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CP2-RP-1002/FR2

Radiological Protection Contamination Control and Monitoring Technical Basis Document for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

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CP2-RP-1002/FR2

Radiological Protection Contamination Control and Monitoring Technical Basis Document for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—October 2018

U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
FOUR RIVERS NUCLEAR PARTNERSHIP, LLC,
managing the
Deactivation and Remediation Project at the
Paducah Gaseous Diffusion Plant
under Contract DE-EM0004895

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APPROVALS

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CP2-RP-1002/FR2

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ACRONYMS

ALARA	as low as reasonably achievable
ARA	airborne radioactivity area
CA	contamination area
CF	correction factor
CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
HCA	high contamination area
HEPA	high-efficiency particulate air
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
NRC	Nuclear Regulatory Commission
PGDP	Paducah Gaseous Diffusion Plant
PPE	personal protection equipment
RADCON	radiological control
RCT	radiological control technician
RPM	radiation protection manager
RPPM	radiation protection project 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 mandatory performance of any practice indicated herein is limited strictly to those required by approved RADCON procedures. The acronyms and terms used are defined in CP2-RP-0002, *Radiation Protection Glossary*.

2. GENERAL

Monitoring is defined in *10 CFR § 835, Occupational Radiation Protection*, as, the measurement of radiation levels, airborne radioactivity concentrations, radioactive contamination levels, quantities of radioactive material, 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 U.S. Department of Energy (DOE) standard DOE-STD-1098-2008, *Radiological Control* [also in the Nuclear Regulatory Commission's (NRC's) *Standards for Protection against Radiation*], which are codified in *10 CFR § 20*], 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 § 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

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 guidelines in Appendix B to CP3-RP-1109, *Radioactive Contamination Control and Monitoring,* 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 techniques. (Perform a more thorough contamination smear survey if a LAW indicates that an area or an item that was wiped is contaminated). 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 protection equipment (PPE), latex gloves at a minimum, when removable contamination surveys are being taken even if the surface is not suspected to be contaminated. Complete surveys using appropriate forms in the field at the job site whenever possible to improve efficiency of completing survey paperwork. Use the disintegrations per minute (dpm) card and L_C/MDC card as tools to quickly make calculations in the field. Refer to Appendix A for instructions on how to use the dpm card and Lc/MDC card.

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. Fixed and removable surface contamination values are specified in Appendix B to procedure CP3-RP-1109. Contamination levels on surfaces outside of contaminated areas should be maintained below these fixed and removable surface contamination values and as low as reasonably achievable (ALARA). Questions concerning which surface contamination values to use should be directed to the RPM or Radiation Protection Project Manager (RPPM). 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 Appendix B to CP3-RP-1109 (e.g., one horizontal row of the Appendix B 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 Appendix B to CP3-RP-1109 (e.g., radionuclides in more than one horizontal row of the Appendix B table).

- If a surface is contaminated with radionuclides all within the same hazard category of Appendix B to CP3-RP-1109 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 Appendix B 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 Appendix B value has been exceeded.

- If a surface is contaminated with combination of alpha and beta-gamma emitting radionuclides, as indicated by the hazard categories, then the values provided in Appendix B to CP3-RP-1109 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 Appendix B values.

- Where radionuclides having removable alpha surface contamination guidelines of 20 dpm/100 cm^2 and total alpha surface contamination guidelines of 100 dpm/100 cm^2 [referred to as transuranic (TRU) limits] are mixed with uranium in a known ratio, uranium surface contamination guidelines

may be used when alpha activity, due to uranium (excludes U-232), exceeds sum of alpha activity from the radionuclides having TRU 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 TRU limit. Use of this same logic may be applied to other combinations of radionuclides (e.g., Th-232).

- If a surface is contaminated with a combination of radionuclides in different hazard categories of Appendix B to CP3-RP-1109, then the values provided in Appendix B may be considered to be 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 Appendix B value. For example, if a surface is contaminated with both U-235 and TRU, and analytical data are available for both, then contamination levels of the two radionuclides may be compared independently to the applicable Appendix B values. Although it is permissible to do so, there is no need to sum the U-235 and TRU contamination levels or their fractions relative to the applicable Appendix B values. (In practice, however, it is acceptable and often more convenient to determine the sum of the contamination levels of the various radionuclides and to compare this figure to the most conservative Appendix B values.) This same rule also applies to all other beta/gamma emitters, except H-3 and Sr-90. Radionuclides, such as Co-60, Cs-137, and Eu-152/154, also may use the 50:1 ratio determination.

- When determining uranium (excluding U-232) surface contamination levels and the presence of TRU radionuclides consist of trace activities only, beta surface contamination measurement may be used in lieu of alpha measurements for depleted to low-enriched (up to approximately 4% weight U-235) uranium. Such measurements may be related to the uranium alpha surface contamination levels on a 1:1 ratio of alpha to beta.

- 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 Appendix B to CP3-RP-1109 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 CP3-RP-1109 apply (i.e., 1,000 dpm/100 cm^2 and 5,000 dpm/100 cm^2).

- If Sr-90 contamination resulted from processes involving the separation and purification of Sr-90, the lesser values (i.e., 200 and 1,000 dpm/100 cm^2) apply. An accepted application of these contamination values may be as described below.

- When surveying for total surface contamination, and Sr-90 is known to be present, the following guidelines may be used:

  1. Where the Sr-90 fraction is 50% or less, the mixed fission products surface activity values apply.

  2. Where the Sr-90 fraction is between 50% and 90% of the total activity, surface radioactivity values should be 3,000 dpm/100 cm^2 or less.

3. Where the Sr-90 fraction exceeds 90% the total activity, Sr-90 surface radioactivity values should be applied to the material.

- If contamination by a radionuclide not listed in Appendix B to CP3-RP-1109 is suspected or verified, the actual contamination level should be compared to the Appendix B value(s) 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), survey forms, 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 (typically one minute) at the survey location before the survey is performed and ensure the following:

  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 Section 15 to determine how to make this calculation.

  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 (e.g., 10 minutes), 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 area 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 the RADCON technician (RCT) supervisor, or his/her designee, for guidance.

- For soils located outside of process buildings within the Limited Area, use uranium limits for alpha surface contamination in Appendix B, CP3-RP-1109, unless TRU postings exist where U:TRU ratio is less than 50:1 (> 2% TRU).

- Follow basic survey techniques for specific types of surveys, in accordance with CP3-RP-1109.

- Calculate contamination survey results and document them on the appropriate electronic or paper form.

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, etc.). 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. A 1-minute count is a practical field survey practice that provides good sensitivities that usually are below threshold levels of concern. The practice of recording direct measurements as less than the appropriate radionuclide-specific total surface contamination guidelines (i.e., 5,000 dpm/100 cm^2) is prohibited. Results should be recorded based on actual measured conditions.

7. ALPHA SURFACE SCANNING GUIDELINES

The following general guidelines were developed when using an alpha probe with a minimum dimension of 4.3 cm in the direction of the scanning motion and a minimum active area of 50 cm^2. Detection sensitivity for alpha scanning should be determined in accordance with Section 18.

Scan the surface at a rate that does not exceed 1½ 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 timed direct count 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.

Longer counts can be used to improve detector sensitivity. Compare the timed count result with the critical level (L_C) in counts for the instrument. Results less than the L_C are recorded as non-detect (i.e., L_C). If the counts are greater than or equal to the L_C, then subtract background counts and convert to radioactivity units. Compare these results with the removable limits and record this as a positive result. Perform smear surveys at locations where the timed result was greater than the removable limits.

8. BETA SURFACE SCANNING GUIDELINES

Detection sensitivity during scanning depends on the protocol used as well as the instrument background and efficiency. Scanning speed should be reduced when Sr-90 is suspected or when Sr-90 activity is greater than the activity of other mixed fission products that also are present. Detection sensitivity for beta scanning should be determined in accordance with Section 19. General guidelines include the following:

- Determine the general area background by taking a timed 1-minute count in the area where the items to be surveyed are located. Use the formulas in Section 15 to determine whether the 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. Longer background counts, longer sample counts 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 1½ inches/second.

- Hold the probe within approximately ¼ 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 timed count at locations where the count rate is greater than background or at the location of the highest count rate in larger contaminated areas. Longer counts can be used to improve detector sensitivity.

- Compare the timed count results with the MDC of the instrument. If the MDC is not less than the radionuclide specific surface contamination guideline, do not release the item from a radiological area to a controlled area for unrestricted use.

- Compare the timed count result with the L_C for the instrument.

- Results less than the L_C are recorded as non-detect (i.e., L_C).

- If the counts are greater than or equal to the L_C, then subtract background counts and convert to radioactivity units. Compare these results with the removable limits and record this as a positive result.

- Smear surveys should be performed at locations where the result was greater than the removable limits.

9. 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. The rule-of-thumb is about 10% of the total removable surface contamination will be removed from a dry surface by this technique. The result is directly compared to the values in Appendix B to CP3-RP-1109. Swiping dry areas is standard practice whenever practicable; however, if necessary, smears also may be collected on damp or wet surfaces, dried, and analyzed.

These smears generally are more efficient in collecting the removable surface contamination. There are two recommended methods for comparing the results of smears collected on damp or wet surfaces with the values in Appendix B to CP3-RP-1109. Those methods are as follows:

- Compare the results unadjusted for increased efficiency of removal, with the values in Appendix B to CP3-RP-1109. This is a conservative approach because the removal of more than 10% of the contamination is expected.

- Collect multiple smears of the exact same area swiped. One can assume all activity is removed when two consecutive wipes show less than 10% of the activity of the initial wipe. Sum all of the smear activity collected and take 10% of the sum for comparison to the values in Appendix B to CP3-RP-1109. The total activity on the smears must not exceed 10 times the applicable values in Appendix B to CP3-RP-1109. [This is a method accepted by NRC and the U.S. Department of Transportation for transportation surveys (NRC IE Information Notice No. 85-46).]

Obtain smears at the location of the highest direct reading in addition to other surface locations or any area where the total measurements exceed the removable surface contamination values of Appendix B to CP3-RP-1109. 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. (Note: 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 radionuclide limits from Rows 2 and 3 in Appendix B to CP3-RP-1109 are suspected. (The additional smears decrease counting error 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 may be used as supplemental information to determine if removable contamination may be present. Smears collected from CAs and high contamination areas (HCAs) must be field checked before being removed from the area.

The field check should consist of a direct frisk of smears and/or smear package. The field check must show that levels on smears do not exceed HCA values (> 100 times the surface contamination values in Appendix B to 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 the RPM. Smears collected from CAs and HCAs should be removed from the area only if background radiation levels make field counting impractical or if the smear was collected for purposes of unconditional release. All smears removed from a CA or HCA must be packaged in a sealed container (i.e., Ziploc®, Whirl-Pak®, or similar container).

Perform smear surveys for removable (transferable) 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 "Remark Section" of the Survey Form.)

- Smears collected for unconditional release or for purposes of removing a CA posting must be counted on a Ludlum 2929 or equivalent if contamination limits from Row 2 or 3 from Appendix B to CP3-RP-1109 apply.

- Perform a timed count by using an appropriate survey instrument for both alpha and beta-gamma contamination. Take care to avoid cross contaminating the probe during counting process. Subtract the background and multiply the net counts by the point-source CF to obtain the activity in dpm/100 cm^2.

Guidelines for performing smear surveys for H-3 and C-14 include the following:

- Use only the smears and the liquid scintillation vials that are designated for H-3 and C-14 contamination surveys.

- Use appropriate PPE (e.g., rubber gloves) when smears are being taken on suspected contaminated surfaces or items.

- Label the vial top with the smear number and location number.

- Write only on the top of the vial and keep surfaces of the vial clear and scratch-free.

- Wet the surface of the smear with deionized water and shake off excess.

- Smear an area that is equivalent to a 100 cm^2 area, as in the other typical smear surveys.

- Place smear in vial by folding or rolling smear, activity side out, and cap vial securely.

- Log the smears on the appropriate survey form and ensure that they are delivered to the appropriate counting facility for analysis.

10. USE OF LARGE AREA WIPES

LAWs are a useful tool for documenting the expected condition that removable contamination on a large surface area (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 the area with a LAW (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 (typically for one 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 of the timed count in counts per minute (cpm)/LAW.

LAWs collected during routine surveys in areas not adjacent to radiological areas (i.e., break rooms, offices, change houses) need not be supplemented with smears unless contamination is detected above contamination limits from Row 2 or 3 in Appendix B to CP3-RP-1109.

If the radionuclide limits from Rows 2 and 3 in Appendix B to CP3-RP-1109 apply, a smear survey should be performed in addition to a LAW survey. The smears should be sent for analysis by a low background system.

Do not perform LAWs for H-3 surveys.

11. 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 (cpm) and the background is a count rate (bkg), the conversion to dpm/100 cm^2 is as follows:

$$\frac{dpm}{100cm2} = \frac{cpm - bkg}{Eff.} X \frac{100}{Area}$$

Where:

dpm	=	Disintegrations per minute that can be compared with surface contamination guidelines
cpm	=	Gross measurement count rate in counts per minute
bkg	=	Background count rate in counts per minute
Eff.	=	Detection efficiency of instrument in counts per disintegration
Area	=	Active surface area of the detector in cm^2

For using an integrated count on a digital instrument:

$$\frac{dpm}{100cm^2} = \left[\frac{\frac{C}{T_s} - \frac{B}{T_b}}{Eff.} X \frac{100}{Area}\right]$$

Where:

dpm	=	Disintegrations per minute that can be compared with surface contamination guidelines
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
Eff.	=	Detection efficiency of instrument in counts per disintegration
Area	=	Active surface area of the detector in cm^2

12. 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 L_C, detection limit (L_D) and minimum detectable activity (MDA) or MDC. These are described in Sections 14 and 15. Detection sensitivity for alpha and beta-gamma scanning requires different approaches as described in Sections 18 and 19. The basis for RADCON use and estimation of detection sensitivity quantities are described below and follow the general guidance in Chapter 6 of the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM).

13. 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:

$$\sigma_n = \sqrt{\frac{R_g}{T_s} + \frac{R_b}{T_b}}$$

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

14. 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 (referred to as 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; therefore, RADCON uses the L_C to make detection decisions for direct measurements.

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 chance of a false positive is considered to be conservative and an acceptable result when the objective is to not release contaminated material. The Lc may be calculated for net counts or net count rates and different source and background count times.

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

$$L_c = 1.645\sqrt{\frac{R_b}{T_b} + \frac{R_b}{T_s}}$$

Where:

Lc	=	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 Lc 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:

$$L_c = 2.33\sqrt{\frac{R_b}{T_b}}$$

Since the Lc 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 Lc. For example, if $T_b = T_s = 1$ minute and the background is 40 cpm, Lc is 14.7 cpm and the gross count rate is 54.7 cpm.

15. DETECTION LIMIT AND MINIMUM DETECTABLE CONCENTRATION

The detection limit, 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 (Type I error) and a 5% chance of a false negative (Type II error). The value of this factor depends on the confidence levels selected and can be obtained from Appendix I of MARSSIM.

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

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:

$$L_D = \frac{3}{T_S} + 4.65\sqrt{\frac{R_b}{T_S}}$$

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). RADCON uses the term MDC for surface contamination measurement sensitivity to be consistent with usage in MARSSIM. 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 (Type I error) and a 5% chance of a false negative (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. The MDC is not used for making detection decisions in lieu of the L_C.

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 ("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 (plane source). The MDC for a point source static measurement is calculated as follows (NUREG 1507):

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

Where:

MDC	=	minimum detectable activity for field applications
Rb	=	background count rate in cpm
Tb	=	counting time for background in minutes
Ts	=	counting time for the sample in minutes
K	=	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:

$$MDC = \frac{3 + 3.29\sqrt{(Rb)(Ts)\left(1 + \frac{Ts}{Tb}\right)}}{(K)(Ts)\left(\frac{Area}{100}\right)}$$

Where:

MDC	=	minimum detectable concentration for field applications
Rb	=	background count rate in cpm
Tb	=	counting time for background in minutes
Ts	=	counting time for the sample in minutes
K	=	detection efficiency of instrument in counts per disintegration
Area	=	active surface area of the detector in cm^2

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

$$MDC = \frac{3 + 4.65\sqrt{(Rb)(Ts)}}{(K)(Ts)\left(\frac{Area}{100}\right)}$$

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. Selecting instrumentation with MDC below the guideline is necessary. Table 1 provides examples of estimated static MDCs 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 (ARA) 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

Instrument Factors				**Approximate Sensitivity**		
Detector Model	Active Area (cm^2)	Background[a] (cpm)	Efficiency (%)	L_C (cpm)	L_D (cpm)	MDC (dpm/100 cm^2)[b]/ (dpm)[c]
Alpha						
43.5	76	0.1	13	0.7	4.5	45/34
43.5	76	1	13	2.3	7.7	78/59
43.5	76	2	13	3.3	9.6	97/74
43-68	126	1	20	2.3	7.7	30/38
43-68	126	2	20	3.3	9.6	38/48
43-93	100	0.1	20	0.7	4.5	22/22
43-93	100	1	20	2.3	7.7	38/38
43-37	582	5	17	5.2	13	14/79
Beta-Gamma						
44-9	15	40	19	15	32	1137/171
44-9	15	50	19	16	36	1259/189
44-9	15	60	19	18	39	1369/205

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

Instrument Factors				Approximate Sensitivity		
Detector Model	Active Area (cm^2)	Background[a] (cpm)	Efficiency (%)	L_C (cpm)	L_D (cpm)	MDC (dpm/100 cm^2)[b]/ (dpm)[c]
Beta-Gamma						
43-68	126	300	30	40	84	221/278
43-68	126	400	30	47	96	254/320
43-93	100	200	15	33	69	458/458
43-93	100	300	15	40	84	557/557
43-37	582	1,500	25	90	183	126/732

[a] Background and contamination measurement times of one minute each.
[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 cm^2 (plane correction).
[c] Assumes the size of the contamination area is equal to or less than the detector area (point correction) as for field counting of smears.

16. 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 is also dependent on the surveyor's ability in recognizing an increase in the audible output of the instrumentation (i.e., generally by headphones). 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.

17. 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; 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.

- 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).

18. 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 1 cm (0.4 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 contamination and attempting to detect radionuclide limits from Rows 2 and 3 in Appendix B to CP3-RP-1109, especially at the unrestricted release limits, is difficult and must be done with extreme care and caution. In general, the Deactivation and Remediation project will not attempt to release, for unrestricted use, large quantities of material for recycling or disposal if TRU contamination is suspected; however, PGDP will release worker's tools and equipment using alpha scanning. The RPM may grant a variance from this policy; any variance granted must be in writing or via e-mail.

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:

$$P(n \geq 1) = 1 - e^{\frac{-GEd}{60v}}$$

Where:

P($n \geq 1$)	=	probability of observing a single count
G	=	contamination activity to be detected (dpm/100 cm^2)
E	=	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:

$$t = \frac{13{,}800}{CAE}$$

Where:

t	=	time or static count (seconds)
C	=	contamination guideline (dpm/100 cm^2)
A	=	physical detector area (cm^2)
E	=	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 1.5 inches per second (3.81 cm/s) using a 100 cm^2 detector with a dimension of 5 cm in the direction of scan and detector efficiency of 20%; is 89%. The pause time for another count is about two seconds. If scanning for 300 dpm/100 cm^2, the probability is reduced to 73% and the pause time is about three seconds. Table 2 shows examples of the probability of detecting 1,000 dpm/100 cm^2 while scanning with common alpha detectors.

Table 2. Examples of Probability of Detecting Alpha Activity While Scanning with Selected Alpha Detectors Using an Audible Output

Detector Model	Alpha Activity (dpm/100 cm^2)	Detection Efficiency (%)	Detector Active Area in Direction of Scan (cm)	Scan Rate (in/s)	Probability of Detection*
43-5	1,000	13	4.5	1.5	92
43-68	1,000	20	11	1.5	100
43-93	1,000	20	8	1.5	100
43-37	1,000	17	14	1.5	100

*Detection of one count while scanning in background of less than five counts per minute. Pause to verify not included.

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.

19. BETA-GAMMA SURFACE SCANNING

Thin window gas-flow proportional counters or Geiger-Müeller detectors are normally used when surveying for beta emitters, although solid scintillators designed for this purpose also may be used. Typically, the beta detector is held less than 2 cm from the surface and moved at a rate such that the desired investigation level can be detected. Low-energy (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.

As with alpha scans, it is not practical to determine a static measurement L_C, L_D, or MDC when scanning for beta-gamma emitters. Thus, the scanning sensitivity determination method for beta-gamma emitters in MARSSIM, Chapter 6, Section 6.7, will be used by RADCON.

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 (efficiency, physical probe area, etc.), the nature (type and energy of emissions) and relative distribution of the potential contamination (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 = 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 (Table 3) 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 3 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:

$$s_i = d'\sqrt{b_i}$$

Where:

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

And then:

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

Where:

i	=	Observation interval (seconds)

The surveyor's actual performance should be determined and taken into account as compared with that which is ideally 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 is then 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.

$$\text{Scan MDC}\,(\text{dpm}/100\,\text{cm}^2) = \frac{\text{MDCR}}{\sqrt{p}\;e_i\;e_s\;\dfrac{\text{probe area}}{100\,\text{cm}^2}}$$

Where:

MDCR	=	Minimum detectable count rate (cpm)
e_i	=	Instrument efficiency (4 pi)
e_s	=	Surface efficiency
p	=	Surveyor efficiency

Table 3. 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

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 1 second during the first stage; therefore, the average number of background counts in the observation interval is 25 [b = 1500 × (1/60)]. 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 3, 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 5 (the square root of 25) 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 6.9. For this example, MDCR is equivalent to 414 cpm (1,914 cpm gross). Table 4 provides examples of beta-gamma "scan MDCs" for selected detectors using a false positive rate of 20%.

Table 4. Examples of the Beta-Gamma Activity "Scan MDC" While Scanning with Selected Beta-Gamma Detectors Using an Audible Output

Detector Model	Background (cpm)	Detection Efficiency (%)	Detector Active Area (cm^2)	Measurement Interval (s)	False Positive Rate (%)	Scan MDC* (dpm/100 cm^2)
44-9	50	19	15	2	20	4,770
43-68	300	30	126	2	20	880
43-93	200	15	100	2	20	1,800
43-37	1,500	25	582	2	20	500

*Detection of suspected elevated area while scanning. Pause to verify not included.

20. GUIDELINES FOR RELEASING MATERIAL AND EQUIPMENT FROM RADIOLOGICAL AREAS

Items that are located in known or suspected CAs with the potential to become contaminated at levels that exceed established surface contamination guidelines shall be treated as potentially contaminated and subject to administrative controls. General requirement for releasing radioactive material includes the following:

- Activated material;
- Sealed and unsealed sources; and
- Materials that emit radiation.

Materials in contaminated areas are considered to be contaminated until surveyed and released. Any equipment or system component removed from a process that may have had contact with radioactive material is considered to be contaminated until:

- Disassembled to a reasonable extent required to perform an adequate survey, or

- Surveyed to demonstrate contamination levels less than the surface contamination guidelines and the requirements of CP3-RP-1109.

Where potentially contaminated surfaces are not accessible for adequate measurement (e.g., pipes, drains, and ductwork), the equipment or system component may be released after case-by-case evaluation and documentation based on the following:

- 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

- RPM approval.

Survey and release requirements previously stated in this section are not applicable to ARAs where only gaseous, short-lived (1/2-life of 1 hour or less) activation products are present.

Once materials and equipment have entered radiological areas controlled for surface contamination or airborne radioactivity, comprehensive radiological surveys for contamination are required prior to releasing the material or equipment to controlled areas. Likewise, exposure of certain materials and equipment to a beam of neutrons or other particles produced in a nuclear reactor or particle accelerator may result in activation of that material or equipment, resulting in the creation of radioactive material requiring controlled use, storage, and disposal. 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 or activation of materials and equipment that do enter these areas.

RADCON uses the criteria described in DOE Order 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 (neutrons, protons, etc.). In such cases, it is PGDP policy not to survey or attempt to release the suspect volumetric contaminated material unless some form of empirical evidence can be provided or obtained to document the lack of volumetric contamination.

Materials that potentially are contaminated in volume are released only if there is no measurable increase in radioactivity in the volume as determined using techniques and procedures accepted by DOE Portsmouth/Paducah Project Office. Property that potentially is volumetrically contaminated is evaluated for release on a case-by-case basis. Guidance on how to perform such evaluations should be obtained from the RPM. The requirements for releasing radioactive material to uncontrolled areas are found in CP3-RP-1109.

21. 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 containment, 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. Small-scale and routine decontamination activities may be performed by using this guidance as a technical work document. A more specific technical work document should be developed to support larger scale and more complex decontamination efforts that include the use of specialized decontamination equipment.

The RPM provides guidance on performing the decontamination activities, including the following:

- 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.

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 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 gradually will 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 in accordance with the guidance in CP3-RP-1109. The survey results should include the following:

- 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.

22. 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 (with or without water) and absorbents, use the following guidance:

- Perform the decontamination in the direction from the outside perimeter to the center.
- 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 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.

23. MANAGING CONTAMINATED PERSONNEL

The actions to be taken in the event of a personnel contamination can be found in CP4-RP-1103, *Personnel and Personal Effects Decontamination*. If an injury or an accident is involved, see CP3-RP-1117, *Accidents and Emergencies*. An RCT supervisor should supervise the field decontamination efforts. The following guidelines should be considered in decontaminating personnel:

- Ensure that the proper equipment and supplies are available, including portable survey instruments with appropriate probes, mild soap, water, absorbent disposable towels, etc.

- Ensure that the location is controlled as a CA and suitable for permitting decontamination, including an adequate shower stall, if appropriate.

- If necessary, transport the contaminated individual to an appropriate decontamination facility. During transportation, the person should wear Tyvek® or clean anti-contamination clothing to cover the areas of concern. The vehicle also must be surveyed before further use after the transport.

- Use the following contamination controls during the decontamination process:

    1. Place absorbent paper or towels on the floor to catch any water or liquid splashes.

    2. Where appropriate, use PPE (e.g., rubber gloves, Tyvek®, etc.).

    3. Segregate and retain all materials used during decontamination to be used in further evaluations if necessary. Bag clothing and materials and label in a way that identifies the person, location, circumstance, etc.

    4. Perform and document a survey of the surrounding area following the decontamination.

NOTE: Body orifices only should be decontaminated under the direction of a qualified health professional.

Personnel decontamination should proceed in a way that prevents the spread of contamination and does not force the contamination into the pores of the skin. The following precautions and protocol should be used when performing personnel decontamination:

- Carefully decontaminate areas of the body in the following order:

    1. Higher level skin contamination; and
    2. Lower level skin contamination.

- Start decontamination efforts with soap (liquid preferable) and small quantities of lukewarm water. A waterless hand cleaner may be substituted for soap and water.

- Limit decontamination only to contaminated areas.

- Work from the outer edges of the contaminated area inward.

- If hair is contaminated, consider the following:

    1. Use an absorbent paper towel to gently pull dry particles or dust from the hair.
    2. If just the tips of the hair are contaminated, and the person consents, use scissors to cut the ends.
    3. Cover the person’s face with a towel if the hair is washed with water and shampoo.

- After each successive decontamination effort, perform the following:

    1. Ensure the affected areas are dry.
    2. Perform a frisk of the affected areas.
    3. Briefly document the decontamination method and results.
    4. Record the time.

- Decontamination efforts should be discontinued when any of the following occurs:

    1. Levels are reduced to levels that are non-detectable;
    2. Three attempts do not sufficiently reduce the levels that are non-detectable; and
    3. The skin becomes reddened or irritated.

The RPM should provide guidance on further action if decontamination efforts are unsuccessful and provide contamination level guidelines for detectable personnel contamination levels. The follow-up decision will consider the level of skin contamination that persists, the outcome of analyses on nasal smears, and whether the person may have received an internal dose during the incident, etc. A qualified health professional should be consulted before further decontamination is attempted. In cases where an internal dose is suspected, the RPPM should contact the RPM for further action. The RCT should document all notifications and responses to be included in the occurrence report.

The gathered facts are analyzed to identify methods for preventing recurrence and determining where improvements can be made. Lessons learned also should be considered and incorporated in future work when unique activities are completed successfully.

24. USING VACUUM CLEANERS AND PORTABLE AIR-HANDLING EQUIPMENT

Improper use of vacuum cleaners and portable air-handling equipment could result in the generation of airborne radioactivity, loose surface contamination, or high dose rates; therefore, their use is controlled. Vacuum cleaners and portable air-handling equipment that are used in CAs, RMAs, or RBAs are equipped with high-efficiency particulate air (HEPA) filters, unless the material to be vacuumed is wet enough to preclude re-suspension. Vacuum cleaner and portable air-handling equipment HEPA filters are integrity tested following CP4-SM-0057, *Cleaning and Testing Fissile HEPA Vacuum Cleaners*, and CP4-SM-0054, *Cleaning and Testing Non-Fissile HEPA Vacuum Cleaners*:

- Before initial use,
- When units have been opened, and
- Annually.

Vacuum cleaners used for radiological work are:

- Uniquely marked and labeled to identify both their internal and external contamination characteristics,
- Controlled by a RWP,
- Controlled to prevent unauthorized use,
- Designed to ensure HEPA filter integrity under conditions of use, and
- Designed to prevent unauthorized or accidental access to the inner surfaces of the vacuum.

Radiation and contamination surveys are performed periodically during the use of vacuum cleaners. The frequency of radiation surveys is dependent on the specific use of the vacuum cleaner. Labels on the vacuums are updated after each survey or use. Airborne radioactivity levels are monitored when a vacuum cleaner is used in a HCA. A nuclear safety review is performed and documented before the use of a vacuum cleaner for fissile material.

25. DOCUMENTATION

Radioactive contamination surveys are documented in accordance with the requirements contained in procedure CP3-RP-1109. At a minimum, documented contamination survey information should include the following:

- Date, time, and purpose of the survey;
- General and specific location of the survey;
- The survey number;
- Name(s) and signatures of survey performer(s) and reviewer(s);
- Pertinent information needed to interpret the survey results to include efficiencies and/or CFs, backgrounds, count times, types of radiation, fixed or removable;
- Reference to a specific RWP when the survey is performed to support a RWP;
- Survey and counting instrument model numbers and serial numbers (or other unique identifier) and calibration due dates;
- Results of measurements of area contamination and exposure rates;
- Cross-reference decontamination follow-up survey results to the original survey, as applicable;
- Sketches should be provided, as applicable, for identifying the specific location where measurements or smears were taken, liquid or air samples were collected, including locations of interest (e.g., such as where high dose rates were measured, hot particles identified, or localized contamination distinguished);
- Comments, if pertinent;
- Descriptions of the property being released from a radiological area or controlled area; and
- Recipient (individual or company) of property released from the controlled area. (Property sales maintain records of property released through property sales.)

Appropriate forms, tags, maps should be completed. Documentation of surveys should provide sufficient information to be meaningful after appreciable passage of time. Sketches 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 completed documentation, including review and approval, and make results available to project management when requested.

26. GUIDELINES FOR RELEASING LIQUIDS AND SLUDGE

Field RCTs and frontline RADCON supervisors are not approved to release liquids or mixtures of liquids. The following five steps delineate the process for releasing liquids and sludge.

1. Contact a RADCON RPPM for guidance,
2. Develop an analysis plan,
3. Sample the subject material,
4. Compare analytical results to available release standards, and
5. Based on the comparison, either approve or disapprove the material release.

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APPENDIX A

SURVEY PROTOCOL USING INSTRUMENT CRITICAL LEVEL/MINIMUM DETECTABLE CONCENTRATION CARDS AND DISINTEGRATION PER MINUTE CONVERSION CARD

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Performing survey measurements involves a number of basic steps. These steps are outlined below.

Perform a timed background count for alpha and beta contamination at the location in which the measurement will be performed.

- Determine the appropriate minimum detectable concentration (MDC) value based on that background and verify that the plane MDC value is less than the applicable contamination limit. If not, consult your radiological control technician (RCT) supervisor for guidance.

- Perform a single measurement and compare the measured activity in counts per minute (cpm) to the instrument critical level (L_C) (see note below) to determine if the critical level has been exceeded. Results less than the instrument L_C should be recorded as L_C on the survey form.

- If the L_C has been equaled or exceeded then utilize the applicable correction factor (CF) to convert the measured cpm to disintegrations per minute (dpm).

NOTE: The instrument L_C is determined by calculating the L_C (based on the measured background) and adding the background cpm to the L_C cpm.

These steps are detailed below and demonstrate the use of the Instrument L_C/MDC and instrument cpm to dpm cards.

Measuring the Background and Determining the Instrument L_C:

Perform a 1-minute background count for alpha or beta contamination at the survey location and record that number. Find the row on the L_C card that corresponds to that background number. Record the Instrument L_C in cpm in the appropriate block. Record the plane MDC in dpm in the appropriate block.

Example #1

You are performing a direct survey of a tabletop using the instrument on the example L_C card shown below. You have performed a 1-minute background count that yielded 48 counts and recorded that background on the survey form. Using the L_C card, you determined that the Instrument L_C is 64 cpm, L_C is 16 cpm, and the Plane MDC is 1145 dpm. The information would be recorded on the example survey form as shown below.

Inst Type	Serial No.	Cal Due Date	αBkgd	βγBkgd	Inst L_C	L_C	Plane MDC
L-2221	K30195	5/15/07	N/A	48	64	16	1,145

In this case, the instrument background is 48 cpm, the calculated L_C is 16 cpm, and the sum of the two values (Instrument L_C) is 64 cpm; therefore any measurements that yield 63 cpm or less are L_C regardless of whether the measurement involves a smear, a LAW or a direct (total) reading. Any response of the instrument that is greater than or equal to L_C is considered above background.

Example Instrument L_C/MDC Card

Plane Correction 32.52 Instrument No. K30195l													
Bkgd	**Inst L_C**	**Lc**	**Plane MDC (dpm)**		**Bkgd**	**Inst L_C**	**L_C**	**Plane MDC (dpm)**		**Bkgd**	**Inst L_C**	**L_C**	**Plane MDC (dpm)**
25	36	11	854		50	66	16	1,167		70	89	19	1,363
31	43	12	940		51	67	16	1,177		71	90	19	1,372
32	45	13	953		52	68	16	1,188		72	91	19	1,381
33	46	13	966		53	69	16	1,198		73	92	19	1,390
34	47	13	979		54	71	17	1,209		74	94	20	1,398
35	48	13	992		55	72	17	1,219		75	95	20	1,407
36	49	13	1,005		56	73	17	1,229		76	96	20	1,416
37	51	14	1,017		57	74	17	1,239		77	97	20	1,424
38	52	14	1,030		58	75	17	1,249		78	98	20	1,433
39	53	14	1,042		59	76	17	1,259		79	99	20	1,442
40	54	14	1,054		60	78	18	1,269		80	100	20	1,450
41	55	14	1,066		61	79	18	1,279		81	101	20	1,459
42	57	15	1,078		62	80	18	1,288		82	103	21	1,467
43	58	15	1,089		63	81	18	1,298		83	104	21	1,475
44	59	15	1,101		64	82	18	1,307		84	105	21	1,483
45	60	15	1,112		65	83	18	1,317		85	106	21	1,492
46	61	15	1,123		66	84	18	1,326		86	107	21	1,500
47	62	15	1,134		67	86	19	1,335		87	108	21	1,508
48	64	16	1,145		68	87	19	1,345		88	109	21	1,516
49	65	16	1,156		69	88	19	1,354		89	110	21	1,524

Plane Correction 32.52 Instrument No. K30195l													
Bkgd	**Inst L_C**	**Lc**	**Plane MDC (dpm)**		**Bkgd**	**Inst L_C**	**L_C**	**Plane MDC (dpm)**		**Bkgd**	**Inst L_C**	**L_C**	**Plane MDC (dpm)**
90	112	22	1,532		110	134	24	1,684		130	156	26	1,822
91	113	22	1,540		111	135	24	1,691		131	157	26	1,828
92	114	22	1,548		112	136	24	1,698		132	158	26	1,835
93	115	22	1,556		113	137	24	1,705		133	159	26	1,841
94	116	22	1,564		114	138	24	1,712		134	160	26	1,848
95	117	22	1,571		115	139	24	1,719		135	162	27	1,855
96	118	22	1,579		116	141	25	1,726		136	163	27	1,861
97	119	22	1,587		117	142	25	1,733		137	164	27	1,868
98	121	23	1,595		118	143	25	1,740		138	165	27	1,874
99	122	23	1,602		119	144	25	1,747		139	166	27	1,880
100	123	23	1,610		120	145	25	1,754		140	167	27	1,887
101	124	23	1,617		121	146	25	1,761		141	168	27	1,893
102	125	23	1,625		122	147	25	1,768		142	169	27	1,900
103	126	23	1,632		123	148	25	1,775		143	170	27	1,906
104	127	23	1,640		124	149	25	1,781		144	171	27	1,912
105	128	23	1,647		125	151	26	1,788		145	173	28	1,918
106	129	23	1,654		126	152	26	1,795		146	174	28	1,925
107	131	24	1,662		127	153	26	1,802		147	175	28	1,931
108	132	24	1,669		128	154	26	1,808		148	176	28	1,937
109	133	24	1,676		129	155	26	1,815		149	177	28	1,943

Determining if a Single Measurement Exceeds L_C:

Perform a one-minute count and note the number of counts detected. If the number of counts detected is less than the Instrument L_C (see Example #1) then the measurement is L_C and you may enter " L_C" on the survey form for that measurement.

Example #2

Having performed the background count and noting the Instrument L_C in Example #1, you have determined that 63 cpm is the maximum number of counts that can be yielded on a single measurement and that measurement still be L_C. You perform your first 1-minute direct count of a tabletop and the instrument reads 62 cpm.

Since this value does not exceed the maximum value of 63 cpm you determine that this measurement is L_C. Record "LC" for that measurement on the survey form. You perform a second 1-minute direct count on the tabletop that yields 72 cpm. Since you have exceeded the maximum value of 63 cpm, it is necessary to subtract background and calculate the activity associated with this measurement and record the results on the survey form in dpm. Any response of the instrument that is greater than or equal to L_C is considered above background.

Converting Counts per Minute (cpm) to Disintegrations per Minute (dpm):

When converting measurements collected in cpm to dpm, there are two possible protocols for background subtraction that may be used. These protocols are detailed below.

- Protocol one allows using the exact measured background, in cpm, as the value to be subtracted from the gross cpm to determine the net cpm for a single measurement.

- Protocol two allows the RCT to round the background down to the next lower value of 10 (e.g., if the measured background is 48 cpm the RCT may round the background down to 40 cpm) to simplify background subtraction in the field. If using this method, however, the L_C values reported on the survey should be based on the measured background, not the rounded down value.

- The protocol to be used should be selected by the RCT in consultation with the RCT supervisor. The objective should be to select the protocol that is most efficient for use by the RCT in the survey environment. In cases of differing opinions, the RCT supervisor shall have final decision in protocol selection.

When converting net cpm to dpm, there are two protocols available from which the RCT may choose. These protocols are detailed below.

- Protocol one allows the RCT to convert net cpm to dpm by multiplying the net cpm by the appropriate CF (point or plane), as determined during instrument setup. This function should be performed using a calculator.

- Protocol two allows use of the instrument cpm to dpm conversion card that is attached to each instrument. This protocol is detailed in this document.

- The protocol to be used should be selected by the RCT in consultation with the RCT supervisor. The objective should be to select the protocol that is most efficient for use by the RCT in the survey

environment. In cases of differing opinions, the RCT supervisor shall have final decision in protocol selection.

Example #3

In Example #2, the second measurement performed on the tabletop yielded 72 cpm and was determined to be greater than L_C. The RCT may proceed at this point using either of the two protocols detailed in Example #2. If using the measured background protocol, the RCT would subtract the measured background (48 cpm) from the gross cpm determined in the second measurement in Example #2 above (72 gross cpm). The result would be 24 net cpm. If using the rounded down background protocol detailed above, the rounded down background of 40 cpm would be subtracted from the 72 gross cpm of the second measurement yielding 32 net cpm. Having determined the cpm for that measurement, the RCT would convert the cpm to dpm using either of the two protocols detailed above. If using protocol 1, the RCT would use a calculator to multiply the net cpm (either 24 or 32) by the instrument plane CF (32.52) that would result in the total dpm for that measurement (781 dpm/100 cm^2 or 1041 dpm/100 cm^2). Note that the dpm reported when using the rounded down background protocol is higher (more conservative) than the dpm reported using the measured background protocol. That is the reason why when rounding the background you always round down.

If using the cpm to dpm conversion card protocol, the RCT would refer to the cpm to dpm conversion card (see sample below), find the net cpm value of 24 or 32, then round up the value shown in the column labeled dpm Plane to determine the exact number of dpm to report. The results would have been identical to that produced above by using the calculator.

Example Conversion Card for cpm to dpm

Instrument Number K30195
Point Correction 5.04 198.41 cpm = 1.000 dpm with Point CF
Plane Correction 32.52 153.75 cpm = 5,000 dpm with Plane CF

Net cpm	dpm Point	dpm Plane		Net cpm	dpm Point	dpm Plane		Net cpm	dpm Point	dpm Plane
10	50.40	325.20		25	126.00	813.00		40	201.60	1,300.80
11	55.44	357.72		26	131.04	845.52		41	206.64	1,333.32
12	60.48	390.24		27	136.08	878.04		42	211.68	1,365.84
13	65.52	422.76		28	141.12	910.56		43	216.72	1,398.36
14	70.56	455.28		29	146.16	943.08		44	221.76	1,430.88
15	75.60	487.80		30	151.20	975.60		45	226.80	1,463.40
16	80.64	520.32		31	156.24	1,008.12		46	231.84	1,495.92
17	85.68	552.84		32	161.28	1,040.64		47	236.88	1,528.44
18	90.72	585.36		33	166.32	1,073.16		48	241.92	1,560.96
19	95.76	617.88		34	171.36	1,105.68		49	246.96	1,593.48
20	100.80	650.40		35	176.40	1,138.20		50	252.00	1,626.00
21	105.84	682.92		36	181.44	1,170.72		51	257.04	1,658.52
22	110.88	715.44		37	186.48	1,203.24		52	262.08	1,691.04
23	115.92	747.96		38	191.52	1,235.76		53	267.12	1,723.56
24	120.96	780.48		39	196.56	1,268.28		54	272.16	1,756.08

Example Conversion Card for cpm to dpm (Continued)

Instrument Number K30195 **Point Correction 5.04 198.41 cpm = 1,000 dpm with Point CF** **Plane Correction 32.52 153.75 cpm = 5,000 dpm with Plane CF**										
Net cpm	**dpm Point**	**dpm Plane**		**Net cpm**	**dpm Point**	**dpm Plane**		**Net cpm**	**dpm Point**	**dpm Plane**
55	277.20	1,788.60		70	352.80	2,276.40		86	433.44	2,796.72
56	282.24	1,821.12		71	357.84	2,308.92		87	438.48	2,829.24
57	287.28	1,853.64		72	362.88	2,341.44		88	443.52	2,861.76
58	292.32	1,886.16		73	367.92	2,373.96		89	448.56	2,894.28
59	297.36	1,918.68		74	372.96	2,406.48		90	453.60	2,926.80
60	302.40	1,951.20		75	378.00	2,439.00		91	458.64	2,959.32
61	307.44	1,983.72		76	383.04	2,471.52		92	463.68	2,991.84
62	312.48	2,016.24		77	388.08	2,504.04		93	468.72	3,024.36
63	317.52	2,048.76		78	393.12	2,536.56		94	473.76	3,056.88
64	322.56	2,081.28		79	398.16	2,569.08		95	478.80	3,089.40
65	327.60	2,113.80		80	403.20	2,601.60		96	483.84	3,121.92
66	332.64	2,146.32		81	408.24	2,634.12		97	488.88	3,154.44
67	337.68	2,178.84		82	413.28	2,666.64		98	493.92	3,186.96
68	342.72	2,211.36		83	418.32	2,699.16		99	498.96	3,219.48
69	347.76	2,243.88		84	423.36	2,731.68		100	504.00	3,252.00
				85	428.40	2,764.20				

Converting Net cpm to dpm Using the Conversion Card:

In Example #3, above, using the cpm to dpm conversion card was very simple because the cpm was a value listed on the card, so the values for point and plane dpm were exact for those values. This will often be the case. There also will be instances, however, where the net cpm is less than 10 or greater than 100.

Example #4

The RCT performs a measurement on a tabletop that yields 183 net cpm. To convert the activity to dpm, the RCT would perform the following:

- Move the decimal point one position to the left creating a value of 18.3.
- Round this number to the next highest whole number (19).
- Locate the value 19 in the net cpm column of the conversion card (see example card above).
- Observe the corresponding value in the plane dpm column of the table (617.88).
- Move the decimal point one position to the right (6178.8).
- Round that number (6179).
- Record that number as the activity in dpm/100 cm^2.

The RCT performs a second measurement on the tabletop that yields 18,300 cpm. To convert the activity to dpm the RCT would perform the following:

- Move the decimal point three positions to the left creating a value of 18.3.
- Round this number to the next highest whole number (19).
- Locate the value 19 in the net cpm column of the conversion card (see the example card above).

- Observe the corresponding value in the plane dpm column of the table (617.88).
- Move the decimal point three positions to the right (617,880). Note that a 0 had to be added to the end of the number in order to provide a sufficient number of significant digits to allow the decimal point to be moved three places to the right.
- Record that number as the activity in dpm/100 cm^2.

Modification of Instrument L_C/MDC cards and Instrument cpm to dpm conversion cards are necessary because of differences that might arise due to the use of a variety of instruments and probes. The Instrument L_C/MDC cards and Instrument cpm to dpm conversion cards may have to be modified. For example, the L-2224 often is used in combination with the Ludlum 43-89 dual probe. This instrument is capable of detecting both alpha and beta radiation and has a 100 cm^2 probe. The instrument cpm to dpm conversion card is modified to reflect the higher beta background for the probe (see example of cards below). The instrument group will perform card modifications as necessary during instrument setup.

Example L_C/MDC Card for a Ludlum 43-89
Dual Phosphor Detector for Beta-Gamma

CF 4.15 **Instrument No. K54321**										
Bkgd	**Inst L_C cpm**	**MDC cpm**		**Bkgd**	**Inst L_C cpm**	**MDC cpm**		**Bkgd**	**Inst L_C cpm**	**MDC cpm**
90	113	196		110	135	215		130	157	233
91	114	197		111	136	216		131	158	234
92	115	198		112	137	217		132	159	235
93	116	199		113	138	218		133	160	235
94	117	200		114	139	219		134	161	236
95	118	201		115	140	220		135	163	237
96	119	202		116	142	221		136	164	238
97	120	203		117	143	222		137	165	239
98	122	204		118	144	223		138	166	240
99	123	205		119	145	223		139	167	240
100	124	206		120	146	224		140	168	241
101	125	207		121	147	225		141	169	242
102	126	208		122	148	226		142	170	243
103	127	209		123	149	227		143	171	244
104	128	210		124	150	228		144	172	245
105	129	211		125	152	229		145	174	245
106	130	212		126	153	230		146	175	246
107	132	213		127	154	230		147	176	247
108	133	213		128	155	231		148	177	248
109	134	214		129	156	232		149	178	249

Example L_C/MDC Card for a Ludlum 43-89
Dual Phosphor Detector for Beta-Gamma (Continued)

CF 4.15 **Instrument No. K54321**										
Bkgd	**Inst L_C cpm**	**MDC cpm**		**Bkgd**	**Inst L_C cpm**	**MDC cpm**		**Bkgd**	**Inst L_C cpm**	**MDC cpm**
150	179	249		170	201	65		190	223	279
151	180	250		171	202	265		191	224	280
152	181	251		172	203	266		192	225	280
153	182	252		173	204	267		193	226	281
154	183	252		174	205	268		194	227	282
155	185	253		175	206	268		195	228	282
156	186	254		176	207	269		196	229	283
157	187	255		177	208	270		197	230	284
158	188	256		178	210	270		198	231	284
159	189	256		179	211	271		199	232	285
160	190	257		180	212	272		200	233	286
161	191	258		181	213	273		201	235	287
162	192	259		182	214	273		202	236	287
163	193	259		183	215	274		203	237	288
164	194	260		184	216	275		204	238	289
165	195	261		185	217	275		205	239	289
166	197	262		186	218	276		206	240	290
167	198	262		187	219	277		207	241	291
168	199	263		188	220	278		208	242	291
169	200	264		189	222	278		209	243	292

Example L_C/MDC Card for a Ludlum 43-89 Dual Phosphor Detector for Beta-Gamma (Continued)

CF 4.15
Instrument No. K54321

Bkgd	Inst L_C cpm	MDC cpm		Bkgd	Inst L_C cpm	MDC cpm		Bkgd	Inst L_C cpm	MDC cpm		Bkgd	Inst L_C cpm	MDC cpm
210	244	293		230	266	306		250	287	318		270	309	330
211	245	293		231	267	306		251	288	319		271	310	331
212	246	294		232	268	307		252	289	319		272	311	331
213	248	295		233	269	308		253	291	320		273	312	332
214	249	295		234	270	308		254	292	321		274	313	332
215	250	296		235	271	309		255	293	321		275	314	333
216	251	297		236	272	309		256	294	322		276	315	334
217	252	297		237	273	310		257	295	322		277	316	334
218	253	298		238	274	311		258	296	323		278	317	335
219	254	299		239	276	311		259	297	324		279	318	335
220	255	299		240	277	312		260	298	324		280	319	336
221	256	300		241	278	313		261	299	325		281	321	336
222	257	300		242	279	313		262	300	325		282	322	337
223	258	301		243	280	314		263	301	326		283	323	338
224	259	302		244	281	314		264	302	326		284	324	338
225	260	302		245	282	315		265	303	327		285	325	339
226	262	303		246	283	316		266	305	328		286	326	339
227	263	304		247	284	316		267	306	328		287	327	340
228	264	304		248	285	317		268	307	329		288	328	340
229	265	305		249	286	317		269	308	329		289	329	341

Instrument cpm to dpm conversion for Ludlum 43-93 detector

Instrument No. K383971
Alpha Correction 4.02 248.76 cpm= 1000 dpm with Point CF
Beta Correction 4.19 1193.32 cpm= 5000 dpm with Plane CR

Bkgd	Inst L_C cpm	MDC cpm		Bkgd	Inst L_C cpm	MDC cpm		Bkgd	Inst L_C cpm	MDC cpm
10	40.20	41.90		25	100.50	104.75		40	160.80	167.60
11	44.22	46.09		26	104.52	108.94		41	164.82	171.79
12	48.24	50.28		27	108.54	113.13		42	168.84	175.98
13	52.26	54.47		28	112.56	117.32		43	172.86	180.17
14	56.28	58.66		29	116.58	121.51		44	176.88	184.36
15	60.30	62.85		30	120.60	125.70		45	180.90	188.55
16	64.32	67.04		31	124.62	129.89		46	184.92	192.74
17	68.34	71.23		32	128.64	134.08		47	188.94	196.96
18	72.36	75.42		33	132.66	138.27		48	192.96	201.12
19	76.38	79.61		34	136.68	142.46		49	196.98	205.31
20	80.40	83.80		35	140.70	146.65		50	201.00	209.50
21	84.42	87.99		36	144.72	150.84		51	205.02	213.69
22	88.44	92.18		37	148.74	155.03		52	209.04	217.88
23	92.46	96.37		38	152.76	159.22		53	213.06	222.07
24	96.48	100.56		39	156.78	163.41		54	217.08	226.26

Instrument No. K383971
Alpha Correction 4.02 248.76 cpm= 1000 dpm with Point CF
Beta Correction 4.19 1193.32 cpm= 5000 dpm with Plane CR

Bkgd	Inst L_C cpm	MDC cpm		Bkgd	Inst L_C cpm	MDC cpm		Bkgd	Inst L_C cpm	MDC cpm
55	221.10	230.45		70	281.40	293.30		86	345.72	360.34
56	225.12	234.64		71	285.42	297.49		87	349.74	364.53
57	229.14	238.83		72	289.44	301.68		88	353.76	368.72
58	233.16	243.02		73	293.46	305.87		89	357.78	372.91
59	237.18	247.21		74	297.48	310.06		90	361.80	377.10
60	241.20	251.40		75	301.50	314.25		91	365.82	381.29
61	245.22	255.59		76	305.52	318.44		92	369.84	385.48
62	249.24	259.78		77	309.54	322.63		93	373.86	389.67
63	253.26	263.97		78	313.56	326.82		94	377.88	393.86
64	257.28	268.16		79	317.58	331.01		95	381.90	398.05
65	261.30	272.32		80	321.60	335.20		96	385.92	402.24
66	265.32	276.54		81	325.62	339.39		97	389.94	406.43
67	269.34	280.73		82	329.64	343.58		98	393.96	410.62
68	273.36	284.92		83	333.66	347.77		99	397.98	414.81
69	277.38	289.11		84	337.68	351.96		100	402.00	419.00
				85	341.70	356.15				

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APPENDIX B

SITE-SPECIFIC RADIOLOGICAL SURVEY INSTRUMENTATION SCANNING SENSITIVITY

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SITE-SPECIFIC RADIOLOGICAL SURVEY INSTRUMENTATION SCANNING SENSITIVITY

Radiological control has looked at a number of site-specific radiation detection instruments used for material release with the purpose of determining scan minimum detectable activity (MDA) values for each. The probes were capable of detecting alpha only, alpha and/or beta, and beta-gamma. A summary sheet indicating results and the calculation sheets are presented on the following pages.

Radiological scan surveys are not used exclusively for release, but are used in conjunction with fixed measurements and smears to adequately determine the radiological status of the item being released and to demonstrate compliance with 10 *CFR* § 835.

Ludlum Probe Information

Probe	**43-5**	**43-89**	**43-93**	**44-9/ 44-9-18**	**44-40-2**
Physical dimensions of probe sensitive area [L (cm) × W (cm)]	17.74 cm × 4.29 cm 6-63/64 inch × 1-11/16 inch	16.55 cm × 7.58 cm 6-33/64 inch × 2-63/64 inch	14.48 cm × 6.93 cm 5-45/64 inch × 2-47/64 inch	5.08-cm diameter 2-inch diameter	5.08-cm diameter 2-inch diameter
Probe active area (cm^2)	76	125	100	15.51	15.51
Alpha efficiency/nuclide	13% Pu-239	17% Pu-239	22% Pu-239	N/A	N/A
Alpha background (cpm)	0.1	0.1	0.1	N/A	N/A
MDA_{scan} (alpha) dpm/ 100 cm^2	53	18	19	N/A	N/A
Beta efficiency/nuclide	N/A	12% Tc-99	21% Tc-99	20% Tc-99	24% Tc-99
Beta background (cpm)	N/A	150	160	60	31
MDA_{scan} (beta) dpm/ 100 cm^2	N/A	1010	780	3775	2261

43-5 Probe Scan MDC Calculation

MDC_{scan} = 52.65 dpm/100 cm^2 alpha

b = background (cpm)
b_i = background counts in the observation interval (counts)

d = index of sensitivity from MARSSIM table 6.5 based on 95% detection and 60% false positive
HS_d = diameter for round probes or width in direction of scan for rectangular probes (centimeters) (actual measurement of open area)

MDC_{scan} = Minimum Detectable Concentration for scanning (dpm/100 cm^2)
$MDCR_i$ = Minimum Detectable Count Rate in (ncpm)
$MDCR_{surv}$ = $MDCR_i$ adjusted for the human performance factor p (ncpm)

O_i = Observation interval (seconds)
p = human performance adjustment factor (unitless)
SR = Scanning movement rate (cm/sec)

EFF = efficiency (decimal value) in counts per disintegration
PA =physical probe active area in cm^2

b = 0.1 cpm * p = 0.5 HS_d = 4.29 cm

SR = 5.08 cm/sec d = 1.38

Eff = 0.13 counts/disintegration Pu-239 PA = 76 cm^2

$\frac{HS_d}{SR}$ = 0.8445 = O_i (sec)

$\frac{b*Oi}{60\ sec/min}$ = 0.001 = b_i (counts)

$\frac{d*sqrt(b_i)*60}{O_i}$ = 3.6784 = $MDCR_i$ (ncpm)

$\frac{MDCR_i}{sqrt(p)}$ = 5.202 = $MDCR_{surv}$ (ncpm)

$\frac{MDCR_{surv}}{(Eff.)*(\frac{PA}{100\ cm^2})}$ = 52.6521 = MDC_{scan} (dpm/100 cm^2)

* a value approaching zero must be used since, if b = 0, then MDC_{scan} = 0

Dual Scintillator 43-89 Probe Scan MDC Calculation

MDC_{scan} = 18.42 dpm/100 cm^2 alpha

b = background (cpm)
b_i = background counts in the observation interval (counts)

d = index of sensitivity from MARSSIM table 6.5 based on 95% detection and 60% false positive
HS_d = diameter for round probes or width in direction of scan for rectangular probes (centimeters)
(actual measurement of open area)

MDC_{scan} = Minimum Detectable Concentration for scanning (dpm/100 cm^2)
$MDCR_i$ = Minimum Detectable Count Rate in (ncpm)
$MDCR_{surv}$ = $MDCR_i$ adjusted for the human performance factor p (ncpm)

O_i = Observation interval (seconds)
p = human performance adjustment factor (unitless)
SR = Scanning movement rate (cm/sec)

EFF = efficiency (decimal value) in counts per disintegration
PA =physical probe active area in cm^2

b = 0.1 cpm p = 0.5 HS_d = 7.58 cm

SR = 5.08 cm/sec d = 1.38

Eff = 0.17 counts/disintegration Pu-239 PA = 125 cm^2

$\frac{HS_d}{SR}$ = 1.4921 = O_i (sec)

$\frac{b*Oi}{60\ sec/min}$ = 0.002 = b_i (counts)

$\frac{d*sqrt(b_i)*60}{O_i}$ = 2.7673 = $MDCR_i$ (ncpm)

$\frac{MDCR_i}{sqrt(p)}$ = 3.914 = $MDCR_{surv}$ (ncpm)

$\frac{MDCR_{surv}}{(Eff.)*(\frac{PA}{100\ cm^2})}$ = 18.4165 = MDC_{scan} (dpm/100 cm^2)

* a value approaching zero must be used since, if b = 0, then MDC_{scan} = 0

Dual Scintillator 43-89 Probe Scan MDC Calculation

MDC_{scan} = 1010.47 dpm/100 cm^2 beta

b = background (cpm)
b_i = background counts in the observation interval (counts)

d = index of sensitivity from MARSSIM table 6.5 based on 95% detection and 60% false positive
HS_d = diameter for round probes or width in direction of scan for rectangular probes (centimeters)
(actual measurement of open area)

MDC_{scan} = Minimum Detectable Concentration for scanning (dpm/100 cm^2)
$MDCR_i$ = Minimum Detectable Count Rate in (ncpm)
$MDCR_{surv}$ = $MDCR_i$ adjusted for the human performance factor p (ncpm)

O_i = Observation interval (seconds)
p = human performance adjustment factor (unitless)
SR = Scanning movement rate (cm/sec)

EFF = efficiency (decimal value) in counts per disintegration
PA =physical probe active area in cm^2

b = 150 cpm p = 0.5 HS_d = 7.58 cm

SR = 5.08 cm/sec d = 1.38

Eff = 0.12 counts/disintegration Tc-99 PA = 125 cm^2

$\frac{HS_d}{SR}$ = 1.4921 = O_i (sec)

$\frac{b*Oi}{60\ sec/min}$ = 3.730 = b_i (counts)

$\frac{d*sqrt(b_i)*60}{O_i}$ = 107.1760 = $MDCR_i$ (ncpm)

$\frac{MDCR_i}{sqrt(p)}$ = 151.570 = $MDCR_{surv}$ (ncpm)

$\frac{MDCR_{surv}}{(Eff.)*(\frac{PA}{100\ cm^2})}$ = 1010.4651 = MDC_{scan} (dpm/100 cm^2)

43-93 Probe Scan MDC Calculation

MDC_{scan} = 18.60 dpm/100 cm^2 alpha

b = background (cpm)
b_i = background counts in the observation interval (counts)

d = index of sensitivity from MARSSIM table 6.5 based on 95% detection and 60% false positive
HS_d = diameter for round probes or width in direction of scan for rectangular probes (centimeters)
(actual measurement of open area)

MDC_{scan} = Minimum Detectable Concentration for scanning (dpm/100 cm^2)
$MDCR_i$ = Minimum Detectable Count Rate in (ncpm)
$MDCR_{surv}$ = $MDCR_i$ adjusted for the human performance factor p (ncpm)

O_i = Observation interval (seconds)
p = human performance adjustment factor (unitless)
SR = Scanning movement rate (cm/sec)

EFF = efficiency (decimal value) in counts per disintegration
PA =physical probe active area in cm^2

b = 0.1 cpm p = 0.5 HS_d = 6.93 cm

SR = 5.08 cm/sec d = 1.38

Eff = 0.22 counts/disintegration Pu-239 PA = 100 cm^2

$\frac{HS_d}{SR}$ = 1.3642 = O_i (sec)

$\frac{b*Oi}{60\ sec/min}$ = 0.002 = b_i (counts)

$\frac{d*sqrt(b_i)*60}{O_i}$ = 2.8941 = $MDCR_i$ (ncpm)

$\frac{MDCR_i}{sqrt(p)}$ = 4.093 = $MDCR_{surv}$ (ncpm)

$\frac{MDCR_{surv}}{(Eff.)*\frac{(PA)}{100\ cm^2}}$ = 18.6043 = MDC_{scan} (dpm/100 cm^2)

43-93 Probe Scan MDC Calculation

MDC_{scan} = 779.61 dpm/100 cm^2 beta

b = background (cpm)
b_i = background counts in the observation interval (counts)

d = index of sensitivity from MARSSIM table 6.5 based on 95% detection and 60% false positive
HS_d = diameter for round probes or width in direction of scan for rectangular probes (centimeters) (actual measurement of open area)

MDC_{scan} = Minimum Detectable Concentration for scanning (dpm/100 cm^2)
$MDCR_i$ = Minimum Detectable Count Rate in (ncpm)
$MDCR_{surv}$ = $MDCR_i$ adjusted for the human performance factor p (ncpm)

O_i = Observation interval (seconds)
p = human performance adjustment factor (unitless)
SR = Scanning movement rate (cm/sec)

EFF = efficiency (decimal value) in counts per disintegration
PA =physical probe active area in cm^2

b = 160 cpm p = 0.5 HS_d = 6.93 cm

SR = 5.08 cm/sec d = 1.38

Eff = 0.21 counts/disintegration Tc-99 (nickel-backed) PA = 100 cm^2

$\frac{HS_d}{SR}$ = 1.3642 = O_i (sec)

$\frac{b*Oi}{60\ sec/min}$ = 3.638 = b_i (counts)

$\frac{d*sqrt(b_i)*60}{O_i}$ = 115.7657 = $MDCR_i$ (ncpm)

$\frac{MDCR_i}{sqrt(p)}$ = 163.717 = $MDCR_{surv}$ (ncpm)

$\frac{MDCR_{surv}}{(Eff.)*(\frac{PA}{100\ cm^2})}$ = 779.6068 = MDC_{scan} (dpm/100 cm^2)

Pancake GM Probe 44-9 & 44-9-18 Scan MDC Calculation

MDC_{scan} = 3774.88 dpm/100 cm^2

b = background (cpm)
b_i = background counts in the observation interval (counts)

d = index of sensitivity from MARSSIM table 6.5 based on 95% detection and 60% false positive
HS_d = diameter for round probes or width in direction of scan for rectangular probes (centimeters)
(actual measurement of open area)

MDC_{scan} = Minimum Detectable Concentration for scanning (dpm/100 cm^2)
$MDCR_i$ = Minimum Detectable Count Rate in (ncpm)
$MDCR_{surv}$ = $MDCR_i$ adjusted for the human performance factor p (ncpm)

O_i = Observation interval (seconds)
p = human performance adjustment factor (unitless)
SR = Scanning movement rate (cm/sec)

EFF = efficiency (decimal value) in counts per disintegration
PA = physical probe active area in cm^2

b = 60 cpm p = 0.5 HS_d = 5.08 cm

SR = 5.08 cm/sec d = 1.38

Eff = 0.20 counts/disintegration (Nickel-backed Tc-99) PA = 15.51 cm^2

$\frac{HS_d}{SR}$ = 1.0000 = O_i (sec)

$\frac{b*Oi}{60\ sec/min}$ = 1.000 = b_i (counts)

$\frac{d*sqrt(b_i)*60}{O_i}$ = 82.8000 = $MDCR_i$ (ncpm)

$\frac{MDCR_i}{sqrt(p)}$ = 117.097 = $MDCR_{surv}$ (ncpm)

$\frac{MDCR_{surv.}}{(Eff.)*(\frac{PA}{100\ cm^2})}$ = 3774.8834 = MDC_{scan} (dpm/100 cm^2)

Shielded Pancake GM Probe 44-40-2 Scan MDC Calculation

MDC_{scan} = 2261.14 dpm/100 cm^2

b = background (cpm)
b_i = background counts in the observation interval (counts)

d = index of sensitivity from MARSSIM table 6.5 based on 95% detection and 60% false positive
HS_d = diameter for round probes or width in direction of scan for rectangular probes (centimeters)
(actual measurement of open area)

MDC_{scan} = Minimum Detectable Concentration for scanning (dpm/100 cm^2)
$MDCR_i$ = Minimum Detectable Count Rate in (ncpm)
$MDCR_{surv}$ = $MDCR_i$ adjusted for the human performance factor p (ncpm)

O_i = Observation interval (seconds)
p = human performance adjustment factor (unitless)
SR = Scanning movement rate (cm/sec)

EFF = efficiency (decimal value) in counts per disintegration
PA = physical probe active area in cm^2

b = 31 cpm p = 0.5 HS_d = 5.08 cm

SR = 5.08 cm/sec d = 1.38

Eff = 0.24 counts/disintegration (Nickel-backed Tc-99) PA = 15.51 cm^2

$\frac{HS_d}{SR}$ = 1.0000 = O_i (sec)

$\frac{b*Oi}{60\ sec/min}$ = 0.517 = b_i (counts)

$\frac{d*sqrt(b_i)*60}{O_i}$ = 59.5162 = $MDCR_i$ (ncpm)

$\frac{MDCR_i}{sqrt(p)}$ = 84.169 = $MDCR_{surv}$ (ncpm)

$\frac{MDCR_{surv}}{(Eff.)*\frac{(PA)}{100\ cm^2}}$ = 2261.1403 = MDC_{scan} (dpm/100 cm^2)

APPENDIX C

REFERENCES

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REFERENCES

10 *CFR* § 20, *Standards for Protection against Radiation*

10 *CFR* § 835, *Occupational Radiation Protection*

10 *CFR* § 173, *Shippers–General Requirements for Shipments and Packaging*

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

DOE-STD-1098-2008, *DOE Standard Radiological Control*

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*

CP2-RP-0002, *Radiation Protection Glossary*

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

CP3-RP-1117, *Accidents and Emergencies*

CP4-RP-1103, *Personnel and Personal Effects Decontamination*

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