payload container data packages to verify that the maximum contact radiation dose rate (beta + gamma + neutron) at any point on the RH TRU payload container is equal to or greater than 200 mrem/hr and no greater than 1000 rem/hr.

4.1.6.2 Quality Assurance Objectives

The following QAOs apply to surface dose rate methodologies:

Precision QAO – Precision established and maintained within the recommendations of the manufacturer of the instrument used to measure dose.

Accuracy QAO – Calibration established and maintained within the recommendations of the manufacturer of the dose measurement instrument used.

Representativeness QAO – The measurement applied to the entire waste container.

Completeness QAO – 100% of the measurements needed to determine surface dose rate are performed and useable.

Comparability QAO – Dose rate measurements are performed by site health physics personnel in accordance with the DOE Orders governing radiological control.

4.1.7 Count Containers

The counting of containers will be accomplished by information provided in the WWIS. Information collected by counting containers will be used to calculated amounts of ferrous and nonferrous metals. No method description or associated QAOs are provided for this method. This will be performed by WIPP based on shipment data input into WWIS by the generator sites for each shipment.

4.1.8 Sampling

4.1.8.1 Method

The methods used to collect samples of RH TRU waste shall be such that the samples are representative of the waste from which they were taken. However, the physical and chemical diversity of RH TRU waste, as well as the dissimilarity of storage facilities (tanks, drums, hot cells, storage wells, underground caissons, etc.) and sampling equipment associated with them, preclude a detailed description of any specific sampling plan in this WCPIP. Consequently, the burden of responsibility for developing a technically sound sampling plan rests with the TRU waste generator site.

For TRU waste sites that plan to use DA to directly quantify WIPP-required radionuclides (e.g., analysis of homogeneous solids to develop a curie per unit weight or volume value) or to develop or confirm the mix of isotopic ratios to implement the DTC method, the requirements of the sampling plan are listed below:

A sampling plan shall be developed and documented for each RH TRU waste stream. The sampling plan is a critical component in the development of representative samples and shall be developed using the guidance provided in EPA QA/G-5S, *Guidance on Choosing a Sampling Design for Environmental Data Collection for Use in Developing a Quality Assurance Project Plan*, and EPA QA/G9 *Guidance for Data Quality Assessment*.

- The sampling plan shall be designed to keep personnel radiation exposure to as low as reasonably achievable (**ALARA**) and result in samples that are representative of that waste stream.
- The form, distribution, and type of waste comprising RH TRU waste shall be considered in developing a sampling plan.
  - The variety in operations and the nature of the generation of RH TRU waste is such that a single method of sampling the waste cannot be applied across the DOE complex.
  - Some waste streams (e.g. well mixed sludge) may be relatively easy to sample, but the method used to collect the sample must be representative of the waste.
  - Newly generated waste or waste not yet packaged shall be sampled prior to packaging.
  - If existing sampling data cannot be qualified in accordance with Section 4.3 of the WCPIP, waste already packaged shall be directly sampled.
  - RH TRU material embedded in concrete or other solid material may require samples to be obtained from within the material.
  - Each site shall consider the best means for obtaining samples that are representative of the RH TRU content of a particular waste stream.

The sampling plan shall be submitted to CBFO for review and approval.

To minimize the quantity of waste derived from sampling, laboratories conducting the analytical work may require no more sample than is required for the analysis, based on the analytical methods. However, a sufficient number of samples shall be collected to adequately represent waste being sampled. All sampling will comply with the QC requirements specified in this section.

QC requirements for sampling RH TRU waste include collecting co-located samples to determine precision and radiological measurements to verify cleanliness of the sampling tools and sampling equipment. Sampling of RH TRU waste shall comply, at minimum, with the following QC requirements.

Duplicate co-located samples shall be collected to determine the precision of the sampling procedures. A co-located sample may be collected from a sample (e.g., scoop) collected from approximately the same location in the waste stream. Co-located samples shall be collected side

by side as close as feasible to one another, handled in the same manner, visually inspected, and sampled in the same manner at the same randomly selected sample location(s). If the visual examination detects inconsistencies such as color, texture, or waste type in the waste at the sample location, another sampling location may be randomly selected, or the samples may be invalidated and co-located samples may again be collected. Co-located samples shall be collected at a frequency of one per sampling batch or once per week, whichever is more frequent. A sampling batch is a suite of RH TRU waste samples collected consecutively using the same sampling equipment within a specific time period. A sampling batch can be up to 20 samples (excluding field QC samples), all of which shall be collected within 14 days of the first sample in the batch.

Sampling equipment (e.g., bowls, spoons, chisels, swipes, coring tubes, grain thiefs, calawasas) shall also be cleaned or purchased clean. Sampling equipment, at least that portion that contacts the waste during sampling, shall be verified to be free of radiological contamination prior to use. This can be verified by normal radiological control survey techniques. The results of cleanliness surveys of sampling equipment shall be traceable to sampling equipment batches.

Inspection of sampling equipment and work areas shall include the following:

Sample collection equipment in the immediate area of sample collection shall be inspected daily for cleanliness. The waste sampling work areas shall be maintained in a condition to minimize the potential for cross contamination between waste streams. Sampling equipment shall be visually inspected prior to use. All sampling equipment that comes into contact with waste samples shall be stored in protective wrapping until use. Prior to removal of the protective wrapping from sampling equipment, the condition of the protective wrapping shall be visually assessed. Sampling equipment with torn protective wrapping should be discarded or returned for cleaning. Sampling equipment visibly contaminated after the protective wrapping has been removed shall not be used and shall be returned for cleaning or properly discarded. Cleaned sampling equipment will be physically segregated from all equipment that has been used for a sampling event and has not been decontaminated.

Chain-of-custody on field samples (including field QC samples) will be initiated immediately after sample collection or preparation. Sample custody will be maintained by ensuring that samples are custody sealed during shipment to the laboratory. If custody sealing is not practical due to radiological considerations associated with the sample, the generator site may implement administrative controls to ensure that samples are not tampered with. After samples are accepted by the analytical laboratory, custody is maintained by assuring the samples are in the possession of an authorized individual, in that individual's view, in a sealed or locked container controlled by that individual, or in a secure controlled-access location. Sample custody will be maintained until the sample is released by the site project manager or until the sample is expended. The sampling plan or site-specific procedures shall include a copy of the sample chain-of-custody form and instructions for completing sample chain-of-custody forms. This form will include provisions for each of the following:

- Signature of individual initiating custody control, along with the date and time.
- Documentation of sample numbers for each sample under custody.

- Sample numbers will be referenced to a specific sampling event description that will identify the sampler(s) through signature, the date and time of sample collection, type/number containers for each sample, sample matrix, preservatives (if applicable), requested methods of analysis, place/address of sample collection and the waste container number (if applicable).
- For off-site shipping, method of shipping transfer, responsible shipping organization or corporation, and associated air bill or lading number.
- Signatures of custodians relinquishing and receiving custody, along with date and time of the transfer.
- Description of final sample container disposition, along with signature of individual removing sample container from custody.
- Comment section.
- Documentation of discrepancies, breakage or tampering.

All samples and sampling equipment will be identified with unique identification numbers. Sampling equipment will be identified with unique equipment numbers to ensure that all sampling equipment is traceable to equipment cleanliness survey records.

All samples will be uniquely identified to ensure the integrity of the sample and to identify the generator/storage site and date of collection. Because of the high radiation dose rates associated with samples of RH TRU waste, traditional sample tags or labels may be impractical and are not required.

4.1.8.2 Quality Assurance Objectives

The following QAOs apply to sampling methodologies:

Precision QAO – Sampling precision is established by comparing the relative percent difference (RPD) between duplicate samples. A nonconformance report shall be issued for any duplicate samples with RPDs greater that 25%. Nonconformance reports shall be dispositioned in accordance with Section 3.5.2.2 of this WCPIP.

Accuracy QAO – Sampling accuracy through the use of standard reference materials shall not be measured. Because waste containers containing RH TRU waste with known quantities of radionuclides are not available, sampling accuracy cannot be determined. Sampling accuracy as a function of sampling cross-contamination will be measured. Sampling equipment will be verified as clean by the use of standard radiological control survey methods.

Representativeness QAO – A sampling plan must be developed by the RH TRU generator site that describes the sampling strategy for obtaining representative samples. This sampling plan must be approved by CBFO and EPA.

Completeness QAO – Sampling completeness shall be expressed as the number of valid samples collected as a percent of the total number of samples collected for each waste stream. The participating sampling facilities are required to achieve a minimum 90 percent completeness.

Comparability QAO – Compliance with the requirements of this section of the WCPIP will ensure comparability between RH TRU waste generator sites.

4.2 Implementation of Characterization Methods to Satisfy DQOs

The DOE has identified waste acceptance criteria that each site must satisfy in order to ship RH TRU waste to the WIPP facility. These are specific characteristics of the waste that need to be determined in order to track the significant waste components and to control the inventory of RH TRU waste in the repository so as to ensure compliance with the requirements of the LWA, the EPA, and the PA. These are grouped by DQO and are discussed in subsequent sections. Specific QAOs for the methods have been described in previous sections. Table 4.5 gives the methods for obtaining the needed information and the corresponding acceptance criteria being met. For all RH TRU waste streams, the AK record must address each of the DQOs. The AK information is then qualified by confirmatory testing using the characterization methods described in Section 4.1 or qualified in accordance with Section 4.3, with the exception of the defense waste determination.

Table 4.5. Characterization Methods and Acceptance Criteria

Characterization Methods	Acceptance Criteria
Acceptable Knowledge	TRU Waste Determination, Total Activity, Activity per Canister, Defense Determination, Physical Form, Residual Liquid
Dose-to-Curie	TRU Waste Determination, Total Activity, Activity per Canister
Visual Examination	Physical Form, Residual Liquid
Radiography	Physical Form, Residual Liquid
Radioassay	TRU Waste Determination, Total Activity, Activity per Canister
Surface Dose Rate	Surface Dose Rate
Count Containers	Metals

4.2.1 TRU Waste Determination

An assessment of the TRU curie-per-gram concentration of waste in each waste stream is necessary to demonstrate the waste contains greater than 100 nCi/g of alpha-emitting TRU radionuclides with half-lives greater than 20 years. In addition, the radionuclide activity (including ^{241}Am, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{233}U, ^{234}U, ^{238}U, ^{90}Sr, and ^{137}Cs) must be reported in the WWIS[4] in order to track the radionuclides of interest. The reported value will indicate the related uncertainty of the measurements. The quantification will include documentation that establishes the basis for the calculation of isotopic distributions.

The following sections describe the methods that will be used to obtain the required information for this DQO (see Section 4.1 for the methods and their associated QAOs).

[4] The WWIS is used by the DOE to track waste parameters and their uncertainty as required by the EPA WIPP Certification: "However, since DOE's waste limits do not address uncertainty, the Department must account for uncertainty in the quantification of waste components when tracking compliance with the waste limits."

4.2.1.1 Dose-to-Curie Conversion

Dose-to-curie conversions for radionuclide activity are estimates based on a dose rate measurement taken with a calibrated instrument. An isotopic conversion factor is used to relate the dose to radionuclide activity. The conversion factor is based on documented studies concerning the isotopic mix in the waste as defined by its origin and computer modeling (from a program such as ORIGEN) or by sampling and analysis. The study will be referenced in the site's certification documentation.

4.2.1.2 Qualification of AK Information

Radiological characterization information obtained prior to implementing a QA program that meets the requirements of the CBFO QAPD may be qualified in accordance with Section 4.3. Plans for qualification of such data require review and approval by CBFO and the process used must be audited by CBFO before waste characterized in this manner may be shipped to the WIPP.

4.2.1.3 Radioassay Method

If a site has a radioassay system that is capable of performing measurements on containers of RH TRU waste, and the system meets the program requirements of Section 4.1.5.1, a site can make measurements with this equipment. Sites may also use DA to determine the TRU curie-per-gram concentration of the waste. Sites are to report activity to meet two requirements: the calculation to show that the waste meets or exceeds the threshold for classification as TRU waste (100 nCi/g), and the requirement to report the radionuclide activity for purposes of tracking.

4.2.2 Total Activity

An estimate of the total curie content of the waste in each waste stream is necessary to comply with the LWA limit of 5.1 million curies of RH TRU waste. The following sections provide the methods that will be used to obtain the required information for this DQO.

4.2.2.1 Dose-to-Curie Conversion

DTC conversions for total activity are estimates based on a dose rate measurement taken with a calibrated instrument. An isotopic conversion factor is used to relate the dose to total activity. The conversion factor will be based on a documented study concerning the isotopic mix in the waste as defined by its origin and computer modeling (from a program such as ORIGEN) or by sampling and analysis. The study will be referenced in the site's certification documentation.

4.2.2.2 Qualification of AK Information

Radiological characterization information obtained prior to implementing a QA program that meets the requirements of the CBFO QAPD may be qualified in accordance with Section 4.3. Plans for qualification of such data require review and approval by CBFO, and the process used must be audited by CBFO before waste characterized in this manner may be shipped to the WIPP.

4.2.2.3 Radioassay Method

If a site has a radioassay system that is capable of performing measurements on containers of RH TRU waste, and the system meets the program requirements of Section 4.1.5.1, a site can use the system to make measurements. Sites may also use DA to determine the total activity of the waste. Sites are to report total activity to meet the LWA tracking requirement.

4.2.3 Activity Limit Per Canister

An estimate of the activity of the waste in each container is determined. That value will then be averaged over the volume of the RH TRU canister to ensure compliance with the LWA limit of 23 curies per liter. The following sections provide the methods that will be used to obtain the required information for this DQO.

4.2.3.1 Dose-to-Curie Conversion

Dose-to-curie conversions for total activity are estimates based on a dose-rate measurement taken with a calibrated field instrument. A radionuclide conversion factor is used to relate the dose to total activity. The conversion factor will be based on a documented study concerning the radionuclide mix in the waste as defined by its origin and computer modeling (from a program such as ORIGEN), or by sampling and analysis. The study will be referenced in the site's certification documentation.

4.2.3.2 Qualification of AK Information

Radiological characterization information obtained prior to implementing a QA program that meets the requirements of the DOE/CBFO QAPD may be qualified in accordance with Section 4.3. Plans for qualification of such data require review and approval by CBFO and the process used must be audited by CBFO before waste characterized in this manner may be shipped to the WIPP.

4.2.3.3 Radioassay Method

If a site has a radioassay system that is capable of performing measurements on containers of RH TRU waste, and the system meets the program requirements of Section 4.1.5.1, a site can use the system to make measurements. Sites may also use DA to determine the activity per liter of the waste. Sites are to calculate and report activity per canister to meet the LWA tracking requirement.

4.2.4 RH Determination

The dose rate from the payload container must be known to demonstrate that the waste is RH, to comply with the disposal limitations, and to allow the WIPP to track the dose rates to ensure that less than five percent of the payload containers have dose rates greater than 100 rem/hr. The following sections provide the methods that will be used to obtain the required information for this DQO.

4.2.4.1 Compliance Methods for Surface Dose Rate

Payload container dose rates must be measured and reported using calibrated field instruments that meet calibration tolerances defined by the manufacturer.

4.2.5 Waste Generated by Atomic Energy Defense Activities

Only AK can be used to determine this parameter. AK documentation describes the origin of the waste. Source documents will be included in the AK record that establish the defense-related activities performed at the site and how this work resulted in the generation of the waste. Documentation such as studies or reports generated as a result of the work, contracts or payment schedules that establish the nature of the work, correspondence concerning the work, interviews with personnel directly involved with the work, or material transfer records that establish the defense nature of the material, will be considered adequate documentation that the material was generated by defense-related activities.

If defense waste is co-mingled with non-defense waste, the description will explain how the wastes were co-mingled, and why they cannot be segregated. If a non-defense waste has been mixed with a defense waste and it is not feasible to segregate it, it is considered defense waste.

4.2.6 Physical Form

AK information will be used to establish the physical form of waste and as the basis to prepare the waste packaging procedures for waste not yet in containers. The SCGs are S3000, solidified solids; S4000, soil/gravel; and S5000, debris. The SCG indicates the physical form of the waste. The identification of physical form applies to the entire waste stream and is based on the majority of the waste stream. That is to say a stream that has mostly debris may also have homogeneous solids and soils/gravels. The following sections provide the methods that will be used to obtain the required information for this DQO.

4.2.6.1 Qualification of AK Information

Information documenting the physical form of the waste obtained prior to implementing a QA program that meets the requirements of the CBFO QAPD may be qualified in accordance with Section 4.3. Plans for qualification of such data require review and approval by CBFO and the process used must be audited by CBFO before waste characterized in this manner may be shipped to the WIPP.

4.2.6.2 Visual Examination

For RH TRU waste that requires packaging or repackaging, 100 percent of the waste will be subjected to VE in accordance with the requirements of Section 4.1.2. A subpopulation of those RH TRU wastes that are already packaged in payload containers may be subjected to VE (or radiography). A minimum of 10 percent of the packaged waste will be subjected to VE (or radiography). If the physical form of the waste does not match the waste stream description (including the packaging configuration) in this subpopulation, an additional 10 percent of the packaged waste will be subject to VE (or radiography). If additional waste is identified that does not match the waste stream description (including the packaging configuration) in this second subpopulation, the entire waste stream must be subjected to VE (or radiography). This is

referred to as 10-10-All. When implementing the 10-10-All method, VE shall be performed in accordance with Section 4.1.2 and radiography shall be performed in accordance with Section 4.1.4. If the generator site requires other waste characteristics to be determined, (e.g., fill percentage, primary container contents, or other matrix information) in order to implement NDA or DTC, these characteristics will be evaluated as part of the waste stream description when implementing the 10-10-All method.

Alternatively, for RH TRU waste that is already packaged in payload containers, AK information concerning the physical form of the waste may be qualified. The requirements for qualification are contained in Section 4.3.

4.2.6.3 Radiography

Radiography may be used to establish the physical form of the waste. The examination will be recorded on a signed data form accompanied by visual evidence such as audio/videotape, photographs, or other unalterable medium.

4.2.7 Residual Liquids

Residual liquids in excess of one percent are prohibited in RH TRU waste. By maintaining residual liquid content below the one percent limit, the waste remains consistent with an assumption used in the PA. The following sections provide the methods that will be used to obtain the required information for this DQO. These methods, along with their associated QAOs, are described in Section 4.1.

4.2.7.1 Qualification of AK Information

Information documenting the absence of free liquids in the waste obtained prior to implementing a QA program that meets the requirements of the CBFO QAPD may be qualified in accordance with Section 4.3. Plans for qualification of such data require review and approval by CBFO and the process used must be audited by CBFO before waste characterized in this manner may be shipped to the WIPP.

4.2.7.2 Visual Examination

For RH TRU waste that requires packaging or repackaging, 100 percent of the waste will be subjected to VE. A subpopulation of those RH TRU wastes that are already packaged in payload containers may be subjected to VE (or radiography). A minimum of 10 percent of the packaged waste will be subjected to VE (or radiography). If residual liquids in excess of one percent are identified in this subpopulation, an additional 10 percent of the packaged waste will be subject to VE (or radiography). If additional residual liquids in excess of one percent are identified in this second subpopulation, then the entire waste stream must be subjected to VE (or radiography). This is referred to as 10-10-All.

Alternatively, for RH TRU waste that is already packaged in payload containers, AK information concerning residual liquids may be qualified. These requirements for qualification are contained in Section 4.3.

4.2.7.3 Radiography

Radiography may be used to establish the absence of excess residual liquid in the waste. The results of the examination will be recorded on a signed data form accompanied by visual evidence such as audio/videotape or other unalterable media.

4.2.8 Metals

The amount of ferrous and nonferrous materials will be determined by counting the number of canisters disposed of multiplied by the construction weights of each type of material in RH TRU canisters. These parameters will be tracked by the WWIS.

4.2.9 Cellulose, Plastic, and Rubber (CPR)

Visual examination, radiography, and qualification of AK information are the primary methods for determining this parameter on a waste stream basis. Each is capable of determining the physical form of the waste. The amount of CPR for debris waste (S5000) will be determined by multiplying the volume of the waste container by the maximum loading density of plastic (620 kg/m^3). Weights up to the net weight of the waste will be assigned using this method. The derived weight will be entered into WWIS with a waste material parameter type of "plastic." For soils and gravel (S4000), the net weight of the waste will be entered into the WWIS with a waste material parameter type of "soil." For homogeneous solids (S3000), the net weight of the waste will be entered into the WWIS with the waste material parameter type appropriate to the waste (e.g., solidified inorganic material, solidified organic material, cement). For S3000 and S4000 wastes that also contain debris, the generator sites will estimate the weight of debris in each payload container of waste. The debris in S3000 and S4000 wastes will be entered into WWIS with a waste material parameter type of "plastic." For all summary category groups, weights for plastics in packaging (e.g., drum liners) will be entered into the WWIS. The total CPR mass in RH TRU waste will be tracked and controlled through the WWIS such that the repository limit on CPR is not exceeded.

4.3 Qualification of AK Information

There may be some RH TRU waste streams for which detailed characterization information exists that was generated prior to the generator site establishing an approved QA program that implements the requirements of the CBFO QAPD. The CBFO QAPD incorporates the EPA-required QA elements from ASME NQA-1-1989 edition, ASME NQA-2a-1990 addenda, part 2.7, of ASME NQA-2-1989 edition, and ASME NQA-3-1989 edition (excluding Section 2.1 (b) and (c) and Section 17.1) as required by 40 CFR §194.22. A QA program meeting these requirements must be applied to waste characterization activities performed under this WCPIP. 40CFR §194.22 also allows qualification of information collected prior to the establishment of a compliant QA program. The information may be qualified by one or a combination of the following four methods:

- Peer review, conducted in a manner compatible with NUREG-1297, *Peer Review for High-Level Nuclear Waste Repositories*, February 1988
- Corroborating data

- Confirmatory testing
- Evidence of a QA program that is equivalent in effect to ASME NQA-1-1989 edition, ASME NQA-2a-1990 addenda, part 2.7, of ASME NQA-2-1989 edition, and ASME NQA-3-1989 edition (excluding Section 2.1 (b) and (c) and Section 17.1).

For all qualification methods, the following requirements apply:

- The qualification process shall be conducted in accordance with approved procedures that provide for documentation of the decision process, the factors used in arriving at the choice of the qualification method, and the decision that the data are qualified for their intended use. Factors to be considered include:
  - qualifications of personnel or organizations generating the data
  - technical adequacy of the equipment and procedures used to collect and analyze the data
  - environmental conditions under which the data were obtained (if germane)
  - quality and reliability of the measurement control program under which the data were generated
  - extent to which data demonstrate properties of interest (e.g., physical, chemical, or radiological)
  - extent to which conditions generating the data may partially meet requirements of the ASME NQA-1-1989 edition, ASME NQA-2a-1990 addenda, part 2.7, of ASME NQA-2-1989 edition, and ASME NQA-3-1989 edition (excluding Section 2.1 (b) and (c) and Section 17.1).
  - prior uses of the data and associated verification processes
  - prior peer or other professional reviews of data and their results
  - extent and reliability of the documentation associated with the data
  - extent and quality of corroborating data or confirmatory testing results
  - degree to which data generating processes where independently audited

Implementation requirements for the use of these methods are described below.

4.3.1 Peer Review

Peer reviews conducted to qualify AK characterization information must comply with the following requirements:

- Generator sites must develop a peer review procedure that complies with the requirements of NUREG-1297, *Peer Review for High-Level Nuclear Waste Repositories*, February 1988.
- The generator site must obtain DOE/CBFO approval of the peer review procedure and the peer review plan prior to conducting the peer review.

- The peer review scope must explicitly define the waste characterization DQOs and QAOs that the peer review panel will be evaluating. The peer review scope must explicitly require the peer review panel to determine whether the data being reviewed satisfy the defined DQOs and QAOs.

The peer review process shall be audited and approved by the CBFO during each peer review process, and prior to shipping to the WIPP RH TRU waste that has been characterized using data approved by peer review.

4.3.2 Corroborating Data

At this time, the use of corroborating data is not approved by CBFO for qualification of AK information as waste characterization data. Generator sites may propose to use corroborating data as a method of data qualification. The use of corroborating data will require revision of this WCPIP and approval of CBFO and EPA prior to shipment to the WIPP of waste characterized using this method.

4.3.3 Confirmatory Testing

Methods for confirming AK are described in Section 4.1. Confirmation methods include:

- 100 percent VE at the time of packaging
- 10-10-All
- obtaining a representative number of samples from the waste stream or waste stream lot to confirm AK on isotopic distribution
- 100% NDA
- DA
- DTC

Use of the confirmatory testing methods described in Section 4.1 shall be described in the Waste Certification Plan described in Section 3.2.2.

If a generator site proposes to qualify AK information by means of confirmatory testing other than that described in Section 4.1, the requirements of Section 4.3 apply. Confirmatory testing methods that could be proposed include, but are not limited to:

- Qualification of existing VE or radiography audio/videotapes by the review of a percentage of the tapes by qualified operators
- Qualification of existing radiological characterization data by analyzing representative samples of the waste
- Qualification of existing waste container packaging records by VE or radiography of a representative subpopulation of the waste
- Qualification of existing radiological sampling and analytical information by the use of confirmatory modeling (e.g., ORIGEN)

Generator sites that propose to use confirmatory testing to qualify AK information as characterization data must submit a confirmatory testing plan to CBFO for review and approval. This plan must include:

- A description of the waste stream or waste stream lots to which the plan applies
- An explicit description of the waste characterization DQOs and QAOs that will be satisfied with the data being qualified
- A description of the DQOs and QAOs that will not be confirmed with the data being qualified and an explanation of how compliance with those DQOs and QAOs will be demonstrated
- A description of the confirmatory testing proposed, including the percentage of waste containers that will be subject to confirmatory testing
- A description of how the tested subpopulation will be representative of the waste stream or waste stream lot
- Quantitative acceptance criteria for determining that the AK information in question can be qualified as characterization information

Prior to shipping waste to the WIPP that has been characterized using data qualified via confirmatory testing under this section, the confirmatory testing processes shall be audited and approved by the DOE/CBFO.

4.3.4 Equivalent QA Program

To qualify AK information using an equivalent QA program, the generator site must be able to demonstrate that the program in use at the time the data were generated implemented requirements equivalent in effect to the applicable requirements of ASME NQA-1-1989 edition, ASME NQA-2a-1990 addenda, part 2.7, of ASME NQA-2-1989 edition, and ASME NQA-3-1989 edition (excluding Section 2.1 (b) and (c) and Section 17.1).. Implementation of the QA program on the waste characterization program that generated the AK information must be auditable. The following records, at a minimum, must exist and be retrievable:

- Evidence that the organization performing the work identified persons or organizations responsible for verifying quality with sufficient independence from cost and schedule considerations (e.g., organizational charts and QA policies)
- Training records for waste characterization and verification personnel
- Assessment records (audits and surveillances)
- Nonconformance and corrective action records
- Procurement documentation for items and services that could affect the quality of the characterization data
- Approved QA plans and programs
- Standard operating procedures used for characterization and QA activities

- Document control records that demonstrate that documents were reviewed and approved in accordance with procedural requirements
- Calibration records
- Software qualification records
- Documented and verifiable evidence that a records program was in existence that required records important to quality be controlled, stored, maintained and retrievable.

Generator sites proposing to use the equivalent QA program method for qualifying AK information as characterization data shall submit a "procedure matrix" providing a crosswalk that identifies the generator sites plans and procedures that implemented the applicable requirements of ASME NQA-1-1989 edition, ASME NQA-2a-1990 addenda, part 2.7, of ASME NQA-2-1989 edition, and ASME NQA-3-1989 edition (excluding Section 2.1 (b) and (c) and Section 17.1). were implemented. Those ASME NQA elements that are determined to not be applicable to RH TRU waste characterization activities will be identified on the matrix along with a description of why the element is not applicable. The generator site shall also submit plans and procedures referenced on the matrix for CBFO review. The matrix and associated plans and procedures must include the applicable document revisions that were in affect when the AK information was originally generated.

Prior to shipping waste to the WIPP that has been characterized using data qualified under an equivalent QA program, the site's documentation of an equivalent QA program shall be audited and approved by the DOE/CBFO.

5.0 References

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Attachment A

Acceptable Knowledge Procedure for Remote-Handled TRU Waste

ACCEPTABLE KNOWLEDGE PROCEDURE FOR REMOTE HANDLED TRU WASTE

Rev. 0D

October30, 2003

Waste Isolation Pilot Plant
Carlsbad, New Mexico

1.0 Purpose

This procedure describes the process for the identification, compilation, documentation, qualification and reconciliation of acceptable knowledge (AK) for remote-handled (RH) transuranic (TRU) waste to be disposed of at the Waste Isolation Pilot Plant (WIPP). This procedure describes the process used to meet the data quality objectives (DQOs) established through the U. S. Environmental Protection Agency (EPA) regulatory requirements for the RH TRU waste characterization program.

2.0 Scope

The AK process is used as a method to characterize RH TRU waste and support demonstration of compliance with applicable EPA regulatory requirements.

3.0 Responsibilities

AK personnel:

- Identify and compile AK source documents that will be used to characterize the waste
- Use compiled information to characterize the waste and document any and all pertinent information
- Compile AK information to demonstrate compliance with the applicable EPA RH TRU waste DQOs
- Assign unique tracking numbers to AK source documents
- Write AK source document summaries, identifying the relevant information and noting any limitations associated with source documents
- Resolve discrepancies in or between AK source documents
- Based upon compiled information, delineate waste streams and assign waste stream numbers
- Recommend the process for the qualification of all AK information
- Compile the AK information into an auditable record
- Demonstrate compliance with applicable DQOs
- Develop an AK Summary Report for each RH TRU waste stream in accordance with the format described in Attachment 1
- Review and concur with the Waste Stream Profile Form

Site Project Manager (SPM):

- Review the AK source document summaries for source documents listed on the source document reference list to ensure adequacy of AK information

- Review the results of the qualification of AK information by a) confirmatory testing, b) equivalent QA, c) peer review, or d) corroborative data to determine if the AK information compiled can be used for DQO compliance
- Document the reconciliation of AK confirmation data with the AK record
- Review and approve the AK Summary Report and any confirmatory data compiled and verify that all DQOs are met, documenting this compliance in a characterization reconciliation report (CRR) that is an attachment to the AK Summary Report. The CRR, in a checklist format, identifies the individual DQO, the data compiled that satisfies the DQO, the sources of those data, and how the data were qualified in accordance with 40 CFR §192.22(b)
- Complete the Waste Stream Profile Form (Attachment 6)

Site Project Quality Assurance (SPQA) Officer

- Perform duties and responsibilities described in Appendix E of the CBFO QAPD
- Ensure that all required data reviews have been performed and documented.
- Review the AK Summary Report to assess compliance with the WCPIP
- Prepare an AK Accuracy report as required by WCPIP Section 4.1.1.2

4.0 Training

Generator/storage site personnel responsible for compiling AK, characterizing RH TRU waste streams using the AK process, and assessing the AK characterization shall be qualified and trained in:

- The RH TRU WIPP Waste Characterization Program Implementation Plan (WCPIP)
- The nonconformance and corrective action process
- This procedure
- Site-specific training relative to the contents of the site's waste streams
- Determining radiological contents of individual containers

5.0 Compiling AK Documentation

5.1 Research relevant information to support characterization of the RH TRU waste stream. Personnel who will be responsible for characterization of the RH TRU waste stream(s) of interest should be involved in the process of AK compilation to ensure that adequate AK information is compiled. Sources of AK information may include:

- Published documents and controlled databases
- Unpublished data
- Internal procedures and notes such as logbooks, correspondence, such as memoranda, letters, telephone logs, interviews, and e-mails

- Engineering documents
- Mission statements
- Procurement documents

5.2 AK personnel compile available relevant information that can be used to characterize the waste and help delineate waste streams. This information may include:

- Previous NDA, radiochemistry, dosimetry, and nondestructive examination (NDE) data
- Waste generating procedures
- Physical, chemical and radionuclide inputs to the process
- Time period that the process took place
- Facilities involved
- Types of waste generated (waste material parameters)
- Process descriptions and flow diagrams
- Packaging logs and video tapes
- Material Safety Data Sheets
- Procurement records
- Administrative controls used as a basis for the absence of residual liquids.
- The information as compiled should include as much container-specific information as is available such as radionuclide, waste material parameter data and the presence of prohibited items from waste container input forms, data sheets, or logbooks.

5.3 If correlations and similarities between CH TRU and RH TRU waste operations at the generator/storage site can be demonstrated, include characterization information for the CH TRU waste as part of the RH TRU waste stream AK information to meet the required DQOs. Such correlations must be documented on the Correlation and Surrogate Summary Form (Attachment 3) and included as part of the AK Summary Report.

5.4 If correlations and similarities with the RH TRU waste operations at other generator/storage sites can be demonstrated, include characterization information for that RH TRU waste stream as part of the AK information to meet the required DQOs. Such correlations must be documented on the Correlation and Surrogate Summary Form (Attachment 3) and included as part of the AK Summary Report.

5.5 Identify the source documents and records that will be used in the process of compiling the AK record to assist in characterizing the waste, assign them a number unique to the site and list them on the AK Source Document Reference List (Attachment 2). A source document summary (Attachment 5) shall be developed for each source document (or interview) that provides a summary of the relevant information in the AK source document. Limitations of the

information in the AK source document shall be listed on the AK source document summary. The AK Source Document Summaries and the AK Source Document Reference List shall be maintained in an auditable file and reviewed and updated as necessary.

5.6 Identify and resolve discrepancies in the AK record through the compilation of additional AK information, which may include the interview of additional personnel. In the effort to resolve discrepancies, the site shall apply the most conservative characteristics to the waste steam based on the available AK information. For example, the site may chose to conservatively assign the presence of a radionuclide based upon discrepant AK. AK discrepancy resolutions must be documented in the AK record and referenced in the source document reference list (Attachment 2). Discrepancy resolutions must identify the affected waste stream(s), identify all relevant AK source documents, state the nature of the discrepancy, and make conservative assignments unless otherwise justified. If discrepancies in the AK record cannot be resolved or if the resolution results in failure to meet a DQO, the waste cannot be approved for shipment to the WIPP without further evaluation.

6.0 Characterize the Waste and Prepare the AK Summary Report

6.1 From a review of the AK documentation, AK personnel will delineate a waste stream consisting of waste material generated from a single process or activity, or waste with similar physical, chemical, and radiological properties, and assign a waste stream number.

6.2 AK personnel examine the compiled AK information and develop documentation relevant for demonstrating compliance with each of the EPA RH DQOs. If there is insufficient AK information to address each of the DQOs, the sites shall collect additional AK. For each of the DQOs listed in the report, the AK personnel must clearly identify the DQO and supporting AK information, justify the assignments/conclusions, reference the AK source documents and applicable pages supporting the assignments/conclusions, and indicate by which method of 40 CFR §194.22(b) these AK data are being qualified (if applicable). Information used to establish compliance with a DQO, with the exception of the defense waste determination, must be qualified in accordance with Section 4.3 of the WCPIP, or qualified by confirmatory testing using the characterization methods described in Section 4.1 of the WCPIP. See Section 7.0 for additional discussion of qualification methodologies. The applicable DQOs are addressed as follows.

- Review the AK information to determine whether the waste was generated by defense activities or is commingled with RH TRU waste generated by defense activities. This determination will be established by the AK data compiled.
- Review the AK information to determine the nuclear properties of the waste stream. The nuclear properties relevant to RH TRU waste include:
  - TRU activity of the waste stream greater than 100 nCi/g of waste. Is this TRU waste?

- Dose equivalent rate equal to or greater than 200 mrem/hr and less than 1,000 rem/hr at the surface of the payload container. Is this RH waste?
- Report activity of the 10 required radionuclides (TRU isotopes ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, and ^{241}Am; and non-TRU isotopes ^{137}Cs, ^{90}Sr, ^{233}U, ^{234}U, and ^{238}U)
- Total activity in each canister. Must be less than 23 curies per liter.

Note: If the waste is not defense waste, TRU waste, or RH waste, it will be reassigned. The defense determination will be made on an entire waste stream. TRU and RH designations will initially be made on a waste stream basis but will be verified on a container basis.

6.3 If there are AK records that can be used to calculate, compute, or otherwise derive the total activity and/or TRU activity of the waste and the records, a) can be qualified per Section 7, or b) were collected under an EPA-approved program, those records may be used to meet all or part of the above radiological DQO characterization objectives. Otherwise, the above characterization objectives must be met by collecting additional radionuclide data during the packaging/repackaging activity, if applicable, and using, for example, the dose-to-curie conversion method to meet the radiological DQOs. This additional radionuclide information, if collected by a CBFO- and EPA-approved technique, could be used without further qualification to supplement the characterization process. For example, it could provide needed data for the DTC process.

6.4 AK personnel review the information in the source documents to determine the physical form of the waste at the Summary Category Group (SCG) level. The SCGs are:

- S3000 Homogeneous Solids: Homogeneous solids or solid process residues defined as solid material that do not meet the criteria for classification as debris. This SCG includes wastes that are a majority by volume solid process residues.
- S4000 Soil/Gravel: Waste streams that are at a majority by volume soil/gravel.
- S5000 Debris: Heterogeneous waste that are a majority by volume material that meets the criteria for debris. Debris is solid material exceeding a 2.36-inch (60-millimeter) particle size that is intended for disposal and that is a manufactured object, plant or animal matter, or natural geologic material. Particles smaller than 2.36 inches in size may be considered debris if the debris is a manufactured object and if it is not a particle of S3000 or S4000 material.

AK personnel shall also compile sufficient information regarding the waste stream waste material parameters to provide a detailed description of the waste stream in accordance with the format of the AK Summary Report.

6.5 AK personnel review the AK information to determine the absence of residual liquids. This review may include waste packaging procedures and other documented administrative controls, such as training records, that identify control of residual liquids. It may also include previous waste characterization data or information from waste-container-specific packaging logs. The criterion in the DQO is that residual liquids must be less than 1 percent by volume of the waste container.

6.6 AK personnel prepare an AK Summary Report following the format in Attachment 1, including the development of program and waste stream narrative sections. The AK personnel will provide a detailed description of the waste stream including information on, for example, specific waste matrix materials and fill volumes. The report shall address all of the DQOs as noted in previous steps with appropriate justifications and references in the text.

6.7 AK personnel send the completed AK Waste Summary Report, AK Source Document Reference List, Correlation and Surrogate Summary Form, AK discrepancy resolution documentation and the AK source document summaries to the SPM for review.

6.8 AK personnel recommend to the SPM the process(es) for the qualification of the AK information based on an assessment of which are most appropriate for the type of AK information complied.

7.0 Qualification of the AK Characterization Information

Information compiled into the AK record and applied in the AK Summary Report to RH Characterization DQOs may be qualified by one or more of the four processes listed in 40 CFR 194.22(b). Requirements for implementing these qualification processes can be found in Section 4.3 of the Waste Characterization Program Implementation Plan (DOE/WIPP-02-3214).

8.0 Reconciling Compiled AK Information

The SPM reviews the AK Summary Report, AK Source Document Reference List, Correlation and Surrogate Summary Forms, the referenced source document summaries, if applicable, batch data reports from any confirmatory activities such as VE or NDA and, if applicable, supplemental data collected during repackaging using an approved technique, to determine if the AK record is reconciled and is adequate to characterize the waste stream or waste stream lot and satisfy the relevant DQOs. Discrepancies between the AK record and confirmatory test results identified during this reconciliation process must be resolved and documented. The discrepancy resolution process may involve a reevaluation of the AK record, reassignment of waste stream parameters and a revision to the AK Summary Report.

The SQAO, consistent with the requirements of Section 4.1.1.2 of the WCPIP, will review the AK Summary Report, confirmatory test data and identified AK discrepancies, and prepare an AK Accuracy Report. This report will identify the percentage of containers that have been assigned to another SCG. It will also identify the percentage of containers for which there are significant discrepancies in radionuclide information between the AK record and measured values. What constitutes a significant discrepancy will depend on site- and waste stream-specific considerations. The AK Accuracy Report will be updated annually. If AK accuracy falls below

90%, the site shall document this as a significant condition adverse to quality as defined by the CBFO QAPD. The site shall notify the CBFO of this condition and implement appropriate corrective actions before proceeding with further characterization activities on the affected waste stream(s).

The SPM reviews the qualified AK characterization information and the corresponding required DQOs and documents this review in an RH TRU waste AK Characterization Reconciliation Report (CRR). At a minimum the CRR shall include:

- Specification of applicable site and waste stream.
- A listing of each DQO
- Data from the AK record that addresses each DQO
- AK source document references that support/provide the data
- A listing of AK record discrepancy resolutions, if any, that are relevant to each DQO
- Documentation, including specific references, of how the AK data for each DQO were qualified, such as batch data reports, corroborative data, proceedings of a peer review, etc.
- Radiography and/or visual examination summary to document that liquids greater than 1 percent are absent from the waste and to confirm AK concerning the physical properties of the waste
- A summary presentation of radiological measurement data used to meet the DQOs and to confirm AK
- A complete AK summary
- A complete listing of all container identification numbers used to generate the WSPF, cross-referenced to each batch data report.
- A listing of AK discrepancies generated by an AK qualification process and the corresponding resolutions
- Signature of the SPM

The SPM also verifies that the applicable QAOs (accuracy, completeness, representativeness, and comparability) associated with the AK process have been met. Changes to the AK Summary Report and attachments based upon this review will be reviewed by AK personnel and properly documented.

9.0 Preparation of the Waste Stream Profile Form

The SPM completes the Waste Stream Profile Form (WSPF) (Attachment 4) based on AK characterization and confirmation results and other relevant characterization data. The WSPF, the RH AK Summary Report and the Characterization Reconciliation Report, resulting from waste characterization activities, shall be transmitted to the Department of Energy Carlsbad Field Office (DOE/CBFO). Only RH TRU waste that is characterized in accordance with the EPA requirements and WCPIP will be accepted for disposal at the WIPP.

10.0 Records

The records that may be generated as part of this procedure include:

- AK Summary Report (Attachment 1)
- AK Source Document Reference List (Attachment 2)
- Correlation and Surrogate Summary Form (Attachment 3)
- Waste Stream Profile Form (Attachment 4)
- AK Source Document Summary (Attachment 5)
- Characterization Reconciliation Report
- AK Source Documents
- AK Training Records
- AK Discrepancy Resolution Documentation
- AK Accuracy Report

Attachment 1
AK Summary Report

Acceptable Knowledge Summary Report
For
RH TRU Waste

NAME OF THE SITE
NAME OF THE PROCESS

REVISION NUMBER
DATE

Printed Name

APPROVED FOR USE

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<Generate Table of Contents Here>

LIST OF TABLES
LIST OF FIGURES
LIST OF ATTACHMENTS

LIST OF ACRONYMS AND ABBREVIATIONS

DEVELOP AS NEEDED

1.0 EXECUTIVE SUMMARY

UPDATE AS NECESSARY

This document has been prepared for (site) for remote-handled (RH) transuranic (TRU) waste generated and managed by *NAME THE SITE.* The procedure, *Acceptable Knowledge Procedure for Remote-Handled TRU Waste*, describes how acceptable knowledge (AK) is compiled, qualified, reconciled and used to address RH TRU waste DQOs by the (site).

SUMMARIZE THE SITE AND THE PROCESS

This document, along with referenced supporting documents, provides a defensible and auditable record of AK for designated RH TRU waste streams from the *NAME THE PROCESS or Activity* . All documentation used to derive AK information for this report is denoted by alphanumeric designations corresponding to the Source Document Tracking Number (where applicable). References are provided in Appendix 1.

This AK report includes information relating to the facility's history, configuration, equipment, process operations, and waste management practices. Information contained in this report was obtained from numerous sources, including facility safety basis documentation, historical document archives, generator and storage facility waste records and documents, and interviews with cognizant personnel. These RH TRU waste streams were generated from *START DATE* to *END DATE*.

This report compiles data relevant to applicable EPA requirements and provides an auditable record that satisfies WIPP criteria for AK for RH TRU waste.

2.0 WASTE STREAM IDENTIFICATION SUMMARY

Site Where TRU Waste Was Generated: *SITE ADDRESS*

Facility Where TRU Waste Was Generated: *NAME OF FACILITY*

Facility Mission: *DESCRIBE THE MISSION AND HOW THE WASTE WAS GENERATED*

Summary Category Group: *NAME*

Waste Stream Description: *DEFINE THE WASTE STREAM. PROVIDE SUFFICIENT DETAIL TO ALLOW THE CHARACTERIZATION PROCESSES THAT WILL BE USED TO CONFIRM AK TO PERFORM THAT FUNCTION BASED ON THIS DESCRIPTION.*

3.0 ACCEPTABLE KNOWLEDGE DATA AND INFORMATION

DESCRIBE THE AK INFORMATION AND SOURCE OF DATA

Include a summary of the types of information used to summarize AK documentation, identify the sources of waste characterization information used to delineate waste streams and provide a summary of the basis and rationale for delineating each waste stream. This information shall be traceable to referenced source documents.

4.0 PROGRAM INFORMATION

- 4.1 Facility Location, Description, Mission, and Defense Determination
- 4.2 RH TRU Waste Management
  - 4.2.1 Types and Quantities of RH TRU Waste Generated
  - 4.2.2 Description of the Waste Generating Processes

5.0 WASTE STREAM INFORMATION

- 5.1 Area and Building of Generation
- 5.2 Waste Stream Volume and Period of Generation
- 5.3 Waste Generating Activities and Waste Stream Description
- 5.4 Waste Material Parameters
  - 5.4.1 Material Inputs Related to Physical Form
  - 5.4.2 Radiological Characterization
  - 5.4.3 Residual liquids

6.0 QUALIFICATION OF AK INFORMATION

7.0 CONTAINER SPECIFIC INFORMATION

Attachment 2
RH TRU Waste AK Source Document Reference List

References

Source Documents List/Index (based on different categories)

Abbreviation (Example)	Category (Example)
C1	Correspondence
D1	Documents (e.g., published reports)
M1	Miscellaneous (e.g., unpublished information)
P1	Procedures

Site:

Waste Stream/ Waste Stream Lot:

Waste Stream/ Waste Stream Lot Number:

Source Document Tracking #	Title	Document/ Revision #	Source Doc. Page #	Summary

SPM Signature: **Date:**

Attachment 3
RH TRU Waste Correlation and Surrogate Summary Form

Generator/Storage Site:_____
Waste Stream:_____
Waste Used to Correlate:_____
Waste Used as Surrogate:_____

Information	Y/N	Source of Information
Is physical form identified?		
Is absence of residual liquids confirmed?		
Are radiological data described?		

Narrative: (Explain/Justify the Correlation/Surrogate Waste Stream)

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Attachment 4
Waste Stream Profile Form

Waste Stream Profile Number:

Generator Site Name:

Technical Contact:

Generator Site EPA ID:

Technical Contact Phone Number:

WIPP ID:

Summary Category Group:

Waste Stream Name:

Description from the WTWBIR:

Defense Waste: ? Yes ? No Check one: ? CH ? RH

Number of SWBs

Number of Drums

Number of Canisters

Batch Data Report numbers supporting this waste stream characterization:

Applicable TRUCON Content Codes:

Acceptable Knowledge Information [(1)]

(For the following, enter supporting documentation used {i.e., references and dates})

Information Used: (list)

Program Information:

_____

_____

_____

Waste identification/categorization schemes:

Types and quantifies of waste generated:

Correlation of waste streams generated from the same building and process, as applicable:

_____

Waste Stream Information: (list)

_____

_____

_____

_____

Testing, if needed:

Radiography or Visual Examination:

Procedure Title: _____

Number:_____ Date: _____

Waste Stream Profile Form certification

I hereby certify that I have reviewed the information in this Waste Stream Profile Form, and it is complete and accurate to the best of my knowledge. I understand that this information will be made available to regulatory agencies and that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowing violations.

_____ _____ _____

Signature of Site Project Manager Printed Name and Title Date

NOTE: (1) Use back of sheet or continuation sheets, if required.

Attachment 5
RH TRU Waste Acceptable Knowledge Source Document Summary

Waste Stream Number(s):_____		
Site(s):	Source Document Tracking Number:	
Acceptable Knowledge Documentation Type: TRU Waste Management Program Information Waste Stream-Specific Information Supplemental Information		Category: Published Document or Controlled Database Unpublished Data Internal Procedure or Note Correspondence Discrepancy
Title of Source Document:		
Source Document Reference Information (author(s), document and revision number, date, publisher):		
AK #[a]	Source Doc. Page #[b]	AK Information Summary
Source Document Data Limitations (if any):		
Acceptable Knowledge Expert: _____/_____ Date: _____ Print Sign		
[a] Obtain from Acceptable Knowledge Documentation Checklist [b] For microfilm or microfiche, identify box, tape, reel number and location.		

Attachment B
Dose-to-Curie Survey Procedure for Remote-Handled TRU Waste

Dose-to-Curie Survey Procedure for Remote Handled TRU Waste

1.0 Purpose

This procedure is used to determine the total transuranic (TRU) activity concentrations and the individual isotopic activity in containers of remote-handled (RH) TRU waste.

> **NOTE**: This procedure may be revised only to address site-specific formatting, safety, and operational issues.

2.0 Scope

This procedure applies to RH TRU waste packaged in 55-gallon containers. This procedure does not address the radiation protection or container handling requirements that will be imposed by site-specific policies, conditions, and equipment.

3.0 Responsibilities

3.1 Operator:

- Perform dose rate measurements
- Perform dose-to-curie conversions
- Assemble testing batch data report

3.2 Independent Technical Reviewer

Perform independent technical review of the batch data report

3.3 Site Project Manager

Perform review of the testing batch data report

4.0 Training

The operator must be trained in the operation of the equipment and use of the dose-to-curie conversion program.

5.0 Prerequisites

5.1 Obtain a remote-reading ion chamber radiation dose rate instrument.

5.2 Obtain the instrument check source.

5.3 Place the instrument in the instrument jig.

6.0 Dose Rate Procedure

6.1 Verify the instrument is in calibration. Record the instrument number and calibration date on the container data sheet.

6.2 Verify the instrument has acceptable battery life with the battery check function on the instrument. Replace if necessary. Record on the container data sheet.

6.3 Perform a source check the dose rate instrument according to the manufacturer's instructions. Record on the container data sheet.

6.4 Record the date, container number, and operator's name on the container data sheet.

6.5 Record the gross weight on the container data sheet. Calculate the net waste weight by subtracting the container (and liner) weights from the gross weight. Container and liner weights can be average default values based on site procurement records. Record in the "Net Weight" block. Record the gross weight error as reported for the scale calibration.

6.6 Record the fill range as listed on the visual examination or radiography data form on the container data sheet.

6.7 Record the material type as listed on the visual examination or radiography data form on the container data sheet.

6.8 Position the instrument in a standard jig such that it will be focused at the mid-height of the container and centered between the sides. The instrument detector must be 1.0 meters from the container. A jig that exactly positions the instrument with relation to the container is used to ensure reproducible results. Place the remote instrument readout according to site-specific requirements.

6.9 Measure the background radiation dose rate. Record the background dose rate in the "Background" block.

6.10 Estimate the expected container dose rate. Record in the "Estimated Dose Rate" block. Evaluate the expected dose rate with respect to the background dose rate. Background radiation levels must be no greater than one-tenth of the measured RH container value. If it is expected that the background measurements are too high, actions must be taken to reduce the background level or a new location must be found. Once it has been determined that background radiation levels are acceptable, record in the "Background Evaluation" block and continue.

6.11 Position the container with respect to the instrument jig according to site-specific handling instructions. The entire container must be exposed to the detector.

6.12 Record the dose rate in the "Dose Rate 1" block.

6.13 Rotate the container 180 degrees.

6.14 Record the dose rate in the "Dose Rate 2" block.

6.15 Return the container to the staging area according to the site-specific handling instructions.

6.16 Sign and date the sheet

6.17 Repeat for other containers.

7.0 Curie Conversion Procedure

7.1 Enter the date on the conversion record.

7.2 Enter the name of the operator performing the curie conversions on the conversion record.

7.3 Transcribe the procedure and revision number, the container number, the gross weight, net weight, fill range, material type, and the four dose rates from the container data sheet information onto the conversion record in the appropriate fields. The program will automatically calculate the activities.

7.4 Print the conversion record.

7.5 Review the conversion record for technically reasonable results and transcription errors.

7.7 Review the QAO results:

- Precision – The precision QAO is demonstrated by a satisfactory source check of the instrument.
- Accuracy – The accuracy QAO was demonstrated when the instrument was calibrated.
- Representativeness – This was performed when the model was developed, no review necessary.
- Completeness – Ensure the instrument checks were satisfactory and the measured dose rate was at least 10 times greater than the background. Ensure that dose rate measurements were made for each container in the batch.
- Comparability – Ensure the correct revision of the procedure was used.

7.8 Sign and date the sheet

8.0 BDR Preparation and Review

8.1 Obtain and complete the cover sheet.

8.2 Obtain container data sheets and conversion records for no more than 20 containers

8.3 Obtain and attach ITR and SPM data review checklists.

8.4 Submit the testing batch data report to the Independent Technical Reviewer for technical review.

9.0 Independent Technical Review

9.1 Review the spreadsheet for technically reasonable results and transcription errors.

9.2 Verify there is a container data sheet and conversion record for each container listed on the cover sheet.

9.3 Verify the container data sheets are complete and signed.

9.4 Verify the instrument was within it's calibration date, the battery check was satisfactory, and the source check was satisfactory.

9.5 Review the QAO results:

- Precision – The precision QAO is demonstrated by a satisfactory source check of the instrument.
- Accuracy – The accuracy QAO was demonstrated when the instrument was calibrated.
- Representativeness – This was performed when the model was developed, no review necessary.
- Completeness – Ensure the instrument checks were satisfactory and the measured dose rate was at least 10 times greater than the background.
- Comparability – Ensure the correct revision of the procedure was used.

10.0 SPM review

10.1 Verify the Independent Technical Review was performed and the checklist was signed.

10.2 Review the spreadsheet for technically reasonable results and transcription errors.

10.3 Review the QAO results:

- Precision – The precision QAO is demonstrated by a satisfactory source check of the instrument.
- Accuracy – The accuracy QAO was demonstrated when the instrument was calibrated.
- Representativeness – This was performed when the model was developed, no review necessary.
- Completeness – Ensure the instrument checks were satisfactory and the measured dose rate was at least 10 times greater than the background.
- Comparability – Ensure the correct revision of the procedure was used.

Forward completed testing batch data report to site records.

11.0 Records

The following records are generated by this procedure:

Testing batch data report

Attachment 1

CONTAINER DATA SHEET

Date				
Container No.				
Operator				
Procedure and revision				
Inst No.		Calibration due		
Batt Check	Sat/Unsat	Source Check	Sat/Unsat	
Gross Wt.		Error		
Net Weight				
Fill Range	0 –25%	26 – 66%	67 – 90%	>90%
Material Type	Concrete	Steel	Organic	
Background				
Expected Dose rate				
Background Evaluation	Bkg < 10% of the expected highest dose rate?			
Dose rate 1		Dose Rate 2		
Signature		Date		

Attachment 2

DOSE-TO-CURIE CONVERSION RECORD

Date				
Operator				
Procedure and revision				
Container Number				
Gross Wt.				
Net Weight				
Fill Range				
Material Type				
Dose Rate 1				
Dose Rate 2				
Average				
Average within 2 of high and low?				
Isotope	Ratio	Conversion factor	Curie	LLD
Cs137				
Am241				
Pu238				
Pu239				
Pu240				
Pu242				
U233				
U234				
U238				
Sr90				
Total Activity		Error		
TRU Concentration		Error		
Curie per Liter				
OP signature		Date		

Attachment 3

Dose-To-Curie Testing Batch Data Report

Testing Batch Data Report Number

Testing Facility Name

Table of Contents

Containers

1.	2.
3.	4.
5.	6.
7.	8.
9.	10.
11.	12.
13.	14.
15.	16.
17.	18.
19.	20.

Attachment 4

Independent Technical Reviewer Checklist

Batch Data Report Number:

	YES	NO	Comments
The batch data report contains no more than 20 containers.			
There is a container data sheet present for each of the containers listed on the batch data report cover sheet.			
The container data sheets are complete and contain: • Instrument calibration is satisfactory.(Accuracy) • Instrument battery check is satisfactory. • Instrument source check is satisfactory (Precision) • The dose rate was at least 10 times the measured background (Completeness) • The correct revision of the procedure was used (Comparability) • Operator signature			
The QAOs have all been meet.			
The dose rates on the container data sheets are technically reasonable.			
The data has been checked for transcription errors between the container data sheets and the conversion records.			
There is a conversion record present for each of the containers listed on the batch data report cover sheet.			
The conversion records are complete and show: • Total activity concentration is greater than 100 nCi/gm. • Operator signature			

The results shown on the conversion records are technically reasonable.			
The batch data report is complete (i.e., contains the forms listed in the table of contents) for this point of generation.			
Any non-conformance reports generated are contained in the testing batch data report.			

Signature:_____ Date:_____

Independent Technical Reviewer

Attachment 5

Site Project Manager Checklist

Batch Data Report Number:

	YES	NO	Comments
The Independent Technical Review has been completed and signed.			
The results are technically reasonable.			
The data has been checked for transcription errors.			
The applicable QAOs have all been meet. • Instrument calibration is satisfactory.(Accuracy) • Instrument source check is satisfactory (Precision) • The dose rate was at least 10 times the measured background (Completeness) • The correct revision of the procedure was used (Comparability)			
The batch data report is complete (i.e., contains the forms listed in the table of contents).			
Any non-conformance reports generated are contained in the testing batch data report.			

Signature:_____ Date:_____

Site Project Manager

Attachment C
General Procedure for Dose-to-Curie Estimation for Remote-Handled TRU Waste

General Procedure For Dose-to-Curie Estimation for Remote-Handled TRU Waste

1.0 Purpose

This procedure describes a general method and provides program requirements for estimating transuranic and other significant radionuclides in RH TRU waste. This method is referred to as the dose-to-curie (DTC) method. The method involves measuring the gamma dose rate[5] at a fixed distance from the exterior of the waste container and using the results from the analysis described herein to estimate the activity levels (i.e., curie content) of desired isotopes.

2.0 Scope

This procedure applies to RH TRU waste placed in 55-gallon containers having an external gamma dose rate proportional to the distribution of key radioisotopes within the container. This procedure does not address radiation protection or other specific operational requirements for handling RH TRU. Requirements are provided for programmatic elements necessary to implement this methodology including sampling, calculations, and determination of Total Measurement Uncertainty (TMU). Detailed implementation of these components of the DTC methodology will be found in site-specific procedures.

3.0 Responsibilities

Technical Staff

- Identify waste streams potentially containing RH TRU
- Develop and document sampling plan for each waste stream
- Perform statistical analysis of sample results
- Identify operational parameters leading to generation of RH TRU waste
- Perform isotope generation and depletion calculations for operations leading to generation of RH TRU waste
- Develop "Standard Mix" of key radioisotopes for each RH TRU waste stream
- Perform shielding calculations to determine gamma dose rate external to RH TRU containers for each "Standard Mix" of key radioisotopes
- Develop conversion factors for site-specific DTC waste streams
- Propagate components of uncertainty in DTC and determine and document TMU
- Evaluate DTC survey results and determine activities of key radioisotopes in each container.
- Determine if container contents meet RH TRU criteria

[5] The term dose rate (i.e., rads per hour or grays per hour) is used throughout this procedure; however the actual radiation field measurement may be of an exposure rate (roentgens per hour). For gamma-rays in air, at the energies of interest, the exposure rate is very near the dose rate as measured by radiation detectors. Some radiation detectors give results in dose equivalent units (rem per hour or sieverts per hour). The concept of dose equivalency is only defined for radiation doses that result in stochastic effects. For gamma-rays of the energy of interest the absorbed dose rate is related to the dose equivalent rate by a quality factor of unity. Thus, for the purpose of this procedure, all such measured radiation fields are referred to as dose rate regardless of being reported as R/hr, rads/hr, or rem/hr. Appropriate conversions must be made by the user for units of Gy/hr or Sv/hr.

Technical Reviewer

- Perform technical review of documents and analyses performed by the Technical Staff

Site Management

- Ensure that appropriate resources and technical expertise are applied to the implementation and documentation of the DTC methodology including the development of site-specific procedures.
- Ensure that to the extent practicable RH TRU waste is loaded into containers in a manner that facilitates the implementation of the DTC methodology and that appropriate documentation is maintained of the waste placed into containers.

4.0 Training and Qualifications

Technical Staff

One or more individuals with responsibilities defined above shall:

- Have a bachelor of science degree in nuclear engineering or the equivalent knowledge and experience to perform assigned tasks, including:
    - Calculation of reactor neutron spectra
    - Generate ORIGEN format cross sections
    - Perform ORIGEN isotope generation and depletion calculations
    - Ensure that appropriate samples are collected and analyzed from waste
    - Perform shielding calculations of waste containers
- Have a bachelor of science degree in statistics or the equivalent knowledge and experience to perform assigned tasks, including
    - Develop sampling plan to obtain representative samples of waste
    - Propagate uncertainties to determine Total Measurement Uncertainty

Technical Reviewer

One or more individuals performing the technical review functions shall:

- Have the equivalent qualifications necessary to have originally performed the task under review.
- Have at least 5 years experience in the technical area applicable to the review task.

5.0 Loading Waste Containers

The following criteria shall be implemented when waste is newly generated or not yet packaged into containers:

- Newly generated waste shall be sampled prior to placement into waste containers.

- Waste should be loaded into containers in a homogeneous fashion. The RH TRU contamination on or in the waste should be distributed randomly throughout the waste container. Random distribution means there shall be no specific placement of particular waste components within any container. Waste pieces should be relatively small (less than about 4 inches) and like-type materials should be grouped by containers.
- Waste containers should contain either steel (or other metals), concrete, or organics (wood, paper, rags, etc.) with a minimum of mixing of dissimilar types of materials.
- Waste sludge should be well mixed, to the extent practicable, prior to being placed in the waste containers.
- The RH TRU waste generated shall be placed in a steel liner which is, in turn, placed in a steel 55-gallon drum. The steel liner has an outside diameter of 19.5 inches (49.53 cm) and a height of 32.25 inches (91.92 cm). The top and bottom of the liner circular steel plates have a thickness of 0.5 inches (1.27 cm). The liner wall is 0.105 inches (0.27 cm) thick. The liner has a tare weight of 160 pounds (72.7 kg). The liner can hold 39.5 gallons (149.7 liters) of waste. The liner shall eventually be placed in a standard steel 55-gallon drum.
- The type of waste (steel, concrete, organics), in each container shall be recorded. The height of the waste in the container shall be recorded as being in one of the following categories: less than 25% full, 25% to 66% full, 66% to 90% full, more than 90% full. A video system can be useful as a means of documenting the filling of each waste container.

6.0 Sampling

Representative sampling of each waste stream is the preferred method for characterizing the isotopic distribution of key radioisotopes. Existing sampling and analytical data may be used, if the data can be qualified in accordance with the requirements of Section 4.3 of the WCPIP.

6.1 Sampling Plan

Each site will develop a sampling plan prior that will ensure the isotopic ratios developed are representative of the subject waste stream. Requirements for the sampling plan include:

- A sampling plan shall be developed and documented for each RH TRU waste stream. The sampling plan is a critical component in the development of representative samples and shall be developed using the guidance provided in EPA QA/G5-S and QA/G-9.
- The sampling plan shall be designed to keep personnel radiation exposure to as low as reasonably achievable (ALARA) and result in samples that are representative of that waste stream.
- The form, distribution, and type of waste comprising RH TRU waste shall be considered in developing a sampling plan.
    - The variety in operations and the nature of the generation of RH TRU waste is such that a single method of sampling the waste cannot be applied across the DOE complex.
    - Some waste streams, e.g. well mixed sludge may be relatively easy to sample, but the method used to collect the sample must be representative of the waste.

- Newly generated waste or waste not yet packaged shall be sampled prior to packaging.
- If existing sampling data cannot be qualified in accordance with Section 4.3 of the WCPIP, waste already packaged shall be directly sampled.
- Wastes comprised of paper, plastics, and other materials with surface contamination may be subject to sampling through removal of a small amount of surface material.
- RH TRU material embedded in concrete or other solid material may require samples to be obtained from within the material.
- Each site shall consider the best means for obtaining samples that are representative of the RH TRU content of a particular waste stream.

- The sampling plan shall be submitted to CBFO for review and approval.

6.2 Sample Collection

Samples will be collected according to the following:

- Each RH TRU waste stream shall have a sufficient number of samples to determine the abundance of key radioisotopes present in each waste stream. Key radioisotopes include the gamma-ray emitters which account for the majority of the dose rate and certain uranium and TRU isotopes.
- A statistically sound method shall be used to determine the selection of samples from each waste stream. Guidance on developing an effective sampling strategy is provided in the reference section.
- The total number of samples collected will be determined based on the type of waste and the comparison of the sample results with the calculated results.

6.3 Sample Analysis

Analysis will be performed in accordance with the following:

- These samples shall be evaluated using gamma spectroscopy and radiochemistry, including alpha spectroscopy, or other appropriate methods to determine the relative activity levels of key radioisotopes. Destructive assay techniques shall meet the requirements of Section 4.1.5.2 of the WCPIP.
- The minimum detectible activity levels and measurement uncertainty shall be recorded for each sample.
- The sampling approach shall result in key isotopes for each waste stream having a mean value and associated uncertainty.
- There are 10 radioisotopes that shall be tracked for TRU wastes. Those isotopes are: Am-241, Pu-238, Pu-239, Pu-240, Pu-242, U-233, U-234, U-238, Sr-90, and Cs-137. The sample analysis should provide data on the activity of as many of these isotopes as possible.

- The sampling shall be such that a high level of confidence is obtained that the activity distribution, mean, and variance accurately represent the waste stream. The sampling should be at a 95 percent confidence level or higher.
- The sampling approach shall result in an activity distribution being generated for key isotopes.
- The measured activity distributions for isotopes shall be compared with one another and that comparison shall be documented. The measured activity distributions should be similar (i.e., of a log-normal distribution) in order for the DTC method to be effective.
- The isotopic activity levels shall be normalized to the activity of that isotope responsible for the preponderance of the external dose rate (the major isotope). The normalization allows for a consistent basis for comparison of the activity distributions without having to maintain a sample mass basis. For RH TRU waste generated from spent nuclear fuel, the fission product Cs-137 is likely to be the isotope producing the vast majority of the dose rate. If spent nuclear fuel has undergone a separations process, the RH TRU waste may have less Cs-137 and other gamma emitting isotopes may produce the majority of the dose rate.
- It may not be possible to measure activities for each of the 10 isotopes by sampling. Some isotopes activities may be less than the lower limit of detection or could be masked by other isotopes. In such cases calculations shall be used to augment the sample results.

  Note: If the primary gamma emitting isotope's activity does not vary linearly with the activity of the TRU isotopes, the DTC method will not be effective. Such would be the case if the activity distribution for the primary gamma-emitting isotope is dissimilar to the activity distributions of the TRU isotopes. For example, if Co-60, an activation product, is the primary gamma emitting isotope a bi-modal or other activity distribution could be observed that differs significantly from that of TRU isotopes.

7.0 Characterization of Waste by Calculation

Calculations of isotopic activity levels are performed by considering the production and depletion of these isotopes in a nuclear reactor, after reactor shutdown, upon removal of certain chemical species in reprocessing or separations processes, and after additional decay. Production of an isotope can continue after removal from a nuclear reactor as a result of decay of another parent isotope. For the purpose of this procedure, it is assumed that all TRU is the result of nuclear reactor operation. Transuranic isotopes produced by other means will require a similar calculation. Sophisticated computer programs exist to calculate these isotopic production and depletion effects. The calculations will meet the following requirements:

- Calculations shall be performed to determine the relative activity levels of key radioisotopes to augment sample data. Such augmentation is necessary when sample results are incomplete in establishing relative activity levels for Am-241, Pu-238, Pu-239, Pu-240, Pu-242, U-233, U-234, U-238, Sr-90, and Cs-137.
- These calculations shall be performed using computer programs that account for the beginning conditions of the fuel used to produce the TRU isotopes, the exposure of this fuel to neutron fields in a nuclear reactor, and the change in radioisotope activities following irradiation.

- The appropriate cross-sections shall be used or generated for each reactor condition.
- The reactor neutron energy spectrum shall be known or calculated to determine the effective cross sections of isotopes leading to the creation of Am-241, Pu-238, Pu-239, Pu-240,
  Pu-242, U-233, U-234, U-238, Sr-90, and Cs-137. The characteristics of the reactor's neutron flux energy spectrum affects the effective cross sections for fission and transmutation. For many reactor types these calculations have been performed and cross section libraries exist.
- The fuel exposure history shall be used in the isotope generation and depletion calculation. RH TRU waste in a particular waste stream may have been produced as the result of numerous campaigns involving differing exposure and decay times and differing fuel properties.

    - In order to avoid calculating each campaign, assuming that such detail is available, a strategy shall be developed to perform a set of calculations that represent the range of exposure, decay, and specific fuel properties. The fuel properties include the concentration of fissile and fertile isotopes. For production of plutonium, the U-235 enrichment is a key characteristic.
    - The isotope generation and depletion calculations strategy shall require that parametric calculations represent the entire range of conditions leading to RH TRU waste.
    - These parameters may include fuel enrichment, burn-up, and decay. Post irradiation processing could introduce a fourth parameter to consider. The span of the evaluated parameters are considered AK information and will be compiled and documented for the waste under the AK process.
    - It may be necessary to take additional steps to obtain information to bound the range of operational parameters. The additional information may be obtained through consultation with senior and retired employees familiar with the RH TRU generating facility's operating history. From this consultation each of the parameters (enrichment, burn-up, and decay) may have low, high, and average values developed. These values establish the bounds of the space in which calculational permutations will be developed.
    - In order to keep the number of permutations to a manageable number and yet thoroughly evaluate the parametric space a systematic method shall be used. The Latin Hyper Cube technique is one such systematic method which may be used to establish conditions of enrichment, burn-up, and decay for the isotope generation and depletion calculations.

- The most commonly used computer program for performing isotope generation and depletion calculations is the ORIGEN computer program. There is a stand-alone version (i.e., ORIGEN 2.2) and a version incorporated into a larger code system (i.e., ORIGEN-S). Either version may be used to estimate isotopic activity levels. The ORIGEN isotope generation and depletion code can produce activities for many more isotopes than can be measured.

- For the isotopes of interest, including key gamma emitters and TRU isotopes, activities shall be extracted from the output of each run (permutation of input conditions).
- These isotopic activity values shall be evaluated (i.e., entered into a spreadsheet or database) and statistical metrics produced.
- The statistical metrics shall include mean and standard deviation for each measured isotope.
- The calculated data shall be evaluated to determine if they are well represented by Gaussian or other distribution functions (e.g., lognormal). The isotopic activity values shall be normalized to the major isotope responsible for the external container dose rate.

- In order to thoroughly evaluate the conditions leading to the generation of RH TRU waste, multiple permutations or runs of the isotope generation and depletion calculation will be required.
- The sample and calculated normalized mean values for those isotopes represented in both the sample and calculated results (e.g., Am-241, Pu-238, Pu-239, and Pu-240) shall be compared.
  - If the ratio of the sample and calculated mean values for these isotopes is less than 0.5 or larger than 2.0 then there shall be a reconciliation of the differences.
  - The reconciliation shall be documented in accordance with Attachment A of the WCPIP.
  - The basis for the factor of two is a general "rule of thumb" drawn from experience with measured and calculated data for various nuclear systems of an experimental nature or where significant uncertainties exist.
  - Where there is poor agreement between the calculated and sample results, justification shall be provided as to the validity of the calculated results. If the agreement is poor, there should be consideration given to how well the sample data represent the waste stream. It may be necessary to revise the input assumptions for the calculations and re-perform them or to collect more samples.
  - The major isotope values will be unity for both the normalized sample and calculated results. The Co-60 values are not likely to be in good agreement for sample and calculated results, nor are any other isotopic activities that are produced by activation.
  - Sample results should be used for Co-60 and other key isotopes produced by activation in the generation of a "Standard Mix" for the waste stream.

8.0 Determination of "Standard Mix" of Isotopes Per Waste Stream

The set of radioisotopes that will be used to determine and report activity levels in waste containers will be based on the following:

- A “Standard Mix” of key radioisotopes expected in the RH TRU waste shall be generated for each waste stream using the methods described above.
- The sample based results are the preferred means of deriving the “Standard Mix”.
- Calculations from isotope generation and depletion computer programs shall be used to supplement the sample data for isotopes for which measured data is not easily obtainable.
- For each “Standard Mix” of isotopes associated with a waste stream:
    - A multi-energy group gamma-ray source term shall be established.
    - The 18 energy groups structure associated with the ORIGEN output shall be used.
    - Normalized isotopic activities in the “Standard Mix” source term shall be based on mean sample values for measured TRU isotopes (e.g., Am-241, Pu-238, Pu-239, and Pu-240) and key isotopes produced by activation (i.e., Co-60).
    - Activities for other isotopes of interest for which there is insufficient or no sample data shall be from normalized mean activities from the ORIGEN calculated results.
    - Each isotope in the “Standard Mix” shall have a relative mean value and associated uncertainty.
- Each waste container shall be associated with a waste stream for which there is a “Standard Mix” of radioisotopes.

The isotopes that shall be included in the “Standard Mix” are the 10 that are required to be tracked (i.e., Am-241, Pu-238, Pu-239, Pu-240, Pu-242, U-233, U-234, U-238, Sr-90, and Cs-137). Also included shall be other isotopes that contribute to 95% of the dose rate outside the waste container.

9.0 Determination of Expected Exposure or Dose Rate Outside Waste Container

The sampling and calculation results will be used to develop the factors used to convert the measured dose rate to activity levels as follows:

- The dose-to-curie (DTC) measurements shall be performed using gamma radiation detectors.
- The dose rate shall be determined at a distance of one meter from the outer surface of the waste container, at the mid-height of the container. It is assumed that the waste is uniformly distributed within the container and that intervening shielding material is uniform in distribution and composition.
- Conversion factors shall be developed for each waste stream’s “Standard Mix”, waste type (i.e., metal, concrete, or organic), waste height (i.e., less than 25%, 25% to 66%, 66% to 90%, and more than 90%) per unit mass of waste.
- The conversion factors shall include the shielding effect of the container and/or liner wall.
- The calculation of expected dose rates outside a RH TRU container shall be performed through straightforward shielding analysis techniques. These techniques include discrete ordinates, Monte-Carlo, and point-kernel methods that have been implemented in numerous computer programs. Some of the more common programs implementing these

methods are MCNP and QAD-CGGP. MCNP is a Monte-Carlo type program and QAD-CGGP uses the point-kernel technique.
- The shielding computer program shall be used to develop a model of the waste container (liner for the 55-gallon drum).
- The multi-energy (18 groups) source term for the "Standard Mix" shall be used for each waste stream. The source shall be normalized to the major isotope and then to some convenient unit activity.
- The actual measured dose rate shall be ratioed to the calculated dose rate to obtain a scaling factor that is applied to the "Standard Mix". In this manner actual isotopic activities for a waste container can be estimated.

10.0 Measurement of Radiation Dose or Exposure Rate

Specific procedural steps for conducting the radiation survey of the exterior of the waste container for the purpose of DTC measurements are provided in Appendix B. General programmatic requirements are provided below.

- A gamma radiation detector suitable for measuring the gamma radiation fields outside the loaded waste container (e.g., ion chamber or compensated GM detector) shall be used.
- The detector's response function (e.g., R/hr or rads/hr) shall be consistent with that used in the calculation of the dose rate.
- The detector shall not be subject to saturation in high radiation fields and shall have the capability for remote reading.
- Measurements shall only be made within the calibrated range of the instrument.
- Consideration shall be given to keeping personal radiation exposure as low as reasonable achievable (ALARA).
- Remote measurement devices, shield walls, and other techniques should be used to reduce personnel radiation exposures.
- For the purpose of this procedure the background dose rate shall be as low as practicable. The background radiation level shall be less than 10 percent of that produced by the waste container.
- The background radiation dose rate shall be measured prior to the RH TRU container and that background dose shall be recorded.
- The position of the detector relative to the waste container and any intervening shielding shall be consistent with that used in the calculation of the expected radiation dose or exposure field.
- The radiation field shall be measured at two locations about the container.
- Measurements shall be made at the mid-height of the container at the 12 and 6 O'clock positions (i.e., on opposite sides) at a distance of one-meter from the surface of the container.
- The average value of the measurements shall be used for the DTC calculation of isotopes in the drum.
- The measured dose rates about the waste container shall be recorded.

11.0 Determination of Waste Container Radioisotope Loading

- Each loaded waste container shall be weighed.
- The net weight of the waste shall be determined.
- The calculated dose rates per unit mass of waste (by waste type) and per unit activity of the normalized "Standard Mix" shall be ratioed to the measured dose rate to determine a scaling factor.
- The scaling factor shall then be applied to the "Standard Mix" of isotopes to determine the estimated activities of radioisotopes in that container.

12.0 Determination if the Container Meets the Criteria for RH TRU

- These calculations and determinations shall be made using software developed by the CBFO.
- All calculations and measurement data shall be recorded on standard forms according to a standard procedure developed by the CBFO.
- Containerized waste shall be determined to be RH TRU waste if the dose equivalent rate at the exterior of the surface of the container is between 200 mrem/hr and 1000 rem/hr and the concentration of TRU isotopes is greater than 100 nCi / grams waste. TRU isotopes have an atomic number greater than 92 and half-lives greater than 20 years.
- The determination of the concentration of TRU isotopes shall be made using the mean values established in the "Standard Mix" adjusted by the conversion factors for the loading of waste in the container and the measured dose rate.

13.0 Total Measurement Uncertainty

There are many factors that contribute to the Total Measurement Uncertainty (TMU) of the estimated isotopic activity of the RH TRU waste containers. Due to the wide variety in operations conducted throughout the DOE complex and differing means for decontamination and decommissioning activities, there is no generic method for characterizing the RH TRU generation and characterization, including determination of TMU.

- Each RH TRU waste stream shall have a method for estimating TMU based upon the propagation of uncertainties present in all aspects of the determination of the isotopic content of RH TRU waste.
- The TMU shall be based on the propagation of uncertainties from components of the DTC method which will include:
    - The sampling of each waste stream
    - Measured sample isotopic activities
    - Relative uncertainties associated with each isotope in the "Standard Mix" from sampling and calculations
    - Inhomogeneous waste (to the extent practicable)

- Measuring the dose rate about the container
- Determination of waste mass (unless shown to be insignificant)
- Modeling errors or biases

- The TMU estimation methodology shall be documented.
- The TMU document shall be submitted to CBFO for review and approval.

An example of the methodology used to develop a TMU value for the DTC measurements is provided as an attachment to this appendix. It provides a through discussion of factors that impact the total measurement uncertainty, shows how to combine those factors, and provides the results for one specific set of parameters for a specific waste stream. While it may not be possible to apply this technique directly to every waste stream, it is a representation of the breadth and detail that is necessary to prepare a satisfactory TMU value.

14.0 Technical Review

- Each calculation and document produced through the implementation of this procedure shall be subjected to a review by a Technical Reviewer.
- All Technical Review comments and their resolution shall be documented.

15.0 Records

- Records generated through the implementation of this procedure shall be managed according to a defined formal Quality Assurance Program that meets the Waste Isolation Pilot Plan Quality Assurance Program Document (QAPD).
- Records to retain shall include, but not be limited to:

  - Site specific procedures developed to implement this method
  - Sample Plan for each waste stream
  - Results from the analysis of each sample
  - Documented comparison of measured isotopic activity distributions
  - Isotope depletion and generation calculations
  - Basis for the determination of the waste stream's "Standard Mix"
  - Shielding calculations for waste containers
  - Basis for determination of DTC conversion factors
  - Total Measurement Uncertainty estimation document
  - Isotopic content estimation for each waste container.

16.0 References

"Low Level Waste Characterization Guidelines," EPRI Report TR-107201, Electric Power Research Institute, Pleasant Hills, California, 1996.

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"Guidance for Data Quality Assessment – Practical Methods for Data Analysis," EPA QA/G-9 EPA/600/R-96/084, Environmental Protection Agency, 2000.

"Experimental Statistics," Natrella, M.G., PB93-196038, National Bureau of Standards Handbook 91, 1963, reprinted 1966 with corrections, available from National Technical Information Service, Springfield, Virginia, 1966.

"Statistical Methods for Nuclear Material Management," W.M. Bowen and C.A. Bennett, NUREG/CR-4604 PNL-5849, Pacific Northwest National Laboratories, Richland, Washington, prepared for the Office of Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, D.C., 1988.

"Large Sample Properties of Simulations Using Latin Hypercube Sampling," M. Stein, Technometrics, Vol. 29, No. 2, pp. 143-151, American Statistical Association and the American Society for Quality Control, 1987.

"A Fortran 77 Program and User's Guide for the Generation of Latin Hypercube and Random Samples for use with Computer Models," R.L. Iman and M.J. Shortencarier, NUREG/CR-3624 SAND83-2365, Sandia National Laboratories, Albuquerque, NM, 1984 - available as "LHS – Code System to Generate Latin Hypercube and Random Samples", PSR-394, Radiation Safety Information Computational Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1999.

"ORIGEN 2.2 – Isotope Generation and Depletion Code Matrix Exponential Method," CCC-371, Radiation Safety Information Computational Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 2002.

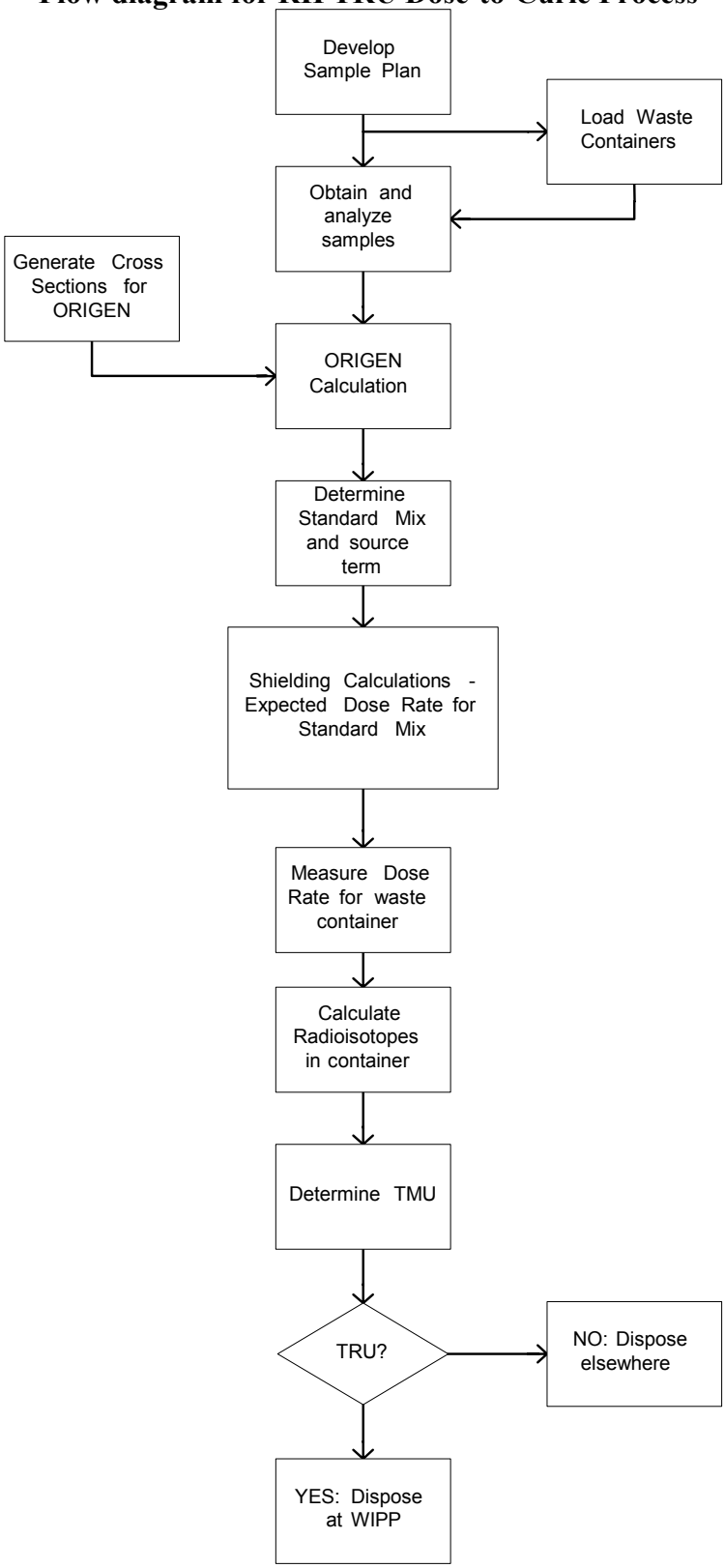
"ORIGEN-S: SCALE System Module to Calculate Fuel Depletion, Actinide Transmutation, Fission Produce Build-Up and Decay, and Associated Radiation Source Terms," Volume 2, Section F7 of SCALE 4.4a, CCC-545, Radiation Safety Information Computational Center, NUREG/CR-0200, rev. 6, ORNL/NUREG/CSD-2/V2/R6, Ridge National Laboratory, Oak Ridge, Tennessee, 2000.

"MCNP4C – Monte Carlo N-Particle Transport Code System," CCC-700, Radiation Safety Information Computational Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 2001.

"QAD-CGGP – Point Kernel Code System for Neutron and Gamma-Ray Shielding Calculations Using the GP Buildup Factor," CCC-645, Radiation Safety Information Computational Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1995.

Attachment to Dose-to-Curie Procedure

Flow diagram for RH TRU Dose-to-Curie Process



Attachment to Dose-to-Curie Procedure

Example Determination of Total Measurement Uncertainty

The example determination of Total Measurement Uncertainty (TMU) below was taken from the Dose-to-Curie report prepared by the Battelle Columbus Laboratories Decommissioning and Decontamination Program (BCLDP) for their RH TRU wastes. This example is only used to illustrate the complexity of calculating the TMU. Each site will need to determine the appropriate means of calculating and documenting the TMU for their waste streams.

The "Standard Mix" of radioisotopes used in the BCLDP RH TRU characterization program are shown below in Table 1. There was only one waste stream to which the DTC method was applied.

Table 1. Radioisotopes included in the BCLDP "Standard Mix"

Isotope	Atomic Number	Half-life [years]	TRU
Co-60	27	5.271	no
Sr-90	38	29.1	no
Cs-137	55	30.17	no
Ba-137m[6]	*56*	*4.85E-06*	*no*
U-233[7]	92	1.59E+05	no
U-234	92	2.46E+05	no
U-235	92	7.04E+10	no
U-236	92	2.34E+07	no
U-238	92	4.47E+09	no
Pu-238	94	87.7	yes
Pu-239	94	2.41E+04	yes
Pu-240	94	6.56E+03	yes
Pu-241	94	14.4	no
Pu-242	94	3.75E+05	yes
Am-241	95	432.7	yes
Cm-244	96	18.1	no

[6] Ba-137m, is not usually included in listings of the "Standard Mix" because it is a daughter product from the decay of Cs-137. Since the half-life of Ba-137m is much less than that of Cs-137, Ba-137m exists in a state of transient equilibrium with Cs-137 and the daughter product decays at essentially the same rate as the parent. However, the Ba-137m is important in the application of the methodology of using gamma rays emitted from the waste as a measure of the TRU activity. Cs-137 does not yield a gamma ray upon decay, but Ba-137m does.

[7] Although U-233 is not included in the definition of TRU isotopes as specified in the Land Withdrawal Act for WIPP, i.e., having an atomic number greater than 92 and a half-life greater than 20 years, other guidance did require that it be included in the accounting of TRU activity. Thus U-233 is included in the calculations of TRU activity in the BCLDP example.

In order to predict the degree of variation in specific radionuclide populations, i.e. TRU and fission products, a number of calculations are performed using the ORIGEN computer code. ORIGEN calculates isotope depletion and generation for specified conditions. A series of calculational parameters are to be selected based upon the best understanding of the range of conditions of fuel enrichment, exposure, and decay. The ORIGEN calculations predict core average conditions. In reality, particular fuel rods or segments of fuel will come from areas of a particular reactor core that may vary from the average conditions in that reactor.

As the waste is an amalgam of isotopes from many differing sources, it is expected that the variations will tend to "average out." Examining the set of samples, obtained for each waste stream, should validate this assumption. Otherwise the higher values are used to obtain a conservative measure of the isotopic contents. For the example shown below, the samples are of non-fixed contamination on the surface of waste, equipment, and facilities. The samples were obtain prior to and as waste was placed in the containers. The Cs-137 fission product is expected to dominate the gamma activity. From radiochemistry techniques using alpha spectroscopy, activities of TRU (Am-241, Pu-238, Pu-239, and Pu-240) and other isotopes are measured. Measurement uncertainty is to be recorded.

The distribution of waste in the waste containers contributes to uncertainty by two means. First, via variation in the distribution of solid material, this acts as an absorber of gamma rays from the waste. A non-uniform distribution of solid material will cause uneven attenuation of the gamma rays and will affect the prediction of the TRU content. Second, the amount of radioactive material in the waste container is likely to be non-uniformly distributed. The various regions of source will have to travel through differing thickness of absorber material and through differing distances to the detector.

The measurement of the exposure rate external to the 55-gallon container will also contribute to measurement uncertainty. The exposure rate is a direct measure of the various energies of gamma rays emitted during the radioactive decay of the radionuclides in the waste. Radioactive decay is a statistical process and this directly translates to the detection probability. In the measurement methodology described herein, an ionization chamber, calibrated in roentgens per hour (R/hr) provides a measure of the exposure rate external to the waste container.

Estimation of the uncertainty associated with the characterization of TRU-level waste, therefore, has three components:

- Uncertainty in measuring the exposure rate emanating from the container;
- Uncertainty in the weight of the container being characterized; and,
- Uncertainty in the "Standard Mix" for each waste stream used to estimate the limiting (consistent with TRU-level waste) dose emanating from the container.

Finally, it is important to stress that there are steps that can be taken to reduce the various sources of uncertainty. These steps are best considered as procedural recommendations for the completion of the packaging of the waste and preparation for shipment to a repository. Specifically,

- Filling waste containers involve cutting and crushing the waste into fairly small components. The result is components in a waste container that are somewhat uniform in size but likely randomly distributed in location. Compaction of the waste further reduces void spaces and evens out the attenuation of the gamma rays for equivalent shield distance.

- The determination of the exposure rate is to be made at the same location for each measurement (i.e., at the mid-height of the waste container one meter from the surface). Two measurements are made 180 degrees apart (i.e., at the 12 and 6 o'clock positions) for the container. These measurements are averaged to determine the exposure rate for use in estimating the isotopic contents of the waste in that container. The measurement of the radiation exposure rate is made in a location where the background radiation is a relatively low (10% or less) contribution to the total measured dose rate.

The discussion below provides more detail on the calculations and assumptions associated with estimating the relative uncertainty of the methods, described in this procedure, for characterizing the inventory of potentially TRU waste. As such, it is assumed the reader has some knowledge of statistical theory and methodology. The terms "variance" and "standard deviation" will always have their precise statistical meaning. The term "relative uncertainty" will mean the standard deviation divided by the mean and will generally be reported as a percentage. When talking about transuranics we are specifically addressing the isotopes Am-241, Pu-238, Pu-239, Pu-240, and Pu-242.

The purpose of this analysis is to estimate the mean TRU inventory consistent with 100 mCi of the "Standard Mix" of isotopes associated with a given waste stream and the variance associated with that estimate. Also estimated are the means and variances of the inventories of individual isotopes consistent with 100 mCi of "Standard Mix" as well as the variance of the total inventory.

TRU waste is encased in 55-gallon drums in preparation for shipment. In order to determine the inventories of the individual isotopes, inferences are made using the proportion of inventory expected based on the distribution of isotopes in the "Standard Mix" and the ratio between observed and a predicted total inventory dose. Thus, the inventory I_i of each isotope present in 100 mCi of the "Standard Mix" can be determined using the formula

$$I_i = \frac{100 D_{Meas}(p) f_i}{D_{QAD}(p)}$$

where $D_{Meas}(p)$ is the measured dose rate, $D_{QAD}(p)$ is the calculated dose rate for the "Standard Mix"(as a function of container configuration and density *p*) by the QAD software calculations, and f_i is the activity of the i^{th} isotope present in an activity unit of a waste stream's "Standard Mix". The ratioed dose rates establish a *de facto* scaling factor.

As such, estimation of the total variance associated with the characterization of TRU waste has five components:

- Uncertainty in the weight of the container being characterized;
- Uncertainty in the assumed "Standard Mix" isotopic distribution;
- Uncertainty in measuring the dose rate;
- Uncertainty in the calculated dose rate (as a function of container configuration and weight) by the calculations; and,
- Bias.

Since the weight of a waste container can be determined to within two pounds, this variation relative to the weight of a drum is insignificant compared with the other sources. It will not be considered further.

Uncertainty in a waste stream's isotopic distribution in its "Standard Mix"

The method of determining the activity of individual isotopes in the "Standard Mix" actually measures activity of the isotope relative to a unit activity of Cs-137. For this reason we refer to *ratioed activities* of individual isotopes in the discussion below.

In considering the isotopic distribution in the "Standard Mix" for a waste stream and the uncertainty in its estimation, the parameter of interest for any given isotope represented in the distribution is the aggregate dose emanating from the collection of items in the container. In other words, the (ratioed) isotopic activity of an individual item is less of interest than is the aggregate activity of the items within the container. Through methods described below the variance in activity associated with individual items is estimated. Since a container is filled with randomly chosen items, statistical theory indicates that an isotope's aggregate activity has variance (the squared standard deviation) equal to the variance in that isotope's ratioed activity of any given item divided by the number of items being aggregated (i.e., in the container). Based on operator experience at BCLDP, the number of items in a container can be conservatively assumed to be at least 100 and it is not uncommon for drums to contain 200 or more items. The loading of all containers should have video documentation.

What then about the variance in each isotope's estimated activity relative to that of Cs-137 (i.e., ratioed activity)? As noted above, the ratioed activity of some isotopes in the expected waste is estimated using available data, while for others the estimation depend upon the ORIGEN software and assumed values for fuel enrichment, decay, and burn-up. As such, the uncertainty associated with the isotopic distribution in the "Standard Mix" depends upon how the ratioed activity assumed for each isotope is estimated.

For Am-241, Cm-244, Co-60, Pu-238, and Pu-239, and Pu-240, activities ratioed to Cs-137 are to be measured for a representative sample of the waste stream. Between 10 and 50 samples are to be obtained per waste stream. Inspection of the data may reveal that the ratioed activities have skewed distributions. Assuming that is the case, several distributions may be fit to the data including Poisson, Lognormal, Normal (i.e.. Gaussian), Weibull, and Gamma. It is assumed that the Lognormal distribution demonstrates the best fit in terms of both goodness-of-fit statistics and review of fitted curves superimposed on histograms. Use of Lognormal over Normal for the sampled data has three justifications: 1) The data are not symmetric (i.e., bell-shaped) but instead skewed to the right, 2) the Lognormal distribution fits the observed data better; and 3) while the means obtained for the Normal and Lognormal are similar, the Lognormal provides a more

conservative (larger) variance estimate. It should be noted that while a Poisson distribution might be expected as activities are being measured, it would not be expected from ratioed activities (the ratio of Poisson random variables is not Poisson). Further, since the data will represent measurement from many samples on site reflecting a range of isotopic mixes, the choice of distribution based on empirical grounds is appropriate.

Reported in Table 2 below are examples of the estimated parameters of the fitted distributions. The parameter (μ) estimated for each studied isotope represented the mean in log-transformed activity ratio (to Cs-137). The estimate for the standard deviation parameter (σ), in turn, represents the spread in log-transformed activity ratio due to variability in the true ratioed activity and due to measurement error in the available data.

Table 2. Typical Estimated Parameters of Fitted Lognormal Distribution for Isotopes with Available Data

Transuranic Isotope	Estimated Parameters of Lognormal Distribution	
	μ–hat	σ–hat
Am-241	-3.4308	0.9356
Cm-244	-3.6680	0.9573
Co-60	-3.3750	2.0988
Pu-238	-3.2906	0.7213
Pu-239/240	-4.4316	0.7944

For each isotope with available data, then, the mean and standard deviation in ratioed activity of a 100-item container can be estimated as,

$$e^{\hat{\mu}+\frac{\hat{\sigma}^2}{2}},$$

and,

$$\sqrt{\frac{e^{2\cdot\left(\hat{\mu}+\hat{\sigma}^2\right)}-e^{2\cdot\hat{\mu}+\hat{\sigma}^2}}{100}},$$

respectively, and are reported in Table 3.

Table 3. Typical Estimated Mean and Uncertainty in Aggregate Ratioed Activity of 100-Item Container—Isotopes with Available Data

Isotope	Basis	Estimated Ratioed Activity	Estimated Standard Deviation
Am-241	Samples	5.013E-02	5.93E-03
Cm-244	Samples	4.036E-02	4.94E-03
Co-60	Samples	3.096E-01	2.78E-01
Pu-238	Samples	4.829E-02	3.99E-03
Pu-239/240	Samples	1.631E-02	1.53E-03

For Sr-90, Pu-241, Pu-242, U-233, U-234, and U-238, the ORIGEN software is used in combination with assumed parameter values representing the working range of values for fuel enrichment, decay, and exposure (i.e., burn-up) to estimate ratioed activity. Experts familiar with the history of the facility and its operation (including the AK) set the bounding values. Four replicates of a five-run Latin Hypercube design[8] is applied within the ORIGEN software in order to estimate for each isotope the mean ratioed activity and the uncertainty in that estimated mean. Table 4 below reports typical values, for each considered isotope, the mean ratioed activity and uncertainty in mean ratioed activity. The latter is estimated by calculating the standard deviation in mean ratioed activity observed (in the ORIGEN output) across the four replicates. Since the resulting variance is supposed to be representative of the variance seen in the items on site, the variance associated with an aggregate of items in a container is reduced by a factor of 100 (representing the estimate of the number of items per container).

Table 4. Typical Values of Mean Ratioed Activity and Uncertainty in Mean Ratioed Activity as Estimated Using ORIGEN

Isotope	Estimated Ratioed Activity	Estimated Uncertainty in Ratioed Activity
Pu-241	8.10E-01	8.12E-03
Pu-242	2.98E-05	3.60E-07
Sr-90	6.59E-01	2.79E-03
U-233	5.41E-10	6.93E-12
U-234	1.75E-05	2.85E-07
U-235	2.56E-07	7.43E-09
U-236	3.38E-06	3.20E-08
U-238	4.90E-06	2.82E-08

The isotopes in the Tables above represent the distribution typical for a waste stream "Standard Mix". Summing the isotopes estimated ratioed activities and then normalizing to the resulting

[8] Latin hypercube sampling is based on the procedure outlined in "*Large Sample Properties of Simulations Using Latin Hypercube Sampling*"[5] by Michael Stein.

total estimates the percentage contribution of each isotope to a unit of activity. Table 5 below reports by isotope the resulting normalized activity ratios and their associated uncertainty, appropriately scaled from that reported in Tables 2 and 3.

Table 5. Typical Values of Mean Normalized Activity and Uncertainty in Mean Normalized Activity as Estimated Using Available Data and ORIGEN

Isotope	Basis	Ratios Normalized to 1 m Ci	
		Mean	Uncertainty
Cs-137	Samples	3.41E-01	0.00E+00
Am-241	Samples	1.71E-02	2.02E-03
Pu-238	Samples	1.65E-02	1.36E-03
Pu-239/240	Samples	5.56E-03	5.21E-04
Cm-244	Samples	1.38E-02	1.69E-03
Co-60	Samples	1.06E-01	9.49E-02
Pu-241	ORIGEN2	2.76E-01	2.77E-03
Pu-242	ORIGEN2	1.02E-05	1.23E-07
Sr-90	ORIGEN2	2.25E-01	9.53E-04
U-233	ORIGEN2	1.84E-10	2.36E-12
U-234	ORIGEN2	5.95E-06	9.70E-08
U-235	ORIGEN2	8.73E-08	2.53E-09
U-236	ORIGEN2	1.15E-06	1.09E-08
U-238	ORIGEN2	1.67E-06	9.63E-09

Uncertainty in Dose Measurement

Dose rate levels are determined by measuring the Cs-137 activity using a gamma radiation detector (ion chamber) held at two locations a distance of one meter from the centerline of the waste container being examined. There are two main sources of variation in measuring dose: heterogeneity in distribution of the shielding and sources within the waste container; and uncertainty in the ion chamber measurements. (A third source of variation, bias due to either instrument bias or calibration bias was determined to be negligible relative these other sources by experts familiar with the measurement process.) These sources are confounded and it is infeasible to isolate the effects due to each of these sources. Measurements at multiple locations about the container capture both variation in the measurement instrument and variation in the geometry of the shielding and sources. Specifically, dose levels will be determined by taking two measurements at a distance of one meter from two opposite sides of the drum (i.e., 12 and 6 o'clock positions). The discussion below presumes that two measurements are taken on opposite sides of a drum (i.e., 12 and 6 o'clock positions).

To estimate the variance in the measurement of dose, pairs of measurements, X_1 and X_2, are taken for a number of waste containers that are believed to be representative of the population of drums to follow. Since the observed distribution is skewed and since the ion chamber manufacturer reports multiplicative errors of 10% in ion chamber readings (under idealized

conditions), it is reasonable to consider X_1 and X_2 as being lognormally distributed. Consistent with the use of Lognormals, the geometric mean $\sqrt{X_1 X_2}$ will be taken as our estimate of the activity for each container. To compute the uncertainty in the dose measurement, we need to compute the uncertainty in measuring $\sqrt{X_1 X_2}$. In order to allow for uncertainties that vary with dose level (such as ion chamber uncertainty) and for uncertainties that are dose independent (such as shielding variations) while remaining consistent with Lognormal theory, we assume that each container reading X_i has the form $Y_i \varepsilon_i$, where Y_i has a Lognormal distribution with parameters μ_Y and σ_Y^2 and ε is Lognormal with parameters $\mu_\varepsilon = 0$ and σ_ε^2. From basic properties of Lognormal distributions, X_i is also Lognormal with parameters μ_Y and $\sigma_Y^2 + \sigma_\varepsilon^2$. We observe that if $Z_j = \ln X_{1j} - \ln X_{2j}$ is calculated for each container j, the Z_j are independent, Normally distributed random variables with mean 0 and variance $2(\sigma_Y^2 + \sigma_\varepsilon^2)$. The maximum likelihood estimate (MLE) of $\sigma_Y^2 + \sigma_\varepsilon^2$ is,

$$\frac{\sum_{j=1}^{n} Z_j^2}{2n}.$$

Using the data to evaluate the MLE, we are able to estimate the mean and variance of $\sqrt{X_1 X_2}$. An example set of 24 pairs of data are shown below. From this example data it may be determined that the relative uncertainty in measured dose is 23.86%.

Table 6. Example Set of Waste Container Measurements

Drum ID	L-Side-1m [R/hr]	R-Side-1m [R/hr]
32	0.1	0.1
33	2	3
35	6	7
37	0.05	0.05
40	2	2
41	0.05	0.04
42	2	2.5
43	5	5
44	1.2	2
45	0.025	0.025
46	0.7	0.7
47	3	3.5
48	5	1
49	0.9	0.7
50	0.1	0.1
51	1	0.7
52	0.025	0.025
53	0.35	0.4
54	2	1.5
55	0.1	0.15
56	5	5
57	1	0.75
61	0.1	0.15
62	3	10

Uncertainty in Predicted Dose

Predicted dose varies with both the weight of the container and the shielding configuration. For a given container configuration and density, p, the measured dose (in mR per hour) predicted by the QAD software can be approximated as:

$$D_{QAD}(p) \cong a * T_{Cs-137}(p) + a * g_{Co-60} T_{Co-60}(p),$$

where,

$T_{Cs-137}(p)$, $T_{Co-60}(p)$ are transfer functions reflecting the assumed material composition;

g_{Co-60} is the activity ratio for Co-60 consistent with an activity of an activity unit (e.g., 1 mCi) of Cs-137; and

a is a variable derived from Cs-137 in an activity unit (e.g., 1 mCi) of the "standard mix" for a waste stream.

The standard deviation of the transfer functions—specifically, the ability to predict the correct result for a known source and absorber (density) distributions—is to be based on a comparison of results using an iron buildup factor and a cellulose buildup factor. The results from a series of QAD calculations of varying weights and shielding configurations is expected to show that although the absolute uncertainty in the transfer functions varied, the fractional uncertainty is fairly constant. For this discussion, 10% is assumed to be a conservative representative value for the ratio of standard deviation to the mean for both of the transfer functions across the range of weight and shielding configurations expected from waste containers.

Consideration of Bias

In the approach taken to estimate the uncertainty in the measured inventory of waste, no distinction is made between uncertainties that arise from random or non-random sources. The major sources of uncertainty have been identified and the contribution from each source has been included in the assessment of overall uncertainty. It is recognized that some of the sources of uncertainty are not random in nature and could introduce bias in the "best estimate" (mean value presented). However, because of the nature of these uncertainties, it has not been practical to attempt to quantify the associated bias or to correct the "best estimate" values to account for the bias.

There is a potential for the introduction of bias through calibration error or instrument error in the direct measurements of dose rate external to the container. However, it is assumed for typical waste containers, these sources of error represent a negligible contribution to the overall uncertainty.

Modeling error is another source of bias. The approach used to estimate the inventory of waste relies on two analytical models: the ORIGEN code and the QAD code. Twenty permutations of ORIGEN cases are to be executed to characterize the enrichment, pre-irradiation history and the decay of each waste stream. The basis for the ranges used for these parameters is the AK information. Thus, there is the potential for bias in the input to ORIGEN analyses as well as in the physical constants in the code. The output of the ORIGEN analyses is to be used to augment the radionuclides for which insufficient sample measurements were available. Thus, the affected isotopes tend to be the less significant ones. Comparisons are to be made between Cs-137 normalized ORIGEN-predicted activities and measured activities, for the radionuclides that are well represented in the database of measured samples. If the comparison of averaged activities from the ORIGEN calculated values differ by more than a factor of two from the averages obtained from the samples from each waste stream, then justification must be provided for the validity of the calculations. Where available, sample values are to be used for the Co-60 and TRU isotopes. For other isotopes the values to be used are the calculated values. Experience with light water reactors (LWRs) has indicated that ORIGEN calculated values may be over predicted by 20 to 30 percent. The literature should be consulted for any known biases associated with ORIGEN calculations for the type of reactor that produced a given site's RH TRU waste.

The QAD analyses are also a potential source of bias. The method used to quantify the uncertainty in QAD was to change the material used in the calculation of buildup factor. The

inability of the QAD type of analysis to properly account for buildup in shields of varying composition or layered shields is well recognized as the principal limitation of the methodology. Although the variation was used to characterize the magnitude of the modeling error, it was not possible to conclude whether this error would result in an over-estimation or under-estimation of the waste inventory.

The other two large sources of uncertainty, non-uniform source distribution and non-uniform distribution of absorber material in loading the containers were treated empirically through an analysis of measurements made at different detector locations. This uncertainty is primarily random in nature.

In summary, then, the uncertainty estimate provided by the methodology is a mixture of random and non-random contributors. The mean values provided are intended to be "best estimates" and are not intentionally biased (i.e., conservative). Because the uncertainty is a mixture of random and non-random contributions, the recipient of the waste should not assume that the uncertainty of the inventory of a number of containers will be proportionally less than the uncertainty in the inventory of each container.

Variance in Inventory

In the preceding we presented an equation for inventory,

$$I_i = \frac{100 D_{Meas}(p) f_i}{D_{QAD}(p)}$$

and an equation for the QAD predicted dose,

$$D_{QAD}(p) \cong a * T_{Cs-137}(p) + a * g_{Co-60} T_{Co-60}(p)$$

These combine to yield

$$I_i = \frac{100 D_{Meas}(p) f_i}{a * T_{Cs-137}(p) + a * g_{Co-60} T_{Co-60}(p)}$$

Note that a is the factor by which the activities of isotopes in a waste stream's "Standard Mix" consistent with an activity unit (e.g., 1 mCi) Cs-137 must be divided to yield the proportions of isotopes in a "Standard Mix" consistent with a unit of total activity. Thus f_i (the activity of isotope *i* in a "Standard Mix" consistent with a unit of total activity) is equal to g_i (the activity of isotope *i* in a "Standard Mix" consistent with an activity unit of Cs-137) divided by a. Appropriate simplification yields the equation

$$I_i = \frac{100 D_{Meas}(p) g_i}{T_{Cs-137}(p) + g_{Co-60} T_{Co-60}(p)}.$$

While we do not know the distribution of this expression, by assuming the independence of $D_{meas}(p)$, g_i, g_{Co-60}, $T_{Cs-137}(p)$, and $T_{Co-60}(p)$ we can approximate the variance in I_i by using a first order Taylor's expansion of this function. The result is

$$Var(I_i) = \frac{100^2 E(g_i)^2 Var(D_{Meas})}{(E(T_{Cs-137}) + E(g_{Co-60})E(T_{Co-60}))^2}$$

$$+ \frac{100^2 E(D_{Meas})^2 Var(g_i)}{(E(T_{Cs-137}) + E(g_{Co-60})E(T_{Co-60}))^2}$$

$$+ \frac{100^2 E(D_{Meas})^2 E(g_i)^2 Var(T_{Cs-137})}{(E(T_{Cs-137}) + E(g_{Co-60})E(T_{Co-60}))^4}$$

$$+ \frac{100^2 E(D_{Meas})^2 E(g_i)^2 E(T_{Co-60})^2 Var(g_{Co-60})}{(E(T_{Cs-137}) + E(g_{Co-60})E(T_{Co-60}))^4}$$

$$+ \frac{100^2 E(D_{Meas})^2 E(g_i)^2 E(g_{Co-60})^2 Var(T_{Co-60})}{(E(T_{Cs-137}) + E(g_{Co-60})E(T_{Co-60}))^4}$$

where *Var( )* is the variance and *E( )* is the expected value or mean.

Completing the Calculations

In order to use the inventory variance equation, we need estimates for the various components. For a range of weights consistent with the waste container to be used, the QAD software computed values for D_{QAD} and the transfer functions. These are reported in Table 7. Since D_{QAD} is the predicted dose consistent with 1.0 mCi total inventory, it is a reasonable estimate for the expected value of the measured dose D_{Meas} for the purposes of computing variance. Values for the g_i come from Tables 2 and 3 and variances for D_{Meas} and the transfer functions were discussed in their respective section above.

Recalling that the inventory consistent with 100 mCi of total activity is

$$I_i = \frac{100 D_{Meas}(p) f_i}{D_{QAD}(p)},$$

we can estimate I_i (the inventory of isotope *i*) when the observed dose is equal to the predicted dose by

$$\hat{I}_i = 100\hat{f}_i .$$

The relative uncertainty of isotope i is computed by dividing the standard deviation of I_i by the estimate $\hat{I}_i$, namely

$$\frac{Sqrt(Var(I_i))}{\hat{I}_i} .$$

The estimated inventory of transuranics is the sum of the estimated inventories, $\hat{I}_i$, of Am-241, Pu-238, Pu-239/40, and Pu-242. In order to compute the variance of the inventory of the transuranics, we assumed the worst (i.e., conservative) case of perfect correlation between the I_i. Thus the standard deviation is the square root of the sum of the variances and the pair-wise covariances with correlations assumed to be one. The relative uncertainty of the inventory of transuranics is the ratio of standard deviation of transuranics to their estimated inventory. Similarly the estimated total inventory is the sum of the inventories of all isotopes in the "Standard Mix". For the standard deviation, however, we assume that the inventory of Co-60 is independent of all other isotopes, while all other isotopes have perfectly correlated inventories. Thus the variance of the total inventory is the sum of the variances of each inventory item (including Co-60) and the pair-wise covariances of all pairs of isotopes with the exception of Co-60. The standard deviation is the square root of the variance and the relative uncertainty in total activity is the ratio of the standard deviation to the total activity.

Table 7. Typical Values for Transfer Functions and D_{QAD}

Weight (lbs)	DQAD (mR/hr)	TCs	TCo
34.7	1.34E+01	1.61E+01	7.52E+01
114.9	1.19E+01	1.40E+01	6.77E+01
179.1	1.07E+01	1.24E+01	6.18E+01
285.2	9.05E+00	1.01E+01	5.31E+01
347.4	8.20E+00	8.94E+00	4.88E+01

Results

Typical results expected from application of this methodology are presented in the accompanying spreadsheet. To summarize, for these typical values the relative uncertainty in the inventory of the individual isotopes is about 60% across the container weights, with the exception of Co-60, which has relative uncertainty of nearly 110%. The consistency in the variance of isotopes other than Co-60 can be explained by noting that the variance of Co-60

contributes 80% or more to the total variance in an isotope's inventory. Over the range of weights of interest the relative uncertainty in the transuranic inventory is about 60% and the relative uncertainty in the total inventory is around 55%.

TRU and Total – Typical Values

55 Gallon Drum							
Weight (lbs)	Dose (mR/hr)	Transuranic Inventory I_{trans} (mCi)	StDev{I_{trans}} (mCi)	Relative Uncertainty in Transuranics (%)	Total Inventory I_{total} (mCi)	StDev{I_{total}} (mCi)	Relative Uncertainty in Total Inventory (%)
34.70	13.43	3.91E+00	2.33E+00	59.6%	1.00E+02	5.38E+01	53.8%
114.90	11.92	3.91E+00	2.36E+00	60.3%	1.00E+02	5.44E+01	54.4%
179.10	10.75	3.91E+00	2.38E+00	60.8%	1.00E+02	5.49E+01	54.9%
285.20	9.05	3.91E+00	2.42E+00	61.9%	1.00E+02	5.58E+01	55.8%
347.40	8.20	3.91E+00	2.45E+00	62.6%	1.00E+02	5.65E+01	56.5%

Typical Values - Relative Uncertainty of Inventory

55 Gallon Drum															
Relative Uncertainty in Inventory I_i															
Weight (lbs)	Dose (mR/hr)	Am-241	Pu-238	Pu-239/240	Cm-244	Co-60	Cs-137	Sr-90	Pu-241	Pu-242	U-233	U-234	U-235	U-236	U-238
34.70	13.43	59.89%	59.29%	59.46%	59.98%	107.40%	58.71%	58.72%	58.72%	58.73%	58.73%	58.74%	58.79%	58.72%	58.72%
114.90	11.92	60.57%	59.97%	60.13%	60.65%	107.77%	59.40%	59.40%	59.41%	59.41%	59.41%	59.42%	59.47%	59.41%	59.40%
179.10	10.75	61.15%	60.56%	60.72%	61.23%	108.10%	59.99%	59.99%	60.00%	60.00%	60.01%	60.01%	60.06%	60.00%	59.99%
285.20	9.05	62.17%	61.59%	61.75%	62.25%	108.68%	61.03%	61.04%	61.04%	61.05%	61.05%	61.06%	61.10%	61.04%	61.04%
347.40	8.20	62.89%	62.31%	62.47%	62.97%	109.10%	61.76%	61.76%	61.77%	61.77%	61.78%	61.78%	61.83%	61.77%	61.77%

Typical Values - Variation in Inventory

55 Gallon Drum															
Variance in Inventory $Var(I_i)$ (mCi^2)															
Weight (lbs)	Dose (mR/hr)	Am-241	Pu-238	Pu-239/240	Cm-244	Co-60	Cs-137	Sr-90	Pu-241	Pu-242	U-233	U-234	U-235	U-236	U-238
34.70	13.43	1.05E+00	9.53E-01	1.09E-01	6.81E-01	1.28E+02	4.01E+02	1.74E+02	2.63E+02	3.56E-07	1.17E-16	1.22E-07	2.63E-11	4.57E-09	9.62E-09
114.90	11.92	1.07E+00	9.75E-01	1.12E-01	6.96E-01	1.29E+02	4.10E+02	1.78E+02	2.69E+02	3.65E-07	1.20E-16	1.25E-07	2.70E-11	4.68E-09	9.84E-09
179.10	10.75	1.09E+00	9.94E-01	1.14E-01	7.10E-01	1.30E+02	4.18E+02	1.82E+02	2.74E+02	3.72E-07	1.22E-16	1.28E-07	2.75E-11	4.77E-09	1.00E-08
285.20	9.05	1.13E+00	1.03E+00	1.18E-01	7.34E-01	1.32E+02	4.33E+02	1.88E+02	2.84E+02	3.85E-07	1.27E-16	1.32E-07	2.85E-11	4.94E-09	1.04E-08
347.40	8.20	1.15E+00	1.05E+00	1.21E-01	7.51E-01	1.33E+02	4.43E+02	1.93E+02	2.91E+02	3.94E-07	1.30E-16	1.35E-07	2.91E-11	5.06E-09	1.06E-08

Typical Values - Inventory

55 Gallon Drum															
Inventory I_i (mCi)															
Weight (lbs)	Dose (mR/hr)	Am-241	Pu-238	Pu-239/240	Cm-244	Co-60	Cs-137	Sr-90	Pu-241	Pu-242	U-233	U-234	U-235	U-236	U-238
34.70	13.43	1.71E+00	1.65E+00	5.56E-01	1.38E+00	1.06E+01	3.41E+01	2.25E+01	2.76E+01	1.02E-03	1.84E-08	5.95E-04	8.73E-06	1.15E-04	1.67E-04
114.90	11.92	1.71E+00	1.65E+00	5.56E-01	1.38E+00	1.06E+01	3.41E+01	2.25E+01	2.76E+01	1.02E-03	1.84E-08	5.95E-04	8.73E-06	1.15E-04	1.67E-04
179.10	10.75	1.71E+00	1.65E+00	5.56E-01	1.38E+00	1.06E+01	3.41E+01	2.25E+01	2.76E+01	1.02E-03	1.84E-08	5.95E-04	8.73E-06	1.15E-04	1.67E-04
285.20	9.05	1.71E+00	1.65E+00	5.56E-01	1.38E+00	1.06E+01	3.41E+01	2.25E+01	2.76E+01	1.02E-03	1.84E-08	5.95E-04	8.73E-06	1.15E-04	1.67E-04
347.40	8.20	1.71E+00	1.65E+00	5.56E-01	1.38E+00	1.06E+01	3.41E+01	2.25E+01	2.76E+01	1.02E-03	1.84E-08	5.95E-04	8.73E-06	1.15E-04	1.67E-04

Typical Values - Inventory

Isotope	Basis	Activity Ratio to 1 mCi Cs-137			Ratios Normalized	
		Mean	Uncertainty	Variance	Mean	Variance
Co60	Samples	3.10E-01	2.78E-01	7.75E-02	1.06E-01	9.01E-03
SR90	ORIGEN2	6.59E-01	2.79E-02	7.81E-04	2.25E-01	9.07E-05
Cs137	Samples	1.00E+00	0.00E+00	0.00E+00	3.41E-01	0.00E+00
U233	ORIGEN2	5.41E-10	6.93E-11	4.81E-21	1.84E-10	5.58E-22
U234	ORIGEN2	1.75E-05	2.85E-06	8.10E-12	5.95E-06	9.41E-13
U235	ORIGEN2	2.56E-07	7.43E-08	5.52E-15	8.73E-08	6.42E-16
U236	ORIGEN2	3.38E-06	3.20E-07	1.03E-13	1.15E-06	1.19E-14
U238	ORIGEN2	4.90E-06	2.82E-07	7.97E-14	1.67E-06	9.27E-15
Pu238	Samples	4.83E-02	3.99E-03	1.59E-05	1.65E-02	1.85E-06
Pu239240	Samples	1.63E-02	1.53E-03	2.34E-06	5.56E-03	2.72E-07
PU241	ORIGEN2	8.10E-01	8.12E-02	6.59E-03	2.76E-01	7.66E-04
PU242	ORIGEN2	2.98E-05	3.60E-06	1.30E-11	1.02E-05	1.51E-12
Am241	Samples	5.01E-02	5.93E-03	3.52E-05	1.71E-02	4.09E-06
Cm244	Samples	4.04E-02	4.94E-03	2.44E-05	1.38E-02	2.84E-06

Typical Values - Transfer Functions

55 Gallon Drum									
Weight (lbs)	Density (g/cm^3)	TCs	TCo	TCs Relative Error	TCo Relative Error	Var(TCs)	Var(TCo)	Dose (mR/hr)	Var(Dose) $(mR/hr)^2$
34.70	0.11	16.10	75.20	0.10	0.10	2.59	56.55	13.43	10.26
114.90	0.35	14.00	67.70	0.10	0.10	1.96	45.83	11.92	8.09
179.10	0.54	12.40	61.80	0.10	0.10	1.54	38.19	10.75	6.58
285.20	0.87	10.10	53.10	0.10	0.10	1.02	28.20	9.05	4.66
347.40	1.06	8.94	48.80	0.10	0.10	0.80	23.81	8.20	3.83