Use Of In-Situ Gamma Spectrum Analysis To Perform
Elevated Measurement Comparisons In Support Of Final Status Surveys

YA-REPT-01-018-05

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Rev. 1

Technical Report YA-REPT-01-018-05, Rev. 1

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1.0 REPORT

1.1 Introduction

Revision 1 was prepared to clarify and better highlight assumptions applied in the original version of this Technical Report. Minor edits in the document's text have also been made to improve readability.

This report describes the technical approach for using in-situ gamma ray spectroscopy (ISGRS) to survey for localized areas of elevated radioactivity. General methodologies are described for deriving investigation levels. Examples provided are specific to a particular detector configuration and address open land areas as well as building surfaces. This methodology is to be applied for alternate detector configurations. Implementation of this survey technique provides a quantitative evaluation as opposed to the qualitative evaluations traditionally provided via hand-held field instruments. The data produced by ISGRS is capable of accurately assaying a well-defined area so as to demonstrate that no single one-square-meter area in a survey unit exceeds the applicable $DCGL_{EMC}$.

The primary assumption made is that a potential one-square-meter of elevated radioactivity exists at the edge of the area being evaluated by a single in-situ measurement. To account for detection (i.e. efficiency) radionuclide-specific investigation levels are developed. Because the resultant investigation levels closely approximate the $DCGL_W$, assay results below investigation level(s) satisfy both the $DCGL_W$ and $DCGL_{EMC}$ criteria. The ability of ISGRS to perform radionuclide identification is also beneficial where influences from background radioactivity (e.g. ISFSI) impede survey efforts. Count times can be tailored to achieve required detection sensitivities and the detector can be collimated.

Validation of the ISOCS efficiency calibration software is beyond the scope of this report. Canberra Industries has performed extensive testing and validation on both the MCNP-based detector characterization process and the ISOCS calibration algorithms used by the software. The full MCNP method has been shown to be accurate to within 5% (typically). ISOCS results have been compared to both full MCNP and to 119 different radioactive calibration sources. In general, ISOCS is accurate to within 4-5% at high energies and 7-11% for low energies. The ISOCS technology has been independently qualified in Yankee Atomic Technical Report YA-REPT-00-022-04, "Use Of Gamma Spectrum Analysis To Evaluate Bulk Materials For Compliance With License Termination Criteria."

1.2 Discussion

1.2.1 Detector System Description

Two reverse-electrode ISOCS-characterized HPGe detectors, manufactured by Canberra Industries, have been procured. As the project progresses, other ISOCS detectors (e.g. standard electrode coaxial) may be employed. The key factor regarding the use of other ISOCS® characterized detectors is that specific efficiency calibrations will be developed and evaluated to account for each detector's unique characteristics.

The HPGe detector is mounted on a bracket designed to hold the detector / cryostat assembly and associated collimators. This bracket is mounted in a cage-like frame. This frame permits the detector to be oriented (pointed) over a full range from a horizontal to vertical orientation while being positioned above the surface being evaluated. Photographs of the frame-mounted system are presented in Attachment 1.

The InSpector (MCA) unit that drives the signal chain and the laptop computer that runs the acquisition software (Genie-2000) are mounted either in the frame or on the wheeled cart. These components are battery powered. Back-up power supplies (e.g. inverter) may be used to support the duty cycle. A wireless network has been installed so that the laptop computers used to run the systems can be controlled from any workstation at the facility. This configuration enables the use of a script to automatically write data files directly to a centralized file server following each assay. Radio communication is used to coordinate detector positioning and system operation.

1.2.2 Traditional Approach

With respect to Class 1 Survey Units, a surveillance for elevated activity is performed via scan surveys using hand-held field instruments. Acceptance criteria (i.e. $DCGL_{EMC}$) is derived by multiplying the $DCGL_W$ by the area factor associated with that area bounded by the grid used to locate soil samples. Occasionally, due to either background radioactivity or the size of the sample location grid, the detection sensitivity for these hand-held instruments exceeds the $DCGL_{EMC}$. In such instances, the survey grid is reduced so that area factors yielding higher $DCGL_{EMC}$ values can be used. This approach has a side effect of additional sampling, which impacts project schedules and costs. Additional sampling is further experienced to distinguish between natural radioactivity and plant-derived radioactivity to investigate elevated instrument responses.

1.2.3 Innovative Approach Methodology

The ISGRS supports the use of alternate area factors for determining $DCGL_{EMC}$ values because this technology, with the use of collimators, is capable of quantitatively evaluating well-defined localized areas. At the Yankee Rowe decommissioning project, area factors for a one-square-meter area are used to derive the $DCGL_{EMC}$. The application of these alternate area factors is based on the premise that the ISGRS can demonstrate that no single one-square-meter area in a survey unit exceeds the applicable $DCGL_{EMC}$. $DCGL_{EMC}$ values for a one-square-meter area are presented in Table 1 (soils) and Table 2 (building surfaces) below.

TABLE 1,
SOIL $DCGL_{EMC}$ FOR ONE-SQUARE-METER

	Soil $DCGL_W$ (pCi/g) (NOTE 1)	Soil $DCGL_W$ (pCi/g) (NOTE 2)	1 m^2 Area Factor (NOTE 3)	$DCGL_{EMC}$ for 1 m^2 (pCi/g) (NOTE 4)
Co-60	3.8	1.4	11	15
Ag-108m	6.9	2.5	9.2	23
Cs-134	4.7	1.7	16	28
Cs-137	8.2	3.0	22	66

NOTE 1 – LTP Table 6-1
NOTE 2 – Adjusted to 8.73 mRem/yr
NOTE 3 – LTP Appendix 6Q
NOTE 4 – Soil $DCGL_W$ (adjusted to 8.73 mRem/yr) for a 1 m^2 area

TABLE 2,
BUILDING SURFACE $DCGL_{EMC}$ FOR ONE-SQUARE-METER

	Bldg $DCGL_W$ (dpm/100m^2) (NOTE 1)	Bldg $DCGL_W$ (dpm/100cm^2) (NOTE 2)	1 m^2 Area Factor (NOTE 3)	$DCGL_{EMC}$ For 1 m^2 (dpm/100cm^2) (NOTE 4)
Co-60	18,000	6,300	7.3	46,000
Ag-108m	25,000	8,700	7.2	62,600
Cs-134	29,000	10,000	7.4	74,000
Cs-137	63,000	22,000	7.6	167,000

NOTE 1 – LTP Table 6-1
NOTE 2 – Adjusted to 8.73 mRem/yr
NOTE 3 – LTP Appendix 6S
NOTE 4 – Building $DCGL_W$ (adjusted to 8.73 mRem/yr) for a 1 m^2 area

Because the detector's field-of-view is greater than one-square-meter, it is assumed that the (potential) one-square-meter of elevated radioactivity is situated at the edge of the area being evaluated. To compensate for reduced detection efficiencies associated with this assumption, an offset geometry adjustment factor is developed. The $DCGL_{EMC}$ is multiplied by this adjustment factor to derive investigation levels. When an investigation level is encountered an investigation is conducted, which may include the use of hand-held field instruments and soil sampling.

Before the offset geometry adjustment factor can be developed, the detector's field-of-view must be determined based on the detector configuration (e.g. collimator, detector height above the surface to be evaluated, etc.). For the purposes of this technical report, the detector is configured with a 90-degree collimator and the detector is positioned at 2 meters from the surface to be evaluated. For this case, the detector's field-of-view was empirically determined as presented in Attachment 2. Alternately, the field-of-view may be determined by comparing efficiency values for various diameters. For instance, considering a detector positioned at one meter above a surface, a 200-meter diameter could be considered an infinite plane. Efficiencies for this "infinite" diameter would be determined. Subsequently, efficiencies would be determined for other, much smaller, diameters (e.g. 5.5m, 6m, 7m, etc.) and then compared to the efficiencies associated with the infinite plane. The diameter that yields efficiency values at 95% that of the infinite plane would be considered the field-of-view for the detector configuration. As alternative collimator configurations are implemented specific evaluations will be conducted.

Based on the field-of-view, a grid pattern (i.e. detector spacing) convention is selected to ensure that 100% of the survey unit is evaluated. Naturally, overlapping will occur between adjacent measurements. Due to this overlapping, the area assumed to be evaluated with each assay is smaller than the field-of-view. The primary dimension of concern is the distance from the center of the grid to the corner of the grid (2.12m). This dimension (i.e. hypotenuse) is used to determine the distance the one-square-meter is offset from the center of the detector's position. The hypotenuse is reduced by the radius of a one-square-meter circle (i.e. 0.56 m). For the case of the 3-meter grid spacing example provided in this Technical Report, the offset dimension is 1.56m (2.12m – 0.56m).

Once a grid convention is selected, an adjustment factor can be derived by taking the ratio of MDA values (or efficiency values) between the following two scenarios:

- Uniformly distributed activity over the detector's field-of-view.
- Activity restricted to a one-meter-square circle offset at the edge of the grid area. The dimension for the offset is the distance from the center of the grid to the center of a one-meter-square circle situated at the edge of the area (grid) being evaluated by the assay.

This ratio, referred to as the offset geometry adjustment factor, is nuclide specific. As in the examples provided in this technical report, nuclide-specific ratios may be averaged. Investigation levels are then derived as follows:

Nuclide Investigation Level (pCi/g) = ($DCGL_{EMC}$) * CF

Where: $DCGL_{EMC}$ = ($DCGL_W$ or $DCGL_{SURR}$) * $AF_{(1\ m^2)}$, and
CF = (Mean) Offset geometry adjustment factor

1.2.4 Investigation Level Examples

For the purposes of this technical report, the detector configuration evaluated employs a 90-degree collimator with the detector positioned at 2-meters above the surface being evaluated. Separate examples are provided for open land areas (i.e. soil) and building surfaces, however the approach for both scenarios is identical. Likewise, the approach is similar for other detector configurations.

Empirical data used to determine the field-of-view for this configuration is presented in Attachment 2. As exhibited, the field-of-view has a radius of at least 2.3 meters (16.6 m^2). Considering a 3-meter grid convention, this radius exceeds the distance from the center to an outermost corner of the grid, therefore sufficient overlap will occur.

Because the one-meter-square $DCGL_{EMC}$ values listed in Table 1 and Table 2 do not account for a one-square-meter area of elevated activity positioned at the edge of the field-of-view, these $DCGL_{EMC}$ values are adjusted by the offset geometry adjustment factor. To develop this adjustment factor, a spectrum free of plant-related radioactivity was analyzed using two different efficiency calibrations (i.e. geometries). The first scenario assumes radioactivity uniformly distributed over the detector's field-of-view (i.e. 4.6 meter diameter). The second scenario assumes radioactivity localized within one-square-meter situated at the edge of the detector's field-of-view. A ratio of the resultant MDC values characterizes the difference in detection efficiencies between the two scenarios. This ratio is the offset geometry adjustment factor.

Off-set geometry adjustment factors, and the resultant investigation levels for soils, are presented in Table 3.

TABLE 3,
SOIL INVESTIGATION LEVEL DERIVATION

	MDC pCi/g (NOTE 1)	MDC pCi/g (NOTE 2)	RATIO (NOTE 3)	$DCGL_{EMC}$ for 1 m^2 (NOTE 4)	INVESTIGATION LEVEL pCi/g (NOTE 5)
Co-60	0.121	1.86	0.0651	15	1.0
Ag-108m	0.184	2.82	0.0652	23	1.5
Cs-134	0.189	2.90	0.0652	28	1.8
Cs-137	0.182	2.78	0.0655	66	4.3

NOTE 1 – Assumed activity distributed over the detector's field-of-view.
NOTE 2 – Efficiency calibration modeled for a 1 m^2 area situated (off-set) at the edge of the detector's field-of-view. The model assumes that all activity is distributed within the 1 m^2.
NOTE 3 – Ratio = (field-of-view MDC ÷ 1 m^2 MDC).
NOTE 4 – $DCGL_{EMC}$ values for 1 m^2 (from Table 1)
NOTE 5 – Investigation levels derived by applying of the off-set geometry adjustment factor (e.g. 0.0653) to the $DCGL_{EMC}$ for a 1 m^2 area for each radionuclide.

With respect to building surfaces, the development of the investigation level is identical to that for soil surfaces. Using the same approach, an offset geometry adjustment factor is developed. The MDC values for these two geometries were compared to characterize the difference in detection efficiencies. As expected, the condition with localized (one-square-meter) radioactivity at the edge of the detector's field-of-view yielded higher MDC values. The ratio between the reported MDC values for the two scenarios is used as the offset geometry adjustment factor. The MDC values, the associated ratios, and the derived investigation level for building surfaces are presented in Table 4.

TABLE 4,
BUILDING SURFACE INVESTIGATION LEVEL DERIVATION

	12.6 m^2 MDC ($dpm/100cm^2$) (NOTE 1)	1 m^2 MDC ($dpm/100cm^2$) (NOTE 2)	RATIO (NOTE 3)	$DCGL_{EMC}$ For 1 m^2 ($dpm/100cm^2$) (NOTE 4)	BUILDING SURFACE INVESTIGATION LEVEL ($dpm/100cm^2$) (NOTE 5)
Co-60	785	12,400	0.0633	46,000	2,900
Ag-108m	839	13,000	0.0645	62,600	3,900
Cs-134	900	14,200	0.0634	74,000	4,700
Cs-137	922	14,600	0.0632	167,000	10,600

NOTE 1 – Assumed activity distributed over the detector's field-of-view.
NOTE 2 – Efficiency calibration modeled for a 1 m^2 area situated (off-set) at the edge of the detector's field-of-view. The model assumes that all activity is distributed within the 1 m^2.
NOTE 3 – Ratio = (field-of-view MDC ÷ 1 m^2 MDC).
NOTE 4 – $DCGL_{EMC}$ values for 1 m^2 (from Table 3)
NOTE 5 – Investigation levels derived by applying of the off-set geometry adjustment factor (e.g. 0.0636) to the one-square meter $DCGL_{EMC}$.

In summary, suitable investigation levels for both open land areas (i.e. soils) and for building surfaces can be applied to in-situ gamma spectroscopy results. Note the MDC values associated with the detector's field-of-view were well below the derived investigation levels.

The investigation levels presented in Table 3 and Table 4 do not address the use of surrogate DCGLs. Use of surrogate DCGLs will be addressed in Final Status Survey Plans, particularly where it is necessary to evaluate non-gamma emitting radionuclides on building surfaces. When surrogate DCGLs are employed, investigation levels will be developed on a case-by-case basis using the approach outlined in this document. Similarly, the offset geometry adjustment factor presented in Table 3 and Table 4 will vary for different geometries. Where different detector configurations are employed, the offset geometry adjustment factor and applicable investigation levels will be determined using the methodology reflected in this Technical Report. Such evaluations will be documented via a Technical Evaluation, or similar.

For both open land areas and for building surfaces, when an investigation level is encountered, investigatory protocols will be initiated to evaluate the presence of elevated activity and bound the region as necessary. Such evaluations may include both hand-held field instrumentation as well as additional sampling as necessary.

1.2.5 Detector Sensitivity

For Class 1 survey units, the minimum detectable concentration is governed by the $DCGL_{EMC}$ associated with the grid area used to locate fixed-point measurements. The system's count time can be controlled to achieve the required detection sensitivity. Therefore, the grid spacing for the fixed-point measurements can be optimized thus eliminating unnecessary increases to the number of fixed-point measurements while ensuring that elevated areas between fixed measurement locations can be identified and evaluated.

Based on preliminary work, it has been determined that a count time of 900 seconds will yield an acceptable sensitivity for many areas on the site. In practice, it has been demonstrated that 600 second count times are sufficient to achieve MDAs at or below the associated investigation levels presented in Table 2 and Table 4. Count times will be adjusted as necessary where alternate detector configurations are employed or where background conditions warrant ensuring detection sensitivities are below the applicable investigation level. Since each assay report includes a report of the MDC values achieved during the assay, reviews of these reports can be used to verify that required MDC values were met.

1.2.6 Area Coverage

As discussed, based on the detector configuration's field-of-view determination, a 3-meter spacing between each survey point will result in over 100% of the survey unit to be evaluated. This spacing convention employs a grid pattern independent from the grid used to locate fixed-point measurements. An example of the grid pattern and spacing is presented in Attachment 3.

Alternate spacing conventions may be applied on a case-by-case basis. For instance, spacing may be decreased when problematic topographies are encountered. Note that decreased grid spacing in this context is not associated to the fixed-point measurements. Occasionally it may be necessary to position the detector at one meter or less from the target surface to evaluate unusual (e.g. curved) surfaces or to assist in bounding areas of elevated activity. In cases where it may be desirable to increase the field-of-view via collimator or source-to-detector distances, grid-spacing conventions (and applicable investigation levels) will be determined using the approach described in this document.

1.2.7 Moisture Content in Soil Matrix

In-situ gamma spectroscopy of open land areas is inherently subject to various environmental variables not present in laboratory analyses. Most notably is the impact that water saturation has on assay results. This impact has two components. First, the total activity result for the assay is assigned over a larger, possibly non-radioactive mass introduced by the presence of water. Secondly, water introduces a self-absorption factor.

The increase in sample mass due to the presence of water is addressed by the application of a massimetric efficiency developed by Canberra Industries. Massimetric efficiency units are defined as [counts per second]/[gammas per second per gram of sample]. Mathematically, this is the product of traditional efficiency and the mass of the sample. When the efficiency is expressed this way, the efficiency asymptotically approaches a constant value as the sample becomes very large (e.g. infinite). Under these conditions changes in sample size, including mass variations from excess moisture, have little impact on the counting efficiency. However, the massimetric efficiency does not completely address attenuation characteristics associated with water in the soil matrix.

To evaluate the extent of self-absorption, (traditional) counting efficiencies were compared for two densities. Based on empirical data associated with the monitoring wells, typical nominally dry in-situ soil is assigned a density of 1.7 g/cc. A density of 2.08 g/cc, obtained from a technical reference publication by Thomas J. Glover, represents saturated soil. A density of 2.08 g/cc accounts for a possible water content of 20%. A summary of this comparison is presented in Table 5.

TABLE 5, COUNTING EFFICIENCY COMPARISONS

keV	Efficiencies 1.7 g/cc	2.08 g/cc	Deviation due to density increase (excess moisture)
434	3.3 E-6	2.7 E-6	-18.7%
661.65	2.9 E-6	2.4 E-6	-17.5%
1173.22	2.5 E-6	2.1 E-6	-15.4%
1332.49	2.4 E-6	2.1 E-6	-14.8%

In cases when the soil is observed to contain more than "typical" amounts of water, potential under-reporting may occur. In general, the presence of standing water (or ice or snow) on the surface of the soil being assayed will be not be tolerated during Final Status Survey activities. In cases where minor surface water is present, notes will be made in field logs so that associated measurement results can be reviewed and reanalyzed if necessary as prescribed in implementing procedures.

1.2.8 Discrete Particles in the Soil Matrix

Discrete particles are not specifically addressed in the License Termination Plan. However, an evaluation was performed assuming all the activity in the detector's field-of-view, to a depth of 15 cm, was situated in a discrete point-source configuration. A concentration of 1.0 pCi/g (Co-60), corresponding to the investigation level presented in Table 3, correlates to a discrete point-source of approximately 3.2 μCi. This activity value is considered as the discrete particle of concern. Since the presence of any discrete particles will most likely be accompanied by distributed activity, the investigation level may provide an opportunity to detect discrete particles below 3.2 μCi.

Discrete particles exceeding this magnitude would readily be detected during characterization or investigation surveys. The MDCs associated with hand-held field instruments used for scan surveys are capable of detecting very small areas of elevated radioactivity that could be present in the form of discrete point sources. The minimum detectable particle activity for these scanning instruments and methods correspond to a small fraction of the TEDE limit provided in 10CFR20 subpart E. Note that the MDC values presented in Table 3 are significantly lower than those published in Table 5-4 of the License Termination Plan.

When the investigation level in a Class 1 area is encountered, subsequent investigation surveys will be performed to include the use of hand-held detectors. The detection sensitivities of instruments used for these surveys have been previously addressed in the LTP. Furthermore, discrete point sources do not contribute to the uniformly distributed activity of the survey unit. It is not expected that such sources at this magnitude would impact a survey unit's ability to satisfy the applicable acceptance criteria.

Noting that Class 2 or Class 3 area survey designs do not employ elevated measurement comparisons, associated investigation levels are based on positive indications of licensed radioactivity above the $DCGL_W$ or above background. Because such areas are minimally impacted or disturbed, potential discrete particles would most likely be situated near the soil surface where detection efficiencies are highest.

1.2.9 Procedures And Guidance Document

General use of the portable ISOCS system is administrated by departmental implementing procedures that address the calibration and operation activities as well as analysis of the data. These procedures are listed as follows:

- DP-8869, "In-Situ (ISOCS) Gamma Spectrum Assay System Calibration Procedure."
- DP-8871, "Operation Of The Canberra Portable ISOCS Assay System."
- DP-8872, "ISOCS Post Acquisition Processing And Data Review."

Where the portable ISOCS® system is used for Final Status Surveys, the applicable FSS Plan will address detector and collimator configurations, applicable (surrogated) investigation levels, MDC requirements, and appropriate Data Quality Objectives, as applicable.

A secondary application of the portable ISOCS® system is to assay surfaces or bulk materials for characterization or unconditional release evaluations. Use of the portable ISOCS® system for miscellaneous evaluations will be administrated under a specific guidance document (e.g. Sample Plan, etc.). Operating parameters such as physical configuration, efficiency calibrations, count times, and MDCs will be applied so as to meet the criteria in the associated controlling documents. Such documents will also address any unique technical issues associated with the application and may provide guidance beyond that of procedure AP-0052, "Radiation Protection Release of Materials, Equipment and Vehicles."

1.2.10 Environmental Backgrounds

If background subtraction is used, an appropriate background spectrum will be collected and saved. Count times for environmental backgrounds should exceed the count time associated with the assay. In areas where the background radioactivity is particularly problematic (e.g. ISFSI), the background will be characterized to the point of identifying gradient(s) such that background subtractions are either appropriate or conservative. Documentation regarding the collection and application of environmental backgrounds will be provided as a component of the final survey plan.

1.2.11 Quality Control

Quality Control (QC) activities for the ISOCS system ensure that the energy calibration is valid and detector resolution is within specifications. A QC file will be set up for each detector system to track centroid position, FWHM, and activity. Quality Control counts will be performed on a shiftly basis prior to the system's use to verify that the system's energy calibration is valid. The Na-22 has a 1274.5 keV photon which will be the primary mechanism used for performance monitoring. If the energy calibration is found to be out of an acceptable tolerance (e.g. greater than ±4 channels), then the amplifier gain may be adjusted and a follow-up QC count performed. If the detector's resolution is found to be above the factory specification, then an evaluation will be performed to determine if the detector should be removed from service and/or if the data is impacted. Evaluations associated with QC counts shall be documented. Such documentation may be limited to a remark directly on the applicable QC report or in a logbook if the resolution does not render the system out of service. Otherwise the evaluation should be separately documented (e.g. Condition Report, etc.) so as to address the impact of any assay results obtained since the last acceptable QC surveillance.

Where it is determined that background subtraction is necessary, a baseline QC background will be determined specific to that area or region. When background subtraction is required, a QC background surveillance will be performed before a set of measurements are made to verify the applicability of the background to be subtracted. Due to the prevailing variability of the background levels across the site, the nature and extent of such surveillances will be on a case-by-case basis and should be addressed in the documentation associated with the applicable survey plan(s).

In addition to the routine QC counts, each assay report is routinely reviewed with respect to K-40 to provide indications where amplifier drift impacts nuclide identification routines. This review precludes the necessity for specific (i.e. required) after-shift QC surveillances. It also minimizes investigations of previously collected data should the system fail a before-use QC surveillance on the next day of use.

1.2.12 Data Collection

Data collection to support FSS activities will be administered by a specific Survey Plan. Survey Plans may include an index of measurement locations with associated spectrum filenames to ensure that all the required measurements are made and results appropriately managed. Personnel specifically trained to operate the system will perform data collection activities.

Data collection activities will address environmental conditions that may impact soil moisture content. Logs shall be maintained so as to provide a mechanism to annotate such conditions to ensure that efficiency calibration files address the in-situ condition(s). In extreme cases (e.g. standing water, etc.) specific conditions will be addressed to ensure that analysis results reflect the conditions. As previously discussed with respect to water, when unique environmental conditions exist that may impact analysis results, conservative compensatory factors will be applied to the analysis of the data.

1.2.13 Efficiency Calibration

The central feature of the portable ISOCS technology is to support in-situ gamma spectroscopy via the application of mathematically derived efficiency calibrations. Due to the nature of the environment and surfaces being evaluated (assayed), input parameters for the ISOCS efficiency calibrations will be reviewed on a case-by-case basis to ensure the applicability of the resultant efficiency. Material densities applied to efficiency calibrations will be documented. In practice, a single efficiency calibration file may be applied to the majority of the measurements.

The geometry most generally employed will be a circular plane assuming uniformly distributed activity. Efficiency calibrations will address a depth of 15 cm for soil and a depth up to 5 cm for concrete surfaces to account for activity embedded in cracks, etc. Other geometries (e.g. exponential circular plane, rectangular plane, etc.) will be applied if warranted by the physical attributes of the area or surface being evaluated. Efficiency calibrations are developed by radiological engineers who have received training with respect to the ISOCS® software. Efficiency calibrations will be documented in accordance with procedure DP-8869, "In-Situ (ISOCS) Gamma Spectrum Assay System Calibration Procedure."

1.2.14 Data Management

Data management will be implemented in various stages as follows:

- An index or log will be maintained to account for each location where evaluations for elevated activity are performed. Raw spectrum files will be written directly or copied to a central file server.

- Data Analysis – After the spectrum is collected and analyzed, a qualified Radiological Engineer will review the results. The data review process includes application of appropriate background, nuclide libraries, and efficiency calibrations. Data reviews also verify assay results with respect to the applicable investigation levels and the MDCs achieved. Data reviews may include monitoring system performance utilizing K-40. When the data analysis is completed, the analyzed data file will be archived to a unique directory located on a central file server.

- Data Reporting – The results of data files whose reviews have been completed and are deemed to be acceptable may be uploaded to a central database for subsequent reporting and statistical analysis.

- Data Archiving – Routinely (daily) the centralized file server(s) where the raw and analyzed data files are maintained will be backed up to tape.

1.3 Conclusions And Recommendations

The in-situ gamma ray spectroscopy system is a cost-effective technology well-suited to replace traditional scanning survey techniques to evaluate areas for elevated radioactivity. The static manner in which this system is operated eliminates variables and limitations inherent to hand-held detectors moving over a surface. This system provides a controllable and defendable detection sensitivity. This attribute qualifies ISGRS as an alternative survey method to that of hand-held field instruments in areas where background radiation levels make the use of such detectors problematic. The MDC to which this system will be operated satisfies (or exceeds) criteria applied to traditional scan surveys using hand-held field instruments.

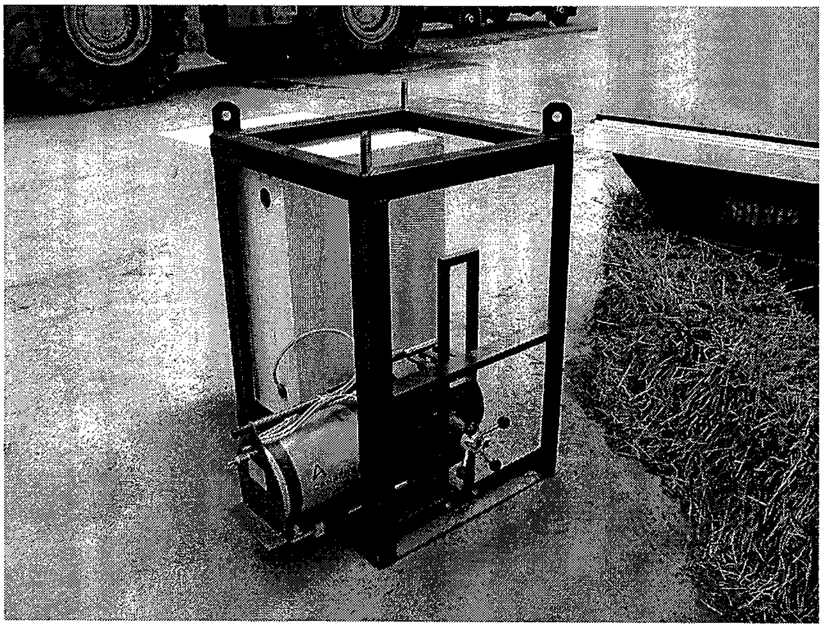
Applicable investigation levels for both open land areas (i.e. soils) and for building surfaces can be derived and applied to in-situ gamma spectroscopy results. Where surrogate DCGLs are employed, investigation levels will developed on a case-by-case basis using the approach outlined in this document.

The manner in which investigation levels are derived introduces a conservative bias in that it is assumed that aside from a one-square meter, no other residual radioactivity is present in the area being evaluated. Additionally, spacing applied to in-situ measurement locations yields an overlap providing redundant opportunities to detect localized elevated activity.

1.4 References

1. YNPS License Termination Plan, Revision 1
2. Multi-Agency Radiation Survey And Site Investigation Manual (MARSSIM) Revision 1, 2000
3. Canberra User's Manual Model S573 ISOCS Calibration Software, 2002
4. Decommissioning Health Physics - A Handbook for MARSSIM Users, E.W. Abelquist, 2001
5. Canberra's Genie 2000 V3.0 Operations Manual, 2004
6. In-Situ (ISOCS) Gamma Spectrum Assay System Calibration Procedure DP-8869, Revision 0
7. Operation of the Canberra Portable ISOCS Assay System DP-8871 Revision 0
8. Technical Ref., by Thomas J. Glover.

Attachment 1
Portable ISOCS® Detector System Photos



Attachment 2
Field-Of-View Characterization

Generally, the HPGe detector will be outfitted with a 90-degree collimator situated at 2 meters perpendicular to the surface being evaluated. Note that characterizing the detector's field-of-view could be performed without a source by comparing ISOCS-generated efficiencies for various geometries. If a different collimator configuration is to be employed, a similar field-of-view characterization will be performed.

To qualify the field-of-view for this configuration, a series of measurements were made at various off-sets relative to the center of the reference plane. The source used for these measurements was a 1.2 μCi Co-60 point-source with a physical size of approximately 1 cm^3. Each spectrum was analyzed as a point source both with and without background subtract. It was observed that the detector responded quite well to the point source.

Figure 1 presents the results with background subtraction applied. Note that there is a good correlation with the expected nominal activity and that outside the 2-meter radius of the "working" field-of-view (i.e. at 90 inches) some detector response occurs. This validates that the correct attenuation factors are applied to the algorithms used to compute the efficiency calibration.

FIGURE 1

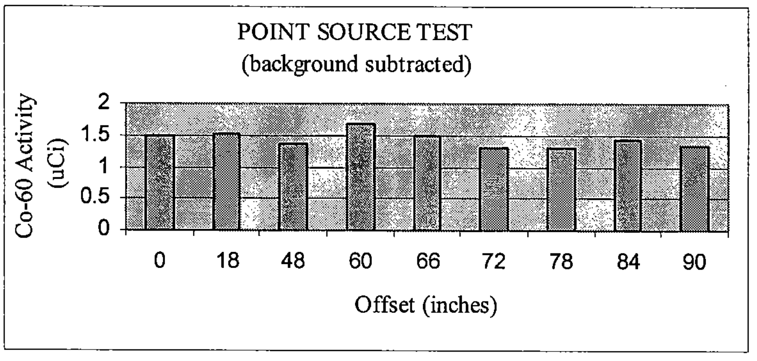
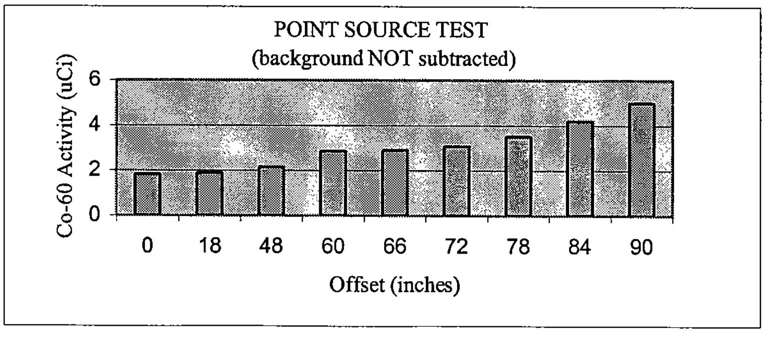
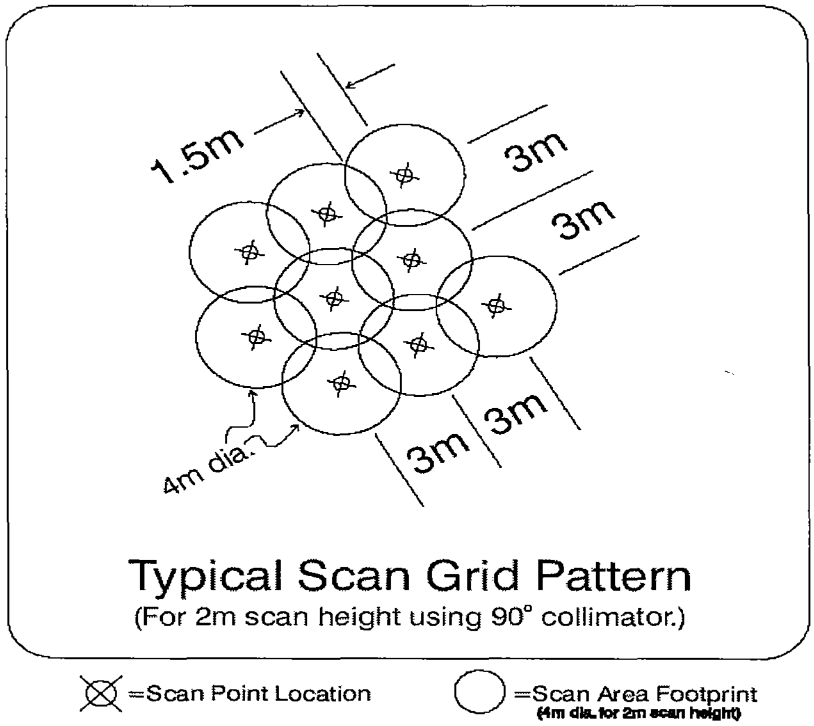


Figure 2 shows the effect of plant-derived materials present in the reference background, which indicates an increasing over-response the further the point source is moved off center. Detector response outside the assumed (i.e. 2-meter) field-of-view would yield conservative results. Normally, source term adjacent to the survey units should be reduced to eliminate background interference.

FIGURE 2



Attachment 3
Typical Grid Pattern For In-Situ Gamma Spectroscopy



Typical Scan Grid Pattern
(For 2m scan height using 90° collimator.)