Performance of Radiological Surveys

Revision 2

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Table of Contents

1.0 SCOPE

1.1 Purpose

The purpose of this procedure is to specify the general survey requirements for performing surveys. Any specific survey protocols including detection sensitivity requirements, types of surveys to be performed, survey frequencies, survey design and Data Quality Objectives (DQOs) will be included in the site specific plans or other project specific documentation.

1.2 Applicability

This procedure applies to all personnel performing radiological surveys on Commercial Services field projects. The specific types of surveys addressed within this procedure include:

- Exposure rate surveys,
- Total contamination surveys (direct measurement),
- Removable contamination surveys, and
- Surface scan surveys

Additional survey requirements such as sampling and analysis are not addressed within this procedure.

2.0 REFERENCES

2.1 CS-AD-PR-002, *Commercial Services Project Records*

2.2 CS-FO-PR-002, *Calibration and Maintenance of Radiological Survey Instruments*

2.3 CS-FO-PR-004, *QA/QC of Portable Radiological Survey Instruments*

2.4 CS-FO-PR-005, *General Operations of Radiological Survey Instruments*

2.5 CS-RS-PR-106, *Unconditional Release of Tools and Equipment*

2.6 ISO Standard 7503-1, *Evaluation of Surface Contamination - Part 1 Beta Emitters (Maximum Beta Energy Greater than 0.15 MeV) and Alpha Emitters*

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

2.8 NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*

2.9 NUREG-1757, *Consolidated Decommissioning Guidance*, Volume 1 (*Decommissioning Process for Materials Licenses*) and Volume 2 (*Characterization, Survey and Determination of Radiological Criteria*)

3.0 GENERAL

3.1 Definitions

3.1.1. *Beta Correction Factor (BCF)* – A factor used to correct the instruments beta response to the true exposure rate at the center of the ion chamber.

3.1.2. *Direct Measurement* – A measurement of the surface activity using a contamination monitor or meter which determines the total surface contamination, fixed plus removable surface contamination.

3.1.3. *Fixed Surface Contamination* – Contamination adhering to a surface in such a way it is not transferable under normal working conditions.

3.1.4. *Indirect Measurement* – A measurement of the removable activity on a surface by using a smear sample.

3.1.5. *Instrument Efficiency* (ε_i) - The ratio between the instruments reading and the surface emission rate of a source under given geometric conditions.

3.1.6. *Radiological Survey Instrument* – A complete system designed to quantify one or more characteristics of ionizing radiation or radioactive material.

3.1.7. *Removable Surface Contamination* – Surface contamination that is removable or transferable under normal working conditions.

3.1.8. *Smear Test* – Taking a sample of removable activity by wiping the surface with a dry or wet material and a subsequent evaluation of the amount of activity transferred to the smear.

3.1.9. *Surface Efficiency* (ε_s) – The ratio between the number of particles emerging from the front face of a source, surface emission rate, and the number of particles released within the source or saturated layer per unit time.

3.1.10. *Surface Emission Rate* – The number of particles emerging from the front face of a source per unit time (2π).

3.2 Responsibilities

Note: Depending upon personnel qualifications and the size of the project, project personnel may be assigned multiple roles and/or responsibilities.

3.2.1. Project Manager (PM)

The Project Manager is responsible for ensuring that the proper procedures and programs are implemented on the project site as required by customer agreements and contracts. The PM is responsible for ensuring that these programs and procedures are properly incorporated into project specific plans and procedures. The PM is responsible for ensuring that Commercial Services (CS) and/or client programs and procedures are available for use by field personnel.

3.2.2. CS Radiation Safety Officer (RSO)

The CS RSO maintains and oversees the implementation of the CS Radiation Protection Program (RPP). The CS RSO shall ensure that radiation safety, radioactive materials management, and radiological operations procedures and programs are kept up to date, such that they comply with current regulations and incorporate current and relevant industry practices and regulatory guidance.

3.2.3. Radiation Protection Supervisor (RPS)

The RPS is responsible for implementing the CS RPP and the project specific radiological requirements at the field project location. The RPS manages and oversees the technicians performing radiation protection surveys and site monitoring, and reports directly to both the PM and the CS RSO.

3.2.4. Project Health Physicist (PHP)

The PHP is responsible for assisting the CS RSO in providing health physics support to the PM and RPS. This includes technical support to ensure procedural and regulatory compliance and to ensure that the project specific Data Quality Objectives are met.

3.3 Precautions and Limitations

3.3.1. This procedure is for the exclusive use of Energy*Solutions* Commercial Services field projects.

3.3.2. An evaluation of the environmental conditions at the project site should be performed by the PHP as significant changes in temperature or changes in elevation may affect the performance of the field instrument depending upon the calibration settings. General rules of thumb may be used to adjust the instruments high voltage to correct for changes in temperature and/or elevation based upon the manufacturer's recommendations or the calibration facility. The PHP may also determine that a plateau test may be required to re-establish the high voltage based upon the specific field conditions.

3.3.3. Ensure the proper instrumentation is used that can detect the radionuclides of concern with adequate detection sensitivities.

3.3.4. Ensure that the survey instruments are properly calibrated for the radionuclides of concern (i.e., type of radiation and emission energies), so the proper instrument efficiencies are defined and used.

3.3.5. As applicable, establish the survey protocols and the release or survey criteria to which surveys will be performed. This will typically be defined in the project specific work plans and documents.

3.3.6. When performing surveys in which there are multiple radionuclides of concern, use the most limiting efficiencies unless an average efficiency is calculated by the PHP. Average efficiency is based upon the radionuclides of concern and their relative abundance.

3.3.7. When establishing the MDC for a survey protocol, the MDC should be less than 50% of the limit as practical.

3.3.8. Operate instruments in accordance with Reference 2.4, CS-FO-PR-005, *General Operations of Radiological Survey Instruments*.

3.4 Records

3.4.1. The following records shall be maintained by the RPS or designee as applicable:

- Survey log(s)
- Survey forms and documentation
- Instrument QA/QC records

3.4.2. Copies of all the instrument and survey records shall be maintained at the field project location in accordance with Reference 2.1.

4.0 REQUIREMENTS AND GUIDANCE

4.1 Pre-requisites

4.1.1. Ensure the proper instrumentation is selected to perform the surveys. Consideration shall be given to the following:

- Radionuclides of concern,
- Types of emissions and energies,
- Required detection sensitivities,
- Types of surfaces and surface geometry, and
- Data Quality Objectives and goals of the survey.

4.1.2. Ensure the instrumentation has been properly calibrated and inventoried in accordance with Reference 2.2.

4.1.3. Ensure the proper quality assurance and quality control parameters and testing criteria have been established for the survey instrumentation prior to instrument use in accordance with Reference 2.3.

4.1.4. Ensure the survey instrumentation has been response tested or source checked in accordance with Reference 2.3 prior to instrument use.

4.1.5. Design, plan and perform surveys in accordance with the project work plans such as a Characterization Plan or Final Status Survey Plan following regulatory guidance as applicable, including References 2.8 and 2.9.

4.1.6. Establish a survey log (see Attachment 5.1), and assign each survey a unique survey ID in order to index surveys for filing and record keeping.

4.2 Efficiencies

The survey efficiency consists of two components, the instrument efficiency and the surface efficiency as discussed in the ISO standards, Reference 2.6, and the applicable regulatory guidance such as MARSSIM, Reference 2.7. In order to appropriately document the survey results, both the instrument and surface efficiencies must be determined as follows:

4.2.1. The instrument efficiency, (ε_i), is the quantitative measure or ratio of the specific detector response to the surface emission rate from a source.

4.2.1.1. The instrument efficiency shall be established with a NIST traceable calibration source that is representative of the types of emissions and energies of the radionuclides of concern.

4.2.1.2. The instrument efficiency shall be established during the efficiency calibration. This will either be determined at the calibration facility and documented on the calibration paperwork, or it can be performed on site in accordance with Reference 2.3.

4.2.1.3. If the instrument efficiency from the calibration paperwork is used, determine whether the efficiency was determined based upon the source activity (i.e., 4π emission) or the surface emission rate.

4.2.1.4. If the instrument efficiency as reported is based upon the source activity, adjust the efficiency to reflect the surface emission rate. This can be estimated as follows based upon the type of emission and energy, source backing material and the amount of backscatter.

Note: Efficiency loses due to self-adsorption within the cal source are considered negligible, specifically for electroplated sources, and are not included within the calculations.

$$\varepsilon_i = \frac{2 \cdot \varepsilon_{4\pi}}{(1 + BS)}$$

Where:
ε_i = Instrument efficiency (%)
$\varepsilon_{4\pi}$ = 4π Instrument efficiency (%)
BS = Backscatter (%)

Emission	Source Backing	Backscatter[1] (BS)
Alpha	NA	5 %
Beta > 0.15MeV	Aluminum / Metal	30 %
	Low-Z	20 %

[1] ISO Standard 7503-1, Reference 2.6

4.2.1.5. If the instrument efficiency is determined on site, use the surface emission rate as specified on the source certificate. If only the source activity is reported, determine the surface emission rate as follows:

$$q_{2\pi} = \frac{A}{2} \cdot (1 + BS)$$

Where: $q_{2\pi}$ = Surface emission rate (α or β/m)

A = Source Activity (dpm)

4.2.1.6. Use the average net detector response from the series of source counts performed during the instruments Chi-Square test in accordance with Reference 2.3 or a single source count with a minimum of 10,000 net counts and the surface emission rate of the source to determine the instruments efficiency as follows:

$$\varepsilon_i = \frac{\bar{x}}{q_{2\pi}}$$

Where: $\bar{x}$ = Average net source count rate (cpm) from the Chi-Square test or the net source count rate from a source count with at least 10,000 counts.

4.2.1.7. Document the instrument efficiency with the instrument's calibration paperwork and Chi-Square test forms as applicable in accordance with Reference 2.3.

4.2.2. The surface efficiency, ε_s, is a function of the surface emission rate to the activity located on a surface or within a saturated layer.

4.2.2.1. The surface efficiency is largely dependent upon the type and energy of the emission and may be established in accordance with the guidance as provided in the ISO Standard, Reference 2.6.

Emission	Surface Eff.[1] (ε_s)
Alpha	25 %
Beta: 0.4 MeV > $E_{\beta\text{-max}}$ > 0.15 MeV	25 %
Beta: $E_{\beta\text{-max}}$ > 0.4 MeV	50 %

[1] Recommended Values; ISO Standard 7503-1, Reference 2.6

4.2.2.2. Additional factors may impact the surface emission rate including the type of surface material, dust loading, surface condition and contour and the thickness of the saturation layer. The surface efficiency may also be evaluated and determined experimentally or based upon the data as provided in NUREG-1507, Reference 2.7.

4.2.3. The PHP shall ensure that both the instrument and surface efficiencies used for the survey represent the measured field conditions. Consultation with a Certified Health Physicist (CHP) may be warranted to validate the instrument and surface efficiency as implemented.

4.3 Background Surveys

There are two components to background that must be considered when performing surveys. These include the ambient background as measured by shielding the face of the detector and natural background activity in materials such as granite, concrete, tile, etc.

4.3.1. Perform ambient area background measurement within the survey area as directed by the RPS or PHP.

4.3.1.1. Shield the detector face.

4.3.1.2. Perform a 10 minute background reading prior to performing the survey.

4.3.1.3. Perform a 10 minute background reading at the end of the survey.

4.3.1.4. Perform periodic background measurements as determined necessary depending up fluctuating background.

4.3.1.5. If the background fluctuates significantly, the RPS or PHP may determine that location specific backgrounds may be required, i.e., a background measurements at each measurement location.

4.3.2. Perform background surveys to assess any natural activity within building materials for either material specific background subtraction or statistical comparison as directed by the PHP.

4.3.2.1. Select a background area representative of the areas to be surveyed, which is known to be unaffected and not contaminated.

4.3.2.2. Perform ambient area background measurements within the background area in accordance with Step 4.3.1.

4.3.2.3. Perform a series of direct measurements on a variety of construction materials as directed by the PHP. Typically, a minimum of 10 to 20 measurements is required for each type of material.

4.3.2.4. The PHP shall statistically assess the data and determine any levels of natural activity within the construction materials for either subtraction from the survey results or for statistical comparison.

4.3.3. Document all background surveys in accordance with Section 4.9.

4.4 Exposure Rate Surveys

Exposure rate surveys should be conducted in accordance with the project work plans and as follows:

Caution: Be aware that the response of some instruments is affected by the way the instrument is held known as "geotropism". If geotropism is a factor, take note and notify the RPS.

4.4.1. Perform exposure or dose rates surveys as required including contact and general area exposure rates as applicable.

4.4.1.1. Contact surveys are typically performed within 1-inch of a particular surface.

4.4.1.2. General Area surveys are typically performed in areas that may normally be occupied but no closer than 30-cm or 1-foot from any surface.

4.4.2. For ion chambers, understand where the effective center is located for the instrument so the instrument may be properly located and positioned during surveys.

4.4.3. Hold the instrument at the location of interest and allow the meter to stabilize.

4.4.4. Obtain open and closed window readings as applicable if beta exposure rates are of concern.

4.4.5. Record the reading(s) on the survey form in accordance with Section 4.9 and identify the specific measurement location(s) using the appropriate units and geometries (i.e., contact vs. general area and open window vs. closed window readings).

4.4.6. As applicable, determine and record any beta exposure rates as follows for ion chamber instruments:

$$ER_{\beta} = (OW - CW) \cdot BCF$$

Where:

	ER_{β}	=	Beta exposure rate (mrad/hr)
	OW	=	Open window reading (mR/hr)
	CW	=	Closed window reading (mR/hr)
	BCF	=	Beta correction factor (mrad/hr per mR/hr)

4.5 Direct Contamination Surveys

Direct surveys should be conducted in accordance with the project work plans and as follows:

4.5.1. The RPS or PHP shall determine the appropriate background and measurement count times in order to meet the applicable DQOs and detection sensitivities for scalar/integrating counters.

4.5.2. Perform area background measurements as necessary in accordance with Section 4.3.

4.5.2.1. Cover/shield the detector face and obtain an area background measurement prior to and at the end of the survey for each survey area or unit.

4.5.2.2. Perform periodic background counts as necessary during the survey if background is noticed to fluctuate from area to area.

4.5.2.3. For widely fluctuating background, location specific backgrounds may be required (i.e., a background reading for each measurement location).

4.5.3. Calculate and document the detection sensitivities or MDCs for the survey in accordance with Section 4.8.1.

4.5.4. Place the unshielded detector probe on or near the surface to be measured.. For surfaces where removable surface contamination is expected, hold the detector as close as possible to the surface without touching the surface, in order to minimize the potential of contaminating the detector.

4.5.4.1. For scalar counters, collect a static count for the appropriate count time.

4.5.4.2. For rate meters, allow the instrument to stabilize for approximately 5 to 10 seconds and note the average reading.

4.5.5. Record the background measurements and gross measurement reading(s) in counts or counts per minute (cpm) on the appropriate survey form in accordance with Section 4.9 and identify the specific measurement location(s) and units.

4.5.5.1. For scalar counters, record the gross counts and the applicable count time.

4.5.5.2. For rate meters, record the gross count rate in cpm and record a count time of 1 minute.

4.5.6. If data logging instruments are used to automatically record measurements, the data should be downloaded periodically to a computer to prevent the loss of any data.

4.5.7. Convert the measurements to units of dpm per 100 cm^2 using the following equation to determine the gross activity:

$$Gross\ Activity = \frac{(R_S - R_B)}{\varepsilon_i \cdot \varepsilon_s \cdot \left(A_{det} / 100\,cm^2 \right)}$$

Where: R_S = Gross sample measurement (cpm)

R_B = Ambient Background count rate (cpm)

ε_i = Instrument efficiency (%)

ε_s = Surface efficiency (%)

A_{det} = Detector Active Area (cm^2)

Note: Use a maximum value of 126 cm^2 for the detector area (A). Any detectable activity would be averaged over the entire detector area, so detectors with an active area greater than 126 cm^2 would potentially under-report the activity of a localized spot.

4.5.8. Determine the net activity by subtracting material specific background, if applicable, and as determined necessary by the PHP. For relatively high release criteria (where material background is a small percentage of the release criteria), it may not be necessary to subtract material specific background due to natural activity:

$$Net\ Activity = Gross\ Activity - Mat_{Bkg}$$

Where: Mat_{Bkg} = Material Background (dpm/100 cm^2)

4.6 Removable Contamination Surveys

Removable contamination surveys should be conducted in accordance with the project work plans and as follows:

4.6.1. The RPS or PHP shall determine the appropriate background and measurement count times in order to meet the applicable DQOs and detection sensitivities for scalar/integrating counters.

4.6.2. Calculate and document the detection sensitivities or MDCs for the survey in accordance with Section 4.8.2.

4.6.3. Obtain a smear at each measurement location as follows:

4.6.3.1. Pass a Whatman filter paper smear, cloth smear with adhesive backing, or equivalent over a representative portion of the surface in an "S" or "Z" pattern using moderate pressure. For a 2-cm diameter filter paper, the length of the smear or swipe should be about 50 cm or 16 inches for an area of 100 cm^2.

4.6.3.2. Do not damage the smear by wiping the area with too much pressure.

4.6.3.3. Avoid excessive "loading" of the smear surface with dirt and avoid wet surface areas.

4.6.3.4. Protect the smear from cross contamination or loss of activity by using a "smear book" composed of wax paper sheets, placing smears in coin envelopes, or other similar method.

4.6.3.5. Smears must be numbered or identified with the location of the smear when taking multiple smears.

4.6.3.6. For tritium measurement, paper smears should be dampened prior to obtaining the smear and placed directly into the liquid scintillation vial already pre-loaded with liquid scintillation cocktail solution. Synthetic smears that dissolve in the cocktail solution may be used.

4.6.4. Record the smear location(s) on the appropriate survey form.

4.6.5. Smears should be counted on a stationary scalar or automated smear counter such as the Ludlum Model 2929, 3030 or 3030E, Eberline Models BC-4 and SAC-4, Protean counter or Tennelec counter.

4.6.6. Smears collected for low energy beta emitters such as tritium shall be counted on a liquid scintillation counter, which is not addressed in this procedure.

4.6.7. Pre-screen the smears using a portable survey instrument prior to loading smears into a stationary or automated smear counter to avoid potential contamination of the counter.

4.6.7.1. If a smear exceeds 1,000 cpm using a portable survey instrument, do not count the smear on the stationary or automated counter unless approved by the RPS or PHP and the appropriate actions are taken to minimize any potential of contaminating the instrument.

4.6.7.2. Estimate the activity of the smear using the portable field instruments following Step 4.6.11.

4.6.8. Place the smear in a counting tray or planchet.

4.6.9. Dry the smears, if needed.

4.6.10. Count the smear for the predetermined count time and record the gross counts on the appropriate survey form.

4.6.11. Convert the gross cpm readings to units of dpm per 100 cm^2 using the following equation:

$$Activity = \frac{(R_S - R_B)}{\varepsilon_i \cdot \varepsilon_s}$$

Note: For heavily loaded smears with low-energy beta or alpha-emitters, the RPS should contact the PHP for guidance in determining the surface efficiency, ε_s.

4.7 Scanning Surveys

Scan surveys should be conducted in accordance with project work plans and the following instructions for the detection and identification of elevated areas of activity for further investigation:

4.7.1. Gamma scans are normally performed by slowly walking, while moving the detector above the surface using an "S" shaped serpentine motion. The survey or work plan should specify walking speed and the appropriate coverage (% of area to be surveyed) depending on the DQOs. The detector distance from the surface should also be specified in the survey or work plan, and typically range from 4 inches to 1 foot for soil surveys.

4.7.2. Calculate and document the scan MDC(s) for the survey in accordance with applicable Sections 4.8.3, 4.8.4 or 4.8.5.

4.7.3. For alpha and beta surface scans, move the detector probe over the surface, generally within light contact to 1 cm of the surface being scanned. The distance can be greater for higher energy beta and gamma emitters.

4.7.4. Instrument alarm rates may be established for certain instruments in accordance with Reference 2.4, to aid in the detection of elevated activity.

4.7.5. Scan at the predetermined rate as specified in the project specific work plans or procedures, depending upon the detection sensitivities required. The scanning rate may be calculated by using the equation for the scan sensitivity and back calculating the scan rate depending upon the type of instrument(s) used, instrument efficiencies and the acceptable decision errors.

4.7.6. As a minimum, document the maximum and average observed count rates (in gross cpm) on the appropriate survey form in accordance with the project work plans and procedures.

4.7.7. If an elevated area is identified during surface scans, re-survey the area to allow the instrument to fully respond, obtain direct measurements as applicable, and identify and mark the area as appropriate.

4.7.8. As required by the project and the PHP, convert the recorded scan results from cpm to dpm/100 cm^2 following the applicable equation in Section 4.5.

4.8 Detection Sensitivities

The Minimum Detectable Concentration (MDC) is a measure of the instrument's detection sensitivity based upon the field conditions including the background count rate, instrument efficiency, observation or counting interval and the acceptable decision errors (Type I and Type II or false positive and false negative errors). The following equations may be used when determining the MDC for the specific types of measurements as performed during radiological surveys. The calculated MDC should be less than 50% of a "limit", (e.g., the DOT contamination limit on the exterior of a package in transportation).

4.8.1. Direct or Static Measurements

4.8.1.1. For stationary or static measurements, the MDC can be calculated by using the following equation, derived from References 2.7 and 2.8, in terms of dpm/100 cm^2.

Note: Use a maximum value of 126 cm^2 for the detector area (A). Any detectable activity would be averaged over the entire detector area so detectors with an active area greater than 126 cm^2 would potentially under-report the activity of a localized spot.

$$MDC_{Static} = \frac{(k_\alpha \cdot k_\beta) + (k_\alpha + k_\beta) \cdot \sqrt{R_B \cdot t_S \cdot \left(1 + \frac{t_S}{t_B}\right)}}{\varepsilon_i \cdot \varepsilon_s \cdot t_S \cdot \left(A / 100\ cm^2 \right)}$$

Where:

- k_α = Critical value of falsely interpreting background as activity at a given rate. Type I error.
- k_β = Critical value of falsely interpreting activity as background at a given rate. Type II error.
- R_B = Background count rate (cpm)
- t_S = Sample counting time (min)
- t_B = Background counting time (min)
- A = Detector active area (cm^2).

4.8.1.2. Assuming standard decision error rates of 5% for both Type I and Type II errors and critical values (provided in Attachment 5.2) of k_α and k_β both equal to 1.645, the above equation can be simplified to the following:

$$MDC_{Static} = \frac{\frac{2.71}{t_S} + (3.29) \cdot \sqrt{\frac{R_B}{t_S} + \frac{R_B}{t_B}}}{\varepsilon_i \cdot \varepsilon_s \cdot \left(A / 100\,cm^2 \right)}$$

4.8.1.3. For very low background count rates (i.e., alpha counting), the constant 2.71 should be 3, based upon the Poisson distribution.

4.8.1.4. For the situation where a rate meter or analog instrument is used (i.e., frisker) to determine the total surface activity, the MDC equation is:

$$MDC_{Static} = \frac{(4.65) \cdot \sqrt{\frac{R_B}{2 \cdot T}}}{\varepsilon_i \cdot \varepsilon_s \cdot \left(A \big/ 100\, cm^2 \right)}, \text{ and}$$

$$T = 0.44 \cdot RT$$

Where: T = Rate meters time constant

RT = Instruments response time required for the instrument to change from 10% to 90% of the final reading as specified by the manufacturer

4.8.2. Smears

4.8.2.1. For removable activity measurements, the MDC can be calculated by using the following equation, derived from References 2.7 and 2.8, in terms of dpm/100 cm^2 and assuming the smear area is approximately 100 cm^2 in size.

$$MDC_{Smear} = \frac{(k_\alpha \cdot k_\beta) + (k_\alpha + k_\beta) \cdot \sqrt{R_B \cdot t_S \cdot \left(1 + \frac{t_S}{t_B}\right)}}{\varepsilon_i \cdot \varepsilon_s \cdot t_S}$$

Where: k_α = Critical value of falsely interpreting background as activity at a given rate. Type I error.

k_β = Critical value of falsely interpreting activity as background at a given rate. Type II error.

R_B = Background count rate (cpm)

t_S = Sample counting time (min)

t_B = Background counting time (min)

4.8.2.2. Assuming standard decision error rates of 5% for both Type I and Type II errors and the critical values (provided in Attachment 5.2) of k_α and k_β both equal to 1.645, the above equation can be simplified to the following:

$$MDC_{Smear} = \frac{\frac{2.71}{t_S} + (3.29) \cdot \sqrt{\frac{R_B}{t_S} + \frac{R_B}{t_B}}}{\varepsilon_i \cdot \varepsilon_s}$$

4.8.2.3. For very low background count rates (i.e., alpha counting), the constant 2.71 should be 3, based on the Poisson count distribution.

4.8.2.4. For the situation where a rate meter or analog instrument is used (i.e., frisker) to field screen the amount of removable activity, the MDC equation is:

$$MDC_{Static} = \frac{(4.65)\cdot\sqrt{\frac{R_B}{2\cdot T}}}{\varepsilon_i \cdot \varepsilon_s}$$

4.8.3. Beta Surface Scans

4.8.3.1. Calculate the observation interval (i) or the time that any one point remains under the detector or within the field of view in seconds during the surface scans as follows:

$$i = \frac{W_{Det}}{Rate}$$

Where: W_{Det} = Detector width or the width of the field of view (inches)

Rate = Scan speed or rate (inches/sec)

4.8.3.2. Determine the anticipated or expected background counts within the observation interval as follows:

$$b_i = R_B \cdot \frac{i}{60\,(\text{sec/min})}$$

Where: R_B = Background count rate (cpm)

4.8.3.3. Determine the minimum detectable source counts, s_i, within the observation period using the following equation as provided in Reference 2.8.

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

Where: d′ = Index of sensitivity selected from Attachment 5.2, based upon the acceptable decision errors and the guidance from Reference 2.8

4.8.3.4. Calculate the Minimum Detectable Count Rate (MDCR) in cpm within the observation interval using the follow equation.

$$MDCR = s_i \cdot \frac{60}{i}$$

4.8.3.5. The beta scan MDC can then be calculated by using the following equation as provided in Reference 2.8, in terms of dpm/100 cm^2.

$$MDC_{Scan-\beta} = \frac{MDCR}{\sqrt{p} \cdot \varepsilon_i \cdot \varepsilon_s \cdot \left(A / 100\,cm^2 \right)}$$

Where: p = Surveyor efficiency, which is typically considered to be 50% (0.50).

A = Detector area (cm^2)

Note: Use a maximum value of 126 cm^2 for the detector area (A). Any detectable activity would be averaged over the entire detector area so detectors with an active area greater than 126 cm^2 would potentially under-report the activity of a localized spot.

4.8.4. Alpha Surface Scans

Scanning for alpha emitters is significantly different from scanning for either beta or gamma emitters because the release limits are generally low and because the alpha background rate is very low and close to zero. Registering one count is often enough cause for the surveyor to stop and investigate. As a result, the scan MDC for alpha scanning can be calculated by determining the probability of detecting an area of contamination at a given contamination level and scan rate, which can be represented in one of two ways as follows:

4.8.4.1. Determine the probability of detecting a single count while passing over a contaminated area of a given activity as follows:

$$P(n \geq 1) = 1 - e^{\frac{-1 \cdot G \cdot \varepsilon_i \cdot \varepsilon_s \cdot W_{det}}{60 \cdot Rate}}$$

Where: G = activity (dpm)

4.8.4.2. If the probability is greater than 70%, then the scan speed is generally considered acceptable.

4.8.4.3. If the probability is less than 70%, notify the PHP. The scanning methodology either needs to be re-evaluated or it may be determined that this is the best than can be achieved.

4.8.4.4. The scan MDC may also be determined by solving for the activity level assuming that the scan MDC is defined as the amount of activity, G, that can be detected at a given Poisson probability by rearranging the probability equation as follows:

$$MDC_{Scan-\alpha} = \frac{-1 \cdot \ln\left(1 - P(n \geq 1)\right) \cdot Rate \cdot 60}{\varepsilon_i \cdot \varepsilon_s \cdot W_{det}}$$

Note: For surface scans where there are elevated alpha counts (i.e., 5-10 cpm and detecting an individual event is not required, the MDC is determined differently. Consult the PHP for the proper MDC determination.

4.8.5. Walk-over Gamma Scans

4.8.5.1. For surface scans of soil using exposure rate instruments such as a NaI(Tl) detector, consult the PHP for assistance. The methodology in Section 4.8.3 may be used to calculate the Minimum Detectable Concentration (MDC) within the surface soil; however, dose modeling must be performed using MicroShield or field experimentation.

4.8.5.2. The use of data logging and positional instruments, (e.g., GPS), may increase the surveyor efficiency and reduce the MDA or the MDC by enabling scan data to be reviewed in more detail. MDA or MDC may be determined through biased sampling following a review of the scan results.

4.9 Survey Documentation

4.9.1. Assign each survey a unique survey number or ID based upon a numbering system as designated by the RPS or PHP.

4.9.2. Enter the survey number on the survey log, Attachment 5.1 or equivalent.

4.9.3. Document the survey results on the survey form, Attachment 5.3, or equivalent.

4.9.4. The survey documentation should be of sufficient detail to allow for the recreation of the survey as applicable.

4.9.5. All measurements must be documented, including any direct measurements, scanning results, removable contamination measurements, and/or other media sample results.

4.9.6. Document all instrumentation used during the survey, including the instrument type, serial number, calibration and calibration due dates.

4.9.7. Document the minimum detectable activities for the various measurements performed.

4.9.8. The survey documentation should include the following as a minimum and as applicable:

- The location of all measurements or samples
- The date and time of the survey
- Gross and/or net instrument readings
- Activity calculation results
- Name of the surveyor
- Sample analysis results and dates
- Instrument data
- Minimum detectable concentrations or activities
- Name of person reviewing the survey results

4.9.9. As required in work plans and procedures or as directed by the PHP, subtract natural activity background based upon the types of materials surveyed.

4.9.10. It should be noted, that some net activity results may be less than the MDA. Always retain the actual calculated results, including negative results, as these are required for proper statistical analysis of the data.

4.9.11. Each survey shall receive an independent review to ensure the survey is complete and properly documented. This review shall be documented by signature and date.

4.9.12. Any measurement results determined to be suspect shall be reviewed by the PHP and investigated as needed.

5.0 ATTACHMENTS AND FORMS

5.1 Survey Log

5.2 Critical Values ***(k_α, k_β and d′)***

5.3 Survey Cover

5.4 Direct/Removable Activity (α/β)

5.5 Direct/Removable Activity (α/β) Cont.

5.6 Exposure Rates (β-γ)

Attachment 5.1 Survey Log

Page ___ of ___

Equivalent

Survey Number	Survey Type	Description	Performer	Start Date	End Date

Reviewed by: ________________________________ Date: __________

Attachment 5.2 Critical Test Values for Type I and Type II Errors

Error Type	t - Statistic				
	$t_{0.100}$	$t_{0.050}$	$t_{0.025}$	$t_{0.010}$	$t_{0.005}$
k_α or k_β	1.282	**1.645**	1.960	2.326	2.576

Values of d′ for the Selected True Positive and False Positive Proportions

False Positive Proportion	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	2.08	2.32	2.68
0.20	1.10	1.22	1.36	1.52	1.68	1.88	2.12	2.48
0.25	0.93	1.06	1.20	1.35	1.52	1.72	1.96	2.32
0.30	0.78	0.91	1.05	1.20	1.36	1.56	1.80	2.16
0.35	0.64	0.77	0.91	1.06	1.22	1.42	1.66	2.02
0.40	0.51	0.64	0.78	0.93	1.10	1.30	1.54	1.90
0.45	0.38	0.52	0.66	0.80	0.97	1.17	1.41	1.77
0.50	0.26	0.38	0.52	0.68	0.84	1.04	1.28	1.64
0.55	0.12	0.26	0.40	0.54	0.71	0.91	1.15	1.51
0.60	0.00	0.13	0.27	0.42	0.58	0.82	1.02	**1.38**

Attachment 5.3 Survey Cover

Equivalent

Survey ID: ______________

Page ____ of ____

Survey Type: ______________________________
Description: ______________________________
Performed by: ______________________________
Date: ______________________________

☐ Direct Survey
☐ Smear Survey
☐ Exposure Rate Survey

Instrumentation

	Model	Serial Number	Calibration Due Date	Mode Scalar/Rate	Det. Area (cm^2)	Inst Eff. (ε_i) (%)	Surface Eff. (ε_s) (%)
Alpha (Direct/Removable)							
D							
R					NA		
Beta (Direct/Removable)							
D							
R					NA		
Gamma						**BCF** mrad per mR/hr	**Cal. Const.** cts per mR/hr
D					NA		

Diagram

Key

Contamination

S - LAW
○ - Smear
△ - Direct

Dose Rates (OW/CW)

* - Contact
# - Gen. Area

Air Sampling

A/S - Location

Reviewed by: ______________________ Date: ____________

Attachment 5.4 Direct / Removable Activity (α/β) Equivalent

Survey ID: ____________

Page ___ of ___

Parameter	Units	Alpha		Beta	
		Direct	Removable	Direct	Removable
Sample CT	min				
Bkgd CT	min				
Resp. Time	min				
Background	cpm				
MDC	dpm/100 cm^2				
Flag / Limit	dpm/100 cm^2				

GA Direct Bkgd (gross cts)	
Alpha	Beta

Location	Alpha				Beta				
	Direct		Removable		Direct			Removable	
	Gross cts/cpm	dpm/100 cm^2	Gross cts/cpm	dpm/100 cm^2	Gross cts/cpm	Bkgd (cpm)	dpm/100 cm^2	Gross cts/cpm	dpm/100 cm^2
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

Reviewed by: ____________________________ Date: ___________

Attachment 5.5 Direct / Removable Activity (α/β) – Cont.

Survey ID: ____________

Equivalent

Page ___ of ___

Location	Alpha				Beta				
	Direct		Removable		Direct			Removable	
	Gross cts/cpm	dpm/100 cm^2	Gross cts/cpm	dpm/100 cm^2	Gross cts/cpm	Bkgd (cpm)	dpm/100 cm^2	Gross cts/cpm	dpm/100 cm^2

Reviewed by: ____________________________ Date: ___________

Attachment 5.6 Exposure Rates (β-γ) Equivalent

Survey ID: ______________

Page ____ of ____

Location	Ion Chamber			NaI(Tl)		
	OW	CW	Beta	Rate Mode	Scalar Mode	
	mR/hr	mR/hr	mRad/hr	mR/hr	cpm	mR/hr

Reviewed by: ________________________ Date: ___________