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TECHNICAL BASIS DOCUMENT
ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE

RADIOLOGICAL FIELD CHARACTERIZATION OF LOW LEVEL WASTE

BY MEASURING SURFACE CONTAMINATION AND CALCULATING TOTAL AND SPECIFIC ACTIVITY

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RMRS Rocky Mountain Remediation Services, L.L.C.
. . . protecting the environment

Safe Sites of Colorado & Rocky Mountain Remediation Services
779 Closure Project

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EXECUTIVE SUMMARY

The Rocky Flats Environmental Technology Site (Site) is proposing a method to determine total and specific radioactivity of surface contaminated objects (SCOs) using fixed and removable contamination survey data. An SCO is a solid object which is itself not radioactive but which has fixed and removable radioactive contamination distributed on any of its surfaces [1]. Low-level waste (LLW), which is contaminated with plutonium, is currently sorted or disassembled by item description code (IDC) (e.g., metal, plastic) for non-destructive assay (NDA) by passive-active neutron counting or segmented gamma scanning. The proposed method for field characterization eliminates many of the current requirements for segregation of waste and the waste package size restrictions imposed by NDA equipment. Field characterization avoids the costs associated with waste segregation by IDC and NDA. Real-time radiography is replaced by in-process inspection or waste certification at the point of generation. In addition, using larger packages can reduce labor costs for some packaging.

Radiological characterization of SCOs can be performed in the field by using surface contamination survey data. These surveys can be performed using existing instrumentation and procedures for instrumentation calibration and operation. Survey instructions will be obtained from Radiological Engineering. This is similar to current Radiological Engineering procedures for survey and release of property and waste. Process knowledge and/or analytical data will be used to document the radioisotopes in the waste. Survey data and the estimate of the contaminated surface area will then be used to calculate the total activity in a waste package.

This document is primarily focused on the technical approach for using surface contamination survey data to calculate total transuranic activity and activity per gram of waste. Standard statistical methods are reviewed and applied to determine the number of survey points needed to achieve desired results. A general discussion of the types of wastes, projected disposal rates for SCOs, and the waste generating process are described. This document also includes a description of the physical, chemical, and radiological composition of the waste; a regulatory compliance section; and documentation requirements.

As the Site begins the process of decommissioning and decontamination of major buildings, large quantities of LLW will be generated. This proposed method for field characterization will result in streamlining the process of waste characterization and packaging of SCOs-greatly increasing the rate at which LLW waste can leave the Site.

I. INTRODUCTION

(1) Purpose

This document describes the technical basis and methods used to determine total and specific activity of surface contaminated objects (SCOs) from contamination survey data. An SCO is a solid object which is itself not radioactive but which has fixed and removable radioactive contamination distributed on any of its surfaces [1]. SCOs have surfaces that are non-porous and do not absorb radioactive material. Examples of SCOs that are likely to be generated during Rocky Flats Environmental Technology Site (Site) closure activities include ancillary equipment, tools, desks, cabinets, computers, laboratory cabinets, bench tops, sinks, sheet metal, piping, rigid plastics, light fixtures, etc. The Site proposes to use this approach to demonstrate compliance with U.S. Department of Energy (DOE) approved disposal site waste acceptance criteria (WAC) and U.S. Department of Transportation (DOT) regulations.

(2) Scope

Radiological characterization is a process used, in part, to estimate total radioactivity levels. The proposed method uses data from representative surface contamination surveys on surface contaminated objects (SCOs) and surface area to calculate total activity. The total activity and the weight of the waste is used to determine the activity per unit mass of waste. This method requires that an SCO have a known isotopic distribution, a reasonable estimate of contaminated surface area, and sufficient accessible surfaces that can be surveyed to perform radiological surveys. This technical basis document is focused on SCOs contaminated with alpha emitting radionuclides from weapons grade plutonium (WGPu). The technical bases are also applicable to SCOs contaminated with depleted uranium, enriched uranium, or other radioactive isotopes at the Site. The specific application to radioactive material other than WGPu or to disposal of various waste types is addressed in implementing procedures.

(3) Background

As a result of Site operations, property and equipment are contaminated with WGPu, enriched uranium, and depleted uranium. Radiological characterization of low-level waste (LLW) at the Site is accomplished by one of three methods: sampling and destructive radiochemical analysis, non-destructive assay (NDA), or radiological contamination surveys [2]. Sampling and destructive radiochemical analyses are performed on homogeneous types of waste (e.g., sludge). NDA is currently performed on other wastes that may be contaminated with plutonium or enriched uranium. The Site uses gamma spectroscopy or passive/active neutron interrogation to measure the total activity of waste packages assuming a standard nuclide mix for WGPu or enriched uranium. The specific activity is calculated from the total activity and mass of the waste. Radiological contamination surveys have been successfully used for characterization of waste contaminated with depleted uranium [2].

Radiological contamination surveys can be used to quantify WGPu that has been deposited on surveyable surfaces. Based on the distribution of contamination, the appropriate number of survey prints can be determined and the results used to quantify the activity per unit area. The survey results are used to show the surface contamination is less than the DOT limits for SCOs. The total surface area is then determined and used to calculate the total activity. The specific activity in the waste package is calculated by dividing the total activity by the net waste weight. This method was successfully implemented to ship plutonium-contaminated property from the Site to other DOE facilities (e.g., lathes to Los Alamos National Laboratory) in accordance with DOT requirements. Waste packages prepared for disposal must meet DOT requirements and the disposal site WAC.

(4) Benchmarking against Other DOE Facility Practices

The benchmarking results show that Nevada Test Site (NTS) has accepted waste that has been characterized from contamination survey data. Information was received from Lawrence Livermore National Laboratory (LLNL) (Pu waste) and RMI Extrusion (U waste) [3]. Several examples of radiological engineering calculations were used at Mound to estimate the total activity and specific activity of waste being shipped to NTS. Overall, the information shows that NTS has accepted surface contamination surveys for characterization of Pu- and U-contaminated waste. In fact, LLNL has used contamination survey data to derive two default values for plutonium specific activity. The derived value for waste from a plutonium handling facility outside of gloveboxes is 0.2 nCi/g, and the derived value for waste from spills is 5 nCi/g. No additional contamination surveys or NDA are performed to verify compliance with the NTS 100 nCi/g limit.

The benchmarking information did not provide details on how the number of surveys was established. For example, survey data showed roughly 10 to 25 measurements for fume hoods, five sample points for cabinets, and 15 measurements for a large blower. Both the average activity and maximum contamination values were used for total activity calculations. Surface contamination data was also used for potentially contaminated equipment. Calculations were used to ship bulk Pu-contaminated equipment that could not be surveyed for unrestricted release due to inaccessible areas. These calculations assumed contamination levels at the DOE 5400.5 [4] release limits, an average density of the waste, and a conservative contaminated surface area to waste volume to derive a value of approximately 4 nCi/pound for bulk Pu-contaminated waste / equipment.

One of the more innovative approaches for using surface contamination data was for U-contaminated demolition debris. A series of biased measurements on the most contaminated equipment was obtained to reach maximum levels. Then a mass-to-area ratio for the equipment was calculated. This information was used to calculate the total activity for each piece of

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equipment. By knowing the weight of the equipment and the total activity, the specific activity representative of demolition waste could be calculated. The specific activity was then used for all demolition waste.

II. WASTE DESCRIPTION

(1) General

SCOs may be packaged for disposal as LLW or low-level mixed waste (LLMW), although the primary type of waste is LLW. Certain LLMW, RCRA hazardous waste with measurable surface contamination, may be able to be disposed at DOE approved disposal facilities. In addition, property with inaccessible areas that cannot be surveyed or released for unrestricted use per DOE 5400.5 [4] is managed as radioactive waste and may be characterized and transported as an SCO.

(2) Disposal Rates

Based on the Rocky Flats Closure Project Completion Metrics Baseline, Revision 2, 66,316 cubic meters of LLW will be shipped for disposal between FY98 and FY09. Assuming that 50% of this waste could be disposed of as SCOs, the average disposal rate would be 2,709 cubic meters per year. This annual volume of SCO waste requires roughly 100 8-feet by 8-feet by 20-feet cargo containers or 850 boxes (4-feet by 4-feet by 7-feet).

(3) Container Types, Weights, and Dimensions

The minimum required packaging for SCO I material is strong-tight bulk packaging. For SCO II material each non-specification package is limited to an A2 quantity (the A2 quantity is a package activity limit in Curies, see 49 CFR 173), and the shipments must be "exclusive use" within the United States. Examples of approved packaging are 4-feet by 4-feet by 7-feet and 2-feet by 4-feet by 7-feet wooden boxes. Metal boxes of the same or other dimensions could also be used. The Site desires to use 8-feet by 8-feet by 20-feet containers for shipment and disposal for SCOs generated during closure. Other DOT approved industrial packaging may be needed to meet project needs (e.g., nonstandard boxes for odd-shaped objects). Gross package weight for typical containers include the following:

Package	Max Gross Weight (lb.)
Full or half wooden box	5,000
Full or half metal box	9,000
8-feet x 8-feet x 20-feet	20,000-30,000

All packages must be compliant with requirements applicable to the material to be transported.

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(4) Identification of SCOs from Site Closure Activities

SCOs being generated from building decommissioning and decontamination (D&D) and other Site closure activities consist of ancillary equipment, tools, desks, cabinets, computers, laboratory cabinets, bench tops and sinks, sheet metal, metal and plastic pipe, Plexiglas, light fixtures, gloveboxes and hoods. SCOs also include building rubble provided the material does not have chemically absorbed or bound radioactive material [5]. If the radioisotopes are chemically bound or absorbed, then a surface contamination survey cannot be used for characterization and the waste would be packaged as low specific activity (LSA) waste and assayed by NDA (or sampled for radiochemical analysis). Objects with painted surfaces may be classified as an SCO if process knowledge and/or radiochemical analyses are used to evaluate the inaccessible (painted) area contamination levels. Of the 180+ item description codes (IDCs) [6], 14 of these contain materials that may be SCOs and therefore candidates for field characterization. These IDCs are identified in Table 1 and represent 34% of the non-line waste generated between January 1995 and March 1998. For the B779 Closure Project, these 14 IDCs represent 86% of the waste generated between October 1997 and March 1998. This data provides an indication of the amount of potential SCO waste to be created during facility closure.

Table 2 shows the relationship between DOT SCO limits, the Site's non-line generated administrative limit, and the Site's Radiological Control Manual (RCM) limits for Pu surface contamination. Note that the SCO II limits for total contamination (i.e. fixed plus removable contamination) for accessible and non-accessible areas are more than 400 times greater than the Site administrative guideline used for non-line generated waste. Provided the Site continues to use the administrative limit for surface contamination for non-line generated waste, only representative surveys are necessary to determine the range of total contamination and, if required, swipe surveys used to show compliance with the SCO limits for removable contamination.

III. WASTE GENERATING PROCESS

(1) LLW and TRU Waste Stream Components

Currently waste is packaged and characterized according to Waste Generating Instructions [7] and waste packaging procedures, WO-1100 [8], and WO-4034 [6] to meet DOT and disposal site WAC. The site waste generating process is organized by distinct waste types (IDCs). The IDCs are segregated and packaged individually for NDA (or destructive radiochemical analysis is performed), shipment, and disposal. LLW streams are divided into classifications of LLW or LLMW based on hazardous characteristics. LLW/LLMW are characterized for hazardous constituents according to the Waste Stream and Residue Identification and Characterization program (WSRIC) [9]. Another component of the waste stream is material or objects

TABLE 1

CANDIDATE RFETS IDCs
FOR
FIELD CHARACTERIZATION (SURFACE CONTAMINATED OBJECTS)

IDC	Material Description
300	Graphite molds
301	Classified Graphite shapes
302	Benelex and Plexiglas
320	Heavy non-stainless steel metal (Ta, W, Pt)
321	Lead (such as lead sheeting, etc.)
325	Mixed IDCs outside the Protected Area (Mixed Waste)
326	Mixed IDCs outside the Protected Area (Low Level Waste)
337	Plastic (Teflon, PVC, Polyethylene): applicable to rigid plastic only
440	Glass (Except Raschig rings)
444	Leaded Glass
480	Light Metal (such as iron, copper, aluminum, etc.)
484	Classified non-NM Scrap Metal shapes (Non-Be)
486	Classified tooling for disposal
487	Classified Plastic shapes
488	Glovebox parts with lead
489	Classified Be Scrap Metal Shapes
854	Beryllium Metal
863	Plastic Low Level Waste (NMC, NDA & non-PA): applicable to rigid plastic only

Reference 4-D99-WO-1100, Revision 1, *Solid Radioactive Waste Packaging, Table 5.1*, dated 11/4/97 [7]. The IDCs in the above table are a subset of the 180+ IDCs identified in WO-1100. Not all waste of the indicated IDCs will meet the requirements necessary to allow field characterization. Mixed IDCs shall not include LSA or other material which cannot be characterized using surface contamination measurements. The prerequisite conditions spelled out in PRO-267-RSP-09.05, *Radiological Characterization for Surface Contaminated Object Shipment and Disposal*, must be satisfied.

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TABLE 2

SURFACE CONTAMINATION VALUES APPLICABLE TO WGPU (UNITS DPM/100CM^2)

Type of contamination	DOT SCO I Limit [1]	DOT SCO II Limit	RCM Contamination Area Posting Limit [2]
Total (fixed + removable) accessible	2.4 E+7	4.8 E+8	No Established Posting Limit
Total (fixed + removable) non-accessible	2.4 E +7	4.8 E +8	No Established Posting Limit
Removable	2,400	240,000	2,000

(1) Reference 11
(2) As per Table 2-2, Site Radiological Control Manual

originating in a Radioactive Material Management Area as defined in the Site's No-Rad-Added Waste Verification Program [10] that are managed as LLW when they cannot be proven otherwise.

The Site has successfully used process knowledge, contamination surveys, and NDA to show waste segregated as LLW is well below 100 nCi/g. The Site currently uses process knowledge and contamination surveys to segregate LLW from TRU waste generated in the former production buildings. Then the packaged waste is assayed by NDA to determine the final classification as LLW or TRU waste.

The fundamental process knowledge used to denote TRU waste is the identification of components, piping, ventilation, process systems, and gloveboxes as line generated waste [2,8]. TRU waste is defined as radioactive waste containing alpha-emitting radionuclides having atomic numbers greater than 92 and half-lives greater than 20 years in concentrations greater than 100 nCi/g at time of assay [2]. Non-process system and non-line generated waste [1,10] is potentially or slightly contaminated and is packaged as LLW. In addition to process knowledge, contamination surveys are performed to distinguish between line and non-line generated objects or materials originating in radiological areas during waste packaging. Objects or materials contaminated with transuranic isotopes with total TRU contamination levels greater than those which would correspond to a specific activity in excess of 100 nCi/g are segregated and packaged as TRU waste.

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The effectiveness of this system for segregating LLW from TRU at the point of generation is demonstrated by review of historical data. The Waste and Environmental Management System (WEMS) is a database of information on waste containers. From January 1, 1995 through March 1998, 5,062 containers of non-line waste were created, according to WEMS. For those waste types that are candidates for field characterization, this initial LLW designation was accurate more than 99% of the time. This approach to initial characterization tends to overstate the amount of TRU waste. In FY97, approximately 10% of the waste drums being processed to confirm certification to TRU waste disposal site criteria were determined to be LLW.

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Field survey data will be used to show that contaminated objects will meet the SCO I and II limits for total contamination. Provided the total contamination (fixed plus removable) is less than the applicable DOT limit for removable contamination (e.g., 240,000 dpm/100 cm^2 removable alpha for SCO II), only total contamination needs to be measured. Most of the waste in the Protected Area will be SCO I, since high contamination areas represent less than 15% of the contaminated surface area in the former production buildings [12].

(2) Waste Generating Instructions

The Site has developed a set of instructions for waste generators to follow to aid in compliance with disposal site WAC. These Waste Generating Instructions (WGIs) are issued by the RMRS Customer Service Organization (CSO) and apply to newly generated solid waste. A WGI for SCOs will be completed by the customer service representatives by building, room, project, or waste stream.

The WGI for packaging SCOs will require a "Radiological Waste Characterization" per PRO-267-RSP-09.05 to be completed by a trained radiological engineer. Representative surveys and documentation of surface area will be performed in accordance with PRO-267-RSP-09.05. The Waste/Residue Traveler will be used to record each package contents. Contents will be matched with contamination survey data and total activity calculations performed in accordance with PRO-267-RSP-09.05. A process flow description is provided in Attachment 1.

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TABLE 3

**CALCULATED SPECIFIC AND TOTAL ACTIVITIES
FOR
VARIOUS SURFACE CONTAMINATED OBJECTS
(WGPu)
(DELETED)**

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IV. SURFACE CONTAMINATED OBJECTS

(1) Physical, Chemical, and Radiological Properties of SCOs

For purposes of field characterization, SCOs are solid objects that have surfaces that can be measured for surface contamination. Radiological contamination is chemically described as a metal oxide for each of the isotopes making up WGPu (e.g., PuO_2). The contamination is either fixed on the object or removable, and the object itself is not radioactive. Removable contamination is the fraction of the contamination that is available for resuspension. Radiological surveys typically report the total contamination levels and the removable contamination levels in disintegrations per minute (dpm) per 100 cm^2. SCOs must comply with DOT limits for total and removable contamination levels.

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Removable contamination must be shown to be less than the applicable limit (i.e., 240,000 dpm/100 cm^2 for alpha emitters under SCO II, 2,400 dpm/100 cm^2 for alpha emitters under SCO I). Most of the radiological areas on the Site are contaminated areas. Of the 213,750 square feet of contaminated areas in the former Pu production buildings, roughly 34,800 square feet or 16% is posted as a high contaminated area [12]. Based on this information, 84% of the SCOs are going to be less than 2,000 dpm/100 cm^2 removable alpha (CA limits for removable contamination).

(2) Low Specific Activity vs. Surface Contaminated Object Determinations

The basis for classifying material as LSA can be found in DOT regulations and NUREG-1608 [5]. NUREG-1608 is a Nuclear Regulatory Commission guidance document for compliance with DOT regulations for radioactive material shipments. The guidance in NUREG-1608 is being used in WO-1100 to make informed decisions on classifying LLW as LSA or SCO.

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The determination of waste as an SCO will be made by Radiological Engineering and the waste generator prior to packaging the waste. The WGI will provide project-specific waste stream SCO determinations. Process knowledge and data from radiological surveillances will be used to make the initial LSA/SCO determination. Conditions necessary for declaring waste as a SCO include; accessible areas can be surveyed for fixed and removable contamination; median removable contamination is less than one-half the applicable SCO removable limit; maximum removable less than the applicable removable contamination limit; and no chemically bound or absorbed radioactive materials such as found in sludge or filter media. Objects with removable contamination > SCO I or II limits can be shipped in compliance with DOT provided a fixative is applied to the contamination (after obtaining contamination levels). Such an object with fixed contamination would continue to be classified as an SCO.

(3) Accessible vs. Non-accessible Surfaces

One of the more significant technical issues to overcome when performing field measurements is the identification of accessible and non-accessible surfaces. NUREG-1608 [5] defines an accessible surface as any surface that can be wiped by hand or measured using standard radiation measurement techniques. A non-accessible area is any potentially contaminated surface that cannot be surveyed for total or removable contamination. The strategy is to perform a representative number of surveys on accessible areas with sufficient statistical power to demonstrate regulatory compliance for all potentially contaminated surfaces. A non-accessible surface would be treated like a surface that had not been selected as part of the representative survey. Therefore, non-accessible surfaces would not have to be disassembled for a survey provided that all of the survey points on accessible areas are less than the applicable limits and consistent with the assumptions used to determine sample size. An additional assumption is that the surface contamination levels are reasonably considered to be distributed throughout the object. This approach for non-accessible surfaces is supported in NUREG-1608 [5]: "(DOT) regulations do not require measurements of contamination as the only means of accomplishing (SCO) determinations." Furthermore, "A reasoned argument could be used to categorize the great majority of candidate SCOs without the need for detailed quantitative measurements of fixed, accessible contamination, or total inaccessible contamination."

The key to addressing regulatory compliance for non-accessible surfaces is to have a statistically valid sample size and to keep the median contamination levels less than half the regulatory limit. Several types of statistical tests were evaluated for determining the appropriate number of survey points on accessible surfaces. The non-parametric Sign test was selected for determining the appropriate number of survey points. This type of test requires general knowledge about the range and variability of the contamination. The Sign test will require more samples as the contamination levels approach the regulatory limit and when there is a large standard deviation in the contamination levels. Section V.1 provides a technical discussion of the application of the Sign test and null hypothesis to determine sample size.

Another concern at the Site is diversion of special nuclear material. When SCOs are being packaged in Material Access Areas, as defined in the Material Control and Accountability Manual, certain safeguards measurements are performed. Quantitative hold-up measurements are performed to verify that WGPu levels are less than 0.5 g/ft^2 and qualitative measurements are used to verify that there was no diversion of accountable special nuclear material. These analyses confirm there is no significant hold up of special nuclear material for inaccessible areas. Wastes subject to safeguards requirements are identified in the Site's Safeguards & Accountability Manual.

V. TECHNICAL APPROACH TO FIELD CHARACTERIZATION BY PERFORMING SURFACE CONTAMINATION SURVEYS

(1) Statistics and Representative Sampling

Three types of statistical tests were considered for determining the representative number of samples or survey points required to demonstrate regulatory compliance: confidence interval testing, acceptance sampling and the sign test. Confidence internal testing is commonly used in decommissioning applications. For example, in NUREG/CR-5849 [13] the upper 95% confidence interval for a particular radiological parameter must be less than the applicable limit. NUREG/CR-5849 recommends a t-test be used to test data in a survey unit against the release criteria. This assumes the data are normally distributed and the number of surveys points is less than 30 (a Z-test is used when the sample size exceeds 30). In a normal distribution, the mean, mode, and median are all equal and the distribution is symmetric about the mean. Provided the number of sample points is 30 or greater, it is generally acceptable to assume the sample means for these data are normally distributed and then use standard equations to calculate the mean, standard deviation, and upper confidence level of the mean.

Another consideration is to use acceptance sampling. Acceptance sampling is often used by manufacturers to accept a particular lot based on the number of defective parts in the sampling. This approach has been used to survey parts for unrestricted release from the Site. The down side to using acceptance sampling is that the number of samples is independent of the contamination limit and assumed contamination levels. For example, if the test is based on a 5% probability of accepting the survey with 1% defective areas, then the sample size is determined by solving the following equation for n:

$(1 - 0.01)^n = 0.05$ or 300 survey points are required.

Unless there is a large number of "parts" (i.e., number of 100 cm^2 survey units), the acceptance sampling approach is not cost effective.

The spatial distribution of surface contamination on SCOs clearly does not meet the conditions for a normal distribution. Rather, a typical distribution of contamination data is log-normal or skewed and often has reported activity below MDA or outlying data. Since it is not practical to test the data for its fit to a normal distribution, the use of non-parametric statistics that are not dependent on the data being normally distributed should be used to determine sample size.

The Sign test is a non-parametric test that should be used when contaminants are not present in background [14]. The number of data points is based on the contamination limit, the expected range and standard deviation of the contamination levels, and the probability of making type I and type II errors. The objective of the survey design is to demonstrate compliance with the regulatory limits. Hypothesis testing is used to define the Type I and Type II errors. The Null Hypothesis is that the surface contamination levels exceed the regulatory limits. Thus, the Null

Hypothesis (Ho) must be rejected to demonstrate regulatory compliance. The Type I (alpha) error is rejecting Ho when Ho is true. The Type II (beta) error is accepting Ho when Ho is false. Type I errors need to be minimized to reduce the likelihood of stating that SCOs are below regulatory limits when they actually are not. Type II errors lead to incorrectly calling an SCO above the regulatory limits, when it actually is not. The selection of alpha and beta values define the data quality objectives. Alpha is being selected as 0.01, thus there is only a 1% chance of exceeding a regulatory limits. Beta is being selected as 0.05, thus there is only a 5% chance of reporting above the regulatory limits when it is actually not above the limit.

For decommissioning applications, MARSSIM [15] recommends testing the hypothesis that the median concentration of the residual radioactivity in the survey units is less than the applicable limit. Therefore, it is reasonable to use this same basis for determining sample size for compliance with DOT limits, provided no one sample point is greater than the applicable limit. The conditional assumption is that the median contamination limit is one-half the regulatory limit. The following example is used to determine the minimum number of survey points for an SCO II, when the removable contamination is a median value of 100,000 dpm/100cm^2:

1. Process knowledge and routine surveys show contamination levels are generally less than 100,000 dpm/100 cm^2. This is the assumed value of the median and in statistical terms is the Lower Bound of the Gray Region (LBGR)[15].
2. The standard deviation is assumed to be 100,000 dpm/100 cm^2.
3. Type I error Alpha = 0.01, Z 1-alpha = 2.326 (99% error percentile)
4. Type II error Beta = 0.05, Z 1-beta = 1.645 (95% error percentile)
5. Post-survey analysis confirms no sample points are greater than 240,000 dpm/100cm^2. This validates that the population median is significantly less than the regulatory limit.

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The steps for performing the calculation of sample size are as follows [16]:

1. Calculate the relative shift Δ/σ_s = (contamination limit-LBGR)/ σ_s
   Substituting the assumed data (Contamination Limit 240,000 dpm/100cm^2, LBGR = 100,000 dpm/100cm^2, σ_s = 100,000 dpm/100cm^2) the relative shift is approximately equal to 1.2.
2. Determining the Sign P
   Sign P is the estimated probability that a random measurement from the survey unit will be less than the contamination limit when the survey unit median is at the LBGR [16]. The relative shift is used to look up the value of P in standard statistical tables [15,16]. In this case P = 0.885.
3. Calculate the number of survey points (N) where
   $N = (Z\ 1\text{-alpha} + Z\ 1\text{-beta})^2 / 4\ (\text{Sign P} - 0.5)^2 = (2.326 + 1.645)^2 / 4\ (0.885-0.5)^2$
   Substituting assumed data, N, the number of survey points equals 26.6. The recommended number of samples is rounded to 30.

In conclusion, the Site will use the Sign test to determine the number of survey points. The Sign test confirms, for the example listed, that 30 survey points can be used to demonstrate that

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contamination levels are less than the SCO II limit of 240,000 dpm/100 cm^2 (i.e., reject the null hypothesis that the contamination levels are greater than 240,000 dpm/100 cm^2).

Two practical applications arise from this example. First, the mathematical expressions for sample size hold true for any situation where the median contamination levels are about one-half the regulatory limit and the standard deviation is also one-half the regulatory limit. Second, 30 sample points can be used for most applications. The mathematical expression used for calculating the mean, standard deviation, and UCL90 are simplified if the data can be assumed to be normally distributed. Even if the distribution in the original population is far from normal, the distribution of sample averages tends to become normal, under a wide variety of conditions as the sample size increases[19]. In conclusion, 30 is the minimum number of sample points needed to treat survey data as being normally distributed. This is further discussed in Section V.3, Field Characterization Instructions.

(2) Selection and Use of Survey Equipment

Surface contamination surveys are performed for fixed and removable contamination. The Site has a radiological safety procedure to perform these types of surveys. The procedure specifies instrument selection and use, limitations, training, qualifications, and documentation. Each instrument used is calibrated semiannually and performance checked daily. Instrument limitations include rusted objects, oily surfaces, and non-flat surfaces. Specific instrument limitations are listed in Radiological Safety Procedures.

The concentration of removable contamination is determined by lightly swiping a paper disk across 100 cm^2 of the surface and measuring the swipe in a gas flow proportional counter. Instrumentation (e.g., SAC-4) and survey methods for removable alpha contamination have been shown to have an MDA less than 20 dpm/100 cm^2. Total contamination (i.e., fixed plus removable) is measured with a static count, typically for one minute. In general, an instrument with an MDA below 1,000 dpm/100 cm^2 is acceptable for total contamination measurements.

(3) Field Characterization Instructions

At the request of the waste generator, radiological engineers will be responsible for writing the field characterization instructions, identifying the characterization survey unit, assuring the correct number of surveys points have been taken, performing data analysis, calculating total activity, and calculating specific activity. This activity will be performed in accordance with PRO-267-RSP-09.05 "Radiological Characterization for Surface Contaminated Object Shipment and Disposal." Calculations must show that each package containing TRU isotopes is going to be less than the disposal site WAC (e.g., 100 nCi/g NTS limit for TRU isotopes).
In addition, the maximum fixed and removable contamination cannot exceed SCO limits in 49 CFR 173.403 [12] (see Table 2). Instructions for characterization of WGPu, enriched uranium, and depleted uranium contaminated SCOs are provided in PRO-267-RSP-09.05.

PRO-267-RSP-09.05 identifies the number of survey points for fixed and removable contamination, designates the type of surveys as alpha or beta surveys, summarizes the survey data, and documents compliance with applicable limits for SCOs or disposal site requirements. A characterization survey unit represents any area or number of objects with the same radiological characteristics (based on process knowledge and/or general contamination survey data). The isotopic mix is obtained by process knowledge or sampling. Calculations of the sample size in Section V(1) have been performed for the condition that the median contamination level is 100,000 dpm/100cm^2 and the standard deviation is 100,000 dpm/100cm^2. These results show that 30 is the minimum number of survey points for most survey units. PRO-267-RSP-09.05 is developed to reflect the following:

- A graded approach is used for representative sampling to account for the range in contamination levels in a survey unit.
- Perform 30 swipes for removable contamination. For SCO I, removable contamination for alpha emitters is required to be less than 2,400 dpm/100 cm^2. The corresponding limit for beta, gamma and low toxicity alpha emitters is 24,000 dpm/100 cm^2, with median total activity less than 10,000 dpm/100 cm^2.
- Perform 30 swipes for removable contamination. For SCO II, removable contamination for alpha emitters is required to be less than 240,000 dpm/100 cm^2 . The corresponding limit for beta, gamma and low toxicity alpha emitters is 2,400,000 dpm/100 cm^2.
- Perform 30 direct measurements for total contamination.
- For SCO I, total contamination for beta, gamma and low toxicity alpha emitters is required to be less than 2.4 E+8 dpm/100 cm^2 for high toxicity alpha emitters is required to be less than 2.4 E+7 dpm/100 cm^2.
- For SCO II, total contamination for beta, gamma and low toxicity alpha emitters is required to be less than 4.8 E+9 dpm/100 cm^2 for high toxicity alpha emitters is required to be less than 4.8 E+8 dpm/100 cm^2.
- If removable contamination in the survey unit is projected to be greater than the applicable limit, then redefine the survey unit, perform decontamination, or apply fixatives.
- Technicians should be instructed to use the skills of the trade to find the highest readings.
- The Site will reject objects for field characterization as SCO if a single measurement of total TRU contamination exceeds those which would correspond to a specific activity in excess of 100 nCi/g.
- Raw data and background should be reported on the survey form. (Information on the survey form should be gross readings not listed as <MDA). The MDA should be recorded on the survey form.
- Alternative sample size can be calculated using the Sign Test sample size formula and substituting actual values for sample median and standard deviation (step 1, page 13).

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VI. TECHNICAL APPROACH TO CALCULATING TOTAL ACTIVITY AND SPECIFIC ACTIVITY IN A WASTE PACKAGE

(1) Data Analysis and Calculations

Data from each characterization survey unit (which could be a minimum of 30 survey points) will be analyzed and reported at 90 percent upper confidence level of the mean. Other alternatives considered were to use the mean or the maximum contamination levels for calculating total activity. EPA suggests using the 90 percent upper confidence level of the mean in several documents [e.g., SW-846] because it represents a value that is reasonably conservative. The value of surface contamination corresponding to the UCL-90, upper confidence level of the mean, will be used to represent the activity for all the SCOs in the characterization survey unit. The UCL-90 is calculated from the mean and its standard deviation using the following formula:

UCL-90 = mean + 1.645 x standard deviation of the mean.

The last calculation is taking the UCL-90 value in dpm/100 cm^2 and applying this over the contaminated surface area(s) to calculate the total activity in waste packages.
To determine total activity of the characterization survey unit the UCL-90 value in dpm/100cm^2 is applied over the total contaminated surface area.

The total contaminated surface area packaged in a waste container will be documented in a standard format (e.g., on PRO-267-RSP-09.05 form). Surface area estimates can be obtained by measurement of a particular object's dimensions or by establishment of a conversion factor(s) for mass to surface area. A common sense approach is emphasized. For the conversion from mass to surface area, no attempt was made to determine the uncertainty in the estimate of total surface area. The assumption that all surface area is contaminated at the UCL-90 level is by itself reasonably conservative.

(2) Surface Area Determinations

Determinations of total waste container activity for shipping purposes and specific activity for disposal purposes both require knowledge of the total contaminated surface area in the waste container. Two methods have been identified to accomplish this. The first (measured area method) involves estimating the contaminated surface area of each waste item introduced into a waste container. This approach could be used for every waste package, although it is most likely to be useful for waste containers with large numbers of similar items with known surface areas or waste containers with a limited number of larger items. This method would be very labor intensive for waste containers with large numbers of small and varied items.

A second approach (weight-to-area conversion method) was developed using results from extensive surveys of the B779 Closure Project. This approach identifies a conservative conversion value to calculate total waste container surface area based upon the net weight of

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waste in the container. In order to develop the conversion value, candidate SCO materials were measured for thickness during a wall-to-wall walkdown in B779. These thickness' were converted, using standard engineering references, to grams / 100 cm^2. The results of this effort (Table 4) show that the lowest weight to surface area SCO materials were the fluorescent light fixtures. The rest of the measured materials, which represent the vast majority of the total SCO materials, had much higher weight-to-surface area ratios. Using a material such as the light fixture to set the conversion value for calculating total surface area of SCO waste in a waste container will overstate the total surface area in all waste containers except those that contain only light fixtures. A sensitivity analysis shows how the specific activity of various waste materials changes as the contamination levels change. This approach is recommended for waste containers that are filled with many small items.

These approaches are incorporated into PRO-267-RSP-09.05. A third approved method would involve establishing a package specific weight-to-area conversion factor. This may give more accurate results when a waste container is filled with items that have higher weight-to-surface area ratios than the default (conservative) value that has been proposed.

(3) Assigning Activity to a Waste Package

Assigning total activity to a waste package requires assigning results from the survey unit characterization and determining total contaminated surface area in the package. Section VI.2 describes methods for determining total surface area. Given that surveys have been performed and the UCL-90 has been calculated, the next step is to assign the activity to a waste package (and to verify the activity is less than the applicable DOT A2 value).

In all cases, the Waste/Residue Traveler [17] will be used to document the contents in a waste package. The Radiological Characterization instruction, PRO-267-RSP-09.05, will be used to document the method used to assign activity to a waste package and the results of that determination for each waste package.

VII. REGULATORY COMPLIANCE

(1) Comparison of NDA and Surface Contamination Analyses

NDA and surface contamination measurements were evaluated to compare the uncertainty associated with each measurement technique for a typical waste package containing SCOs and the extension of these analyses to calculating the total activity and specific activity.

Measurement uncertainties are classified as either systematic uncertainty or random uncertainty. Systematic uncertainty results from calibration errors, incorrect detection efficiencies, non-representative surveys, and human errors. The systematic error of a particular measurement cannot be estimated or calculated for the data itself, because each data point is affected differently. Thus collecting more data does not reduce systematic error. Curie [14] recommends that if no other information on systematic uncertainty is available, then use 16% as an estimate for systematic uncertainty (1% for blanks, 5% for baseline, and 10% for calibration factors). The random uncertainty is due to the random fluctuations associated with radioactive decay that follows the Poisson distribution. To calculate total random uncertainty both, background and sample measurement must be considered. The random uncertainty is usually expressed in terms of standard deviation for a sample population mean at a corresponding confidence level. For example, reporting the mean activity plus or minus 2 standard deviation is the same as saying you are 95% confident that "true" radioactivity is between the two standard deviation levels.

A reasonable estimate for the uncertainty in a contamination measurement is the relative error or 1 standard deviation. A value of 30% of the count or disintegration rate is recommended for 1 standard deviation in MARSSIM [15]. The WIPP quality assurance objectives for NDA [18] report an accuracy of plus or minus 25% at 1 standard deviation and a total bias of -25% to +400% for <0.1 g WGPu at the 95% confidence level.

Overall, the uncertainty between the two measurement techniques appears to be of the same order of magnitude, 25% vs. 30% at 1 standard deviation. Both measurement techniques rely on the assumption that material being assayed is equivalent to characteristics of the radioactive standards used for instrument calibration.

Total activity is directly measured by NDA and calculated from surface contamination measurements. Because NDA measurements have a much lower sensitivity than surface contamination measurements, the reported grams of WGPu is less than the MDA. No further details about the contamination levels can be provided by NDA measurements. Contamination surveys data show the uniformity of the contamination levels as described by the median contamination level and the standard deviation of the contamination levels from the sample set of data. To provide a margin of safety for total activity calculations, the Site has chosen to use the upper confidence level of the mean contamination level at the 90 percent confidence level to be representative of the characterization survey unit. The total activity in a waste package is based on the methods described in Section VI.

The following prerequisites are applicable to using surface contamination surveys and engineering calculations to determine total and specific activity:

- Safeguards has performed gamma measurements on accessible and non-accessible areas or otherwise determined the SCOs are Category III or IV materials.
- The contamination levels are reasonably uniformly distributed, given that the median removable contamination levels are less than one-half the applicable DOT limit.

TABLE 4

REPRESENTATIVE SURFACE CONTAMINATED OBJECTS FROM B779 CLOSURE PROJECT

Object	Thickness (in) / Gauge	g/100cm^2
X-Ray Camera Table	0.45 / na	460
Vacuum Induction Furnace	0.27 / na	276
Oil Cooling Reservoir	0.19 / 6	199
Security Grill Work	0.20 / 6	199
Glovebox Port Cover	0.20 / 6	199
Molded Lab Bench Top	>1.10 / na	154
Instrument Rack Face	0.13 / 10	137
Glovebox Supports	0.13 / 10	137
Open Faced Hood	0.13 / 10	137
Power Supply Cabinet Door	0.14 / 10	137
Aluminum Work Bench Top	0.38 / na	128
HEPA Filter Guard Plate	0.12 / 11	122
Aluminum Glove Ring	0.35 / na	118
Work Bench Top	0.10 / 12	107
Instrument Support Shelf	0.10 / 12	107
Instrument Support Bracket	0.10 / 12	107
Glass in Wall Cabinet Door	0.23 / na	83
Laboratory Furnace Side Wall	0.07 / 14	76
Instrument Cabinet	0.08 / 14	76
Electrical Panel Door	0.08 / 14	76
Work Bench Drawer	0.05 / 18	49
Desk Drawer	0.05 / 18	49
Instrument Cabinet, Back Cover	0.05 / 18	49
SAM Wall Support	0.05 / 18	49
Sheet Metal Guard	0.05 / 18	49
Stainless Steel Sink	0.05 / 18	49
Fire Call Box, Door	0.05 / 18	49
Rad Monitoring (Combo) Cabinet	0.05 / 18	49
General Supply Cabinet	0.04 / 20	37
¼" Plexiglas	0.25 / na	35
Paper Holder, Side of Open Faced Hood	0.03 / 22	31
Fluorescent Light Fixture	0.03 / 22	31

These objects are typical of the surface contaminated objects located in B779. Measurements were taken in the field during a thorough walkdown of B779. Thickness measurements were taken using a small hand held micrometer. The purpose for the walkdown and the measurements was to field test whether 20 gauge sheet metal (0.0359 inches, 37 g/100cm^2) represents a conservative (somewhat overstated) basis for converting the net weight of a waste container into the total surface in the container.

- The number of survey points is determined by the Sign test using the median and standard deviation for each survey unit, thus accounting for the distribution of contamination levels.
- The SCO's surface area is documented.
- The engineering calculation of total and specific activity is documented.

By completing the prerequisite actions, the result of total activity calculations using survey data provides an ample margin of safety relative to NDA measurements of total activity.

(2) Nevada Test Site Waste Acceptance Criteria

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A revised or new waste profile will be used for SCOs. The waste profile(s), together with this Technical Basis Document and the implementing Radiological Characterization procedure (PRO-267-RSP-09.05) will be submitted for disposal site review and acceptance.

(3) DOT Packaging

The DOT waste classification system for packaging LLW includes Limited Quantity, SCO, or LSA material. DOT allows co-mingling of LSA material and SCOs provided the applicable limits for surface contamination, total activity, and specific activity are not exceeded. When LSA and SCO material are co-mingled in a package, NDA or destructive radiochemical analyses will be used to determine total radioactivity in the package. Limited Quantity shipments of radioactive material apply to materials with a total activity less than 1/1,000 of an A2 quantity. When the total activity in a package is $<10^{-3}$ A2, there is no need to comply with SCO criteria, provided excepted packaging criteria are met and the dose rates requirements are met. The Site intends to use SCO I and SCO II criteria to package waste.

The advantage to using SCO I over SCO II is only SCO I objects can be packaged in strong-tight or IP-1 packages. SCO II objects require packages to be certified to IP-2 standards when A2 values are exceeded.

Swipe efficiency for removable contamination is assumed to be 10%, which is the industry standard practice. No adjustment to the DOT limits is recommended at this time based on this assumed efficiency. The Site will show the median contamination levels are less than one-half the applicable DOT SCO limit and no single measurement is above the applicable SCO limit.

VIII. DOCUMENTATION REQUIREMENTS

Quality assurance records are maintained and dispositioned in accordance with 1-V41-RM-001, Records Management Guidance for Records Sources.

IX. REFERENCES

[1] Title 49 Code of Federal Regulations part 173 Subpart I-Class 7 Radioactive Materials
[2] Low-Level Waste Management Plan, 94-RWP/EWQA-0014 Rev.1
[3] Personal Correspondence from G. Geisinger, Horne Engineering, to B. Colby, GTS Duratek, January, 1998
[4] Radiation Protection of the Public and the Environment, DOE 5400.5
[5] Categorizing and Transporting Low Specific Activity Materials and Surface Contaminated Objects, NUREG 1608
[6] Solid Radioactive Waste Packaging Requirements, WO-4034
[7] Waste Characterization and Generation, WGI-001
[8] Solid Radioactive Waste Packaging, WO-1100
[9] Waste Stream and Residue Identification and Characterization Program (WSRIC)
[10] No Rad Added Waste Verification Program

[11] Methods to Demonstrate Compliance with Performance Requirements for Swipe Counting and Portable Contamination Surveys Instrumentation used to Evaluate Property and Waste for Unrestricted Release, K-H Rad Engineering Technical Bases Document, June 7, 1995
[12] Performance Indicator Report on Building Surface Contamination Areas, K-H Jan. 1998
[13] Manual for Conducting Radiological Surveys in Support of License Termination, NUREG/CR 5849, May 1992

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[14] Curie, D. and Moore R. H., Applying Statistics, NUREG-1475, 1994

[15] Multiagency Radiation Survey and Site Investigation Manual (MARSSIM), December 1997

[16] Abelquist, Eric, Statistics and Decommissioning: Practical Application of Statistics used to Support Decommissioning Activities, ORISE, Feb. 1998

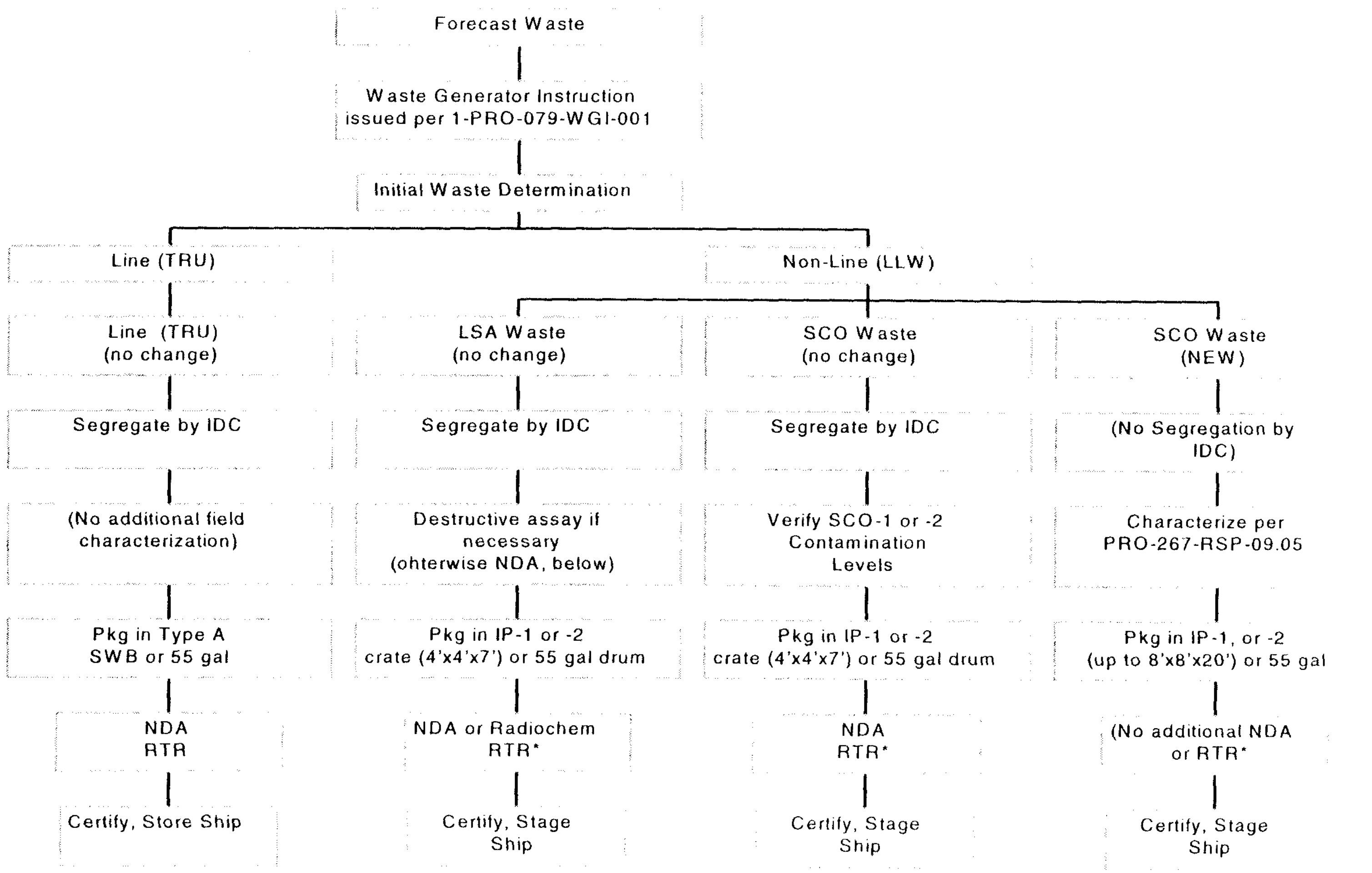
[17] Waste/Residue Traveler Instructions, 1C80-WO1102-WRT

[18] Transuranic Waste Characterization Quality Assurance Program Plan, CAO-94- 1010, November 1996

[19] Statistical Methods, sixth edition, Snedecor and Cochran, Iowa State Press, Ames, Iowa, 1967

Flow Chart - Waste Characterization and Packaging

Attachment 1



* RTR requirements may be satisfied by additional in-process inspection during waste packaging.

Attachment 2

Reference Values and Calculations

Material Densities

Material	lbs/ft³
Plate glass	161
Copper	556
Machine steel	487
Nickel	537
Bronze	509
Aluminum	165
Plexiglas	72
Lead glass	272

Reference: Marks "Mechanical Engineers' Handbook
Product Sheet - Technical Glass Products

Calculations and Conversions

$1Ci = 3.7 \times 10^{10}$ dps

$$\text{Specific TRU Activity} = \frac{(X\ dpm/100cm^2)\ (10^9 nCi/Ci)}{(60\ dpm/dps)\ (3.7 \times 10^{10}\ dps/Ci)\ (Y\ g/100cm^2)}$$

$$= \frac{(X\ dpm/100cm^2)\ (4.5 \times 10^{-4}\ nCi/dpm)}{(Y\ g/100cm^2)} = nCi/g$$

$$\text{Mass per Area} = \frac{(\text{density in } lb/ft^3)\ (\text{thickness in inches})\ (454g/lb)\ (100)}{(1728\ in^3/ft^3)\ (6.45\ cm^2/in^2)\ (2)}$$

$$= (\text{density in } lb/ft^3)\ (\text{thickness in inches})\ (2.04\ g\ ft^3/lb\ in\ cm^2)$$

$$= g/100\ cm^2 \quad \text{(both sides contaminated)}$$

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