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Radiological Protection Contamination Control and Monitoring Technical Basis Document

FOUR RIVERS NUCLEAR PARTNERSHIP, LLC

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REVISION LOG

REVISION NUMBER	DATE	DESCRIPTION OF CHANGES	PAGES AFFECTED
FR0	03/26/2020	Initial Release	All
FR1	10/20/2020	Updates throughout document	All
FR2	03/18/2021	Updated 43-5 efficiency from 13% to 11%. Updated 44-9 probe pause time and scan MDA.	Page 16 Page 19
FR3	04/27/2022	General Revision	All
FR4	05/11/2023	Updated removable contamination Calculation. Updated Table 5, Beta-Gamma Scanning MDC.	Page 7, 21
FR5	03/04/2025	General Revision	All
FR6	04/29/2025	General Revision	All

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CONTENTS

TABLES

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ACRONYMS

ALARA	as low as reasonably achievable
CA	contamination area
CF	correction factor
D&R	deactivation and remediation
DOE	U.S. Department of Energy
HCA	high contamination area
LAW	large area wipe
L_C	critical level
L_D	detection limit
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDA	minimum detectable activity
MDC	minimum detectable concentration
MDCR	minimum detectable count rate
PGDP	Paducah Gaseous Diffusion Plant
PPE	personal protective equipment
RADCON	radiological control
RCT	radiological control technician
RPM	radiation protection manager
RWP	radiological work permit
TRU	transuranic

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1. INTRODUCTION

The purpose of this document is to provide guidance on techniques and practices that are used by qualified radiological control (RADCON) personnel at Paducah Gaseous Diffusion Plant (PGDP) on radioactive contamination control and monitoring in the workplace. The requirements that are contained in procedure CP3-RP-1109, *Radioactive Contamination Control and Monitoring*, must be followed when radiological contamination control surveys are being performed to monitor radiological conditions in the workplace. The use of this guide requires the use of the RADCON procedures, as this document is intended to augment, not duplicate or replace, specific requirements specified in the procedures. No additional RADCON requirements are established by this guide, and performance of any practice indicated herein is limited strictly to those required by approved RADCON procedures.

2. GENERAL

Monitoring is defined in CP2-RP-0002, *Radiological Control Manual*, as the measurement of radiation levels, airborne radioactivity concentrations, radioactive contamination levels, quantities of radioactive material, or individual doses and the use of the results of these measurements to evaluate radiological hazards or potential and actual doses resulting from exposures to ionizing radiation.

Survey is defined in CP2-RP-0002 as an evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present.

Radiological contamination control surveys are considered appropriate techniques for monitoring radioactive contamination levels for compliance with 10 *CFR* Part 835 provided that actual measurements are made and are appropriate for evaluation. Radiological contamination control surveys that are not mandated by regulatory monitoring or survey requirements may be conducted in accordance with the survey definition above.

3. GOOD PRACTICES

The following presents a listing of good practices to follow:

- Determine the identity and extent of the radionuclides that are present to support survey and monitoring decisions. Radionuclide identification should be based upon actual analytical data and supplemented with process history/knowledge, whenever feasible. If identity of the radionuclides is unknown, the most restrictive surface contamination limits should be used.

- Proper measurement technique requires that the item being surveyed for total alpha contamination is not wet with water, oil, or other viscous substance. An item may be surveyed for total beta-gamma contamination under these conditions when source efficiency has been estimated (see NUREG-1507).

- Use large area wipes (LAWs) to supplement standard smear (note: the term “smear” may be used interchangeably with “swipe” in that they refer to the same survey method) techniques. Perform a more thorough contamination smear survey if a LAW indicates that an area or an item that was wiped is contaminated (i.e., the identified activity levels on the LAW are greater than the action levels presented later in this document).

- Treat bulk materials (e.g., sand, sweeping compounds) on a case-by-case basis because they are not suitable for routine contamination survey techniques. Consult with the radiation protection manager (RPM) to determine appropriate survey or sampling techniques.

- Ensure that the smear media is dry when counting the smears, except for cases where H-3 or other technical considerations are being addressed.

- Always wear appropriate personal protective equipment (PPE), surgeon’s gloves at a minimum, when removable contamination surveys are being taken even if the surface is not suspected to be contaminated.

4. SPECIFIC PRACTICES

Radioactive contamination surveys are necessary to ensure that appropriate controls are employed in the workplace to prevent the spread of contamination and to ensure that workers are protected adequately from the hazards. Contamination levels on surfaces outside of area controlled for contamination should be maintained below the removable surface contamination limits specified in CP2-RP-0002 and as low as reasonably achievable (ALARA). Questions concerning which surface contamination values to use should be directed to RADCON Management. When there are combinations of different radionuclides, the following guidance is applicable.

- Generally, there are two different scenarios under which combinations of radionuclides may be present as radioactive surface contamination:

  1. There may be a combination of radionuclides, all of which are within the same hazard category of CP2-RP-0002, Table 2-2 (e.g., one horizontal row of the table, such as U-nat, U-235, U-238, and associated decay products); or

  2. There may be a combination of radionuclides in different hazard categories of CP2-RP-0002, Table 2-2 (e.g., radionuclides in more than one horizontal row of the table).

- If a surface is contaminated with radionuclides all within the same hazard category and analytical data is available for each radionuclide, then contamination levels of the various radionuclides should be summed to determine if contamination levels in any area monitored exceeds the applicable CP2-RP-0002, Table 2-2 value. For example, if a surface is contaminated with both U-235 and U-238, then contamination levels of both radionuclides should be summed to determine whether or not the applicable CP2-RP-0002, Table 2-2 value has been exceeded.

- If a surface is contaminated with a combination of alpha and beta-gamma emitting radionuclides, as indicated by the hazard categories, then the values provided in CP2-RP-0002, Table 2-2 apply independent of one another. It is not necessary to perform a sum of the fractions calculation to determine if contamination levels in any area monitored exceed the applicable CP2-RP-0002, Table 2-2 values.

- Where radionuclides having removable alpha surface contamination guidelines of 20 disintegrations per minute (dpm)/100 cm^2 and total alpha surface contamination guidelines of 100 dpm/100 cm^2 (i.e., transuranic limits) are mixed with uranium in a known ratio, uranium surface contamination guidelines may be used when alpha activity due to uranium, excluding U-232, exceeds the sum of alpha activity from the radionuclides having transuranic limits by a ratio of greater than 50:1. This is justified because the ratio of surface contamination limits is also 50:1. Thus, when survey results do not exceed the uranium limit, they will also not exceed the transuranic limit. The same logic may be applied to other combinations of radionuclides (e.g., Th-232).

- When determining uranium, excluding U-232, surface contamination levels and the presence of transuranic radionuclides consist of trace activities only, beta surface contamination measurement may be used in lieu of alpha measurements for depleted to low-enriched (i.e., up to approximately 5.5% weight U-235) uranium. Such measurements may be related to the uranium alpha surface contamination levels based on the alpha to beta activity ratios presented in Appendix A of CP5-RP-0100, *FRNP Radiological Engineering Methods*.

- Where radioactive decay products of uranium or Th-232 are present, and there are no reasons to suggest that decay products have been chemically separated from the parent radionuclide, then the uranium (excluding U-232) or Th-232 surface contamination guidelines can be used, provided that activity of the parent is greater than or equal to the activity of each of the decay products. Note that Th-228 activity greater than that of Th-232 may indicate the presence of parent U-232 also.

- Footnote 5 to CP2-RP-0002, Table 2-2 discusses application of listed surface contamination values for Sr-90. Typically, Sr-90 is present in equilibrium with its daughter, Y-90; therefore, values given for Sr-90 should be applied to the total activity from Sr-90/Y-90 contamination. When Sr-90/Y-90 is present in mixed fission products, the beta-gamma values in CP2-RP-0002, Table 2-2 apply (i.e., 1,000 dpm/100 cm^2 and 5,000 dpm/100 cm^2). PGDP performed no processes to intentionally separate or purify Sr-90.

- If contamination by a radionuclide not listed in CP2-RP-0002, Table 2-2 is suspected or verified, the actual contamination level should be compared to the limits for radionuclides most similar to the contaminant(s) (i.e., radiological and chemical properties). Appropriate actions (e.g., posting, labeling, access controls) should be based on the results of these comparisons.

5. MONITORING FOR SURFACE CONTAMINATION

Surface contamination surveys are performed to determine existing conditions in a given location and to identify areas that require posting. Standard rules of practice for contamination surveys are as follows:

- Obtain the appropriate field survey instruments (capable of detecting the most limiting applicable surface contamination values) and supplies.

- Confirm that detection instruments are in proper working order and that affixed calibration labels are valid.

- Ensure that required instrument source/operability checks are performed in accordance with applicable requirements.

- Perform a background count (i.e., typically 1 minute) at the survey location before the survey is performed and ensure the following actions occur.

  1. Confirm that background is low enough to yield a minimum detectable concentration (MDC) that is less than the appropriate radionuclide-specific surface contamination guidelines (see MDC discussion later).

  2. If the appropriate radionuclide-specific surface contamination guideline cannot be detected, move items and/or LAWs/smears that are to be surveyed or counted to a low background area or count background and/or sample for a longer period of time, or select a different type of instrument, such as one with an inherently lower background and/or larger probe surface area, to provide a lower correction factor (CF).

  3. When surveying a room or equipment that is not moved easily and appropriate radionuclide-specific surface contamination guideline cannot be detected, contact RADCON supervision, for guidance.

- For soils located outside of process buildings within the historic Limited Area, use uranium limits for alpha surface contamination in CP2-RP-0002, unless transuranic (TRU) postings exist where U:TRU ratio is less than 50:1 (i.e., less than 2% TRU).

- Follow basic survey techniques for specific types of surveys.

- Document survey results using the survey documentation software.

6. MEASURING TOTAL SURFACE CONTAMINATION

Measuring surface contamination depends upon determining total surface activities, removable surface activities, and radionuclide concentrations in various environmental media. While no single instrument generally is capable of adequately measuring all of the parameters that are necessary to satisfy release criterion or of meeting all of the objectives of the survey, significant cost savings can be realized by a technical determination that could limit the type(s) of radiation present.

Field measurement methods that usually are used to generate survey results can be classified as scanning surveys and direct measurements. Scanning is the process by which the operator uses a portable radiation detection instrument to detect the presence of surface contamination on a specific surface (e.g., floor, wall, equipment). When a certain elevated response is detected, the scan may be paused and a direct measurement performed. Scanning locates areas where elevated levels of gross radioactivity are present that may require further investigation or action. Direct measurements are taken by placing the instrument at the appropriate distance above the surface, taking a discrete measurement for a predetermined amount of time, and recording the reading. Results should be recorded based on actual measured conditions.

7. ALPHA SURFACE SCANNING GUIDELINES

Detection sensitivity during alpha scanning depends on the protocol used as well as the instrument background and efficiency. Detection sensitivity for scanning should be determined (see discussion presented later in this document). General guidelines include the following:

- Determine the instrument background by taking a timed 1-minute count. Confirm the background is low enough to yield a high probability of detection at the appropriate radionuclide-specific surface contamination guideline and to meet the purposes of the survey (see probability of detection results present later). Longer background counts, slower scan speeds, and/or selection of instruments with lower background can be used to obtain a sufficiently high probability of detection.

- Scan the surface at a rate that does not exceed 2 inches/second.

- Hold the probe within approximately ¼-inch of the surface and use the audible output of the instrument while scanning. As the counts occur, pause to determine if the count rate is greater than the background rate.

- Perform a direct measurement at the locations where the count rate is greater than background rate or at the location of the highest count rate in larger contaminated areas.

    - For survey where a specific MDA must be met (such as release surveys from radiological areas, release from the controlled area, and surveys perform in unposted areas) the time required for the direct measurements must be such that the MDA is satisfied. Longer count time can be used to improve detector sensitivity.

    - For surveys performed in known contaminated locations, such as characterizing contaminated equipment or surfaces, the direct measurement is performed by holding the probe stationary until the meter display stabilizes (approximately 5 to 15 second but may be longer).

8. BETA SURFACE SCANNING GUIDELINES

Detection sensitivity during scanning depends on the protocol used as well as the instrument background and efficiency. Detection sensitivity for beta scanning should be determined (see discussion presented later in this document). General guidelines include the following items.

- Determine the general area background by taking a timed 1-minute count in the area where the items to be surveyed are located. Verify background is low enough to yield a MDC less than the appropriate radionuclide-specific surface contamination guideline and to meet the purposes of the survey (see MDC discussions later in this document). Longer background counts, slower scan speeds, and/or selection of instruments with lower background per probe area can be used to obtain a sufficiently low MDC.

- Scan the surface at a rate that does not exceed 2 inches/second.

- Hold the probe within approximately ½-inch of the surface and use the audible output of the instrument while scanning.

- As count rate increases, pause to determine if the increased count rate is greater than background.

- Perform a direct measurement at locations where the count rate is greater than background or at the location of the highest count rate in larger contaminated areas.
  - For survey where a specific MDA must be met (such as release surveys from radiological areas, release from the controlled area, and surveys perform in unposted areas) the time required for the direct measurements must be such that the MDA is satisfied. Longer count time can be used to improve detector sensitivity.
  - For surveys performed in known contaminated locations, such as characterizing contaminated equipment or surfaces, the direct measurement is performed by holding the probe stationary until the meter display stabilizes (approximately 5 to 15 second but may be longer).

9. GAMMA SURFACE SCANNING GUIDELINES

Detection sensitivity during gamma surface scanning depends on the protocol used as well as the instrument background and efficiency. Specific survey and release plans gamma surface scanning guidance should be followed where applicable. General guidelines for gamma surface scanning for performing routine radiological surveys include the following items.

- Determine the general area background by taking a timed 1-minute count in the area where the surface to be scanned is located.
- Scan with a NaI detector in a serpentine pattern of approximately 1 meter in width, while walking at a rate of approximately 0.5 meters per second.
- Hold the detector within approximately 5 inches ± 1 inch distance from the surface, as practicable, and use the audible output of the instrument while scanning.
- As count rate increases, pause to determine if the increased count rate is greater than background.
- Perform direct beta/gamma total contamination measurements at any area where NaI field measurement levels are above two times the NaI field background measurements. If two times background is not noted during the NaI walkover, then static beta/gamma total contamination measurements should be taken approximately every 100 linear feet.

10. REMOVABLE CONTAMINATION

Smears should be taken by swiping a dry area of 100 cm^2 with dry media or soft absorbent paper, using moderate pressure. Swiping dry areas is standard practice whenever practicable; however, if necessary, smears also may be collected on damp or wet surfaces, dried, and analyzed.

Obtain smears at the location of the highest direct reading in addition to other surface locations based on experience and probability of being contaminated. Smears may be collected on damp or wet surfaces and processed as described above. Do not smear soil, a person's skin, standing water, or surfaces that have water running over them.

Use only smears that are approved by RADCON for routine surveys and material releases (any absorbent material may be substituted if it is necessary in emergencies or for a rapid screening evaluation of a spill). Include more smears in the contamination surveys if radionuclides from row 2 in Table 2-2 of CP2-RP-0002 are suspected (the additional smears decrease counting errors and provide additional survey documentation).

Obtain at least one smear for each square meter (biased toward suspected surfaces) for material being transferred from a contamination area (CA). LAWs should be used as supplemental information to determine if elevated removable contamination may be present. See additional discussion of the use of LAWs presented later in this document.

Smears collected from CAs and high contamination areas (HCAs) should be field checked before being removed from the area. The field check should consist of a direct frisk of smears. The field check must show that levels on smears do not exceed HCA values (greater than 100 times the surface contamination values in CP3-RP-1109). Smears exceeding that limit should not be removed from the area unless authorized by a radiological work permit (RWP), other work planning documents (i.e., sampling and analysis plan), or prior approval by RADCON Management. All smears removed from a CA or HCA should be packaged in a sealed container (e.g., Ziploc®, Whirl-Pak®, or similar container).

Perform smear surveys for removable alpha and/or beta-gamma contamination according to the following guidelines:

- Ensure that the smears are identified properly in a way that correlates with the locations on the survey record.

- Perform direct contamination survey measurements before a smear is performed unless the survey at that location is only for removable contamination.

- Smear an area that is equivalent to 100 cm^2 or a square that is approximately 4 inches on a side, while moderate pressure is being applied. The physical area that is represented by the smear can be any shape, as long as the area that is contacted by the smear is about 100 cm^2 and is representative of the physical area or object.

- Small objects with surface areas less than 100 cm^2 are surveyed by smearing the entire surface area. (The estimated surface area that is smeared for small objects should be recorded in the "Comments" section of the survey record.)

- Smears collected for unconditional release should be counted using an instrument with a MDC of 50% or less of the applicable removable contamination limit.

- Job coverage smear surveys (or other surveys as allowed by RADCON supervision) may be counted in the field using hand-held instrumentation as follows:

  - For survey where a specific MDA must be met (such as verification of area postings) the time required for the measurements of the swipe must be such that the MDA is satisfied. Longer count time can be used to improve detector sensitivity.

  - For surveys performed in known contaminated locations, such as characterizing contaminated equipment or surfaces, the measurement is performed by holding the probe over the swipe until the meter display stabilizes (approximately 5 to 15 second but may be longer).

- Determine the removable activity collected on the swipe using the following equation:

$$\frac{dpm}{100cm^2} = \frac{cpm - bkg}{\varepsilon} \qquad \text{Equation 1}$$

Where:

dpm	=	Disintegrations per minute
cpm	=	Gross measurement count rate in counts per minute
bkg	=	Background count rate in counts per minute
ε	=	Detection efficiency of instrument in counts per disintegration

11. MEASURING TRANSFERABLE CONTAMINATION

Because of difficulties in implementing conventional removable contamination monitoring techniques (e.g., smear/swipe surveys), the presence of radioactive contamination in or on soil or other surfaces contaminated with granular solids may present significant challenges to the contamination monitoring program. Although the measurement of contamination levels in the granular solid (on a quantity of radioactive material per weight or volume basis) may be relatively straightforward, it may be difficult to compare the results of such measurements to the CP3-RP-1109 values, which are provided in units of contamination levels per unit area. Such comparisons are necessary to ensure compliance with the CP2-RP-0002 requirements for posting and area and material control.

To ensure compliance, an assessment should be performed to determine the likelihood that radioactive contamination may be dispersed from the surface in question to surrounding areas or to items or individuals who may come in contact with the surface. The assessment may include a review of the operating history to determine whether significant contamination dispersion has occurred in the past, calculations based on realistic dispersion scenarios, performance tests to determine the magnitude of contamination dispersion under actual operating conditions, or other technically defensible measures. An example of one method that may be used by RADCON to quantify transferable contamination is as follows:

- Cut a 4 inch by 4 inch (100 cm^2) section out of a Masslinn wipe (or similar material approved by RADCON management);

- Place 100 cm^2 section of Masslinn on the ground and step on the section of the Masslinn;

- Rotate your foot/Masslinn 90 degrees;

- Determine the general area background per Section 5;

- Perform a direct measurement of the dirty side of Masslinn using a hand held detector for both alpha and beta-gamma contamination by placing the instrument probe at the appropriate distance (¼-inch) above the dirty side of the Masslinn and perform a 1-minute count; and

- Determine the activity (transferable activity) collected on the Masslinn using the following equation:

$$\frac{dpm}{100cm^2} = \frac{cpm - bkg}{\varepsilon} \cdot PAC \qquad \text{Equation 2}$$

Where:

dpm	=	Disintegrations per minute
cpm	=	Gross measurement count rate in counts per minute
bkg	=	Background count rate in counts per minute
ε	=	Detection efficiency of instrument in counts per disintegration
PAC	=	Probe Area Correction Factor = $\frac{100}{Probe\ Area}$

12. USE OF LARGE AREA WIPES

LAWs are a useful tool for documenting the expected condition that elevated removable contamination on a large surface area (i.e., nominally greater than one meter square) is not present. LAWs cannot be used to determine surface contamination in dpm/100 cm^2. While all circumstances where LAWs should be used cannot be defined or listed, examples include: (1) in a hallway area expected to contain no contamination due to its location relative to known contaminated areas; (2) in the majority of the floor area in a large room when contamination only is expected in highly controlled or contained areas; (3) on the outside surface of a 55-gal drum; or (4) to screen for contamination on job coverage surveys.

Wipe an area of no larger than 10 m^2 with a LAW (i.e., typically an oil-impregnated, nonwoven cloth). Scan the LAW for the type of radioactivity (e.g., alpha or beta-gamma) by using an appropriate instrument. Perform a timed count (i.e., typically for 1 minute) on the region of the cloth with the highest reading, or on a representative area if no high readings are measured. Record the results in cpm/LAW determined as follows:

$$\frac{cpm}{LAW} = cpm_g - bkg \qquad \text{Equation 3}$$

Where:

cpm_g	=	Gross measurement count rate in counts per minute
cpm	=	Corrected measurement in counts per minute
bkg	=	Background count rate in counts per minute

Action levels have been developed to determine when follow-up smears are required based on the result of the LAW. The action levels are as follows:

- Bγ = 100 cpm above background
- α in areas controlled at the TRU (transuranic) limits = any detectable alpha above background
- α in areas controlled at the modified TRU (transuranic) limits = 20 cpm above background
- α in areas controlled at the uranium limits = 100 cpm above background

LAWs collected during surveys in areas not adjacent to radiological areas (for example, break rooms, offices, change houses) or within RBAs need not be supplemented with smears unless contamination is detected above the action levels.

13. SURFACE ACTIVITY CALCULATIONS

A measurement for surface activity is performed over an area represented by the sensitive surface area of the detector. If the measured result is a count rate (i.e., cpm) and the background is a count rate (i.e., bkg), the conversion to dpm/100 cm^2 is as follows:

$$\frac{dpm}{100cm^2} = \frac{cpm-bkg}{\varepsilon} \cdot PAC \qquad \text{Equation 4}$$

Where:

dpm	=	Disintegrations per minute
cpm	=	Gross measurement count rate in counts per minute
bkg	=	Background count rate in counts per minute
ε	=	Detection efficiency of instrument in counts per disintegration
PAC	=	Probe Area Correction Factor = $\frac{100}{Probe\ Area}$

For using an integrated count on a digital instrument:

$$\frac{dpm}{100cm^2} = \left[\frac{\frac{C}{T_s}-\frac{B}{T_b}}{\varepsilon} \cdot PAC\right] \qquad \text{Equation 5}$$

Where:

dpm	=	Disintegrations per minute
C	=	Total integrated counts recorded by the instrument
T_s	=	Time period (minute) over which the sample count was recorded
T_b	=	Time period (minute) over which the background was recorded
B	=	Background counts recorded during time T_b
ε	=	Detection efficiency of instrument in counts per disintegration
PAC	=	Probe Area Correction Factor = $\frac{100}{Probe\ Area}$

The Probe Area Correction Factor and the instrument efficiency may be combined into a single correction factor as follows:

$$CF = \frac{PAC}{(\varepsilon)} \qquad \text{Equation 6}$$

Where:

CF	=	instrument correction factor
ε	=	detection efficiency of instrument in counts per disintegration
PAC	=	Probe Area Correction Factor = $\frac{100}{Area}$

Thus, equations 3 and 4 may be rewritten as follows:

$$\frac{dpm}{100cm^2} = [cpm - bgd] \cdot CF \qquad \text{Equation 7}$$

And:

$$\frac{dpm}{100cm^2} = \left[\frac{C}{T_s} - \frac{B}{T_b}\right] \cdot CF \qquad \text{Equation 8}$$

Common correction factors used include the following:

- 44-9, 44-9-18 probe (point) = 10 (based on an actual instrument efficiency of greater than 10%)
- 44-9, 44-9-18 probe (plane) = 50 (based on an actual instrument efficiency of greater than 12.9% and actual probe area)
- 43-5 probe = 10 (based on an actual instrument efficiency of greater than 13% and actual probe area)
- 43-93 probe = 10 (based on an actual instrument efficiency of greater than 10%).

14. DETECTION SENSITIVITY

The detection sensitivity of a survey instrument refers to a radiation level or quantity of radioactive material that can be measured or detected with some known or estimated level of confidence. Sensitivity is a factor of both the instrumentation and the technique being used (i.e., scanning or direct measurement). The primary parameters that affect the detection capability of a radiation detector are the background count rate, the detection efficiency of the detector, and the counting time interval. Other factors may affect alpha detection sensitivities such as surface roughness, the presence of dust, or oil, etc., and the particular radiation energy. Terms that are used to express detection sensitivity for direct static measurements are critical level (L_C), detection limit (L_D), minimum detectable activity (MDA), or MDC. Detection sensitivity for alpha and beta-gamma scanning requires different approaches as described later. The basis for RADCON use and estimation of detection sensitivity quantities are described below and follow the general guidance of Chapter 6 in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM).

15. STATISTICAL COUNTING UNCERTAINTY

All radioactivity measurements have associated uncertainty because of the statistical nature of radioactive decay and the random nature of radioactive background fluctuations. A typical way to estimate this uncertainty is to use the standard deviation to calculate the total uncertainty associated with the counting process. The total uncertainty includes both the background and the sample measurements. An example formula for determining standard deviation of a net count rate is as follows:

$$\sigma_n = \sqrt{\frac{R_g}{T_s} + \frac{R_b}{T_b}} \qquad \text{Equation 9}$$

Where:

σ_n = Standard deviation of the net count rate result
R_g = Number of gross sample counts
T_s = Sample count time
R_b = Number of background counts
T_b = Background count time

16. CRITICAL LEVEL

The L_C is the level, in net counts, at which there is a statistical probability (with a predetermined confidence) of incorrectly identifying a background value as a positive net count (i.e., a Type I error). Conversely, any response of an instrument that is above the L_C value is considered to be above background (i.e., counts or a count rate detected above that from background). This relationship allows detection decisions to be made with the desired level of confidence. Limits, such as the contamination limits in CP3-RP-1109; however, are stated in terms of a concentration rather than in terms of detection (see discussion later concerning minimum detectable concentration).

The L_C calculation parameters generally are selected to provide 95% confidence that the count or count rate measurement is above background given a 5% chance of a false positive. As stated above, false positive means that activity is detected and is not truly a result of counts from contamination but is rather within the normal variability of background counts. The L_C may be calculated for net counts or net count rates and different source and background count times.

The L_C for a net count rate above background is calculated as:

$$L_c = 1.645\sqrt{\frac{R_b}{T_b} + \frac{R_b}{T_s}} \qquad \text{Equation 10}$$

Where:

L_C	=	Net critical detection level (count rate)
R_b	=	Background count rate
T_b	=	Time of background count
T_s	=	Time of sample count

A general rule of thumb is that significant reductions in L_C may be achieved by counting background up to 10 times longer than the sample count time. If background and sample count time are the same, then use the following equation:

$$L_c = 2.33\sqrt{\frac{R_b}{T_b}} \qquad \text{Equation 11}$$

Since the L_C calculations above result in the net count rate above background, the value must be added to the background count rate to determine the gross count rate at L_C. For example, if $T_b = T_s$ = 1-minute and the background is 40 cpm, L_C is 14.7 cpm and the gross count rate is 54.7 cpm.

17. DETECTION LIMIT AND MINIMUM DETECTABLE CONCENTRATION

The L_D is a (before the fact) estimate of the detection capability of a measurement system in units of net counts or net count rate above background. L_D usually is calculated using the following equation. The factor of 3+3.29 in the equation is the Poisson probability sum for values given for the count or count rate that provides 95% confidence that the measurement is above L_C given a 5% chance of a false positive (i.e., Type I error) and a 5% chance of a false negative (i.e., Type II error). The value of this factor depends on the confidence levels selected and can be obtained from Appendix I of MARSSIM.

$$L_D = \frac{3+3.29\sqrt{(R_b)(T_s)\left(1+\frac{T_s}{T_b}\right)}}{T_s} \qquad \text{Equation 12}$$

Where:

L_D = Detection limit net above background (count rate)
R_b = Background count rate
T_b = Time of background count
T_s = Time of sample count

In many cases, the counting time for accumulating background counts is the same as the count time used to collect data. For cases in which the background and sample count or count rate reading are measured with the same intervals, the following equation may be used:

$$L_D = \frac{3}{T_s} + 4.65\sqrt{\frac{R_b}{T_s}} \qquad \text{Equation 13}$$

18. INSTRUMENT EFFICIENCY

The instrument efficiency is defined as the ratio of the net counts observed by the detector for each radioactive disintegration occurring in the source as shown in the following equation:

$$\varepsilon = \frac{cpm-bkg}{dpm} \qquad \text{Equation 14}$$

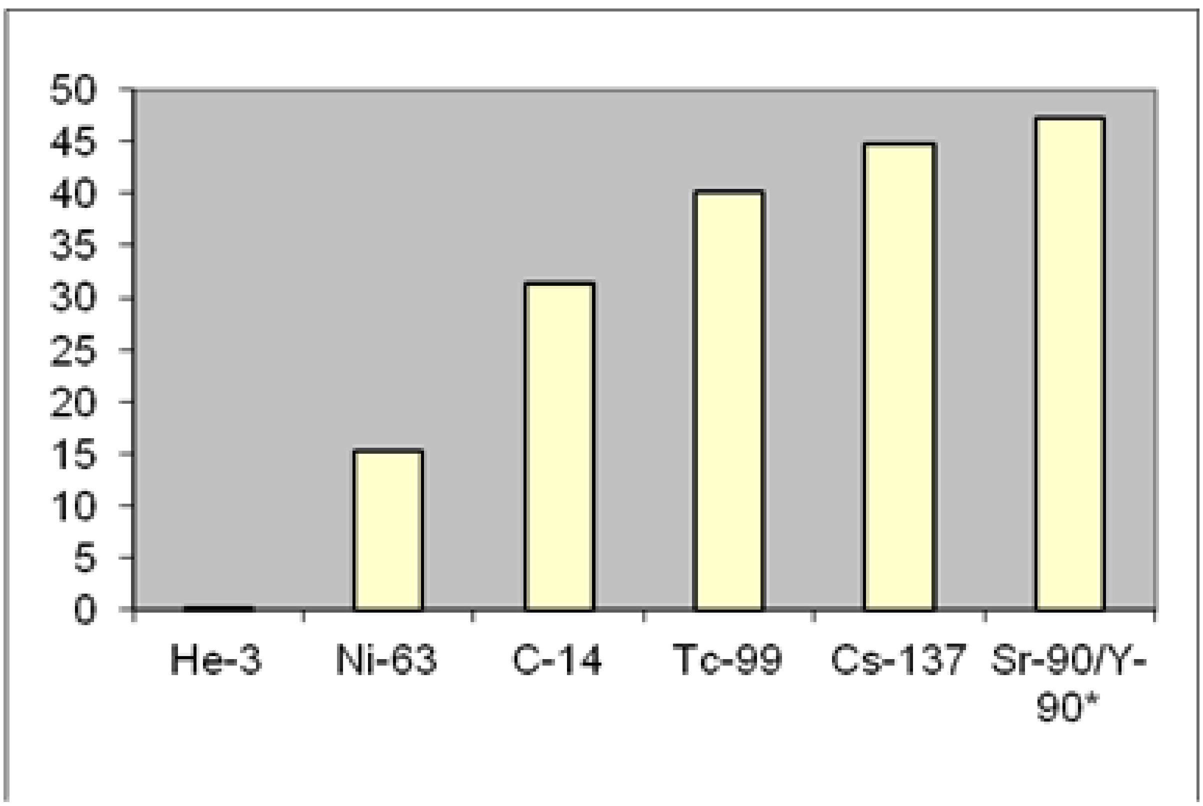
Where:

dpm = Disintegrations per minute
cpm = Gross measurement count rate in counts per minute
ε = Detection efficiency of instrument in counts per disintegration
bkg = Background count rate in counts per minute

Portable, hand-held, beta and alpha instruments used typically have efficiency values for the radionuclides of interest that are greater than 10%. As a conservative measure and to allow surface contamination activity to be readily determined in the field, a default 10% efficiency may be used for these instruments. This default efficiency will not be used for bench counter or laboratory type instrumentation. For this equipment, the efficiency determined during calibration will be used. Additionally, if contamination is identified that exceeds the limits in areas not posted for contamination control or skin or clothing contamination is identified, the instrument efficiency determined during calibration may be used to determine the activity value based on a review of the measurement conditions by RADCON management.

For the Canberra (Tennelec) laboratory low background counting system, the efficiency during calibration will be used. For low energy nuclides (e.g., Ni-63) or other non-routine Paducah radionuclides, the following efficiency chart may be used with Radiological Engineering approval.

Canberra (Tennelec) S5XLB Efficiency Chart



See additional discussion in later sections of this document concerning minimum instrument efficiency values allowed for instruments used by the Deactivation and Remediation (D&R) contractor.

19. MINIMUM DETECTABLE CONCENTRATION

The MDA (or MDC) is the detection limit in net counts (or count rate) converted to radioactivity units by use of appropriate conversion factors. This allows comparison with surface contamination guidelines stated in radioactivity units (e.g., dpm/100 cm^2). When estimating the ability of an instrument to measure radioactivity at a given level of confidence, it is appropriate to calculate the MDC before any measurements (other than background) are made. The MDC is an estimate of the true radioactivity required to give a specified probability that the measured radioactivity will be greater than the L_C. Typically, MDC values are given for the level of radioactivity that provides 95% confidence that the measurement is above background given a 5% chance of a false positive (i.e., Type I error) and a 5% chance of a false negative (i.e., Type II error). As with L_D, the value of this factor depends on the confidence levels selected and can be obtained from Appendix I of MARSSIM. The MDC is a performance goal for selection of instrumentation capable of measuring radioactivity within the confidence criteria selected.

As discussed previously, the L_C is used to determine if contamination is detected (i.e., activity detected above background). For most of the surveys performed by RADCON, the requirement is not if activity is detectable, but rather if the contamination concentration is less than an applicable limit, such as the contamination limits in CP3-RP-1109. The MDC should be determined to demonstrate that it is lower than the applicable limit, and it is generally a good practice to select a measurement methodology with an MDC between 10% and 50% of the applicable limit.

It is more conservative to overestimate the MDC than to underestimate it for a given measurement method. When calculating MDC values, background estimates should be selected that represent the highest (i.e., "worst case") conditions expected during the actual survey.

Background levels may be variable in field applications, and it should be assumed that the background is not well known and may vary from measurement point to measurement point. The MDC may be calculated for the area of the detector (e.g., point source) or related to an area of 100 cm^2 (e.g., plane source). The MDC for a point source static measurement is calculated as follows (NUREG 1507):

$$MDC = \frac{3+3.29\sqrt{(Rb)(Ts)\left(1+\frac{Ts}{Tb}\right)}}{(\varepsilon)(Ts)} \qquad \text{Equation 15}$$

Where:

MDC = minimum detectable activity for field applications (dpm)
R_b = background count rate in cpm
T_b = counting time for background in minutes
T_s = counting time for the sample in minutes
ε = Detection efficiency of instrument in counts per disintegration

The formula for estimating the MDC for a static surface activity measurement relative to 100 cm^2 is as follows:

$$MDC = \frac{3 + 3.29\sqrt{(Rb)(Ts)\left(1 + \frac{Ts}{Tb}\right)}}{(Ts)} \cdot CF$$

Equation 16

Where:

MDC	=	minimum detectable activity for field applications (dpm/100 cm^2)
R_b	=	background count rate in cpm
T_b	=	counting time for background in minutes
T_s	=	counting time for the sample in minutes
CF	=	correction factor

For cases in which the background and surface contamination reading are measured with the same count time intervals, the following equation may be used:

$$MDC = \frac{3+4.65\sqrt{(Rb)(Ts)}}{(Ts)} \cdot CF$$

Equation 17

When selecting instruments for surface contamination surveys, the technician MUST also evaluate whether the detection sensitivity of the equipment being used will be capable of measuring MDC below the guideline levels established for the survey. In order to simplify this process for use in the field, maximum background values have been calculated to ensure the MDC requirements are satisfied. Table 1 provides examples of estimated static MDCs and maximum background values for commonly used alpha and beta-gamma detectors. If the MDC is not less than the appropriate radionuclide-specific surface contamination guideline, a decision cannot be made on whether an item can be released from a CA, HCA, or airborne radioactivity area to an uncontaminated area or released for unrestricted use.

Table 1. Examples of Estimated Static Measurement Detection Sensitivities for Selected Alpha and Beta-Gamma Survey Instrumentation

Radiation	Detector Model	Background Rb (cpm)	Ts	Tb	CF[a]	L_C	MDC[b] (dpm/100 cm²)
α	43-5	0.1	1	1	10	0.74	45
	43-5	1	1	1	10	2.33	77
	43-5	2	1	1	10	3.29	96
	43-5	5	1	1	10	5.20	134
	43-93	0.1	1	1	10	0.74	45
	43-93	1	1	1	10	2.33	77
	43-93	2	1	1	10	3.29	96
	43-93	5	1	1	10	5.20	134
βγ	44-9	40	1	1	50	14.71	1621
	44-9	50	1	1	50	16.45	1795
	44-9	60	1	1	50	18.02	1952
	44-9	70	1	1	50	19.46	2096
	44-9	80	1	1	50	20.81	2231
	44-9	90*	1	1	50	22.07	2357
	44-9	90*	1	1	10	22.07	471***
	44-9	300**	1	1	50	40.29	4179
	44-9	300**	1	1	10	40.29	836***
	43-93	300	1	1	10	40.29	836
	43-93	2500*	1	1	10	116.32	2356
	43-93	10000**	1	1	10	232.64	4683

[a] Plane CF for 44-9 probe assumes an approximate 12.9% efficiency and 13% for the 43-5 probe.
[b] Assumes uniform contamination, and the size of the contamination area is at least as large as the detector area, and an adjustment factor is applied to estimate dpm/100 cm² (i.e., plane correction).
* Maximum allowed background for off-site release surveys
** Maximum allowed background for job coverage and routine surveys where identification of contamination at the βγ total contamination limits is required
*** For use when counting smears

For calculation purposes in the MDC equations above, if the actual alpha background is 0 cpm, this background value should be rounded up to 0.1 cpm (for Ludlum models 2224-1, 2929, and 3030 equipped with model 43-10-1 probes) or 0.2 cpm (for Ludlum models 3, 12, 2221, 2224, and 2224-1 equipped with 43-5 or 43-93 probes) to prevent determining an unrealistic 0 dpm MDC value.

Table 2. Examples of Estimated Measurement Detection Sensitivities for Selected Laboratory Instrumentation

Radiation	Detector Model	Background Rb (cpm)	Ts (min)	Tb (min)	CF	L_C (cpm)	MDC (dpm)
α	43-10-1	0.1	1	5	4	0.57	16.6
	43-10-1	1	1	5	4	1.80	26.4
	43-10-1	2	1	5	4	2.55	32.4
	43-10-1	0.1	1	30	4	0.53	16.2
	43-10-1	1	1	30	4	1.67	25.4
	43-10-1	2	1	30	4	2.36	30.9
	43-10-1	0.1	1	600	4	0.52	16.2
	43-10-1	1	1	600	4	1.65	25.2
	43-10-1	2	1	600	4	2.33	30.6
	43-10-1	0.1	10	600	4	0.17	2.5
	43-10-1	1	10	600	4	0.52	5.4
	43-10-1	2	10	600	4	0.74	7.1
	43-10-1	0.1	60	600	4	0.07	0.8
	43-10-1	1	60	600	4	0.22	2.0
	43-10-1	2	60	600	4	0.31	2.7
	Tennelec	0.1	1	600	4	0.52	16.2
	Tennelec	0.5	1	600	4	1.16	21.3
	Tennelec	0.5	10	600	4	0.37	4.2
	Tennelec	0.5	60	600	4	0.16	1.5
β	43-10-1	40	1	5	3.33	11.40	86.0
	43-10-1	70	1	5	3.33	15.08	110.5
	43-10-1	100	1	5	3.33	18.02	130.1
	43-10-1	40	1	30	3.33	10.58	80.5
	43-10-1	70	1	30	3.33	13.99	103.3
	43-10-1	100	1	30	3.33	16.72	121.5
	43-10-1	40	1	600	3.33	10.41	79.4
	43-10-1	70	1	600	3.33	13.77	101.8
	43-10-1	100	1	600	3.33	16.46	119.8
	43-10-1	40	10	600	3.33	3.32	23.1
	43-10-1	70	10	600	3.33	4.39	30.3
	43-10-1	100	10	600	3.33	5.25	36.0
	43-10-1	40	60	600	3.33	1.41	9.6
	43-10-1	70	60	600	3.33	1.86	12.6
	43-10-1	100	60	600	3.33	2.23	15.0
	Tennelec	1	1	600	3.33	1.65	21.0
	Tennelec	2	1	600	3.33	2.33	25.5
	Tennelec	1	10	600	3.33	0.52	4.5
	Tennelec	2	10	600	3.33	0.74	5.9
	Tennelec	1	60	600	3.33	0.22	1.7
	Tennelec	2	60	600	3.33	0.31	2.3

20. DETECTION SENSITIVITY FOR SCANS

Detection of areas of elevated surface contamination by scanning depends not only on the survey instrumentation used in the scanning mode, but also is dependent on the surveyor's ability in recognizing an increase in the audible output of the instrumentation (e.g., generally by using the built-in speaker on the instrument). Because of this, these factors represent a significant change from the methods of estimating detection sensitivity for static measurements (i.e., L_C, L_D, and MDC). Methods of estimating scanning survey detection sensitivity have been recommended in MARSSIM and will be used by RADCON for surface contamination surveys including scanning requirements.

21. SURFACE SCANNING SENSITIVITY

The framework for determining the scan MDC is based on the premise that there are two stages of scanning; that is, surveyors do not make decisions solely on the basis of a single indication, but rather upon noting an increased number of counts. They pause briefly and then decide whether to move on or take further measurements; thus, scanning consists of two components: (1) continuous monitoring, and (2) stationary sampling. In the first component, characterized by continuous movement of the probe, the surveyor has only a brief look at potential sources, determined by the scan speed. The second component occurs only after a positive response was made at the first stage. This response is marked by the surveyor interrupting the scanning and holding the probe stationary for a period of time, while comparing the instrument output signal during that time to the background counting rate. The sensitivity is relatively high due to the longer observation interval.

Effective scanning detection sensitivity depends upon the protocol that is used as well as the instrument's background and efficiency. The detection sensitivity for a given protocol can be improved by the following actions:

- Selecting an instrument with a higher detection efficiency or a lower relative background;
- Decreasing the scanning speed; and
- Increasing the effective detector area while reducing the detector background per unit area of the detector (i.e., counts/cm^2).

22. ALPHA SURFACE SCANNING

Alpha scintillation survey meters and thin window gas-flow proportional counters typically are used for performing alpha surveys. Alpha radiation has a very limited range and, therefore, instrumentation must be kept close to the surface, usually less than ¼ inch. For this reason, alpha scans generally are performed on relatively smooth, impermeable surfaces (e.g., concrete, metal, and drywall), and not on porous material (e.g., wood), or for volumetric contamination that cannot be detected by scanning for alpha activity and meet the objectives of the survey because of low detection sensitivities.

Scanning for alpha emitters differs significantly from scanning for beta-gamma emitters in that the expected background response of most alpha detectors is low. Since the time a contaminated area is under the detector varies and the background count rate of some alpha survey instruments is 1 cpm or less, it is not practical to determine a fixed L_C or MDC for scanning. Instead, the probability of detecting an elevated area of contamination at a given surface contamination level (e.g., dpm/100 cm^2) can be estimated and used to formulate the scanning protocol.

The probability of detecting a given level of alpha surface contamination with surface scans is addressed in MARSSIM, Chapter 6, Section 6.7, and can be calculated as follows:

$$P(n \geq 1) = 1 - e^{\frac{-G\varepsilon d}{60v}} \qquad \text{Equation 18}$$

Where:

$P(n \geq 1)$	=	probability of observing a single count
G	=	contamination activity to be detected (dpm/100 cm^2)
ε	=	detector efficiency (4 pi)
d	=	width of detector in direction of scan (cm)
v	=	scan speed (cm/s)

Once a count is detected, the technician should pause and wait until the probability of getting another count is at least 90%. This time interval can be calculated by the following relationship:

$$t = \frac{13{,}800}{CA\varepsilon} \qquad \text{Equation 19}$$

Where:

t	=	time of static count (seconds)
C	=	contamination guideline (dpm/100 cm^2)
A	=	physical detector area (cm^2)
ε	=	detector efficiency (4 pi)

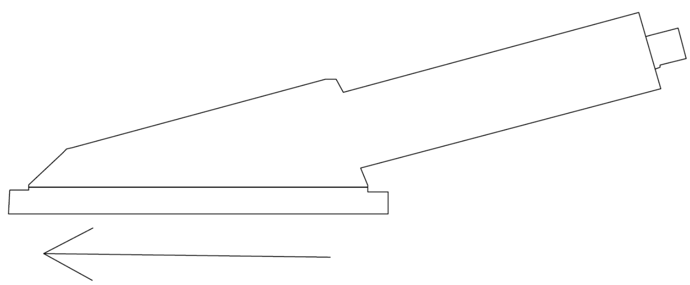
For example, the probability of detecting an alpha count from an isolated area with 500 dpm/100 cm^2 while scanning at a rate of 2 inches per second (i.e., 5.08 cm/s) using a 100 cm^2 detector with a probe dimension of 5 cm in the direction of scan and detector efficiency of 20%; is 81%. The pause time for another count is about two seconds. If scanning for 300 dpm/100 cm^2, the probability is reduced to 62% and the pause time is about three seconds. Table 3 shows examples of the probability of detecting 1,000 dpm/100 cm^2 while scanning with common alpha detectors and the pause time required to detect another count.

Table 3. Examples of Probability of Detecting Alpha Activity While Scanning with Selected Alpha Detectors Using an Audible Output

Probe	Alpha Activity "G" (dpm/100 cm²)	Detection Efficiency "ε" (%)	Probe Dimensions W x L (cm)	Scan Rate (in/s)	Probability of Detection Scan in "W" Direction	Probability of Detection Scan in "L" Direction	Pause Time (seconds)
43-5	1000	13%	4.3 x 17.74	2	84.02%	99.95%	2
43-93	1000	20%	6.93 x 14.48	2	98.94%	99.99%	1
43-93	500	20%	6.93 x 14.48	2	89.71%	99.14%	2
43-93	300	20%	6.93 x 14.48	2	74.44%	94.22%	3
43-93	100	20%	6.93 x 14.48	2	36.54%	61.33%	7

In determining the Table 3 values, an alpha efficiency value of 13% for a Ludlum 43-5 and 20% for a Ludlum 43-93 were assumed to obtain a high probability of detection. If the actual alpha efficiency values determined during calibration are less than these values, the instruments should be tagged out of service and returned to the calibration facility for repair.

As demonstrated in Table 3, the probability of detection is improved when scanning in long, "L", direction of the probe. The arrow in the figure below shows the direction the probe is moved to scan in the "L" direction of the probe.



For alpha survey instruments having background count rates on the order of 5–10 cpm, the guidance for calculation of the detection probability in MARSSIM, Chapter 6, Section 6.7, will be used.

23. BETA-GAMMA SURFACE SCANNING

Thin window, gas-flow proportional counters or Geiger-Müeller detectors normally are used when surveying for beta emitters, although solid scintillators designed for this purpose also may be used. Typically, the beta detector is held at about ½ inch from the surface and moved at a rate such that the desired investigation level can be detected. Low-energy (i.e., 100 keV) beta emitters are subject to the same interferences and self-absorption problems found with alpha emitting radionuclides, and scans for these radionuclides are performed under similar circumstances.

The MDC of a beta-gamma scan survey (MARSSIM terms this "scan MDC" to distinguish from static MDC) depends on the intrinsic characteristics of the detector (e.g., efficiency, physical probe area, etc.); the nature (i.e., type and energy of emissions) and relative distribution of the potential contamination (i.e., point versus distributed source and depth of contamination); scan rate; and characteristics of the surveyor. A net minimum detectable count rate (MDCR) in an observation interval (i.e., I = the time the source is seen by the detector, generally 1 to 2 seconds) is calculated by determining the net source counts per observation interval (s_i) using a detectability value from Poisson statistics (see Table 4) and the expected background counts during the observation interval. The minimum detectable number of net source counts in the interval is given by s_i; therefore, for an ideal observer, the number of source counts required for a specified level of performance can be arrived at by multiplying the square root of the number of background counts by the detectability value associated with the desired performance (as reflected in d'), where the value of d' is selected from Table 4 based on the required true positive and false positive rates, and b_i is the number of background counts in the interval. The net source counts per interval then are used to calculate the MDCR.

These calculations are as follows:

$$s_i = d'\sqrt{b_i} \qquad \text{Equation 20}$$

Where:

s_i = Minimum detectable number of net source counts
d' = Detectability value
b_i = Expected background counts during the observation interval

And then:

$$\text{MDCR (cpm)} = (60/i)(s_i) \qquad \text{Equation 21}$$

Where:

i = Observation interval (seconds)

The surveyor's actual performance should be determined and taken into account as compared with that which ideally is possible. Based on the results of experiments, this surveyor efficiency (p) has been estimated to be between 0.5 and 0.75, and MARSSIM recommends assuming an efficiency value at the lower end of the observed range (e.g., 0.5) when making scan MDC estimates.

The scan MDC then is calculated below using the MDCR, surveyor efficiency factor, instrument and source efficiency factors, and detector area. When the area of elevated radioactivity is identified, a timed direct measurement should be conducted in accordance with the static measurement protocol, as appropriate. The L_C, L_D, or MDC for the static measurements then apply for the timed direct measurement.

$$Scan\ MDC\ \left(\frac{dpm}{100\ cm^2}\right) = \frac{MDCR}{\sqrt{p}\ e_i\ e_s \frac{probe\ area}{100\ cm^2}} \qquad \text{Equation 22}$$

Where:

MDCR = Minimum detectable count rate (cpm)
e_i = Instrument efficiency (4 pi)
e_s = Surface efficiency (assumed to be 1 based on 4 pi efficiency)
p = Surveyor efficiency

Table 4. Values of d' for Selected True Positive and False Positive Proportions

False Positive Proportions	True Positive Proportion							
	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95
0.05	1.90	2.02	2.16	2.32	2.48	2.68	2.92	3.28
0.10	1.54	1.66	1.80	1.96	2.12	2.32	2.56	2.92
0.15	1.30	1.42	1.56	1.72	1.88	1.88	2.32	2.68
0.20	1.10	1.22	1.36	1.52	1.68	1.68	2.12	2.48
0.25	0.93	1.06	1.20	1.35	1.52	1.52	1.96	2.32
0.30	0.78	0.91	1.05	1.20	1.36	1.36	1.80	2.16
0.35	0.64	0.77	0.91	1.06	1.22	1.22	1.66	2.02
0.40	0.51	0.64	0.78	0.93	1.10	1.10	1.54	1.90
0.45	0.38	0.52	0.66	0.80	0.97	0.97	1.41	1.77
0.50	0.26	0.38	0.52	0.68	0.84	0.84	1.28	1.64
0.55	0.12	0.26	0.40	0.54	0.71	0.71	1.15	1.51
0.60	0.00	0.13	0.27	0.42	0.58	0.58	1.02	1.38

The MDC associated with the pause when elevated counts are observed may be determined using Equation 13 with a count time equivalent to the time the probe is paused.

For example, suppose that one wished to estimate the minimum count rate that is detectable by scanning in an area with a background of 1,500 cpm. It will be assumed that a typical source remains under the probe for 2 seconds during the first stage; therefore, the average number of background counts in the observation interval is 50 [b = 1500 × (2/60)]. Furthermore, as explained earlier, it can be assumed that at the first scanning stage a high rate (e.g., 95%) of correct detections is required, and that a correspondingly high rate of false positives (e.g., 60%) will be tolerated. From Table 4, the value of d', representing this performance goal is 1.38. The net source counts needed to support the specified level of performance (assuming an ideal observer) will be estimated by multiplying 7.07 (i.e., the square root of 50) by 1.38. Thus, the net source counts per interval, s_i, needed to yield better than 95% detections with about 60% false positives is 9.8. For this example, MDCR is equivalent to 293 cpm (i.e., 1,793 cpm gross). Table 5 provides examples of beta-gamma "scan MDCs" for selected detectors using a false positive rate of 60%.

Table 5. Examples of the Beta-Gamma Activity "Scan MDC" While Scanning with Selected Beta-Gamma Detectors Using an Audible Output[a]

Detector Model	Background (cpm)	Detection Efficiency	Detector Active Area (cm^2)	Measurement Interval (s)	False Positive Rate (%)	Scan MDC[b] (dpm/100 cm^2)
44-9[c]	50	20%	15.5	2	60	2438
44-9[c]	100	20%	15.5	2	60	3448
44-9[c]	150	20%	15.5	2	60	4223
44-9[c]	200	20%	15.5	2	60	4876
44-9[c]	250	20%	15.5	2	60	5452
44-9[c]	300	20%	15.5	2	60	5972
43-93	500	15%	100	2	60	1593
43-93	1000	15%	100	2	60	2254
43-93	1200*	15%	100	2	60	2469

[a] 50% Surveyor efficiency was assumed.
[b] Pause to verify elevated contamination not included.
[c] Or equivalent probe such as the 44-40, 44-9-18, etc.
* Maximum background allowed during the scan survey for off-site release

For the purpose of releasing items from a radiological area to the Controlled Area, when the Scan MDC exceeds the applicable release limit (for example, scanning with a 44-9 probe with a background slightly above 200 cpm), static surveys are required to demonstrate that the release limits are satisfied.

In determining Table 5 values, a beta efficiency value of 15% for a Ludlum 43-93 and 20% for a 44-9 or equivalent probe were assumed to obtain the necessary scan MDC at reasonably conceivable background levels at some locations at the site. If the actual beta efficiency value determined during calibration is less than these values, the instrument should be tagged out of service and returned to the calibration facility for repair.

24. GUIDELINES FOR RELEASING MATERIAL AND EQUIPMENT FROM RADIOLOGICAL AREAS

Once materials and equipment have entered radiological areas controlled for surface contamination or airborne radioactivity, they are considered contaminated, and radiological surveys are required prior to releasing the material or equipment to controlled areas. The need for evaluation of the radiological characteristics of these materials and equipment and implementation of appropriate controls provides substantial impetus for implementation of measures to limit the amount of material and equipment that enters radiological areas and to prevent contamination of materials and equipment that do enter these areas.

Where potentially contaminated surfaces are not accessible for adequate measurement, the equipment or system component may be released after case-by-case evaluation and documentation based on the following information:

- Process history;
- Available measurements indicate that the inaccessible surfaces are likely less than the surface contamination guidelines and the requirements of CP3-RP-1109 and CP3-RP-1125; and
- RADCON Management approval.

Or the item may require disassembly to allow for survey of these previously inaccessible surfaces.

RADCON uses the criteria described in U.S. Department of Energy (DOE) Order (O) 458.1 for releasing material to uncontrolled areas and for releasing material contaminated in depth or volume, such as activated or smelted contaminated material. Volumetric contamination should be suspected if porous materials have been exposed to liquid or gas, which could have carried contamination into the pores, or if it has been exposed to beams of particles that are capable of causing activation (i.e., neutrons, protons, etc.). In such cases, unless it is a release for the purpose of disposal, it is PGDP policy not to survey or attempt to release volumetric contaminated material unless some form of empirical evidence can be provided or obtained to document the lack of volumetric contamination. When the release is for the purpose of disposal, radiological engineering must evaluate the material and develop a survey and/or sampling plan to confirm the material satisfies the pre-approved volumetric release limits.

24.1. RELEASING MATERIAL AND EQUIPMENT FROM "TRU" AREAS

Scanning for alpha contamination and attempting to detect radionuclides at the transuranic limits is difficult and must be done with extreme care and caution. When the activity ratio of the uranium radionuclides to that of the transuranic radionuclides and Th-230 is less than 12:1 (8% transuranic + Th-230) on an item, the transuranic alpha contamination limits have been historically used associated with the release of the item/material. As presented previously, the probability of detecting alpha contamination at the transuranic total contamination average limits (administratively controlled to 100 dpm/100 cm^2) using a 43-93 probe is low but is higher when detecting at the maximum contamination limit (administratively controlled to 300 dpm/100 cm^2). Because of this, the following survey methodology, based on that presented in DOE-STD-1136-2017, *Good Practices for Occupational Radiological Protection in Uranium Facilities,* is recommended for the release of items and materials from "TRU" areas:

- Perform a scan of the item surface to ensure there are no locations of elevated activity (contamination greater than the maximum contamination limit of 300 dpm/100 cm^2);
- Perform LAWs at biased locations;
- Perform a statistical survey;
    - For items/areas with a surface area greater than 10 m^2, the minimum number of statistical measurements should be 15 or as determined by Radiological Engineering. For items/areas less than 10 m^2, the minimum number of statistical measurements should one per square meter;
    - At each statistical survey point perform both a static measurement and a swipe;
    - The methodology used to perform the static measurement and the counting of swipes should be such that the MDA of the analysis is less than 100 dpm/100 cm^2 for static measurements and less than 20 dpm/100 cm^2 for swipes;
- If not already performed, perform additional biased measurements (static measurements and swipes) at locations identified as potentially containing elevated activity during the scan survey.

25. DECONTAMINATION ACTIVITIES

The following guidance applies to the decontamination of facility components, equipment, and tools. Decontamination activities may be performed in hot cells, glove boxes, fume hoods, temporary containments, designated sinks, bench tops, or in any appropriately posted and controlled area. This guidance does not apply to the decontamination of personnel or facility decommissioning.

RADCON Management provides guidance on performing the decontamination activities, including the following actions:

- Recommending or approving the area or location for performing the decontamination operation;
- Advising and obtaining approvals from the line management and the facility managers;
- Developing any specialized plans, cold testing, mock ups, etc.;
- Approving the proposed decontamination methods and the scope of work; and
- Supporting ALARA considerations and performing dose estimates, as necessary.

Radiological control technicians (RCTs) are responsible for performing RADCON job coverage during decontamination and for obtaining pre-job and post-job survey data. Work preplanning should include a consideration for the handling, temporary storage, disposal, and decontamination of materials, tools, and equipment.

Personnel access and thoroughfares adjacent to the decontamination work areas should be limited and controlled to prevent the spread of contamination. Air movements across areas that contain high contamination levels should be considered when selecting a decontamination method and establishing appropriate engineered controls.

Cleaning agents should be selected based upon their effectiveness, hazardous properties, the amount of waste generated, and ease of disposal. The RPM and Health and Safety should approve the trial use of new cleaning agents. Liquid cleaning agents also should be accompanied with sufficient absorbent materials and appropriate waste receptacles.

ALARA principles always should be considered in planning the decontamination activities. The work should be preplanned to minimize personnel exposures, unless it increases the potential for a worker to receive an internal dose.

The potential for changing dose rates needs to be considered during the job planning process. For example, the dose rates around vacuum cleaners and filtering systems may gradually increase as the work proceeds. Possible changing dose rates also need to be considered when the equipment is being disassembled for decontamination.

The RCT should perform a survey of the area or the item that is to be decontaminated. The survey results should include the following information:

- Deep and shallow dose rates, if appropriate;
- Alpha and beta-gamma contamination levels, if applicable;
- Identified hot spots;
- Conditions of the area or the item; and
- Identified concerns about the areas or activities that are adjacent to where the work will be performed.

26. GUIDELINES FOR PERFORMING DECONTAMINATION

The RCT should ensure that all of the necessary materials and equipment are staged at the work site and are adequate for performing the work as it is described in the RWP or other work authorizations.

Since the amount of material to be taken into the area should be minimized, ensure that the staging arrangement is suitable for the work that is planned.

When decontaminating an area or an item by hand and with the use of detergents (i.e., with or without water) and absorbents, use the following guidance.

- Perform the decontamination in the direction from the lower activity locations proceeding to the locations of higher activity.

- Spray or soak the area or the item with a detergent.
- Wipe in one direction, one time, using the clean sides of the absorbent material.
- Repeat the process, as reasonable, to achieve the desired result.

When using a mop to decontaminate a floor, use the following guidance.

- Use one side of the mop, and then flip the mop over to the clean side.
- Wring out the mop when both sides have been used.
- Use two buckets (i.e., one for wastewater and the other one for rinsing).
- Repeat the process, as reasonable, to achieve the desired result.

When using a HEPA filtered vacuum cleaner to decontaminate a floor, use the following guidance.

- Perform the decontamination from the highest elevation to the lower elevation, when applicable.
- Vacuum from the areas of lower contamination toward the areas of higher contamination.
- Frequently monitor the vacuum for adequate suction and ensure that the exhaust does not create an airborne contamination problem.

Ensure that the decontamination activities and the radiological conditions remain within the scope of the RWP or other written work authorization. The work should be stopped immediately, and the RWP should be modified, as appropriate, before the work proceeds outside the scope of the RWP. A complete post-job survey should be performed when the decontamination work is complete.

27. DOCUMENTATION

At a minimum, contamination survey information should be documented in accordance with CP5-RP-2024, *Guidance for Documenting Radiological Surveys.*

Appropriate survey reports, tags, and/or maps should be completed. Documentation of surveys should provide sufficient information to be meaningful after appreciable passage of time. Maps of buildings, rooms, and equipment layouts should be used to clearly define the areas surveyed and the results. Survey results should be reviewed for accuracy and completeness, and to ensure proper actions have been taken based on the results of the survey; RWP requirements for the area or job are adequate and problem areas, changes, or trends have been identified; and corrective actions assigned, as necessary. Sign (may be electronic signature or equivalent) completed documentation, including review and approval, and make results available to project management when requested.

28. REFERENCES

10 *CFR* 835, *Occupational Radiation Protection*

CP2-RP-0002, *Radiological Control Manual*

CP3-RP-1109, *Radioactive Contamination Control and Monitoring*

CP5-RP-0100, *FRNP Radiological Engineering Methods*

CP5-RP-2024, *Guidance for Documenting Radiological Surveys.*

DOE O 458.1, *Radiation Protection of the Public and the Environment*

DOE-STD-1098-2017, *Radiological Control*

DOE-STD-1136-2017, *Good Practices for Occupational Radiological Protection in Uranium Facilities*

MARSSIM, *Multi-Agency Radiation Survey and Site Investigation Manual*

NUREG 1507, *Minimum Detectable Concentrations with Typical Radiation Surveys Instruments for Various Contaminants and Field Conditions*

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