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ENGINEERING DESIGN FILE

Project/Task RWMC/SWEPP Programs

Subtask SWEPP Certified Waste Sampling Program

TITLE: Description of the SWEPP Certified Waste Sampling Program for FY-95

Abstract: This Engineering Design File (EDF) establishes the requirements for the Stored Waste Examination Pilot Plant (SWEPP) Certified Waste Sampling Program that will be conducted for FY-95. Since FY-91, drums for the sampling program have been examined at the Hot Fuel Examination Facility (HFEF) at Argonne National Laboratory - West (ANL-W) in support of the Waste Isolation Pilot Plant (WIPP) Experimental Test Program. The sampling program conducted prior examinations at Rocky Flats. Since FY-91, the sampling program has incorporated the requirements for TRUPACT-II Authorized Methods for Payload Control (TRAMPAC) in addition to the original WIPP-Waste Acceptance Criteria (WIPP-WAC).

Contents of the containers stored at SWEPP are certified for compliance with WIPP-WAC and TRAMPAC requirements by using real-time radiography (RTR) and radio assay (RA). This EDF concentrates on the quality verification of the RTR process. Once certified, the contents are verified through the SWEPP Certified Waste Sampling Program, in which a statistically determined number of containers are opened and visually examined. The extent of the visual examination is based on the operational capabilities of the facility that is available for performing the examination. During FY 95, HFEF will be the conducting the examination in the Waste Characterization Chamber (WCC). The capabilities of the WCC are less extensive than those at Rocky Flats (FY-83 through FY 88), but more versatile than the HFEF Spray Chamber used from FY-91 through FY-93. Previous years' sampling results form the basis for the number of containers examined. During FY-95, SWEPP will examine approximately 288 drums. Of these, it is estimated that approximately 200 drums will be certified by RTR and RA for the TRU Waste Characterization Program (TWCP). For a population of 200 drums, 55 drums will be required for the sampling program. A description of the tasks included in the sampling program and calculation of the sampling frequency is included in the text of this EDF.

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PURPOSE OF THE EDF

This EDF provides the sampling frequency and examination requirements for the SWEPP Certified Waste Sampling Program. This program samples certified TRU waste before shipment to WIPP to verify compliance with WIPP-WAC and TRAMPAC requirements. Not all WIPP-WAC and TRAMPAC requirements are addressed in the sampling program. The SWEPP Certified Waste Sampling Program includes only those requirements that can be verified by RTR, headspace gas sampling, or established through process knowledge. For instance, RTR has been successful in verifying the absence of pressurized vessels. On the other hand, RTR cannot verify the absence of pyrophorics, but process knowledge indicates that pyrophorics will not be present in any of the waste forms that RTR currently certifies. The SWEPP Certified Waste Sampling Program confirms this type of process knowledge. WIPP-WAC and TRAMPAC requirements requiring direct measurements that are not possible with the RTR technique or gas headspace sampling and that cannot be adequately characterized through process knowledge are excluded from this SWEPP Certified Waste Sampling Program. The excluded criteria exclude those measurements derived from radioassay and surface dose requirements.

INTRODUCTION

The SWEPP Certified Waste Sampling Program uses a random sampling of the certified TRU waste containers being examined at SWEPP. Although a standard sampling frequency, such as one out of six, is determined annually, it is a random sampling because the containers are selected randomly from the storage pads. Operators at the Idaho National Engineering Laboratory (INEL) will open and visually examine a statistically significant number of containers at the HFEF WCC. Before 1989, the sampling was conducted at the Rocky Flats Plant and only addressed WIPP-WAC. Examination was halted at Rocky Flats because of suspension of production operations and plant RCRA compliance issues.

SAMPLING FREQUENCY

The calculation of sampling frequency for FY-95 is described in *FY-95 Sampling Program for SWEPP Certified Wastes*, included as Attachment 1 to this EDF. SWEPP is expected to examine around 288 drums in FY-95 to support the TRU Waste Characterization Program being conducted to support WIPP compliance efforts and data needs. Estimates based on past rejection rates indicate that SWEPP will certify approximately 200 of these drums in FY-95. Based on results of previous years' sampling (see Attachment 1), an estimated 2% of those sampled would be miscertified and not comply with all the WIPP-WAC and/or TRAMPAC requirements. In FY-95, approximately 55 drums will be sampled, which is equivalent to one out of four drums certified by SWEPP.

SAMPLING REQUIREMENTS

Table 1 contains a listing of TRAMPAC and WIPP-WAC sampling requirements. This SWEPP Certified Waste Sampling Program will include a joint effort between Argonne National Laboratory-West (ANL-W), the Radioactive Waste Management Complex (RWMC), and Transuranic Waste Programs (TWP). The drums used in the sampling program will be examined against the requirements outlined in the *TRU Waste Characterization Quality Assurance Program Plan* (QAPP). This EDF establishes the requirements specific to the needs of the SWEPP Certified Waste Sampling Program and ensures that data beyond the requirements of the QAPP are addressed. The extent of

Table 1. WIPP-WAC/TRAMPAC sampling requirements.

T	W	Sampling requirement
X	X	Verify container integrity
—	X	Verify that waste packages contain less than 1 weight percent of <10 μ and/or <15% of <200 μ (in diameter) particulates
X	X	Verify absence of pyrophorics
X	X	Verify absence of pressurized vessels/compressed gases
X	X	Verify absence of explosives
X	X	Identify hazardous materials
X	X	Verify absence of corrosives
X	X	Identify type and quantity of hazardous waste
X	—	Verify that physical form is solid or solidified
X	X	Verify that free liquids are <1% by volume of payload or any inner container
X	—	Verify absence of sealed containers >1 gallon
X	—	Ensure that total flammable VOC concentration is <500 ppmv
X	—	Verify presence of minimum layers of confinement
X	—	Verify presence of twist and tape bag closure

T = TRAMPAC

W = WIPP-WAC

many of the sampling requirements is driven by the examination capabilities of the WCC at HFEF. For example, contents of bags will be identified, whenever possible, without actually opening up the bag to prevent the spread of contamination in the WCC. However, the WCC will be more flexible than the Spray Chamber used from FY-91 through FY-93. Solidified waste forms contained within a single packaging configuration are included in this sampling program, however, visual characterization will be limited to determinations that can be made without removing the waste from the drum.

Container Integrity

Container integrity measurements of the drums will be performed at RWMC by RWMC personnel. Drums will be inspected for excessive external corrosion with the location and description of any corrosion recorded. If significant corrosion is noted, the thickness of the container at the area of corrosion will be measured with a nondestructive, hand-held instrument. In addition, the containers will be visually inspected at Argonne for signs of internal corrosion or the presence of liquid between the drum and rigid liner. If the contents of the drum are not removed, as with sludges, inspection for internal corrosion will not be possible.

Particulates

All waste packages within a drum will be visually examined for the presence of particulate materials. If particulates are observed, the weight and particle size will be estimated and recorded. Absorbent such as vermiculite used to immobilize free liquid is not considered particulate material. The visual estimate of particulate size within the drum should be based on the weight percent of the waste matrix that contains particulates less than 10 micron diameter and less than 200 micron diameter. If the particulate size cannot be quantified, all particulates will be considered to be less than 10 micron diameter for waste certification purposes. The weight of the particulate shall be determined by (a) direct measurement, or (b) an estimate based on volume and an assumed density for the particular waste form. Particulate size and quantity within a container will be estimated by personnel from ANL-W with consultation available from TWP.

Free or Containerized Liquids

Items removed from the waste container will be visually examined for the presence of free liquids. Through visual examination, the location, container size and description, and quantity of the liquid will be visually estimated and recorded. Residual liquids, defined as less than 1% of the total volume of an individual container, will not be characterized chemically. However, if sufficient volume is present (at least 50 ml), an attempt will be made to assess the pH of the liquid, and the results recorded. If the pH cannot be assessed, a note will be included in the report identifying why the measurement could not be performed. A visual test using litmus paper or a pH meter will be adequate for pH determination. ANL-W will record the results.

Pyrophorics

As the waste is characterized, the material will be visually examined for evidence of spontaneous combustion. Combustion within the container may be evident by burning or charring of the material being removed from the drum. ANL-W will record the results of the inspection.

Pressurized Vessels/Compressed Gases/Other Sealed Containers

The waste will be visually examined for the potential presence of compressed gases (aerosol cans, gas cylinders, etc.). If compressed gases are present, their location and size will be noted. Vessels designed to contain pressurized gases will be visually checked for puncture holes, drill holes, opened valves, etc. If any containers larger than 4 liters are detected, ANL-W will estimate the size and type of container. Cardboard fiber packages are not considered to be sealed containers.

Explosives

Examples of explosives are ammunition, dynamite, black powder, detonators, nitroglycerine, urea nitrate, and perchloric acid. The waste will be visually examined to identify unknown material or suspect explosive material. Chemical analysis will not be required, but may be performed on a case-by-case basis if conditions allow. No explosives have been identified by content code assessments or by the previous INEL sampling programs. ANL-W will record the results of the inspection.

Hazardous Materials/Corrosives

Unidentified liquids and solids will be visually characterized. A corrosive material has a pH of less than 2 or more than 12.5. If possible, the pH will be measured using litmus paper or a pH meter. ANL-W will also perform gas sampling of the waste bags in accordance with the headspace volume requirements of the *Transuranic Waste Characterization Quality Assurance Program Plan* (QAPP) which requires that all inner bags with greater than 1 liter of free headspace be sampled. The Analytical Laboratory or TWP will record the packaging method, quantity, and results of the evaluation for any hazardous or corrosive material.

Physical Form

As the waste is visually examined, a physical description of the waste (i.e., vermiculite, glass labware), including its physical form and wet/dry condition, will be recorded. ANL-W will estimate the weight of waste items based on the operator's estimate at the window during the visual examination. Emphasis will be placed on estimating the weights of those items that do not conform to the Item Description Code (IDC). These estimates will be recorded. TWP will compare the estimated weight of the waste to Tables 5.1 through 5.6 of the TRUPACT-II Safety Analysis Report (SAR) for each waste category. This data will be used to support possible revisions to the SAR.

Volatile Organic Compounds (VOCs)

The total concentration of potentially flammable VOCs is limited to 500 parts per million volume (ppmv) in the headspace of a payload container. All of the drums are vented with a carbon composite filter. Prior to shipment in the TRUPACT-II, this requirement will be verified by taking a gas headspace sample in the annular headspace of each drum that will be shipped. Total flammable VOC concentrations for these transportation samples will be reported and compared to determine what effect disturbing the inner layers of confinement has on the flammable VOC concentrations in the headspace of a drum.

Layers of Confinement

Each container will be visually inspected to confirm the presence of a 90-mil high-density polyethylene (HDPE) liner for corrosion protection. Each 90-mil liner will be visually inspected to confirm that it has been punctured by the drum venting facility. ANL-W will determine and record the number of bag liners used to line the 90-mil rigid liner. In addition, ANL-W will determine and record the maximum layers of confinement for the innermost waste.

Method of Bag Closure

Each container will be visually inspected to confirm the bag closure method. Examples of bag closure include "twist and tape," "fold and tape," and the heat-sealed method. ANL-W will record the method of bag closure.

Reporting

ANL-W will transmit a copy of the HFEF Waste Characterization Area (WCA) Drum Characterization Log Sheet, the ANL-W SWEPP Certification Log Sheet as part of the package for the TWCP, and any nonconformance reports (NCRs) documenting the presence of items not complying with WIPP-WAC or TRAMPAC to the TRU Waste Programs Unit (TWP) Site Project Office. Examples of these forms are located in the ANL-W TWCP Quality Assurance Project Plan. These two log sheets and appropriate NCRs are designed to contain all of the information necessary for the SWEPP Certified Waste Sampling program.

TWP will compile the final results on a drum-by-drum basis. This information will be derived from various SWEPP reporting forms and the HFEF forms. The report will include at least the following information:

- Drum identification number
- Date of visual examination
- Waste form category, e.g., Solid Inorganic Waste [original and actual Item Description Code (IDC)]
- TRUPACT-II Content Code (TRUCON) (original and actual)[a]
- IDC Code (original and actual)[a]
- Physical description of the waste form
- Packaging, container integrity, and method of bag closure
- Type of liner and maximum layers of containment of waste

a. ANL-W may make recommendations but final determination will be made by TWP.

- Particulate content (size and weight estimate)
- Estimated volume, location, and container description for free liquids
- Measured pH for liquids > 50 ml
- Description and location of explosives
- Description and location of compressed gases/pressurized vessels and other sealed containers
- Description and location of pyrophoric materials or indication of combustion within a container
- Description and location of hazardous and corrosive materials
- Drum weight (net and gross)
- Date originally packaged
- Container integrity (internal, liquid between drum and liner)
- Drum surface dose rate
- Concentration of total flammable VOCs in annular headspace
- Concentrations of H_2 and CH_4 in annular headspace
- Hazardous VOCs as indicated by headspace gas samples
- Additional comments
- Waste matrix volume comparisons
- WIPP-WAC and/or TRAMPAC certifiable (if no, state reason).

TWP will compile the results of these individual drum reports on an annual basis.

FY-95 Sampling Program for SWEPP Certified Wastes

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August 1994

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TABLES

SAMPLING PROGRAM FOR SWEPP CERTIFIED WASTES

Objective

The objective of the SWEPP Certified Waste Sampling Program is to provide quality control for the SWEPP waste certification process. The SWEPP certification process nondestructively examines the waste using real-time radiography (RTR) to verify compliance with WIPP-WAC and TRUPACT-II payload requirements (TRAMPAC).

A statistically determined number of the certified waste containers will be opened and visually examined. The data obtained from the sampling program will be used to determine the percent of miscertified waste containers. Miscertified containers are those that have been certified by SWEPP, but subsequently are found to be miscertified during visual examination. The difference between SWEPP-certified and the WIPP-WAC or TRAMPAC miscertification normally reflects the limitations of the RTR process. An example would be the detection during visual examination of liquid in an uncemented sludge that was not detected in the SWEPP RTR process. The SWEPP Certified Waste Sampling Programs expects miscertifications of this type since a visual examination is more thorough than an RTR examination. However, it is not practical to perform a visual examination on all stored waste containers. The following sections present the assumptions and statistical calculations used to establish the FY-95 sampling program. Sampling requirements and frequency, based on results of previous sampling programs, are also presented. Results are discussed below.[1-6]

Scope

The containers examined by RTR in FY-95 will be part of the TWCP. The requirements for the physical examination of the waste are established in EDF-RWMC-363 Rev. 6.. The requirements for sampling inner layers of confinement are driven by the TWCP Quality Assurance Program Plan.[7]

Results of Previous Programs

Table 1 summarizes the results of the previous sampling programs up through FY-93.[a] Note that out of 294 drums sampled, only 4 have been miscertified (1.36%).

The TRU Waste SWEPP Certified Waste Sampling Program (1983–1985) was conducted during the research and development phase of the RTR system used at SWEPP. SWEPP was not operational during this program. During this stage, 209 containers were visually examined. It was later determined that 181 of these containers would have been WIPP-WAC-certifiable using the RTR. In actuality, the visual examination indicated that two of the 181 containers were not WIPP-WAC certifiable. Both containers exceeded the previous WIPP-WAC of less than 1 volume % by drum of

a. FY 94 sampling program results were not available at the time that this EDF was prepared. A summary of the FY 94 results will be included in the next revision to this EDF.

Table 1. Sampling program data (1983–1993).[a]

Waste form	TRU waste sampling program (1983–1985)		FY-86–FY-88		FY-91		FY-92, FY-93		Totals		Problem (%)
	Certified	Problem	Certified	Problem	Certified	Problem	Certified	Problem	Certified	Problem	
Uncemented sludge	27	0	43	1	—	—	—	—	70	1	1.43
Combustibles	38	1	1	0	—	—	5	0	44	1	2.27
Metals	33	1	4	0	—	—	11	1	48	2	4.17
Glass	25	0	4	0	13	0	—	—	42	0	0.00
Nonmetal molds and crucibles	10	0	20	0	—	—	—	—	30	0	0.00
Cemented sludge	9	0	3	0	—	—	—	—	12	0	0.00
Concrete and brick	8	0	—	—	—	—	—	—	8	0	0.00
Salts	3	0	2	0	—	—	—	—	5	0	0.00
Leaded rubber	7	0	2	0	—	—	2	0	11	0	0.00
Benelex and plexiglass	7	0	—	—	—	—	—	—	7	0	0.00
Resins	13	0	1	0	—	—	—	—	14	0	0.00
Other	—	—	—	—	—	—	2	0	2	0	0.00
Mixed waste	1	0	—	—	—	—	—	—	1	0	0.00
Totals	81	2	80	1	13	0	20	1	294	4	1.36
Problem (%)	1.10	—	1.25	—	0.00	—	5.00	—	1.36	—	—

a. No sampling was performed in FY-89 or FY-90 due to a shutdown of SWEPP.

free liquids. One of these, which contained combustibles, was number RF038985743, IDC 337. The RTR system was not able to detect 1.4L of a dark viscous liquid. The top layer of the liquid had formed a hardcrust. Without a liquid gas interface, RTR was not able to detect any liquid movement. The second container that was not WIPP-WAC-certifiable was box RF038985811, IDC 480 (Light, Non-Special Source Metals). The box contained metal hardware, predominantly pipe and some wet paper wipes. RTR failed to detect the presence of 3.1L of liquid. It is possible that the paper wipes may have prevented the movement of liquid in a plastic bag during the examination.

From 1986 through 1988, the SWEPP Certified Waste Sampling Program was established and conducted as a quality control for the waste certification process.. During those three years, only one container was miscertified, and the reason was again the failure to detect free liquid in excess of 1 volume % of the drum. This was drum number RF074704299, IDC 7 (an uncemented sludge), which contained ~12L of free liquid at the bottom of the drum in a plastic bag.

During the years 1989 and 1990, the SWEPP facility was placed in a standby condition; no sample drums were examined.

Since the establishment of the most recent program in FY-91, one drum has been miscertified. Drum number RF005400341, IDC 480 (metals) contained a full 230-mL (8-oz) can of a solvent material. From FY-91 through FY-93, 100% of the drums certified by SWEPP and shipped to HFEF were visually examined. This examination process was conducted to the specifications of the WETP. Specific requirements of the SWEPP Waste Sampling Program were not addressed, but the detailed level of the examinations allowed appropriate evaluations to be made. For instance, ANL-W had no specific procedure in place to assess the pH of free liquids. One drum out of the 33 drums examined contained a sufficient volume of liquid for pH evaluation. The pH was not assessed, but the liquid vapors were analyzed and determined to be a solvent. The pH of the solvent would not have been within the corrosive range, but the drum was found to be miscertified because of excess liquid. Through the videotaped recordings of the HFEF examination reporting forms that HFEF supplied for the WIPP Experimental Test Program and the headspace gas analysis, it could be determined that none of the other 32 drums was miscertified.

To date, only 4 drums out of 294 (1.3%) were miscertified. In all cases the miscertification was because of the presence of small amounts of liquids (~0.5 L - 12 L) not detected by RTR because of the lack of a discernible gas-liquid interface. This rate of miscertification will be applied to the FY-95 sampling program.

Statistical Methodology

The SWEPP sampling program provides data to establish the percentage of waste containers properly certified by the SWEPP examination process. The assumptions, calculations, and selection of optimal sample size are presented in the following subsections.

Assumptions

The statistical calculations are based on the following assumptions:

- Drums containing TRU waste were randomly selected, placed in storage, retrieved, and examined by the SWEPP certification process. This random process ensures obtaining a representative sample of drums.

- Only TRU wastes certified by SWEPP for compliance with WIPP-WAC and/or TRAMPAC will be selected.

- There is a definable finite population of drums for which the proportion miscertified is to be estimated (e.g., the 200 drums certified by SWEPP in FY-95 for inclusion in the TWCP).

- Approximately 98% of the SWEPP-certified drums will be properly certified (based on experience to date with the sampling program).

- The SWEPP certification process is uniform for all waste containers and is therefore unbiased regardless of content code.

- The SWEPP RTR system is functioning properly and is operated by qualified personnel.

As stated in the assumptions above, the sampling effort is one of sampling to estimate a proportion in a finite population. For a population of less than 1,200 SWEPP-certified drums, the calculations are based on the hypergeometric probability distribution. If more than 1,200 drums are available, a simpler calculation based on a normal approximation of a binomial distribution can be used. Both approaches are presented in this EDF. For FY-95, the hypergeometric distribution will be used since < 1200 drums of waste are expected to be certified..

Calculations for Hypergeometric Distribution

For the hypergeometric approach, the acceptable level of uncertainty in the estimate of the proportion (along with the information on the previous percentage miscertified) determines the number of drums that must be examined. The rationale and details of this methodology are discussed below.

In a population of size N, there are M miscertified drums, so the true population proportion of miscertified drums is $M/N = p_{true}$. Since p_{true} (or M) is not known, we wish to estimate it by randomly sampling some of the drums. If in a sample of n drums, x are found to be miscertified, the sample estimate of the true population proportion p_{true} is

$$\hat{p} = \frac{x}{n}$$

This value is only an estimate, and as such has some uncertainty associated with it. This uncertainty is quantified by calculating the upper one-sided $(1 - \alpha)\%$ confidence limit for p, call it p_{UCL}. This confidence limit gives the largest value the true proportion could take on and still have a "reasonable" chance (e.g., an $\alpha = .10$ probability) of producing x miscertified drums in a sample of n out of N. This upper confidence limit is calculated as

$p_{UCL} = M_{UCL}/N$

where M_{UCL} is the largest value of M such that the probability of observing x or fewer miscertified drums in a sample of size n is less than or equal to α. That is, it is the largest value of M such that the following inequality is true:

$$\sum_{k=0}^{x} \frac{\binom{M}{k}\binom{N-M}{n-k}}{\binom{N}{n}} \leq \alpha. \tag{1}$$

where each binomial term is defined as in the following:

$$\binom{M}{k} = \frac{M!}{k!\ (M-k)!}$$

Each term in the sum in Equation 1 is the hypergeometric probability of observing k miscertified drums in a sample of size n from a population of size N in which there are M miscertified drums (and hence the population proportion of miscertified drums is $p = M/N$). The value M_{UCL} is obtained by substituting different values for M into Equation 1 until the largest value satisfying the inequality is found.

Calculating Required Sample Size

Note that in Equation 1, the upper confidence limit is dependent on x, the number of miscertifications observed in the sample, as well as on n, the sample size. So, to obtain the required sample size, we also need to consider what values of x are likely to be seen. Sample size is thus determined by setting a desired upper confidence limit value and then manipulating x and n in Equation 1. The detailed steps are given in the following algorithm. An example application is also given to clarify the steps involved.

Algorithm steps	Example
1. Set parameters.	
Estimate the approximate number of miscertified drums in the population of interest (generally based on results from previous sampling efforts), call it M_{est}.	If previous experience shows the miscertification rate to be about 2%, and the population under consideration contains 140 drums, then $M_{est} = 3$ is obtained by multiplying .02 by 140 and rounding up to the next largest integer.

Algorithm steps	Example
Choose a value for α, where $(1 - \alpha)100\%$ is the desired confidence level for the confidence limit calculation.	If a 90% confidence level is desired, then α is $1 - .90 = .10$.
Specify p_{UCL}, the desired upper bound for the confidence limit and calculate $M_{UCL} = Np_{UCL}$, the associated number of miscertified drums. Note that p_{UCL} must be chosen such that M_{UCL} is an integer.	If we think the true value is about 2%, but 10% is an acceptable upper bound on the estimate, then $p_{UCL} = .10$ and $M_{UCL} = 140(.10) = 14$.
Set a value for γ, the desired assurance level, so that the outcome of the sampling will produce the desired result. (i.e. $100\gamma\%$ of the possible sample values for x will yield the desired confidence limit results).	Select $\gamma = .80$. The calculated sample size will produce the desired confidence limit results in 80% of the possible sampling outcomes. (For the 20% of the outcomes not covered, the calculated upper confidence bound will be somewhat higher than the desired value of .10.)
2. Pick an initial guess or starting value for the sample size, call it n_1. Set a counter variable $i = 1$.	Let n_1 be 33.
3. Find the smallest value for x such that $$\sum_{k=0}^{x} \frac{\binom{M_{est}}{k}\binom{N_i - M_{est}}{n_i - k}}{\binom{N}{n_i}} \geq \gamma.$$ Call this x value x_{max}, since it is the largest value of x likely to be observed.	For $M_{est} = 3$, $N = 140$, $n_i = n_1 = 33$, calculating the individual probability terms in the sum for $k = 0$, and 1 give: pr(0 miscertified) = .443 pr(1 miscertified) = .418. The two terms sum to .861, which is larger than $\gamma = .80$, so $x_{max} = 1$.
4. Find a_i, the probability of x_{max} or fewer miscertified if $M = M_{UCL}$ and $n = n_i$, i.e. $$a_i = \sum_{k=0}^{x_{max}} \frac{\binom{M_{UCL}}{k}\binom{N - M_{UCL}}{n_i - k}}{\binom{N}{n_i}}.$$	(example for $i = 1$) $$a_1 = \frac{\binom{14}{0}\binom{140-14}{33-0}}{\binom{140}{33}} + \frac{\binom{14}{1}\binom{140-14}{33-1}}{\binom{140}{33}} = 0.1$$

	Algorithm steps	Example
5.	Compare results to α, and iterate if necessary as follows. If $a_{i-1} < \alpha$ and $a_i > \alpha$, then stop. The required sample size is n_{i-1}. If $a_{i-1} > \alpha$ and $a_i < \alpha$, then stop. The required sample size is n_i. If neither of the above is true then go on to step 6.	At the first iteration, there is no previous value of a_i, so go on to Step 6.
6.	if $a_i > \alpha$, then $n_{i+1} = n_i + 1$ if $a_i \leq \alpha$, then $n_{i+1} = n_i - 1$ Increment i (i.e. i = i + 1) and repeat steps 3, 4, and 5.	.110 > .10 so $n_2 = 34$ i = 2 Step 3: $x_{max} = 1$ Step 4: $a_2 = .099$ Step 5: $a_1 > .10$ and $a_2 < .10$, so stop. The required sample size is n = 34.

Recommended Sampling Size and Frequency—Hypergeometric Distribution

Assuming that the sampling miscertification rate remains at ≤2%, the aim of the program will be to sample enough drums at a 90% assurance level with 95% confidence that no more than 10% of the total population of drums certified in FY-95 have been miscertified by the RTR system. Table 2 presents various results for this set of assumptions for various numbers of certified drums and estimated miscertification rates. For FY-95, 55 drums will need to be sampled to achieve the specified goal. It is expected that ANL-W will be able to sample this number of drums. The actual miscertification rate at the 90% UCL and the 95% UCL will be calculated at the conclusion of the SWEPP Sampling Program for FY-95 and for the total sampling program.

Calculations for Approximated Binomial Distribution

The following set of calculations are presented as an option if the SWEPP certifies more than 1,200 drums in a year. At this number of drums, the population size can be considered to be essentially infinite. These calculations are simpler than the hypergeometric approach. For the normally approximated binomial approach. the formula used to calculate sample size is:[8]

$$n_o = \frac{t^2 \, [p \, (1 - p)]}{d^2} \tag{2}$$

n_o = number of sample drums required

t = tabled value of the t distribution corresponding to an area of $1 - \alpha$

α = one-sided upper confidence level

p = estimated portion of containers miscertified

d = specified bound on the error associated with estimate of p.

Table 2. Proposed sampling plan for FY-95.

Number of certified drums (N)	Estimated miscertification rate based on prior data				
	$p = 0.01$	$p = 0.02$	$p = 0.03$	$p = 0.04$	$p = 0.05$
25	N/A	N/A	N/A	22	N/A
50	N/A	33	N/A	40	N/A
100	39	50	60	69	77
200	42	55	67	90	110
300	43	57	82	116	138
400	44	71	96	131	163
500	44	72	97	133	167
600	45	73	98	134	180
800	45	73	99	136	194
1,000	45	74	100	137	207
1,200	45	74	101	138	220

As an example, let:

$t = 2.575$

$\alpha = 0.05$

$p = 0.02$

$d = 0.05$

$$n_o = \frac{(2.575)^2 \,[\, 0.02 \,(\, 1 - 0.02 \,)\,]}{0.05^2}$$

$$n_o = 52$$

This type of calculation underestimates the number of samples required.[9] To obtain more accurate sample size estimations, an assurance level must be selected, just as in the algorithm used for the hypergeometric calculation. This assurance level specifies how precise the sample number estimate is at a given confidence level. Table 3 contains the necessary correction factors for confidence levels of 90% and 95%.[9] These correction factors are linear with respect to the sample size, so an alternate approach that can be used when the sample size calculated with Equation 2 exceeds 100 is to extrapolate the values in Table 3. For a confidence interval of 90% and an assurance level of 90%, the following equation can be applied:

$$n = 7 + 1.13258n_o \tag{3}$$

where n is the corrected sample size.

For a confidence interval of 95% and an assurance level of 90%, the following equation can be applied:

$$n = 8 + 1.1249n_o \tag{4}$$

In the example on the previous page, n_o is 52. For a 95% confidence level and a 90% assurance level (γ) the corrected sample size is 70. Going back to Table 2 and applying the same set of conditions (1,200 drums certified, 95% confidence level, 2% estimated miscertified, and a 90%

assurance level), the number of sample drums specified is 74. The differences between these two values is probably due in part to the nature of the summations in the hypergeometric approach which tend to yield solutions that are stepwise rather than continuous. Further, the approximated binomial distribution is just an approximation of the exact solution. This approximation is necessary when there are a large number of drums involved, since the factorials of numbers greater than about 1300 are larger than most calculators or software programs can handle.

Table 4 provides a variety of annual sample sizes that would be required for infinite populations (>1,200 drums) at various estimated rates of miscertifications and errors at the 95% and 90% upper confidence levels. For sample sizes less than 100, Table 3 was used to determine the corrected sample size. As in the above example, for sample sizes falling between the ones listed on the table, the next highest value was always used. For n_o greater than 100, the appropriate equation (either 3 or 4) was applied.

Table 3. Corrected sample sizes based on assurance level (γ).

	n - corrected sample size				
n_o	γ = 0.7	γ = 0.8	γ = 0.9	γ = 0.95	γ = 0.99
			Confidence level = 90%		
5	8	9	11	12	13
10	14	15	17	19	21
15	20	21	23	25	28
20	25	27	29	32	35
25	30	33	35	38	42
30	36	38	41	44	49
35	41	44	47	50	55
40	46	49	53	56	61
45	52	55	58	62	68
50	57	60	64	67	74
55	62	65	70	73	80
60	67	71	75	79	86
65	73	76	81	85	92
70	78	81	86	90	98
75	83	87	92	96	104
80	88	92	97	102	110
85	93	97	103	107	116
90	99	103	108	113	122
95	104	108	114	119	127
100	109	113	119	124	133
			Confidence level = 95%		
5	9	10	11	12	14
10	15	16	18	19	22
15	20	22	24	26	29
20	26	27	30	32	36
25	31	33	36	38	43
30	36	39	42	44	49
35	42	44	48	50	55
40	47	50	53	56	62
45	52	55	59	62	68
50	57	60	65	68	74
55	63	66	70	74	80
60	68	71	76	80	86
65	73	77	81	85	92
70	78	82	87	91	98
75	84	87	92	97	104
80	89	93	98	102	110
85	94	98	103	108	116
90	99	103	109	114	122
95	104	109	114	119	128
100	110	114	120	125	134

Table 4. Sample sizes for large populations—normal approximation of binomial distribution.

Range miscertified (%)	Error associated with est. of P (d)	p = 0.01		p = 0.02		p = 0.03		p = 0.04	
		Sample size calculated from eqn. 2	Sample size corrected (Table 3)	Sample size calculated from eqn. 2	Sample size corrected (Table 3)	Sample size calculated from eqn. 2	Sample size corrected (Table 3)	Sample size calculated from eqn. 2	Sample size corrected (Table 3)
				95% confidence level: t = 2.575 one sided					
0–6	0.03	73	92	144	170	214	249	283	326
0–7	0.035	54	70	106	127	158	186	208	242
0–8	0.04	41	59	81	103	121	144	159	187
0–9	0.045	32	48	64	81	95	114	126	150
0–10	0.05	26	42	52	70	77	98	102	125
0–11	0.055	22	36	43	59	64	81	84	103
0–12	0.06	18	30	36	53	54	70	71	92
0–14	0.07	16	30	31	48	46	65	60	76
				90% confidence level: t = 2.326 one sided					
0–6	0.03	60	75	118	141	175	205	231	269
0–7	0.035	44	58	87	108	129	153	170	200
0–8	0.04	33	47	66	86	98	119	130	154
0–9	0.045	26	41	52	70	78	97	103	125
0–10	0.05	21	35	42	58	63	81	83	103
0–11	0.055	18	29	35	47	52	70	69	86
0–12	0.06	15	23	29	41	44	58	58	75
0–14	0.07	13	23	25	35	37	53	49	64

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