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JAMES MADISON UNIVERSITY.

Department of Chemistry MSC 7701
College of Science and Mathematics
Harrisonburg, VA 22807
(540) 568-6246

November 28, 2005

U.S. Nuclear Regulatory Commission- Region I
Attn: Licensing Assistance Team (LAT)
475 Allendale Road
King of Prussia, PA 19406

RE: Control Number 136660
License Number 45-10414-01 03001125

To Whom it May Concern:

The purpose of this letter is to request an amendment to license number 45-10414-01. We are requesting that the Miller Hall location be removed from the license.

Licensed materials were limited to rooms G-21, G-22, G-22A, and 110 in Miller Hall. Following relocation of all radioactive materials to the newly-commissioned facility (Physics and Chemistry Building), a final status survey of Miller Hall was conducted by the Radiation Safety Academy in October 2005. The complete work plan and subsequent data from the final status survey is attached.

At the current time, Miller Hall is scheduled for renovation or demolition in early 2006, pending release of the facility. We appreciate your prompt attention to this matter. If you have any questions concerning this request, please call me at (540) 568-6678.

Sincerely,

Heather K. Armstrong

Heather K. Armstrong
Laboratory Safety Manager/RSO

Attachments: Work Plan for the Final Status Survey of Miller Hall

This is to acknowledge the receipt of your letter/application dated

11/28/2005, and to inform you that the initial processing which includes an administrative review has been performed.

Amendment 45-10414-01

☒ There were no administrative omissions. Your application was assigned to a technical reviewer. Please note that the technical review may identify additional omissions or require additional information.

☐ Please provide to this office within 30 days of your receipt of this card

____.

A copy of your action has been forwarded to our License Fee & Accounts Receivable Branch, who will contact you separately if there is a fee issue involved.

Your action has been assigned **Mail Control Number** 138035.
When calling to inquire about this action, please refer to this control number.
You may call us on (610) 337-5398, or 337-5260.

NRC FORM 532 (RI)
(6-96)

Sincerely,
Licensing Assistance Team Leader

WORK PLAN FOR THE

FINAL STATUS SURVEY OF MILLER HALL

at the

James Madison University
Harrisonburg, Virginia

College of Science and Mathematics

October 2005

Prepared by:

Radiation Safety Academy

CSI

481 North Frederick Avenue, Suite 302
Gaithersburg, MD 20877

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I. INTRODUCTION

As described in the September 2005 proposal, the Radiation Safety Academy has been retained to perform a final status survey (FSS) of formerly posted rooms in Miller Hall of the College of Science and Mathematics at the James Madison University (JMU). The methodology followed in designing, conducting, and evaluating the FSS will be consistent with the Multi-Agency Radiation Survey And Site Investigation manual (MARSSIM). This Work Plan incorporates all of the elements defined in Task 1 of the project, i.e., a historical site assessment (HSA), or review of activities involving radioactive materials incidents, a description of the data collection activities to be conducted in the formerly posted areas, a discussion of data quality objectives (DQOs) established for the project, and the development of derived concentration guideline limits (DCGLs) to be used to evaluate the levels of residual radioactivity found in the building.

II. HISTORICAL SITE ASSESSMENT (HSA)

Final status surveys will be conducted in formerly posted rooms for work with licensed radioactive materials and the adjacent corridor. Radioactive sources were maintained in rooms G-21, G-22, and G-22A in Miller Hall. In addition, samples irradiated with the neutron howitzer in G-22A have been counted in room 110 as part of a physics laboratory exercise. These rooms have been subject to the JMU radiation safety program implemented by the named Radiation Safety Officer (RSO). The program included quarterly contamination surveys consisting of wipe tests and daily contamination monitoring following work with licensed materials. Sealed sources were inventoried and leak tested every six months as required by license condition. As a result of establishing compliance with the survey requirements of the radiation safety program, it is unlikely that significant areas of building surfaces would be contaminated and undiagnosed for any extensive period of time.

The RSO has been instructed to maintain an "incidents file" describing all significant incidents involving radioactive materials, contamination, and worker dose. Based on a compliance evaluation performed in 2003 and subsequent follow-up with the RSO, there have

not been any incidents involving loss of material, spills, contamination events, overexposures, or other events that might impact the final status surveys.

Appendix A contains a summary of licensed materials that were in the possession of the RSO during the recent relocation to the new JMU facility. The radionuclides found in the summary comprise the suite of radionuclides of potential concern, i.e., the possible radioactive contaminants remaining on building surfaces at the time of the final status surveys. Examination of historical isotope usage allow for the following conclusions:

- JMU possessed a number of low activity sources in both liquid and solid forms.
- The majority of sources were beta/gamma emitting radionuclides, although several alpha-emitting sources were also in the inventory.
- Several calibration sources (sealed ampoules or electroplated "button" sources) are extremely unlikely to have caused any contamination.
- Historical records indicate potential past usage of several short-lived radionuclides no longer potentially present due to radioactive decay. They include I-131, Na-24, Fe-59, Cd-100, P-32, K-42, Br-82, and Cr-51.
- Numerous sources were used at times in the Nuclear Chemistry classroom, indicating that the materials may have been used in room 110 in addition to having been stored in G-22 or G-22A. Therefore, the most prudent approach to the final status surveys is to base them on an assumption that any of the sources possessed under the license may have been utilized in any of the four posted areas.

III. DATA QUALITY OBJECTIVES (DQOs)

The DQO process is a tool that may be used to improve the quality of the data collection process by generating data that support defensible decisions. The DQO Process addresses study objectives, data collection and limits on decision errors. Implementation of the DQO Process involves a seven-step data life cycle that generates a set of quantitative and qualitative statements pertaining to data collection activities and is based on the methodology described in the MARSSIM document. The multi-step data life cycle is presented below.

State the Problem

The objectives of this step are the following: identify the planning team members and decision maker(s), summarize available resources and relevant deadlines, and formulate a description of the problem. The problem is to demonstrate that level of radioactive contamination on surfaces in formerly posted rooms in Miller Hall is compliant with levels suitable for unrestricted use by members of the general public. The field team for this investigation consists of RSA certified health physicist Dr. Alan Fellman, field team leader Mr. Mike Jedlicka (assisted by Mr. Leroy Miller), and JMU RSO Ms. Heather Armstrong. Mr. Jedlicka, in consultation with Dr. Fellman, will determine sample and measurement locations and will ensure adherence to all relevant quality assurance elements as they relate to radiation measurements. Data will be evaluated in the field as appropriate to guide additional data collection efforts. If warranted, the FSS data sets will be evaluated via the statistical testing methodology described in MARSSIM to determine the status of each survey unit with regard to suitability for release for unrestricted use.

Identify the Decision

This field investigation, combined with a review of data evaluated during the HSA will provide an answer to the following question: *"Are surveyed areas (laboratories, corridors, etc. and miscellaneous surfaces) suitable for unrestricted use? If not, what is the type and extent of contamination?"* The answer to these questions will be provided in the FSS Report.

Identify the Inputs to the Decision

The required data that need to be generated are discussed in detail in various sections throughout this Work Plan. In general, the characterization and survey activities will consist of:

- Collection of wipe samples in each room for gamma counting and liquid scintillation analysis
- Collection of surface alpha and beta measurements with a 100 cm^2 gas flow proportional detector
- Scan of floors with a large area gas proportional floor monitor

- Scan of lower walls with gas proportional detectors
- Exposure rate measurements, if appropriate, with ion chambers and/or microrem meters
- Hood surveys (wipe samples from hood surfaces and ducts)
- Collection of wipe samples in sinks and sink drains

MARSSIM methodology for final status surveys was specifically developed for building structure surfaces and surface soil. It is not applicable for testing volumetric materials or pieces of equipment. Furthermore, wipe samples collected to delineate levels of removable surface radioactivity are inherently non-quantitative and therefore not suitable for MARSSIM-type hypothesis testing. Wipe test data will be used to qualitatively describe conditions of building surfaces; they will not be used for non-parametric statistical tests to determine compliance with release criteria. Samples of sinks and hoods will also be evaluated with respect to suitable release criteria, but will not be subject to statistical testing. The appropriateness of releasing each survey unit will be based on static measurements of surface radioactivity.

Define the Boundaries of the Study Area

The study area consists of rooms G-21, G-22, G-22A, the adjacent corridor, and room 110. Sinks, fume hoods, duct work, and other surfaces potentially contaminated are included in the study area.

Develop a Decision Rule

This step requires that (1) a statistical parameter, such as the arithmetic mean or median of a group of measurements, be selected as the parameter of interest, (2) a quantitative action level, such as the instrument response, be established for further investigation, and (3) decision rules be generated based on the statistical parameters and the quantitative action levels. The objective of the investigation is to characterize the range of residual radioactivity in Miller Hall and generate sufficient data for final status survey testing. A review of the license history suggests that the potential contributors to any residual contamination are any of a number of intermediate and long-lived beta/gamma or alpha-emitting sources possessed by JMU under the materials license. These include the majority of radionuclides listed in Appendix A. The primary parameter of

interest is the total surface radioactivity in units of dpm per 100 cm^2; surface radioactivity levels will be quantified for both gross beta and gross alpha levels via measurements with gas proportional detectors. Analytical data quantifying levels of removable surface activity will be generated via liquid scintillation counting.

Statistical Parameter

If warranted, nonparametric statistical testing will be utilized to determine if the level of residual radioactivity in each survey unit exceeds the maximum allowable limit. Since data sets exhibiting a severely skewed (to the right) distribution could result in an arithmetic mean exceeding the limit, MARSSIM recommends using the mean as the statistical parameter of interest.

Investigation Level

Rooms G-21, G-22, and G-22A will be initially classified as Class 2 survey units. The assumption behind the classification is that surface contamination in excess of background may be present, although it is unlikely that the levels would exceed the release limit, or $DCGL_w$ established for the final status surveys. [Note: The $DCGL_w$ is discussed in section IV of this Work Plan.] The corridor and room 110 will be initially classified as Class 3 survey units. The expectation in Class 3 survey units is that no contamination exceeding background is present; however, there are not sufficient data to support that conclusion. No areas will initially be established as Class 1 survey units because a finding of residual radioactivity in excess of the $DCGL_w$, is unexpected. For both Class 2 and Class 3 survey units, an investigation level of one half the $DCGL_w$ will be used. Any static or scanning measurements exceeding these levels will be flagged for further investigation.

Decision Rules

Several of the radionuclides used at JMU historically appear in background. Furthermore, since measurements taken during the final status surveys will not be radionuclide specific, MARSSIM recommends the two-sample test of the survey unit data. The decision rule for the 2-sample case states that if the difference between the mean concentration in the survey unit and

the mean concentration in the reference area is less than the investigation level, then the survey unit is in compliance with the release criterion. If, on the other hand, the mean concentration exceeds the $DCGL_w$, then the status of the survey unit with respect to the release criterion will be determined via an appropriate nonparametric statistical test. To implement the decision rules, the final status surveys must provide sufficient data to allow for a statistically valid estimate of the mean concentration and enough sample data to generate a test with the required statistical power.

Specify Limits on Decision Errors

The results of the survey will be used to evaluate if residual radioactivity in Miller Hall is compliant with the appropriate release limit. A yes or no decision on suitability for release will be made for each survey unit based on an evaluation of the Null Hypothesis. In these final status surveys, the Null Hypothesis tested will be that the residual radioactivity in the survey unit exceeds the release criterion. Therefore, evidence to the contrary is necessary to release the survey unit for unrestricted use. In such a situation, it is possible for two incorrect decisions to be made: (1) deciding the answer is yes when the true answer is no, and (2) deciding the answer is no when the true answer is yes. The approach to the surveys in this Work Plan has been designed to minimize the possibility of decision errors at acceptable levels.

There are two types of decision errors associated with hypothesis testing. A Type I error (false positive) would result in release of a survey unit when the level of residual radioactivity is actually greater than the release criterion. Establishing a low Type I error could result in a rejection of the Null Hypothesis in fewer survey units; it also increases the Type II error. A Type II error (false negative) would result in expending resources to clean up residual contamination when the true level of residual radioactivity is compliant with the release criterion. Establishing a low Type II error will minimize the probability of having to perform additional work in survey units that are in fact compliant with the release criterion. The probability of making a Type I decision error is called alpha (α) and the probability of making a Type II decision error is called beta (β). Typically, when α increases, β decreases. In some cases, it may be necessary to increase the number of samples or measurements collected in each survey unit in

order to minimize α and β to acceptable values. What is clear from the discussion of Type I and Type II errors is that there are trade-offs that must be considered in designing a FSS.

To be protective of worker (and possibly public) health, a value of 0.05 will initially be used for α. Fortunately, as shown in Section IV below, given the anticipated range and standard deviation of surface radioactivity levels in Miller Hall, it should be possible to set α and β at 0.05 without requiring an unreasonable number of measurements. If conditions in a laboratory are not found as assumed, it is possible that a reevaluation might lead to a conclusion that the alpha value should be larger to keep the Type II error and sample size requirements acceptable.

Limits on Analytical Data Decision Errors

Quality control checks on hand-held survey instruments and the floor monitor will include measures of battery strength, background response, and response to a check source. More rigorous decision error limits are not warranted for hand-held survey instruments.

There are several types of decision errors associated with analytical data. The data can be biased high (false positive), biased low (false negative), or completely invalid (rejected). The amount of error associated with the data will be minimized through the use of methods that produce precise, high-quality data. As part of the data generation process, appropriate quality control measures and samples (e.g., backgrounds, replicate analysis, etc.) will be included. During the decision making process, the bias of the data, if any, will be considered.

Optimize the Design for Collecting Data

This step is used to produce the most resource efficient investigation design that will meet the DQOs. The approach to final status survey data collection incorporates biased scanning of potentially contaminated surfaces and random sampling and measurement locations necessary for performing the required nonparametric statistical tests to evaluate the Null Hypothesis.

IV. MARSSIM IMPLEMENTATION

The rooms in Miller Hall subject to these final status surveys consist of laboratory/classroom space, corridors, and offices. Each of the rooms is considered to fall under the category of "Impacted Area" as defined by MARSSIM.

Radionuclides of Concern

Radionuclide work in Miller Hall has for the most part involved using sources to calibrate instruments and in laboratory exercises included in various undergraduate science classes. This has included a wide range of radionuclides with respect to decay kinetics and radiation emissions.

Residual contamination with short- and intermediate-lived nuclides is no longer a concern due to radioactive decay. Therefore, the survey measurements and sample analyses will be focused on quantifying the nuclides potentially present on building structural surfaces. An evaluation of the radionuclides included in Appendix A results in the following list of radionuclides of potential concern.

- Co-60
- Po-210
- Mn-54
- Zn-65
- Na-22
- Cd-109
- Fe-55
- S-35
- H-3
- Cs-137
- Co-57
- C-14
- Ra-226
- Ru-106
- Ce-144
- Cs-134
- Pb-210
- Ag-110m
- Cl-36
- Ni-63

- Sr-90
- Pu-239
- Th-230
- Np-237
- U-238
- Am-241

The five long-lived alpha emitters shown at the end of the list above may be dropped from further consideration due to possession limited to very low activity plated sources, which are extremely unlikely to result in contamination. Other radionuclides may be eliminated from concern due to the physical form of the source(s) possessed by JMU. These include the gamma calibration standards solely possessed in unopened, sealed glass ampoules (Ru-106, Ce-144, Y-88, and Cs-134) and as electroplated button sources (Tl-204, Cl-36, Po-210, Ni-63, and Am-241). This leaves the following radionuclides as potential contaminants on building surfaces:

- Ra-226 (several solid and liquid sources)
- Pb-210 (capped vial/liquid source)
- Ag-110m (capped sources in glass vials)
- H-3 (several unsealed sources)
- C-14 (several unsealed sources)
- Sr-90/Y-90 (generators used in classroom experiments)
- Cs-137 (generators used in classroom experiments and set of eight sources)
- S-35 (liquid source used in classroom experiments)
- Co-60 (liquid source used in classroom experiments)
- Zn-65 (liquid source used in classroom experiments)
- Ba-133 (capped glass vial)
- Cd-109 (set of eight sources)
- Co-57 (set of eight sources)
- Mn-54 (set of eight sources)
- Na-22 (set of eight sources)

Determination of Derived Concentration Guideline Levels (DCGLs)

JMU has an objective of attaining compliance with relative sections in the regulations issued by NRC. Applicable or relevant and appropriate regulations include:

- No more than 25 mrem per year to a member of the public following decommissioning and license termination;
- 10 CFR 20.1101 – maintain dose to members of the public as low as reasonably achievable (ALARA);
- 10 CFR 20.1406 – minimization of contamination.

The surface area concentration of radionuclides of concern equivalent to the release criterion, or regulatory limit expressed as an annual dose, is identified in MARSSIM as the DCGL. Exposure pathway modeling is necessary to relate a concentration of a specific radionuclide to an annual dose. Averaged over a large area, the DCGL is expressed as $DCGL_W$. Since it is possible that residual radioactivity will be found in the form of small areas of elevated activity rather than throughout a survey unit, MARSSIM also establishes and evaluates survey data relative to a DCGL for elevated measurement comparisons, or $DCGL_{EMC}$.

In support of license termination, NRC has published screening levels for surface radioactive contamination relating activity level to an annual dose of 25 mrem per year for several isotopes in NUREG 1556 Volume 11; for radionuclides not included in the table, comparable values may be generated with NRC's D and D code, Version 2.1.[1] JMU has determined that compliance with the aforementioned portions of 10 CFR 20 and the 25 mrem per year standard is best attained by establishing screening levels based on the assumption that all surface contamination is due to the beta- or alpha-emitting radionuclide with the lowest value relating activity to dose. These values appear in the table below for all radionuclides of potential concern.

[1] The models used to generate the values utilize an assumption that ten percent of the total surface activity is removable.

DCGL$_w$ Values For Total Surface Radioactivity		
Radionuclide	NRC Screening Value[1] (dpm/100 cm^2)	Source
H-3	1.2 E +08	NUREG 1556
C-14	3.7 E +06	NUREG 1556
Na-22	9.5 E+03	NUREG 1556
S-35	1.3 E+07	NUREG 1556
Mn-54	2.3 E+04	NUREG 1556
Co-57	2.1 E+05	D and D code
Co-60	7.1 E+03	NUREG 1556
Zn-65	4.8 E+04	D and D code
Sr-90/Y-90	8.7 E+06	D and D code
Cd-109	1.1 E+05	D and D code
Ag-110m	1.0 E+04	D and D code
Ba-133	*	Not available in either
Cs-137	2.8 E+04	NUREG 1556
Pb-210	5.4 E+02	D and D code
Ra-226	1.1 E+03	D and D code

[1]From NUREG 1556 Volume 11, Table 11.1 and/or the D and D code; equivalent to 25 mrem per year.

Given the suite of radionuclides of concern in the table above, any surface contamination found on building structures is likely to be due to beta- or beta/gamma-emitting radionuclides. For beta and beta/gamma emitters, the most restrictive of these values is the **7,100 dpm/100 cm^2** determined for Co-60. Therefore, the most conservative approach to establishing a DCGL$_w$ for this project is to assume that all gross beta surface activity is due to Co-60 contamination.

So as not to miss any potential alpha contamination, survey units will also be scanned with the gas proportional detectors in the "alpha only" setting. Any alpha contamination found will be thoroughly characterized.

Identify Survey Units

MARSSIM methodology mandates segmenting impacted areas into survey units based on the probability of finding contamination. As noted above, the posted rooms and corridor in Miller Hall have been designated as either Class 2 or Class 3 survey units. Each laboratory will comprise two survey units, one being the floor area and the other being the lower walls (up to 2 m above the floor). Surface beta and alpha measurements of similarly constructed floors and walls will be taken from a background reference area in another room in the building where radioactive materials were not utilized.

Survey unit record forms have been prepared for use by the field team. Figures 1 and 2 are sample forms prepared for 'Floor' and 'Wall' survey units, respectively. One form will be used for each survey unit and will identify locations for random measurements, wipe tests, and recording relevant information such as room identification, survey unit number, surveyors, etc.

Number and Location of Measurements

To properly implement MARSSIM final status survey nonparametric statistical testing via the Wilcoxon Rank Sum (WRS) test, a determination must be made of the number of measurements required in the survey unit and background reference area used for comparison. The number of measurements, N, is calculated as follows:

$$N = \frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{3(P_r - 0.5)^2};$$
$$\alpha, \beta = 0.05; Z_{0.95} = 1.645$$

P_r is the probability that a random measurement from the survey unit exceeds a random measurement from the background reference area by less than the $DCGL_w$ and is based on the relative shift, i.e., the difference between the $DCGL_w$ and the lower bound of the gray region (LBGR) divided by the magnitude of the anticipated standard deviation, σ, in the survey unit. P_r values are provided in Table 5.1 of MARSSIM.

N can be estimated as follows:

The shift,Δ, is equal to the $DCGL_w$ - LBGR. For the hand-held gas proportional detectors, assuming the detection efficiency is 0.25 and the source efficiency is 0.25, the count rate related to the 7,100 dpm/100 cm^2 $DCGL_w$ for Co-60 is approximately 450 cpm. The LBGR may be set at one-half the $DCGL_w$, so Δ is equal to 225 cpm. Assuming a value of 75 cpm for σ results in a relative shift (Δ/σ) of 3. From Table 5.1 in MARSSIM, the appropriate P_r value is 0.983. Using the equation shown above, N is determined to be 15. The value for N is then increased by 20 percent and rounded upwards to obtain the desired power level with the statistical tests used to evaluate compliance with the $DCGL_w$. This results in 20 measurements in each survey unit/reference area combination, or 10 measurements per survey unit. Since there are no Class 1 survey units, additional evaluation of the measurement number with respect to finding small areas with elevated activity is not warranted.

Consistent with MARSSIM guidance, measurement locations in Class 3 survey units and background reference areas will be determined by generating sets of random numbers (two values, representing X- and Y-axis distances). The random numbers will be generated in the field using a random number generator function with a scientific calculator.

A random-start systematic pattern will be used to determine measurement locations in Class 2 survey units. As per MARSSIM, the number of calculated measurement points, n, is used to determine the spacing. L, of a systemic triangular grid pattern by:

$$L = [A/(0.866 \times n)]^{1/2}$$

The first location is determined via a random number generator and a row of points are identified, parallel to the X-axis, at intervals of L. Survey points are then identified along parallel rows at distances of 0.866 x L from each adjacent row midway between the points on the preceding row. Locations which are found to be either outside of the survey unit or inaccessible are replaced by locations generated with random numbers.

Construction of the Power Curve

A prospective power curve representative of all Class 2 survey units was created with COMPASS Version 9.1 and is shown in Appendix B. The figure shows the probability that the survey unit will pass the release criterion versus the surface area concentration of residual radioactivity expressed as a count rate. Based on the conservative assumption that all long-lived

beta activity is from Co-60, the appropriate $DCGL_w$ is 7,100 dpm/100 cm^2 and the lower bound of the gray region (LBGR) is set equal to one-half that value, or 3,550 dpm/100 cm^2. Converting those parameters into units of count rate, or cpm, based on the characteristics of the gas proportional detectors used to collect static surface activity measurements[2] finds that measured count rates of 450 cpm and 225 cpm are equivalent to the $DCGL_w$ and LBGR, respectively. The power curve shows that the surveys provide 100% power to decide that a survey unit with data at approximately 300 cpm (or 200 cpm greater than background) will pass the statistical test and be found compliant with the release criterion. The curve also establishes that a survey unit with surface activity at the $DCGL_w$ (450 cpm on the hand-held gas proportional detector, or 7,100 dpm/100 cm^2) has a 5% probability of being released.

Minimum Detectable Concentrations (MDC)-Static Measurements

Two important measures of instrument sensitivity must be established to ensure that data quality objectives are met. One is the minimum detectable concentration (MDC) of the static surface beta activity measurements to be used in the WRS tests for compliance with the release level, and the second is the scan MDC attained when surveying walls and floors.

Equation 6.7 in MARSSIM provides the method to calculate the MDC for static measurements when α and β are equal to 0.05:

$MDC = C \times [3 + 4.65(B)^{1/2}]$; where
B = number of background counts expected to occur while performing an actual measurement
C = factors to convert from counts to units of concentration

For a 0.5 minute measurement, B is equal to 50 counts. Given a Co-60 detector efficiency of 0.25 and a source efficiency of 0.25, the 100 cm^2 gas proportional detectors have a MDC approximately equal to **1,150 dpm/100 cm^2**, which makes this instrument appropriate for generating data to be utilized to determine compliance with a $DCGL_w$ of 7,100 dpm/100 cm^2.

[2] The gas proportional detectors have a surface area of 100 cm^2, a Co-60 detection efficiency of 0.25, a surface efficiency for concrete of 0.25, and a background response of approximately 100 cpm.

Minimum Detectable Concentrations (MDC)-Scanning

Several factors influence the minimum concentration detectable when scanning surfaces for total activity levels. These include the detector characteristics (efficiency and probe area), the scan rate, surveyor characteristics, type of radiation (energy and type), and material being scanned (potential loss of efficiency due to absorption of radiations). The methodology used to estimate the minimum detectable count rate (MDCR) and scan MDC for beta emitters is described in section 6.7.2.1 of MARSSIM. Equations for each parameter and appropriate

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

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

$$ScanMDC = \frac{MDCR}{\sqrt{p}\, e_i e_s \frac{probearea}{100cm^2}}$$

parameter values are:

where:

s_i = minimum detectable number of net source counts in the interval
i = observation interval, 2 seconds
d'= index of sensitivity representing the distance between the means of the background and background plus signal (Table 6.5 MARSSIM-1.38, providing 95% correct detection rate or 5% false negative rate and 60% false positive rate[3])
b_i = number of background counts in the two-second interval, 3.3 and 9.3 for the hand-held gas proportional detector and floor monitor, respectively
p = surveyor efficiency, 0.5
e_i = instrument efficiency, 0.25
e_s = surface efficiency, 0.25
probe areas:
Gas Proportional = 100 cm^2
Floor Monitor = 584 cm^2

The appropriate MDCR and Scan MDCs are provided in the following table.

[3] Note that while scanning, it is preferable for the surveyor to have a liberal willingness to decide that a signal is present based on minimal evidence. The "cost" of the false positive is only a little increment of time incurred while taking a closer look at the area in question with the detector.

Detector	Background (cpm)	MDCR (net cpm)	Scan Sensitivity (gross cpm)	Scan MDC (dpm/100 cm^2)
Gas Proportional	100	75	175	**1,700**
Floor Monitor	280	127	407	**500**

As with the MDC for static measurements, the scan MDCs for both detectors provide sufficient sensitivity to investigate survey units with a $DCGL_w$ of 7,100 dpm/100 cm^2.

V. FIELD INVESTIGATION

The approach to the field activities is based on the findings of the HSA and an understanding of the radiation safety program at JMU. The survey will incorporate several types of measurements and sample analyses to fully characterize any residual radioactive contamination and generate the final status survey data necessary to test each survey unit for suitability to be released for unrestricted use. A combination of surface scanning, static measurements, and sample collection and analysis will ensure that all areas of concern are fully evaluated compliant with MARSSIM.

Floor Scan

Comprehensive floor scans will be conducted with a large area floor monitor. All accessible floors will be scanned in Class 2 survey units and not less than 50 percent of accessible floors will be scanned in Class 3 survey units. These will be done for both total alpha and total beta activity.

Lower Wall Scan

The lower walls are defined to consist of the walls from the floor to a height of two meters (approximately six feet). Lower wall scans will be conducted with hand-held gas proportional detectors. Consistent with floor coverage, 100 percent and not less than 50 percent of the lower wall surfaces will be scanned in Class 2 and Class 3 survey units, respectively. These will be done for both total alpha and total beta activity.

Exposure Rate Measurements

External exposure rate measurements will be taken in any areas found exhibiting elevated surface activity levels. These will be taken with a suitable hand-held instrument such as an ion chamber, pressurized ion chamber, or plastic scintillator (micro rem meter). Exposure rate readings will be documented on the survey unit record forms.

Total Surface Activity Measurements

Compliance with the appropriate $DCGL_w$ established for total surface beta activity will be evaluated based on a comparison of static total surface measurements (30 second measurement interval) collected with a 100 cm^2 surface area gas flow proportional detector to like data generated in a suitable background reference area. Measurement locations will be determined following a random pattern consistent with MARSSIM guidance.

Removable Surface Activity – Wipe Sample Surveys

Wipe samples will be collected in each laboratory along floors and walls. Samples will be analyzed via gamma counting and liquid scintillation counting. Ten samples will be collected in each survey unit. These samples will be collected at the randomly generated static total surface activity measurement locations. Additional samples may be taken at biased locations based on professional judgment. These data combined with the total activity measurements will enable an evaluation of the assumption that 10 percent of the surface contamination is removable.

Hood Surveys

Interior hood surfaces will be scanned with appropriate detectors, such as gas proportional and/or GM pancake detectors. Wipe samples will be collected of hood baffle surfaces and from other areas where ducts can be accessed.

Sink and Sink Drain Surveys

Sink surfaces will be scanned with gas proportional detectors. Wipe samples will be collected from each sink and sink drain.

VI. FINAL STATUS SURVEY REPORT

Following completion of survey activities and analysis of all samples, a final status survey report will be prepared. The report will include all radiological data generated in each survey unit with an evaluation of the surface activity data with respect to the $DCGL_W$. Recommendations for additional work in any survey units found not suitable for release will be included.

The radiological status of items not subject to statistical testing, such as sinks and drains will be presented. Recommendations will be offered regarding appropriate remedial options available, including decontamination and reuse and removal for disposal as low level radioactive waste.

VII. HEALTH AND SAFETY

Level D protective clothing will be utilized during the field activities. This includes:

- Work clothes
- Work boots
- Disposable gloves (to be worn during sample collection)

The following radiation detection devices will be utilized:

- Personal dosimeters
- Bicron micro-rem meter, or
- Hand-held ion chamber
- Ratemeter with gas flow proportional detectors
- Floor monitor

Workers will frisk their hands and feet prior to exiting any restricted area. Any items or pieces of clothing identified as contaminated will be placed in plastic bags labeled with "Caution, Radioactive Material" tape.

APPENDIX A

Radioactive Materials for Relocation to A3a

(April 27, 2005)

* Note: Activities given are *not* compensated for amount decayed or removed for use.

(1) Unknown identity radioactive ingot with a length of ~ 4".
(2) Radium, two (2) containers. One is a vial (screw cap) containing a solid (1 g), the other is a sealed ampoule containing a liquid (1 g).
(3) Radium-226, 2 mCi, dated 3/18/68.
(4) Gamma calibration standards, all in sealed unopened glass ampoules. They are identified as follows:
   a. Sodium-22, 1.5E4 dpm/g on 9/1/76
   b. Radium-226, 1.1E4 dpm/g on 7/30/73
   c. Ruthenium-106, 1E4 dpm/g on 3/2/77
   d. Cerium-144, 1.7 E4 dpm/g on 2/10/77
   e. Yttrium-88, 3.9E5 dpm/g on 12/15/76
   f. Cobalt-60, 1.3E4 dpm/g on 7/ 1/76
   g. Cesium-134, 2E5 dpm/g on 3/25/75
   h. Cesium-137, 8.55 nCi/g on 11/1/79
(5) White plastic bucket containing the following:
   a. Lead-210, 0.25 mCi on 7/6/70, capped plastic vial/liquid source
   b. Barium-133, 0.25 mCi on 12/16/85, capped glass vial in lead container as barium chloride
   c. Silver-110m, 2 mCi on 12/16/85, capped glass vial in lead container
   d. Tritium, 1 mCi on 1/1970, labeled compound from Uracil in 1 mL of water or ethanol. 130 uL used on 2/24/02.
(6) Bucket containing the following:
   a. Carbon-14, 0.05 mCi on 4/16/86, sealed glass tube containing gaseous acetic anhydride
   b. Silver- 110m, 2 mCi on 1/17/88, capped glass vial in lead container
(7) Bucket containing buttons used for instrument calibration. Each disk contains small quantities of radioactive materials in the solid form.
   a. Box 1: Cobalt-60 (30 buttons, 1 uCi each)
   b. Box 2: Strontium-90 (12 buttons, 0.1 uCi each)
   c. Box 3: Cesium-137 (20 buttons, mixture of 1 uCi and 5 uCi)
   d. Box 4: Sodium-22 (15 buttons, 1 uCi each)
      Barium-133 (11 buttons, 1 uCi each),
      Thallium-204 (4 buttons, 1 uCi each)

e. Box 5: Chlorine-36 (2 buttons, 0.0129 uCi each)
Cadmium-109 (2 buttons, 1 uCi each)
Manganese-54 (4 buttons, 1 uCi each)

f. Other miscellaneous buttons:
Cadmium-109 (2 buttons, 8 uCi each)
Sodium-22 (2 buttons, 1 uCi each)
Radium (1 button, 1 mR/hr)
Polonium-210 (1 button, 0.105 uCi)
Barium-133 (1 button, 0.145 uCi)
Nickel-63 (1 button, 0.1 uCi)
Cesium-137 (1 button, 1 uCi)
Radium (1 button, 0.0063 uCi)

(8) Radium-Beryllium sealed source, dated 7/27/62, located in paraffin in a five-gallon trashcan bucket. (4.5 mCi)

(9) Trays containing radioactive materials for the Nuclear Chemistry course as follows:

a. Tray for Experiment 1 and 6:Radionuclide generators, including Cs-137/ Ba-137 (6 cows, 9 uCi each) and Sr-90/Y-90 (4 cows, 0.09 uCi each)
b. Tray for Experiment 8: 1 mCi Iodine-131 as radiolabelled NaI in water
c. Tray for Experiment 3: 1 mCi S-35 as radiolabelled sodium sulfate in water.
d. Tray for Experiment 4 and 15: sources in the form of buttons, liquids, or precipitates on planchets, including the following: Carbon-14 (2 each, 50 uCi each), Lead-210 (2 each, 0.1 uCi each), Plutonium-239 (1, 2 x 10^4 dpm), Thorium-230 (2 each, 1 uCi each), Lead-210 (2 each, 0.1 uCi each), Neptunium-237 (2 each, 0.108 uCi each), Uranium-238 (2 each, 6800 cpm), Lead-210 (2 each, 0.1 uCi each), Uranium Nitrate (solid, 1 g), Thorium Oxide (solid, 1 g), [and 10 spent radon seeds, radium daughter products, (6) radioactive plaques (radium), and carnotite (2 each, 1 g) = ~2.0 uCi.]
e. Tray for Experiment 5, 6, and 7: contains the following sources:
Carbon-14 as propionic acid (4 each, 0.25 uCi each)
Carbon-14 as acetic acid (4 each, 0.25 mCi each)
Carbon-14 as sucrose (1 each, 0.05 mCi)
Carbon-14 as glucose (3 each, 0.05 mCi each)
Carbon-14 as sodium bicarbonate (1 each, 1 mCi)
Tritium as norepinephrine (1 each, 0.25 mCi)
Carbon-14 as ornithine (1 each, 0.05 mCi)
Cadmium-109 (1 button, 500 uCi)
Americium-241 (1 button, 6.1 x 10^4 dpm)

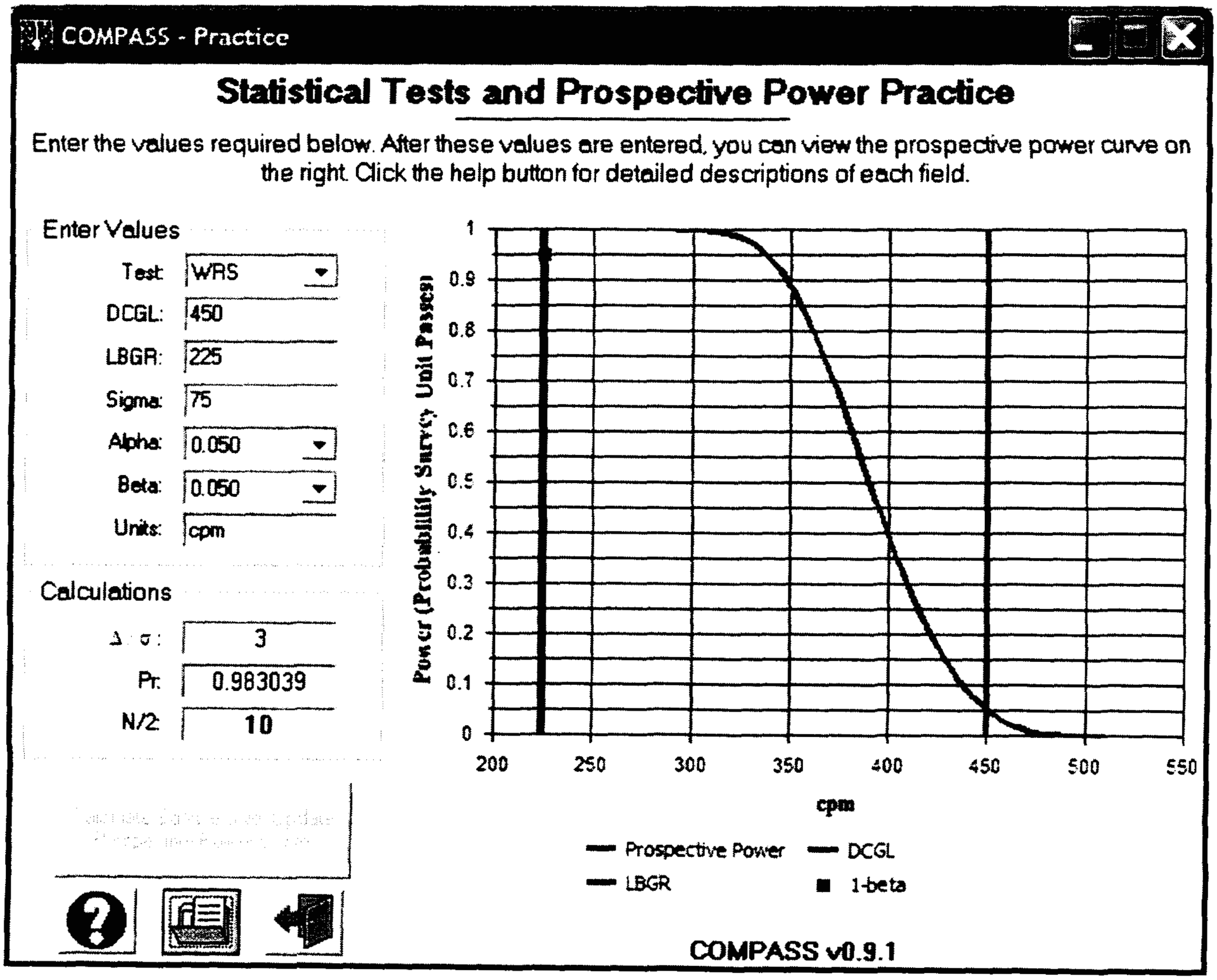
f. Tray for Experiment 8 and 10: Iodine-131 as Sodium Iodide in water (decayed)
g. Tray for Experiment 9: Cobalt-60 solution (1 each, 1 uCi), Zinc-65 solution (1 each, 10 uCi)
h. Tray for Experiment 13: Carbon-14 as acetosalicylic acid (1 each, 0.05 mCi)

(10) Marinelli Beaker (for germanium detector calibration): contains the following: Y-88, Cs-137, Co-60. (0.15 uCi on 2/15/89)
(11) C-14 labelled methane gas (100 uCi)
(12) Pu-Be sealed source (howitzer)
(13) Old Cs-137 calibration source from old liquid scintillation counter.
(14) Liquid Scintillation Standards as follows:
    Carbon-14 (6 each, 99,300 dpm each)
    Tritium (6 each, 492,500 dpm each)
    Tritium (1 each, >1 uCi)
    Carbon-14 (1 each, 1 uCi)
    Carbon-14 (2 each, 1 uCi)
    Carbon-14 (1 each, 0.013 uCi)
    Tritium (1 each, 0.05 uCi)
(15) Set of (8) Sources as follows:
    Barium-133, 0.1-10 uCi
    Cadmium-109, 0.1-10 uCi
    Cobalt-57, 0.1-25 uCi
    Cobalt-60, 0.1-1 uCi
    Cesium-137, 0.1-10 uCi
    Manganese-54, 0.1-10 uCi
    Sodium-22, 0.1-10 uCi
    Zinc-65, 0.1-10 uCi
(16) Cardboard box containing the inventory of radioactive materials (buttons, cow) shown in the table below:

Radiation Inventory – Physics Dept. April 27, 2005

Item	Isotope	Activity (micro Ci)	Qty	Amount each	Date
button	Co-60	10.0	5		
Eluting Solution			1	250 ml	
button	Co-60	1.0	1		Dec-99
button	Sr-90	0.1	1		Dec-99
button	Po-210	0.1	1		Dec-99
button	Cs-137	5.0	1		Dec-99
button	Tl-204	1.0	1		Dec-99
button	Po-210	0.1	1		Jun-00
button	Co-60	1.0	1		Jan-02
button	Sr-90	0.1	1		Jan-03
button	Po-210	0.1	1		Jan-03
button	Cs-137	5.0	1		Jan-03
button	Tl-204	1.0	1		Dec-02
button	Mn-54	1.0	1		Oct-99
button	Co-60	1.0	1		Dec-99
button	Na-22	1.0	1		Oct-99
button	Ba133	1.0	1		Oct-99
button	Zn-65 / Cs-137 mix	1.0	1		Dec-99
button	Cs-137	1.0	1		Aug-99
button	Co-57	1.0	1		Oct-99
button	Cd-109	1.0	1		Oct-99
button	Mn-54	1.0	1		Feb-03
button	Co-60	1.0	1		Feb-03
button	Na-22	1.0	1		Feb-03
button	Ba133	1.0	1		Feb-03
button	Zn-65 / Cs-137 mix	1.0	1		Feb-03
button	Cs-137	1.0	1		Jan-03
button	Co-57	1.0	1		Jan-03
button	Cd-109	1.0	1		Feb-03
isotope generator	Cs-137	5.0	1		

APPENDIX B


COMPASS - Practice
Statistical Tests and Prospective Power Practice
Enter the values required below. After these values are entered, you can view the prospective power curve on the right. Click the help button for detailed descriptions of each field.
Enter Values
Test: WRS
DCGL: 450
LBGR: 225
Sigma: 75
Alpha: 0.050
Beta: 0.050
Units: cpm
Calculations
Δ/σ: 3
Pr: 0.983039
N/2: 10
Power (Probability Survey Unit Passes)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
200
250
300
350
400
450
500
550
cpm
Prospective Power
DCGL
LBGR
1-beta
COMPASS v0.9.1

CSI Radiation Safety Academy
481 N. Frederick Ave, Ste 302, Gaithersburg, MD 20877 800-871-7930 fax: 301-990-9878
csi@RadiationSafetyAcademy.com

Facsimile

To: Heather Armstrong	From: Alan Fellman
	Date: October 17, 2005
Fax: 540-568-7081	Pages including this cover: 26

Subject: FSS Work Plan

James Madison University

College of Science and Mathematics

Miller Hall

FINAL STATUS SURVEY REPORT

October 2005

Prepared by:

Radiation Safety Academy

481 North Frederick Avenue, Suite 302
Gaithersburg, MD 20877

TABLE OF CONTENTS

I. INTRODUCTION

On October 18, 2005, the Radiation Safety Academy performed final status survey (FSS) activities in four rooms and a corridor in Miller Hall on the campus of James Madison University (JMU). The FSS was based on the October 2005 *Work Plan For The Final Status Survey Of Miller Hall at the James Madison University*. As described in that document, the FSS strategy was consistent with the Multi-Agency Radiation Survey And Site Investigation Manual (MARSSIM).

The JMU FSS was conducted following relocation of the College of Science and Mathematics into a new facility. Prior to the move, four rooms in Miller Hall were posted for the presence of radioactive materials. They were rooms G-21, G-22, G-22A, and classroom 110. As described in the Work Plan, each room was divided into two survey units (floor and lower walls). Rooms G-21, G-22, and G-22A were designated as MARSSIM Class 2; room 110 and the corridor adjacent to the Class 2 rooms were designated as MARSSIM Class 3. These classifications were based in part on the findings of a 2003 compliance audit of the JMU radiation safety program and discussions with Ms. Heather Armstrong, the radiation safety officer (RSO) on the JMU license.

The basic FSS activities involved comprehensive scanning for gross alpha and gross beta radioactivity of floors and lower walls with gas proportional detectors, collection of ten static measurements of surface beta activity in each survey unit, collection of ten smear samples in each survey unit for analysis of removable contamination, and collection of smear samples from hoods, sinks, and other appropriate surfaces at biased locations.

Data quality objectives (DQOs) were specified in the Work Plan. They included quantification of minimum detectable count rates for static measurements and scanning, a determination that ten measurements per survey unit would provide the necessary statistical power for nonparametric testing, and the establishment of an appropriate derived concentration guideline limit ($DCGL_w$) as a limit of acceptable activity on building surfaces. Evaluation of historical radioisotope usage led to the conclusion that residual radioactivity remaining on room surfaces could be due to any number of isotopes, but most likely would be from a beta-particle emitting material.

The NRC has developed the D and D code, Version 2.1, enabling projections of radiation doses based on unit levels of surface radioactivity. Several screening levels established at the NRC license termination rule standard of 25 mrem per year have been published by NRC in NUREG 1556 Volume 11. As part of this project, equivalent values were either generated with the D and D code or taken from NUREG 1556 Volume 11 for all radionuclides of potential concern. These values appear in the Work Plan and are reproduced in Table 1.

Table 1 - $DCGL_w$ Values For Total Surface Radioactivity

Radionuclide	NRC Screening Value[1] (dpm/100 cm^2)	Source
H-3	1.2 E +08	NUREG 1556
C-14	3.7 E +06	NUREG 1556
Na-22	9.5 E+03	NUREG 1556
S-35	1.3 E+07	NUREG 1556
Mn-54	2.3 E+04	NUREG 1556
Co-57	2.1 E+05	D and D code
Co-60	7.1 E+03	NUREG 1556
Zn-65	4.8 E+04	D and D code
Sr-90/Y-90	8.7 E+06	D and D code
Cd-109	1.1 E+05	D and D code
Ag-110m	1.0 E+04	D and D code
Ba-133	*	Not available in either
Cs-137	2.8 E+04	NUREG 1556
Pb-210	5.4 E+02	D and D code
Ra-226	1.1 E+03	D and D code

[1]From NUREG 1556 Volume 11, Table 11.1 and/or the D and D code; equivalent to 25 mrem per year.

For the beta particle emitting radionuclides of concern (all of the radionuclides in the table except Pb-210 and Ra-226), the screening level is lowest for Co-60. The most conservative approach to the surveys was to establish the $DCGL_w$ based on the assumption that all gross beta

surface activity was due to Co-60 contamination. As discussed in the Work Plan, the objective in establishing a $DCGL_w$ was to select a level that was not only compliant with NRC's license termination rule but additionally, was consistent with ALARA. These objectives were attained by using the most conservative value, i.e., the 7,100 dpm/100 cm^2 for Co-60, as the $DCGL_w$ for these final status surveys. So as not to miss any potential alpha contamination, survey units were also scanned with the gas proportional detectors in the "alpha only" setting.

The hand-held gas proportional detectors register count rates of approximately 450 cpm at the $DCGL_w$. As described in the Work Plan, all instruments used in the surveys had the desired sensitivity necessary to quantify levels of activity which were less than the $DCGL_w$. Expressed as a count rate, the scanning minimum detectable count rate (Scan MDC) was 175 cpm (equivalent to 1,750 dpm/100 cm^2). The count time for static measurements using the gas proportional detector was 0.5 minutes; for that count interval, the Static measurement MDC was 75 cpm (equivalent to 1,150 dpm/100 cm^2). For a 0.5 minute static measurement, 225 counts indicated the presence of activity at the 7,100 dpm/100 cm^2 $DCGL_w$.

II. DEVIATIONS FROM THE WORK PLAN

The Work Plan did not call for any decontamination activities. However, as described below in Section III, the field team did find five small spots exhibiting elevated surface activity readings. Attempts were made to physically remove each area of concern (mainly by thorough washing) followed by rescanning and sampling of each area.

III. SURVEY RESULTS

A total of 12 survey units were investigated. Each survey unit was assigned a unique survey unit number. Numbers were assigned sequentially in the order that the survey unit was investigated. Each room or laboratory comprised two survey units (floors and lower walls). Table 2 identifies each survey unit and provides its MARSSIM classification number. Background reference survey unit data were collected so as to be available if needed to perform nonparametric statistical tests for survey units found to have measurement data exceeding the $DCGL_w$. Room G-21B was selected for background reference area floor and wall survey units.

TABLE 2 – Survey Units

CLASS 2	**Floor**	**Wall**
Laboratories		
G-21	1	1
G-22	1	1
G-22A	1	1
CLASS 3		
Laboratories		
110	1	1
Corridor	1	1
G-21B	1*	1*
Total	**6**	**6**

*Background Reference Area

Floor Scan

Comprehensive floor scans were conducted with a large area floor monitor. All accessible floors were scanned in Class 2 survey units and not less than 50 percent of accessible floors were scanned in Class 3 survey units. Total surface beta activity and total surface alpha activity were evaluated. No scanning in any survey unit revealed widespread contamination.

Lower Wall Scan

The lower walls, consisting of the walls from the floor to a height of two meters (approximately six feet) were scanned with hand-held gas proportional detectors. Consistent with floor coverage, 100 percent and not less than 50 percent of the lower wall surfaces were scanned in Class 2 and Class 3 survey units, respectively. Total surface beta activity and total

surface alpha activity were evaluated. No scanning in any survey unit revealed widespread contamination.

Total Surface Activity Measurements

Ten static total surface activity measurements were collected with 100 cm^2 surface area gas flow proportional detector in each Class 2 survey unit. The duration for each measurement was 0.5 minute. Measurement locations were determined following the triangular grid methodology described in MARSSIM. When the methodology resulted in an inaccessible location, it was replaced by selecting the nearest accessible location to the desired coordinates.

Removable Surface Activity – Smear Sample Surveys

Ten smear samples were collected in each survey unit. The sample locations were selected based on the methodology found in MARSSIM following a triangular grid pattern in Class 2 survey units and with a random number generator in Class 3 survey units. Samples were also collected from three sinks and three chemical fume hoods as described in the Work Plan. Five biased samples were collected at the locations identified to have elevated surface beta radioactivity. Samples were analyzed via gamma counting and via liquid scintillation counting. Sample locations were identified on the final status survey forms (Appendix A). The sample results are provided in Appendix B.

Hood Surveys

In addition to the smear samples collected in hoods, interior hood surfaces were scanned with gas proportional detectors. The smear samples are identified on the final status survey forms (Appendix A) and the analytical data are provided in Appendix B.

Sink and Sink Drain Surveys

Sink surfaces were scanned with gas proportional detectors. Smear samples were collected in each sink; the sample medium was wiped across the sink surface as well as over the sink drain opening. Samples collected in sinks are identified on the final status survey forms (Appendix A) and the analytical data are provided in Appendix B.

The majority of survey unit results were indistinguishable from background. Table 3 lists the measurements found exceeding the upper range of background. The $DCGL_w$ (equivalent to 450 cpm on the hand-held gas proportional detector) was exceeded for each of the measurements shown in the table. Attempts to decontaminate each spot were made followed by collection of biased smear samples to investigate levels of removable contamination.

The contamination in the sink in room G-22 was thoroughly removed. Following decontamination, the area was rescanned and found to be indistinguishable from background. Surface contamination at the other four locations was determined to be "fixed," as decontamination efforts were unsuccessful. However, none of the smear samples collected at these locations indicated levels of removable activity exceeding background.

Surface contamination can potentially expose persons to both internal and external sources of radiation. Since all of the contamination was found to be "fixed" rather than "removable," it is not possible that any contaminant will be available for an intake (from inhalation or ingestion). To investigate potential external radiation hazards, exposure rate measurements were taken at each spot with a Victoreen Model 451P Pressurized Ion Chamber. Exposure rates ranged from a low of 1 μR/h in the cellar of the former isotope storage room to 13 μR/h at the spot identified on the survey report form on the wall in room G-22. The spot on the sink had also exhibited 13 μR/h initially but, following decontamination had returned to background. Background exposure rates typically range from 5 – 10 μR/h in the mid-Atlantic region and therefore, no potential was found for future occupants of room G-22 to receive any significant radiation dose as a result of the presence of surface radioactivity.

Because of the lack of significant contamination (as evidenced by the magnitude of the surface activity measurements shown on Class 2 survey report forms), statistical testing via the Wilcoxon Rank Sum (WRS) test was not necessary to establish compliance with NRC release limits.

Appendix A contains the individual final status survey unit forms from each survey unit. The total surface activity data collected in Class 2 survey were provided on the forms, as were measurement locations, elevated readings found during surface scans, and sample numbers for sink and hood samples.

TABLE 3 –Rooms With Elevated Count Rates

LOCATION	Survey Unit NUMBER	SU TYPE	Result (cpm)	Exposure Rate (μR/h)*	DESCRIPTION
G-22 Sink	3	NA	521 beta	13	Spot in sink
G-22	4	WALL	4,724 beta	13	Spot on wall between closet door and bench
G-22A	5	FLOOR	635 beta	7	Spot on floor
G-22A	5	FLOOR	1,078 beta	5	Spot on floor
G-22A	5	FLOOR	507 beta	1	Spot on floor

*Contact readings taken with Victoreen Model 451P Pressurized Ion Chamber.

IV. QUALITY CONTROL

All instruments used in the final status surveys were subject to strict quality control measurements. These included evaluation of background response, battery response and source check response. Quality control measurement data were recorded and logged by the field team prior to initiating survey activities. Only instruments operating within acceptable control limits were utilized. The calibration certificates and quality control sheets for the analytical instruments used to scan surfaces and count samples collected during this project are provided in Appendix C.

V. DISCUSSION

The MARSSIM approach to FSS data evaluation calls for using a nonparametric statistical test to evaluate conditions in each survey unit with respect to the allowable limit, or $DCGL_W$. If statistical testing concludes with acceptance of the Null Hypothesis, the survey unit must be remediated and resurveyed prior to being released for unrestricted use. However, since all of the measurement data collected along randomized grid patterns in JMU survey units did not exceed the $DCGL_W$, statistical testing was not necessary to determine compliance with the $DCGL_W$ and a rejection of the Null Hypothesis[1] was warranted.

It should be noted that MARSSIM includes a methodology to account for areas of elevated activity in Class 1 survey units. This is known as the Elevated Measurement Comparison

(EMC). While no survey units were initially classified as Class 1, where measurements exceeded the $DCGL_w$, the survey units can be reclassified as Class 1. The purpose of the EMC is to provide assurance that areas exhibiting unusually large measurements receive proper attention regardless of the outcome of the appropriate nonparametric statistical test such that the potential for significant radiation doses are identified. By incorporating a 100 percent scan in Class 2 survey units, these final status surveys effectively identified all contaminated areas, regardless of how small they were relative to the size of the grids used to establish measurements locations. Rather than using statistical testing to establish compliance with the release criterion, the contaminated areas were investigated such that the final status of the building surfaces in each survey unit supports rejection of the Null Hypothesis.

Based on the results of the FSS investigation, radiological conditions in formerly posted rooms in Miller Hall are such that the building is suitable for unrestricted use.

Prepared by: ______________________ Date: October 27, 2005
Alan Fellman, Ph.D., C.H.P.

[1] The Null Hypothesis states that residual radioactivity in the survey unit exceeds the release limit.

Appendix A – Final Status Survey Forms

James Madison University Final Status Survey Form
Floor Unit

x = 4.37
y = 4.97
L1 = 1.58
L2 = 1.37
(45, 15)

Class: 1 2 3 | Area (m²): 21.7 m²

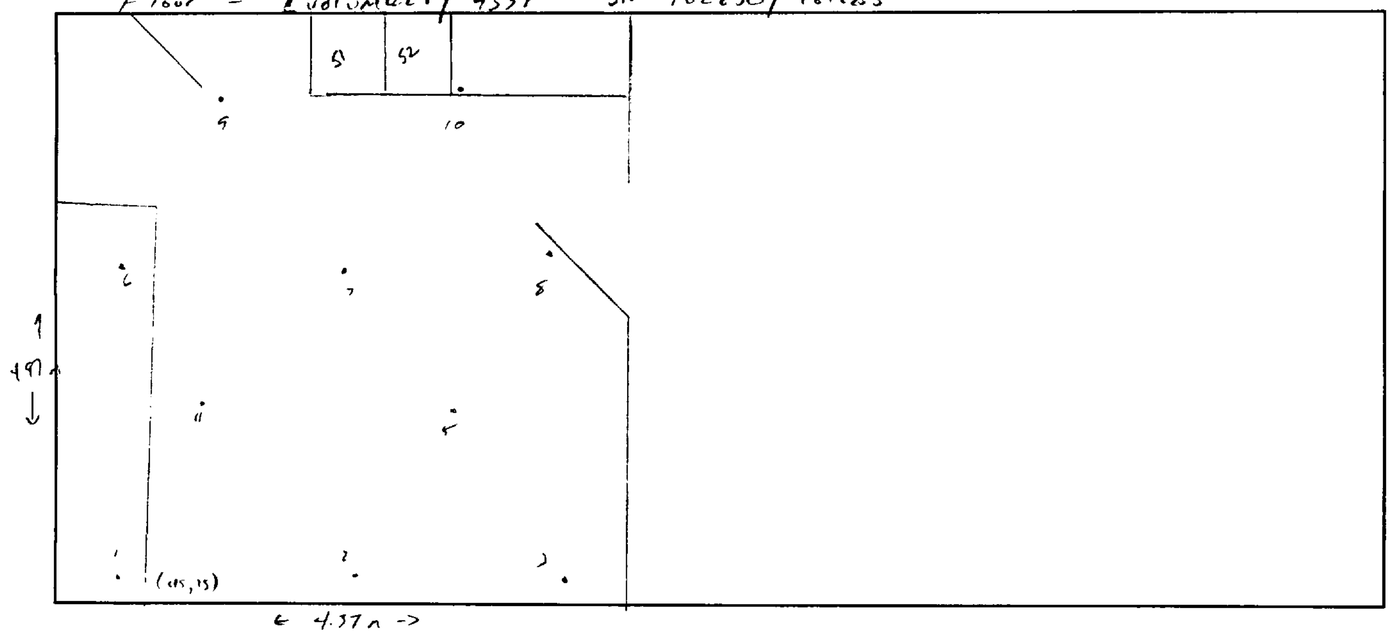
Survey Unit # 1 | Floor: G | Room #: 21

Surveyor: MJ, LM | Date: 10/18/05

Integrated counts
Meter: Ludlum 2224-1 | Serial #: 187244 | Cal Date: 2-16-05
Detector: Ludlum 43-68 | Serial #: PR 216752

UNIT SKETCH

Floor - Ludlum 2224 / 4337 SN# 162850 / 161685



Background CPM: 345 cpm floor monitor
135 cpm handheld

Integrated Counts (30 seconds with 43-68)

Location 1: 50 | Location 4: 64 | Location 7: 52 | Loc. 10: 55

Location 2: 62 | Location 5: 59 | Location 8: 57

Location 3: 66 | Location 6: 54 | Location 9: 65

Comments: S = 2' H = 0 (swipes 1->10)

(Since smears 1 & 2)

Approved: [signature] | Date: 10/20/05

Radiation Safety Academy, Inc.

James Madison University Final Status Survey Form
Wall Unit

Class: 1 2 3   Area (m^2): 37.7 m^2

Survey Unit # 2   Floor: G   Room #: 21

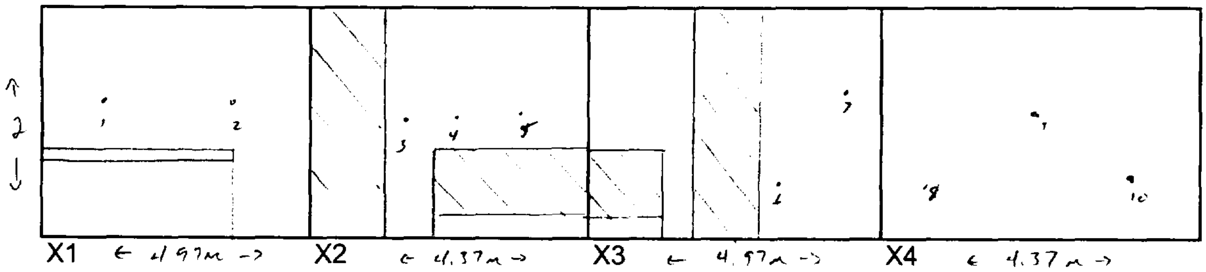
Surveyor: LM, MJ   Date: 10/19/05

Wall & Integ. counts

Meter: Ludlum 2224-1   Serial #: 187244   Cal Date: 2-16-05

Detector: Ludlum 43-68   Serial #: PR 216252

Unit Sketch



Background CPM: 135 cpm

Integrated Counts (30 seconds with 43-68)

Location 1:	66	Location 4:	65	Location 7:	52	Loc 10:	63
Location 2:	69	Location 5:	59	Location 8:	99		
Location 3:	83	Location 6:	60	Location 9:	64		

Comments: (Swipes 11→20)

Approved: [signature]   Date: 10/20/05

Radiation Safety Academy, Inc.

James Madison University Final Status Survey Form
Floor Unit

x = 4.66
y = 5.80

L_1 = 1.77
L_2 = 1.53

Class: 1 2 3

Area (m²): 27.0 m²

Survey Unit # 3

Floor: G

Room #: 22 (95, 143)

Surveyor: MJ, LM

Date: 10/19/05

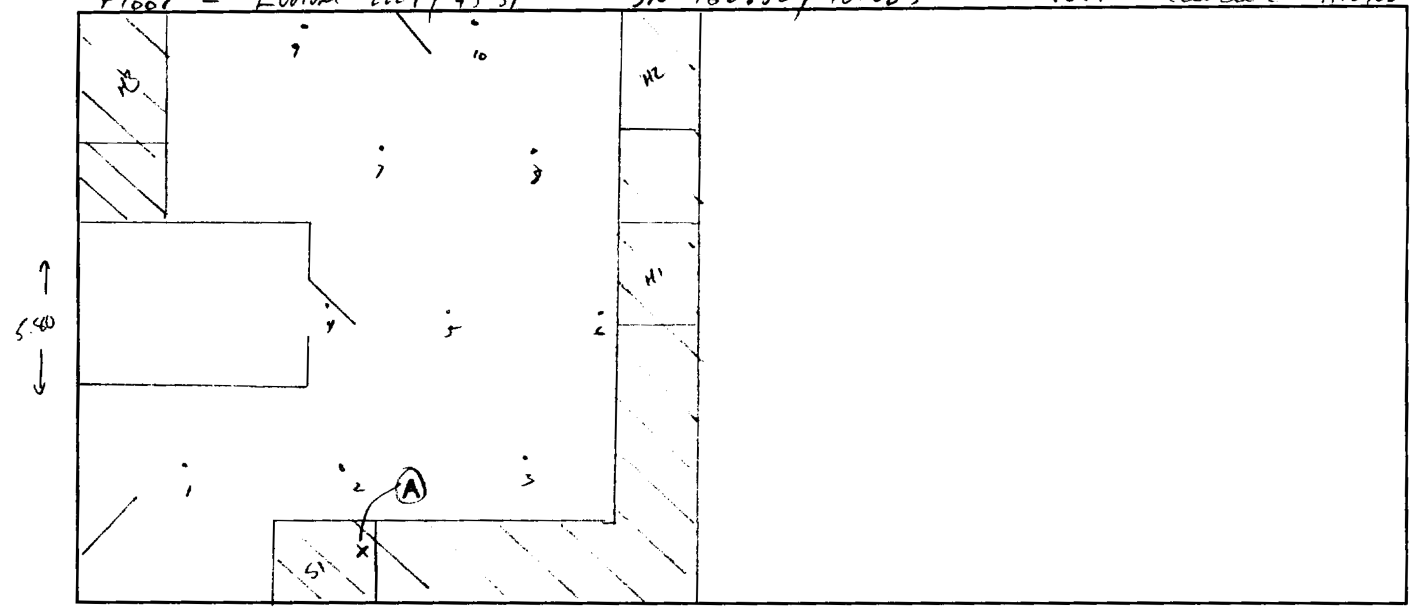
Int. Counts: Meter: Ludlum 2224-1 Serial #: 187275 Cal Date: 2-16-05

Detector: Ludlum 43-68 Serial #: PR 216244

Ionchamber bkg - ≈ 5μR/hr
Victoreen 451P S/N - 6063 Cal date - 7/12/05

UNIT SKETCH

Floor - Ludlum 2224 / 43-37 SN# 162850 / 161685



Background CPM: 345 floor monitor
135 handheld

Integrated Counts (30 seconds with 43-68)

Location 1: 49
Location 2: 59
Location 3: 67
Location 4: 52
Location 5: 98
Location 6: 62
Location 7: 43
Location 8: 43
Location 9: 47

Comments: S=1; H=3 Sink #3 Location 10: 63

A) 521 cpm (5α) inside sink - cleaned removed down to < bkgd (extra Smear 1)
↳ 13 μR/hr w/ Ion Chamber

(Swipes 21-30)
(Hood # 3, 4, 5)

Approved: [signature]

Date: 10/20/05

Radiation Safety Academy, Inc.

James Madison University Final Status Survey Form
Wall Unit

Class: 1 2 3 Area (m²): 41.8m²

Survey Unit # 4 Floor: G Room #: 22

Surveyor: MS, LM Date: 10/18/05

walls + rotating cavity

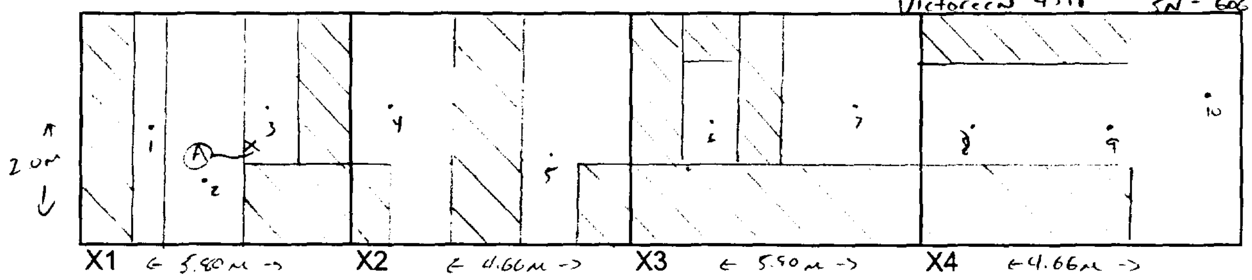
Meter: 2224-1 Serial #: 187244 Cal Date: 2/16/05

Detector: 43-68 Serial #: 216252

Unit Sketch

Ion Chamber Victoreen 451P

bkgd – ≈ 5μR/hr
cal – 7/12/05
SN – 6063



Background CPM: 135 cpm

Integrated Counts (30 seconds with 43-68)

Location 1: 72 Location 4: 69 Location 7: 71

Location 2: 73 Location 5: 76 Location 8: 71

Location 3: 72 Location 6: 71 Location 9: 65

Comments: Location 10: 78 smears (31-240)

A) 4724 cpm on wall (between closet door & bench)
(extra smear #2)
13μR/hr w/ Ionchamber

Approved: [signature] Date: 10/20/05

Radiation Safety Academy, Inc.

James Madison University Final Status Survey Form
Floor Unit

x: 2.10
y: 5.92

Class: 1 2 3   Area (m²): 12.4

L1 1.20
L2 1.04

Survey Unit # 5   Floor: G   Room #: 22A

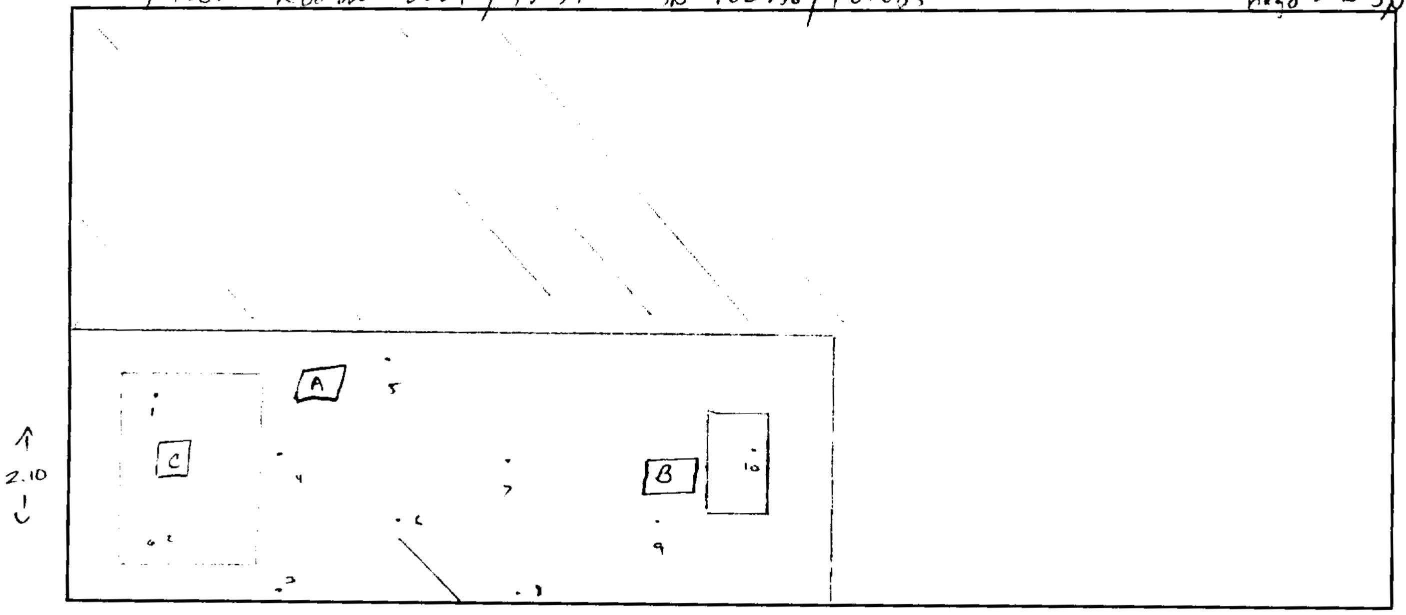
Surveyor: MT, LM   Date: 10/18/05   (64, 86)

Integ. counts + cont spots
Meter: 2224-1   Serial #: 187244   Cal Date: 2/16/05
Detector: 43-68   Serial #: 216252

UNIT SKETCH

Floor - Ludlum 2224 / 43-37 SN# 162450 / 161685

Ionchamber Victoreen 451P S/N - 6063 cal date - 7/12/05 bkgd - ≈ 5 µR/hr



← 5.92 →

Background CPM: 345 floor monitor
135 handheld

Integrated Counts (30 seconds with 43-68)

Location 1: 107   Location 4: 69   Location 7: 77

Location 2: 112   Location 5: 68   Location 8: 65

Location 3: 64   Location 6: 112   Location 9: 86

Comments: 50 H₂O   Location 10: 193

A) 635 cpm floor (extra smear 4) 7 µR/hr w/ Ionchamber (Smears 41-50)

B) 1078 cpm floor (extra smear 3) 5 µR/hr w/ Ionchamber

C) 507 cpm floor (extra smear 5) 1 µR/hr w/ Ionchamber

Approved: [signature]   Date: 10/20/05

Radiation Safety Academy, Inc.

James Madison University Final Status Survey Form
Wall Unit

Class: 1 2 3 Area (m²): 32.1 m²

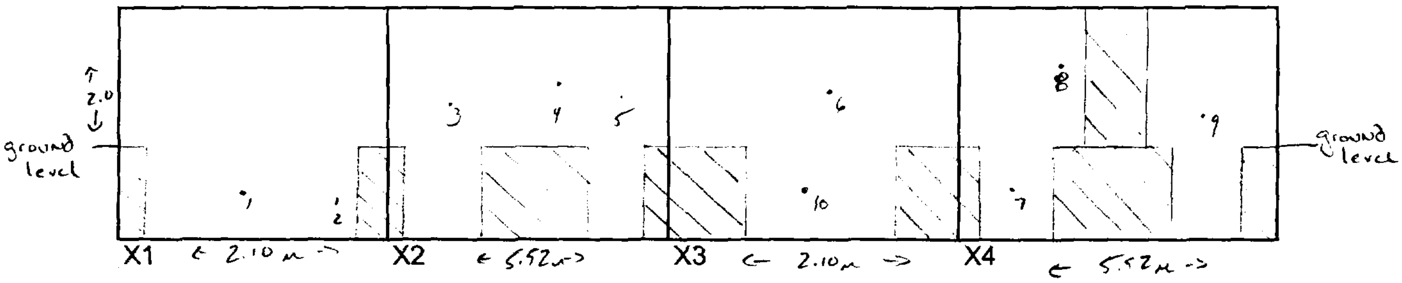
Survey Unit # 6 Floor: G Room #: 22A

Surveyor: MJ, LM Date: 10/18/05

Meter: 2224-1 Serial #: 187244 Cal Date: 2/16/05

Detector: 43-68 Serial #: 216252

Unit Sketch



Background CPM: 135 cpm

Integrated Counts (30 seconds with 43-68)

Location 1: 116 Location 4: 94 Location 7: 98

Location 2: 116 Location 5: 89 Location 8: 110

Location 3: 100 Location 6: 136 Location 9: 84

Comments: Location 10: 79

(Smears 51-60)

Approved: [signature] Date: 10/20/05

Radiation Safety Academy, Inc.

James Madison University Final Status Survey Form
Floor Unit

Class: 1 2 3

Area (m^2): N/A

Survey Unit # 7

Floor: G

Room #: Corridor

Surveyor: MJ, LM

Date: 10/18/05

Meter: 2224

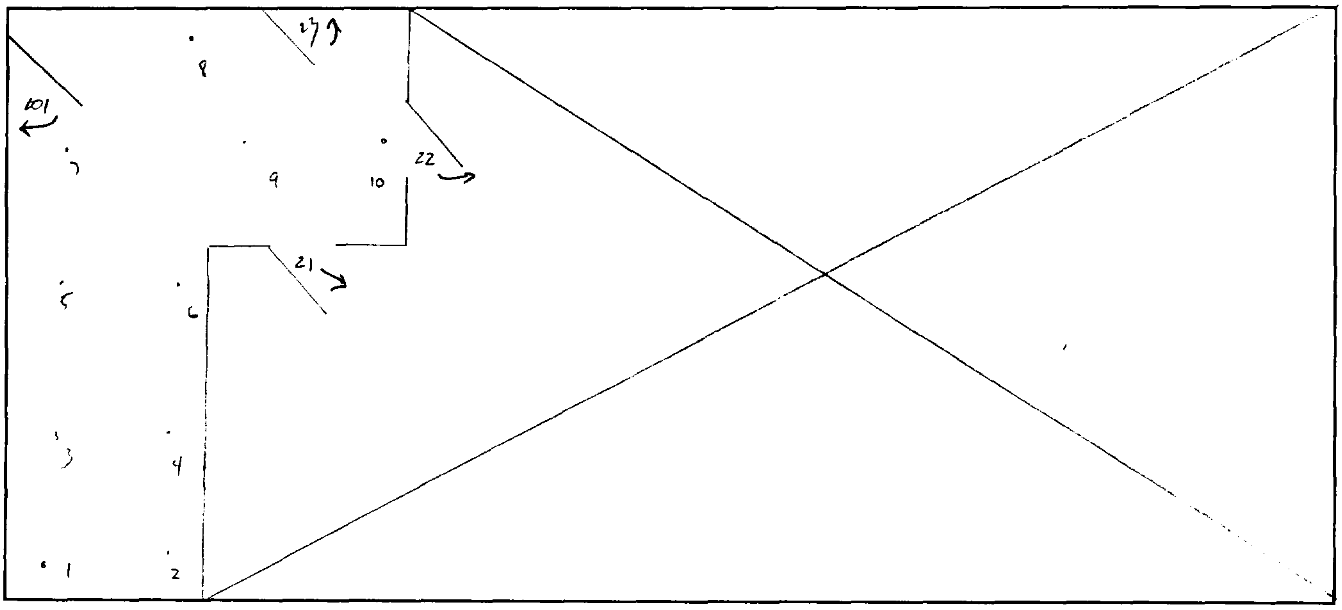
Serial #: 162850

Cal Date: 2/16/05

Detector: 43-37

Serial #: 161685

UNIT SKETCH



Background CPM: 345 cpm

Integrated Counts (30 seconds with 43-68)

Location 1: N/A

Location 2: N/A

Location 3: N/A

Location 4: N/A

Location 5: N/A

Location 6: N/A

Location 7: N/A

Location 8: N/A

Location 9: N/A

Comments: Location 10 : N/A

(Smears 61-70)

Approved: [signature]

Date: 10/20/05

Radiation Safety Academy, Inc.

James Madison University Final Status Survey Form
Wall Unit

Class: 1 2 3

Area (m^2): N/A

Survey Unit # 8

Floor: G

Room #: Corridor

Surveyor: MT, LM

Date: 10/18/05

Meter: 2224-1

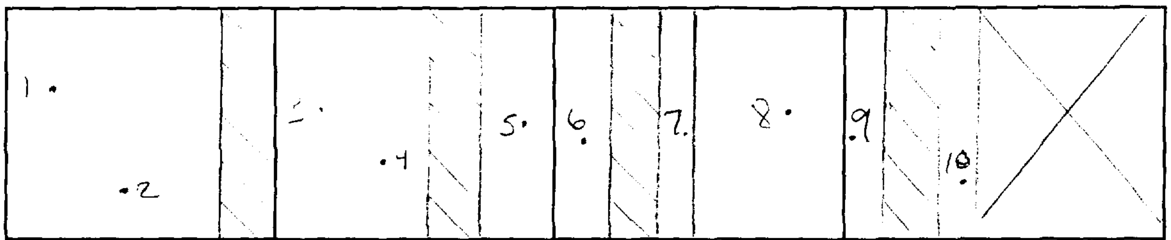
Serial #: 187244

Cal Date: 2/16/05

Detector: 43-68

Serial #: 216252

Unit Sketch



X1 X2 X3 X4

Background CPM: 135 cpm

Integrated Counts (30 seconds with 43-68)

Location 1: N/A

Location 2: N/A

Location 3: N/A

Location 4: N/A

Location 5: N/A

Location 6: N/A

Location 7: N/A

Location 8: N/A

Location 9: N/A

Comments: Location 10: N/A

smears (71-50)

Approved: [signature]

Date: 10/20/05

Radiation Safety Academy, Inc.

James Madison University Final Status Survey Form
Floor Unit

Class: 1 2 3

Area (m^2): N/A

Survey Unit # 9

Floor: 1

Room #: 110

Surveyor: MJ, LM

Date: 10/18/05

Meter: 2224

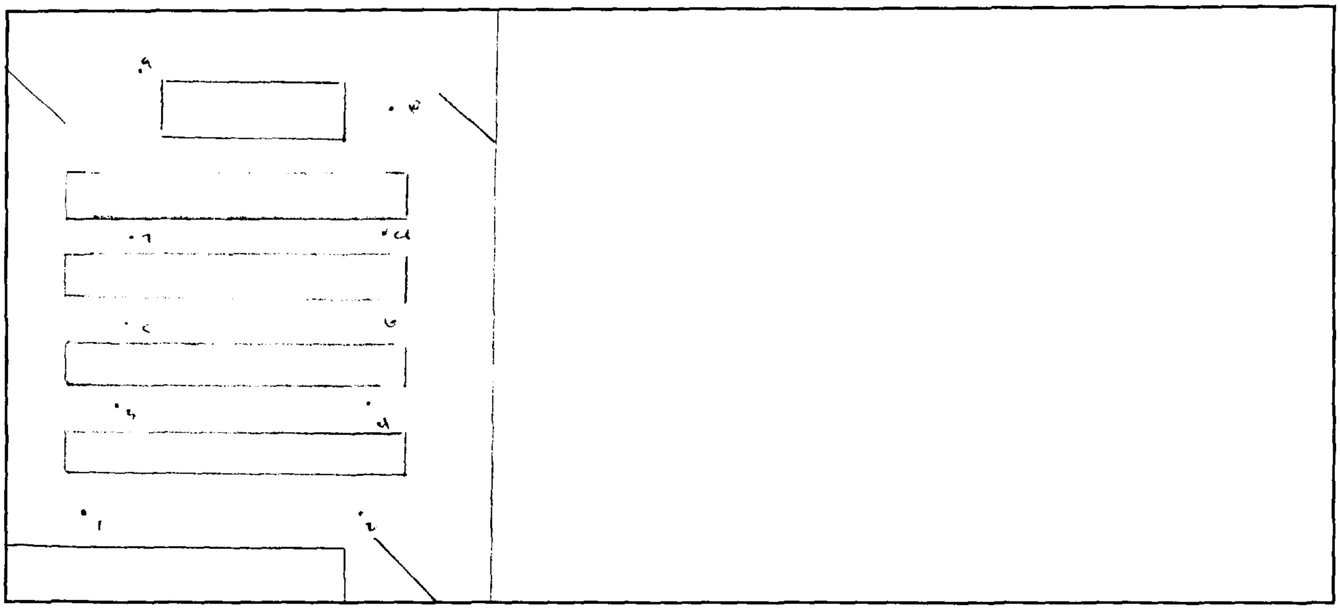
Serial #: 162850

Cal Date: 2/16/05

Detector: 43-37

Serial #: 161685

UNIT SKETCH



Background CPM: 625 cpm

Integrated Counts (30 seconds with 43-68)

Location 1: N/A

Location 4: N/A

Location 7: N/A

Location 2: N/A

Location 5: N/A

Location 8: N/A

Location 3: N/A

Location 6: N/A

Location 9: N/A

Comments: S=1, H=0 Location 10 N/A (Smears 51-50)

Approved: [signature]

Date: 10/20/05

Radiation Safety Academy, Inc.

James Madison University Final Status Survey Form
Wall Unit

Class: 1 2 3

Area (m^2): N/A

Survey Unit # 10

Floor: 1

Room #: 110

Surveyor: MJ, LM

Date: 10/18/05

Meter: 2224-1

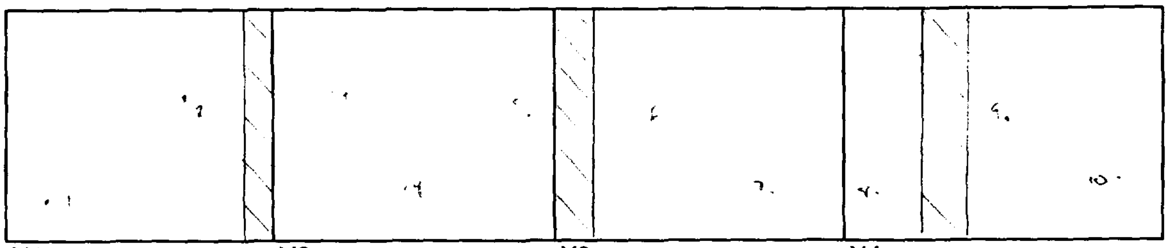
Serial #: 87244

Cal Date: 2/16/05

Detector: 43-68

Serial #: 216252

Unit Sketch



X1 X2 X3 X4

Background CPM: 290 cpm

Integrated Counts (30 seconds with 43-68)

Location 1: N/A

Location 2: N/A

Location 3: N/A

Location 4: N/A

Location 5: N/A

Location 6: N/A

Location 7: N/A

Location 8: N/A

Location 9: N/A

Comments: Location 10 N/A

(Smears 91-100)

Approved: [signature]

Date: 10/20/05

Radiation Safety Academy, Inc.

James Madison University Final Status Survey Form
Floor Unit

x = 7.74 m
y = 4.97 m
Lx = 1.37m
Ly = 1.19m
(110,76)

Class: ~~1~~ 2 ~~3~~ Area (m^2): 16.3m²

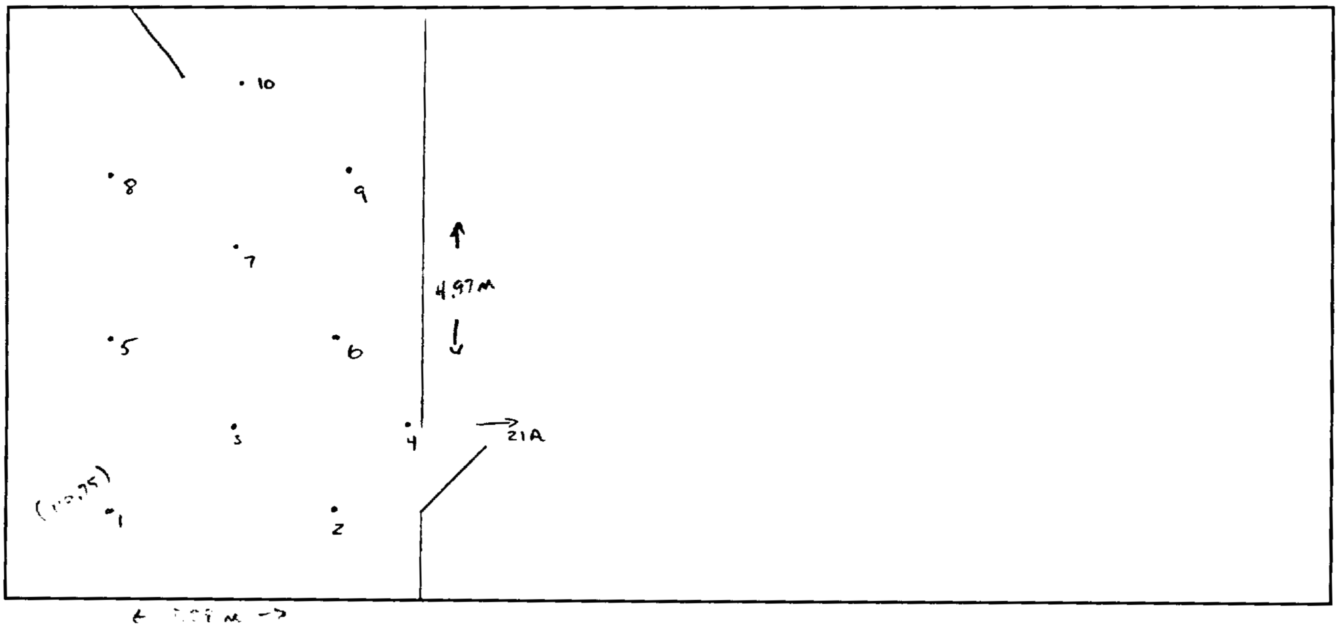
Survey Unit # 11 Floor: 6 Room #: 21B

Surveyor: MJ, LM Date: 10/18/05

Meter: 2224-1 Serial #: 187204 Cal Date: 2/16/05

Detector: 43-68 Serial #: 216252

UNIT SKETCH



Background CPM: 135 cpm (handheld)

Integrated Counts (30 seconds with 43-68)

Location 1:	71	Location 4:	85	Location 7:	73
Location 2:	72	Location 5:	96	Location 8:	72
Location 3:	69	Location 6:	61	Location 9:	69

Comments: Reference Room Location 10: 57

Approved: [signature] Date: 10/20/05

Radiation Safety Academy, Inc.

James Madison University Final Status Survey Form
Wall Unit

Class: ~~1 2 3~~ Area (m^2): [illegible]

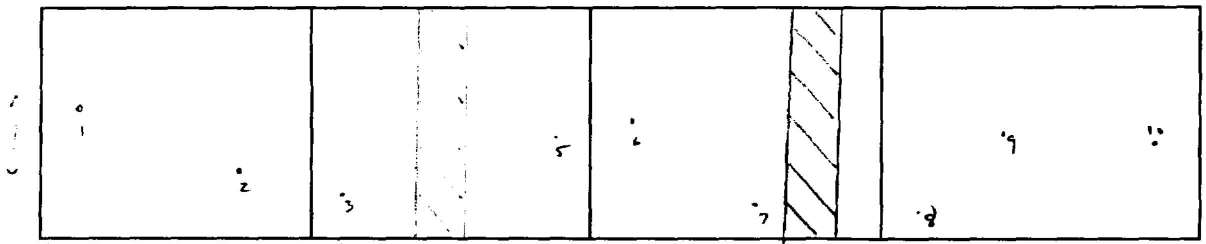
Survey Unit # 12 Floor: G Room #: 21B

Surveyor: MJ, LM Date: 10/18/05

Meter: 2224-1 Serial #: 47744 Cal Date: 2/16/05

Detector: 43-68 Serial #: 216252

Unit Sketch



X1 [illegible] X2 [illegible] X3 [illegible] X4 [illegible]

Background CPM: 135 cpm (handheld)

Integrated Counts (30 seconds with 43-68)

Location 1: 74 Location 4: 85 Location 7: 72

Location 2: 61 Location 5: 71 Location 8: 79

Location 3: 76 Location 6: 72 Location 9: 64

Comments: Reference Room Location 10: 60

Approved: [signature] Date: 10/20/05

Radiation Safety Academy, Inc.

Appendix B – Survey Unit Smear Sample Results

All of the smear samples were analyzed by the Radiation Safety Academy, Inc. at their licensed analytical laboratory in Gaithersburg, Maryland. Gamma counting and LSC data are provided in this appendix.

Gamma Count

on JMU Samples

```
READY->? 2
***ERROR 61

READY->? A
PARAMETER GROUP   (1-99)     ->? 2
ID:NIH SWIPES
MODE 1

 1 LISTING          Y
 2 TIME             60
```

3	COUNTS 1	900000
4	COUNTS 2	900000
5	LCR COUNTS	0
6	LCR TIME	0
7	BACKGROUND 1	0
8	BACKGROUND 2	0
9	WINDOW 1	035-102
10	WINDOW 2	001-256
11	HALF LIFE 1	0
12	HALF LIFE 2	0
13	FACTOR 1	1
14	FACTOR 2	1
15	SUMMATION	N
16	REPLICATE	1
17	REPEAT	1
18	LABELS(1/2)	2
19	CODING	POS-CODE
20	PRINT	-1-3-4-6-7-8-11-12-13

POS	ETIME	CTIME	COUNTS1	CPM1	ERR1%	COUNTS2	CPM2	ERR2%
***ERROR 48								
001	0.02	60	46	46	14.7	448	448	4.7
***ERROR 48								
002	0.04	60	47	47	14.6	441	441	4.8
***ERROR 48								
003	0.06	60	32	32	17.7	426	426	4.8
***ERROR 48								

***ERROR 48

005	0.10	60	50	50	14.1	435	435	4.8

***ERROR 48

006	0.12	60	30	30	18.3	410	410	4.9

***ERROR 48

007	0.14	60	45	45	14.9	445	445	4.7

***ERROR 48

008	0.16	60	38	38	16.2	407	407	5.0

***ERROR 48

009	0.17	60	44	44	15.1	436	436	4.8

***ERROR 48

010	0.19	60	43	43	15.2	442	442	4.8

***ERROR 48

011	0.22	60	45	45	14.9	438	438	4.8

***ERROR 48

012	0.24	60	40	40	15.8	422	422	4.9

***ERROR 48

013	0.26	60	39	39	16.0	389	389	5.1

***ERROR 48

014	0.28	60	40	40	15.8	398	398	5.0

***ERROR 48

015	0.30	60	36	36	16.7	447	447	4.7

***ERROR 48

016	0.32	60	45	45	14.9	432	432	4.8

***ERROR 48

017	0.34	60	44	44	15.1	452	452	4.7

***ERROR 48								
018	0.36	60	48	48	14.4	441	441	4.8
***ERROR 48								
019	0.38	60	39	39	16.0	424	424	4.9
***ERROR 48								
020	0.40	60	47	47	14.6	436	436	4.8
***ERROR 48								
021	0.42	60	40	40	15.8	413	413	4.9
***ERROR 48								
022	0.44	60	40	40	15.8	447	447	4.7
***ERROR 48								
023	0.46	60	46	46	14.7	415	415	4.9
***ERROR 48								
024	0.48	60	32	32	17.7	410	410	4.9
***ERROR 48								
025	0.50	60	45	45	14.9	445	445	4.7
***ERROR 48								
026	0.52	60	33	33	17.4	431	431	4.8
***ERROR 48								
027	0.54	60	41	41	15.6	442	442	4.8
***ERROR 48								
028	0.56	60	43	43	15.2	414	414	4.9
***ERROR 48								
029	0.58	60	36	36	16.7	429	429	4.8
***ERROR 48								
030	0.60	60	55	55	13.5	438	438	4.8
***ERROR 48								
031	0.63	60	37	37	16.4	454	454	4.7
***ERROR 48								
032	0.65	60	42	42	15.4	430	430	4.8
***ERROR 48								
033	0.67	60	40	40	15.8	482	482	4.6
***ERROR 48								

045	0.91	60	29	29	18.6	458	458	[illegible]
***ERROR 48								
046	0.93	60	50	50	14.1	426	426	4.8
***ERROR 48								
047	0.95	60	49	49	[illegible]	434	434	[illegible]
***ERROR 48								
048	0.97	60	37	37	16.4	427	427	4.8
***ERROR 48								
049	0.99	60	[illegible]	[illegible]	[illegible]	412	[illegible]	[illegible]
***ERROR 48								
050	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	466	4.6
***ERROR 48								
[illegible]	[illegible]	60	[illegible]	[illegible]	18.3	408	408	5.0
***ERROR 48								
[illegible]	[illegible]	[illegible]	45	45	14.9	440	440	4.8
***ERROR 48								
[illegible]	1.08	60	40	40	15.8	420	420	4.9
***ERROR 48								
054	1.10	60	36	36	16.7	440	440	4.8
***ERROR 48								
055	1.12	60	37	37	16.4	414	414	4.9
***ERROR 48								
056	1.14	60	42	42	15.4	434	434	4.8
***ERROR 48								
057	1.15	60	39	39	16.0	452	452	4.7
***ERROR 48								
058	1.17	60	38	38	16.2	453	453	4.7
***ERROR 48								
059	1.19	60	40	40	15.8	438	438	4.8
***ERROR 48								
060	1.21	60	43	43	15.2	444	444	4.7
***ERROR 48								
061	1.24	60	32	32	17.7	418	418	4.9
***ERROR 48								
062	1.26	60	41	41	15.6	451	451	4.7
***ERROR 48								
063	1.28	60	41	41	15.6	426	426	4.8
***ERROR 48								

```
***ERROR 48
065      1.32      60        33        33   17.4      441      441    4.8
***ERROR 48
066      1.34      60        43        43   15.2      455      455    4.7
***ERROR 48
067      1.36      60        43        43   15.2      443      443    4.8
***ERROR 48
068      1.38      60        41        41   15.6      431      431    4.8
***ERROR 48
069      1.40      60        51        51   14.0      440      440    4.8
***ERROR 48
070      1.42      60        44        44   15.1      417      417    4.9


***ERROR 48
071      1.44      60        35        35   16.9      447      447    4.7
***ERROR 48
072      1.46      60        43        43   15.2      406      406    5.0
```

```
***ERROR 48
073     1.48    60      47      47   14.6     437     437    4.8
***ERROR 48
074     1.50    60      34      34   17.1     403     403    5.0
***ERROR 48
075     1.52    60      58      58   13.1     437     437    4.8
***ERROR 48
076     1.54    60      40      40   15.8     467     467    4.6
***ERROR 48
077     1.56    60      46      46   14.7     434     434    4.8
***ERROR 48
078     1.58    60      47      47   14.6     441     441    4.8
***ERROR 48
079     1.60    60      48      48   14.4     469     469    4.6
***ERROR 48
080     1.62    60      39      39   16.0     413     413    4.9


***ERROR 48
081     1.65    60      47      47   14.6     447     447    4.7
***ERROR 48
082     1.67    60      45      45   14.9     423     423    4.9
***ERROR 48
083     1.69    60      48      48   14.4     432     432    4.8
***ERROR 48
084     1.71    60      48      48   14.4     427     427    4.8
***ERROR 48
085     1.73    60      36      36   16.7     429     429    4.8
***ERROR 48
086     1.75    60      41      41   15.6     447     447    4.7
***ERROR 48
087     1.77    60      39      39   16.0     431     431    4.8
***ERROR 48
088     1.79    60      47      47   14.6     457     457    4.7
***ERROR 48
089     1.81    60      39      39   16.0     435     435    4.8
***ERROR 48
090     1.83    60      37      37   16.4     451     451    4.7


***ERROR 48
091     1.85    60      39      39   16.0     438     438    4.8
***ERROR 48
092     1.87    60      44      44   15.1     436     436    4.8
***ERROR 48
093     1.89    60      42      42   15.4     432     432    4.8
***ERROR 48
```

***ERROR 48

095	1.93	60	34	34	17.1	437	437	4.8

***ERROR 48

096	1.95	60	49	49	14.3	430	430	4.8

***ERROR 48

097	1.97	60	44	44	15.1	453	453	4.7

***ERROR 48

098	1.99	60	51	51	14.0	476	476	4.6

***ERROR 48

099	2.01	60	48	48	14.4	419	419	4.9

***ERROR 48

100	2.03	60	33	33	17.4	375	375	5.2

***ERROR 48								
101	2.06	60	37	37	16.4	403	403	5.0
***ERROR 48								
102	2.08	60	50	50	14.1	448	448	4.7
***ERROR 48								
103	2.10	60	41	41	15.6	423	423	4.9
***ERROR 48								
104	2.12	60	37	37	16.4	446	446	4.7
***ERROR 48								
105	2.13	60	33	33	17.4	434	434	4.8
***ERROR 48								
106	2.15	60	46	46	14.7	436	436	4.8
***ERROR 48								
107	2.17	60	39	39	16.0	423	423	4.9
***ERROR 48								
108	2.19	60	36	36	16.7	421	421	4.9
***ERROR 48								
109	2.21	60	42	42	15.4	425	425	4.9
***ERROR 48								
110	2.23	60	47	47	14.6	423	423	4.9
***ERROR 48								
111	2.26	60	41	41	15.6	507	507	4.4
***ERROR 48								
112	2.28	60	48	48	14.4	431	431	4.8
***ERROR 48								
113	2.30	60	42	42	15.4	433	433	4.8
***ERROR 48								
114	2.32	60	37	37	16.4	433	433	4.8
***ERROR 48								
115	2.34	60	44	44	15.1	411	411	4.9
***ERROR 48								
116	2.36	60	28	28	18.9	444	444	4.7

*END OF ASSAY

LSC - JMU Samples

I : GENERAL SWIPES 12 OCT 2005 17:30
ER: 1 COMMENT:
UNT TIME : 1.00
TA CALC : DL DPM H# :YES SAMPLE REPEATS: 1 PRINTER :EDIT
UNT BLANK : NO ID# : NO REPLICATES : 1 RS232 : OFF
D PHASE : NO ADC :YES CYCLE REPEATS : 1 1 [illegible] : OFF
INTILLATOR: LIQUID LUMEX: NO LOW SAMPLE REJ: 0
W LEVEL : NO HALF LIFE CORRECTION DATE: none

OTOPE 1: 3H %ERROR: 0.01 FACTOR: 1.000000 BKG. SUB: 0
OTOPE 2: 14C %ERROR: 0.01 FACTOR: 1.000000 BKG. SUB: 0
DE OPEN WINDOW %ERROR: 0.00 FACTOR: 1.000000 BKG. SUB: 0

CKGROUND QUENCH CURVE: Off COLOR QUENCH CORRECTION: Off

ench Limits Low:29.581 High:366.56

M O	POS	TIME MIN	H#	ISO	CORRECTED CPM	%ERROR	DPM	EFF-1	EFF-2	RATIO	LUMEX %	ELAPSED TIME
1	**-1	1.00	111.4	3H	6.00	70.71	13.71	34.00	0.63	0.726	1.09	1.64
				14C	14.00	53.45	18.89	17.67	73.65			
				WIDE	34.00	34.30						
2	**-2	1.00	114.5	[illegible]	[illegible]	[illegible]	19.20	[illegible]	0.63	1.297	0.95	3.25
				14C	11.00	60.30	14.80	17.64	73.51			
				WIDE	29.00	37.14						
3	**-3	1.00	118.6	3H	9.00	66.67	15.99	32.40	0.64	0.738	1.05	4.98
				14C	15.00	50.00	21.68	17.61	73.34			
				WIDE	32.00	35.36						
4	**-4	1.00	115.3	3H	8.00	70.71	21.35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				14C	4.00	100.00	5.26	17.64	73.46			
				WIDE	19.00	45.88						
5	**-5	1.00	114.0	3H	9.00	66.67	19.12	33.42	0.63	1.292	1.02	8.28
				14C	11.00	60.30	14.79	17.65	73.54			
				WIDE	25.00	40.00						
6	**-6	1.00	114.4	3H	7.00	75.59	16.03	33.33	0.63	1.709	1.35	9.94
				14C	7.00	75.59	9.38	17.65	73.52			
				WIDE	21.00	43.64						
7	**-7	1.00	118.1	3H	8.00	70.71	15.08	32.51	0.64	0.857	0.77	11.57
				14C	13.00	55.47	17.59	17.62	73.36			
				WIDE	33.00	34.82						
8	**-8	1.00	118.3	3H	8.00	70.71	15.83	32.48	0.64	0.976	0.90	13.19
				14C	12.00	57.74	16.22	17.62	73.35			
				WIDE	27.00	38.49						
9	**-9	1.00	117.3	3H	9.00	66.67	20.28	32.69	0.64	1.508	0.97	14.93
				14C	10.00	63.25	13.45	17.62	73.39			
				WIDE	24.00	40.82						
0	**-10	1.00	122.7	3H	7.00	75.59	14.66	31.51	0.65	1.083	1.13	16.54
				14C	10.00	[illegible]	13.54	[illegible]	[illegible]			
				WIDE	22.00	42.64						
1	**-11	1.00	112.6	3H	6.00	81.65	11.44	33.74	0.63	0.943	0.87	18.28
				14C	9.00	66.67	12.13	17.66	73.60			
				WIDE	23.00	41.70						
2	**-12	1.00	111.5	3H	4.00	100.00	5.44	33.98	0.63	0.447	0.90	20.01
				14C	9.00	66.67	12.17	17.68	73.65			
				WIDE	22.00	42.64						
3	**-13	1.00	111.5	3H	6.00	81.65	9.23	33.98	0.63	0.569	0.79	21.76
				14C	12.00	57.74	16.21	[illegible]	73.65			
				WIDE	26.00	39.22						

AM IO	POS	TIME MIN	H#	ISO	CORRECTED CPM	%ERROR	DPM	EFF-1	EFF-2	RATIO	LUMEX %	ELAPSED TIME
4	**-14	1.00	109.2	3H	6.00	81.65	**11.90**	34.47	0.63	1.107	0.98	23.37
				14C	6.00	70.71	**10.75**	17.68	73.74			
				WIDE	22.00	42.64						
5	**-15	1.00	111.0	3H	12.00	57.74	**29.01**	34.08	0.63	2.4[illegible]	0.60	25.[illegible]
				14C	9.00	66.67	**11.97**	17.67	73.67			
				WIDE	29.00	37.80						
6	**-16	1.00	112.9	3H	3.00	115.47	**1.08**	33.68	0.63	0.072	0.78	26.76
				14C	11.00	60.30	**14.94**	17.66	73.59			
				WIDE	25.00	40.00						
7	**-17	1.00	112.8	3H	5.00	66.67	**21.12**	33.68	0.63	1.975	0.83	28.50
				14C	8.00	70.71	**10.69**	17.66	73.59			
				WIDE	23.00	41.70						
8	**-18	1.00	114.8	3H	9.00	66.67	**24.30**	33.23	0.63	4.645	1.04	30.12
				14C	4.00	100.00	**5.23**	17.64	73.50			
				WIDE	26.00	39.22						
9	**-1	1.00	114.1	3H	3.00	115.47	**2.53**	33.40	0.63	0.207	0.84	31.98
				14C	9.00	66.67	**12.22**	17.6[illegible]	73.5[illegible]			
				WIDE	19.00	45.88						
0	**-2	1.00	111.0	3H	11.00	60.30	**24.65**	34.08	0.63	1.674	0.59	33.71
				14C	11.00	60.30	**14.72**	17.67	73.67			
				WIDE	27.00	38.49						
1	**-3	1.00	112.0	3H	11.00	60.30	**26.93**	33.67	0.63	2.533	0.66	35.34
				14C	8.00	70.71	**10.63**	17.66	73.63			
				WIDE	26.00	39.22						
2	**-4	1.00	107.7	3H	11.00	60.30	**19.98**	34.82	0.63	0.874	0.43	37.06
				14C	17.00	48.51	**22.86**	17.69	73.81			
				WIDE	44.00	30.15						
3	**-5	1.00	111.2	3H	6.00	81.65	**9.22**	34.03	0.63	0.569	0.94	38.70
				14C	[illegible]	57.74	**16.21**	17.67	73.65			
				WIDE	21.00	43.64						
4	**-6	1.00	111.6	3H	5.00	89.44	**5.57**	33.96	0.63	0.316	0.56	40.32
				14C	13.00	55.47	**17.61**	17.66	73.64			
				WIDE	29.00	37.14						
5	**-7	1.00	115.4	3H	8.00	70.71	**14.81**	33.11	0.64	0.843	0.58	41.96
				14C	13.00	55.47	**17.56**	[illegible]	[illegible]			
				WIDE	29.00	37.14						
6	**-8	1.00	111.4	3H	5.00	89.44	**6.98**	33.99	0.63	0.469	0.75	43.57
				14C	11.00	60.30	**14.88**	17.67	73.65			
				WIDE	24.00	40.82						
7	**-9	1.00	115.0	3H	6.00	81.65	**7.26**	33.20	0.63	0.357	0.59	45.22
				14C	15.00	51.64	**20.35**	17.64	73.50			
				WIDE	29.00	37.14						
8	**-10	1.00	113.4	3H	7.00	75.59	**12.34**	33.54	0.63	0.761	0.66	46.94
				14C	12.00	57.74	**16.21**	17.65	73.56			
				WIDE	26.00	39.22						
9	**-11	1.00	122.7	3H	7.00	75.59	**13.89**	31.52	0.65	0.93[illegible]	0.93	48.57
				14C	11.00	60.30	**14.91**	17.58	73.16			
				WIDE	21.00	[illegible]						
0	**-12	1.00	126.3	3H	5.00	89.44	**9.28**	30.74	0.65	0.75[illegible]	0.93	50.19
				14C	9.00	66.67	**12.25**	17.54	72.99			
				WIDE	22.00	42.64						
1	**-13	1.00	115.3	3H	5.00	89.44	**7.15**	33.14	0.64	0.480	0.87	51.84
				14C	11.00	60.30	**14.91**	17.64	73.48			
				WIDE	23.00	[illegible]						
2	**-14	1.00	115.6	3H	8.00	70.71	**14.19**	32.85	0.64	[illegible]	0.71	53.45
				14C	14.00	53.45	**18.94**	17.63	73.42			
				WIDE	30.00	[illegible]						

NUM NO	POS	TIME MIN	H#	ISO	CORRECTED CPM	%ERROR	DPM	EFF-1	EFF-2	RATIO	LUMEX %	ELAPSED TIME
3	**-15	1.00	114.0	3H	7.00	75.59	**12.39**	33.41	0.63	0.764	0.78	55.09
				14C	12.00	57.74	**16.21**	17.65	73.54			
				WIDE	29.00	37.14						
4	**-16	1.00	114.2	3H	8.00	70.71	**15.41**	33.38	0.63	0.952	0.80	56.83
				14C	12.00	57.74	**16.19**	17.65	73.53			
				WIDE	27.00	38.49						
5	**-17	1.00	118.3	3H	2.00	141.42	**1.73**	32.46	0.64	0.212	1.39	58.47
				14C	6.00	81.65	**8.17**	17.62	73.35			
				WIDE	17.00	48.51						
6	**-18	1.00	115.7	3H	14.00	53.45	**36.74**	33.03	0.64	3.475	0.50	60.09
				14C	8.00	70.71	**10.57**	17.64	73.46			
				WIDE	39.00	32.03						
7	**-1	1.00	115.8	3H	7.00	75.59	**13.62**	32.15	0.64	0.915	0.80	61.94
				14C	11.00	60.30	**14.89**	17.60	73.28			
				WIDE	26.00	39.22						
8	**-2	1.00	114.9	3H	5.00	89.44	**5.69**	33.21	0.63	0.322	0.58	63.57
				14C	13.00	55.47	**17.64**	17.64	73.50			
				WIDE	30.00	36.51						
9	**-3	1.00	112.6	3H	9.00	66.67	**21.81**	33.72	0.63	2.339	0.73	65.20
				14C	7.00	75.59	**9.32**	17.66	73.60			
				WIDE	24.00	40.82						
0	**-4	1.00	113.7	3H	1.00	200.00	**-2.04**	33.47	0.63	-0.214	0.85	66.93
				14C	7.00	75.59	**9.54**	17.65	73.55			
				WIDE	17.00	48.51						
1	**-5	1.00	113.5	3H	6.00	81.65	**12.94**	33.53	0.63	1.376	0.65	68.57
				14C	7.00	75.59	**9.40**	17.65	73.56			
				WIDE	22.00	42.64						
2	**-6	1.00	114.5	3H	8.00	70.71	**17.62**	33.30	0.63	1.457	0.59	70.19
				14C	9.00	66.67	**12.09**	17.64	73.51			
				WIDE	[illegible]	40.82						
3	**-7	1.00	113.5	3H	10.00	63.25	**19.90**	33.52	0.63	1.055	0.50	71.92
				14C	14.00	53.45	**18.86**	17.65	73.56			
				WIDE	32.00	35.36						
4	**-8	1.00	111.6	3H	4.00	100.00	**3.32**	33.94	0.63	0.204	0.60	73.64
				14C	12.00	57.74	**16.27**	17.66	73.64			
				WIDE	25.00	40.00						
5	**-9	1.00	117.6	3H	4.00	100.00	**6.40**	32.63	0.64	0.590	0.93	75.39
				14C	8.00	70.71	**10.85**	17.62	73.38			
				WIDE	17.00	48.51						
6	**-10	1.00	119.0	3H	9.00	66.67	**22.01**	32.31	0.64	2.053	0.71	77.00
				14C	8.00	70.71	**10.72**	17.61	73.32			
				WIDE	25.00	40.00						
7	**-11	1.00	127.4	3H	8.00	70.71	**15.27**	30.50	0.65	0.802	0.45	78.75
				14C	14.00	53.45	**19.06**	17.53	72.94			
				WIDE	38.00	32.44						
8	**-12	1.00	121.9	3H	3.00	115.47	**4.18**	31.68	0.64	0.439	0.76	80.47
				14C	7.00	75.59	**9.53**	17.59	73.19			
				WIDE	24.00	40.82						
9	**-13	1.00	119.5	3H	9.00	66.67	**18.34**	32.20	0.64	1.043	0.55	82.10
				14C	13.00	55.47	**17.58**	17.61	73.30			
				WIDE	29.00	37.14						
0	**-14	1.00	115.6	3H	7.00	75.59	**13.98**	33.06	0.64	1.036	0.47	83.82
				14C	10.00	63.25	**13.49**	17.64	73.47			
				WIDE	29.00	37.14						
1	**-15	1.00	115.5	3H	6.00	81.65	**12.47**	32.86	0.64	[illegible]	0.72	85.47
				14C	8.00	70.71	**10.79**	17.63	73.43			
				WIDE	22.00	42.64						

NO	POS	TIME MIN	H#	ISO	CORRECTED CPM	%ERROR	DPM	EFF-1	EFF-2	RATIO	LUMEX %	ELAPSED TIME
2	**-16	1.00	115.8	3H	4.00	100.00	7.79	33.02	0.64	0.961	1.12	87.09
				14C	6.00	81.65	8.10	17.64	73.46			
				WIDE	14.00	53.45						
3	**-17	1.00	119.6	3H	3.00	115.47	3.37	32.18	0.64	0.309	1.08	88.74
				14C	8.00	70.71	10.89	17.61	73.29			
				WIDE	20.00	44.72						
4	**-18	1.00	115.3	3H	5.00	89.44	9.34	33.13	0.64	0.864	1.13	90.36
				14C	8.00	70.71	10.81	17.64	73.48			
				WIDE	21.00	43.64						
5	**-1	1.00	114.8	3H	8.00	70.71	16.20	33.25	0.63	[illegible]	0.75	92.21
				14C	11.00	60.30	14.83	17.64	73.50			
				WIDE	28.00	37.80						
6	**-2	1.00	116.9	3H	4.00	100.00	8.58	32.77	0.64	[illegible]	1.28	93.84
				14C	5.00	89.44	6.74	17.63	73.41			
				WIDE	15.00	51.64						
7	**-3	1.00	111.6	3H	12.00	57.74	31.96	33.95	0.63	4.904	0.57	95.58
				14C	5.00	89.44	6.52	17.66	73.64			
				WIDE	25.00	40.00						
8	**-4	1.00	114.5	3H	6.00	81.65	10.86	33.31	0.63	0.804	0.79	97.31
				14C	10.00	63.25	13.51	17.65	73.52			
				WIDE	24.00	40.82						
9	**-5	1.00	120.6	3H	3.00	115.47	1.88	31.97	0.64	0.138	1.18	99.04
				14C	10.00	63.25	13.64	17.60	73.25			
				WIDE	19.00	45.88						
0	**-6	1.00	115.4	3H	6.00	81.65	10.92	33.12	0.64	0.808	0.77	100.67
				14C	10.00	63.25	13.51	17.64	73.48			
				WIDE	25.00	40.00						
1	**-7	1.00	119.5	3H	5.00	89.44	9.60	32.21	0.64	0.887	0.86	102.39
				14C	8.00	70.71	10.83	17.61	73.30			
				WIDE	23.00	41.70						
	**-8	1.00	119.6	3H	5.00	89.44	7.36	32.19	0.64	0.493	0.85	104.02
				14C	11.00	60.30	14.94	17.61	73.29			
				WIDE	24.00	40.82						
3	**-9	1.00	117.5	3H	8.00	70.71	20.18	32.65	0.64	2.523	0.97	105.76
				14C	6.00	81.65	8.00	17.62	73.39			
				WIDE	20.00	44.72						
4	**-10	1.00	[illegible]	3H	8.00	70.71	18.72	32.63	0.64	1.743	0.83	107.48
				14C	8.00	70.71	10.74	17.62	73.38			
				WIDE	24.00	40.82						
5	**-11	1.00	119.9	3H	10.00	63.25	24.51	32.13	0.64	2.031	0.81	109.23
				14C	9.00	66.67	12.07	17.60	73.28			
				WIDE	27.00	38.49						
6	**-12	1.00	120.6	3H	2.00	141.42	-1.27	31.96	0.64	[illegible]	0.80	110.84
				14C	10.00	63.25	13.66	17.60	73.25			
				WIDE	24.00	40.82						
7	**-13	1.00	121.8	3H	9.00	66.67	20.15	31.71	0.64	1.357	0.77	112.49
				14C	11.00	60.30	14.85	17.59	73.19			
				WIDE	28.00	37.80						
8	**-14	1.00	125.7	3H	4.00	100.00	1.29	30.86	0.65	0.063	0.54	[illegible]
				14C	15.00	51.64	20.53	17.55	73.02			
				WIDE	32.00	35.36						
9	**-15	1.00	119.1	3H	4.00	100.00	2.73	32.29	0.64	0.154	0.72	115.86
				14C	13.00	55.47	17.71	17.61	73.31			
				WIDE	28.00	37.80						
0	**-16	1.00	119.2	3H	6.00	81.65	8.96	32.27	[illegible]	[illegible]	[illegible]	[illegible]
				14C	[illegible]	55.47	17.66	[illegible]	[illegible]			
				WIDE	27.00	[illegible]						

HM ID	POS	TIME MIN	H#	ISO	CORRECTED CPM	%ERROR	DPM	EFF-1	EFF-2	RATIO	LUMEX %	ELAPSED TIME
1	**-[illegible]	1.00	117.2	3H	11.00	60.30	26.40	32.72	0.64	1.971	0.59	[illegible]
				14C	10.00	63.25	13.39	17.63	73.40			
				WIDE	30.00	36.51						
2	**-18	1.00	115.7	3H	7.00	75.59	16.17	33.05	0.64	1.722	0.83	120.85
				14C	7.00	75.59	9.39	17.64	73.47			
				WIDE	22.00	41.70						
3	**-1	1.00	116.5	3H	8.00	70.71	19.58	32.42	0.64	2.089	0.77	122.60
				14C	7.00	75.59	9.37	17.61	73.34			
				WIDE	26.00	39.22						
4	**-2	1.00	114.9	3H	2.00	141.42	-0.49	33.21	0.63	-0.040	1.26	124.22
				14C	9.00	66.67	12.25	17.64	73.50			
				WIDE	18.00	47.14						
5	**-3	1.00	115.2	3H	7.00	75.59	14.03	32.94	0.64	1.040	1.14	125.87
				14C	10.00	63.25	13.49	17.63	73.44			
				WIDE	18.00	47.14						
6	**-4	1.00	115.1	3H	6.00	81.65	10.17	33.17	0.64	0.684	0.89	127.59
				14C	11.00	60.30	14.88	17.64	73.49			
				WIDE	24.00	40.82						
7	**-5	1.00	117.3	3H	8.00	70.71	17.95	32.68	0.64	1.482	0.91	129.22
				14C	9.00	66.67	12.11	17.62	73.39			
				WIDE	25.00	40.00						
8	**-6	1.00	116.1	3H	6.00	81.65	8.04	32.96	0.64	0.423	0.92	130.85
				14C	14.00	53.45	18.99	17.63	73.45			
				WIDE	31.00	35.92						
9	**-7	1.00	117.3	3H	9.00	66.67	19.54	[illegible]	0.64	1.318	0.65	132.49
				14C	11.00	60.30	14.82	17.62	73.40			
				WIDE	33.00	34.82						
0	**-8	1.00	115.5	3H	12.00	57.74	30.61	33.08	0.64	2.881	0.78	134.23
				14C	8.00	70.71	10.62	17.64	73.47			
				WIDE	33.00	34.82						
1	**-9	1.00	120.2	3H	9.00	66.67	22.94	32.05	0.64	2.453	1.02	135.86
				14C	7.00	75.59	9.35	17.60	73.27			
				WIDE	25.00	40.00						
2	**-10	1.00	120.3	3H	10.00	63.25	27.61	32.02	0.64	4.194	0.97	137.49
				14C	5.00	89.44	6.58	17.50	73.26			
				WIDE	24.00	40.82						
3	**-11	1.00	120.7	3H	6.00	81.65	6.78	31.94	0.64	0.311	0.67	139.23
				14C	16.00	50.00	21.79	17.60	73.24			
				WIDE	32.00	35.36						
4	**-12	1.00	119.1	3H	7.00	75.59	13.55	32.30	0.64	0.911	0.83	140.85
				14C	11.00	60.30	14.89	17.61	73.32			
				WIDE	26.00	39.22						
5	**-13	1.00	115.6	3H	8.00	70.71	17.74	33.06	0.64	1.467	1.10	142.49
				14C	9.00	66.67	12.10	17.64	73.47			
				WIDE	22.00	42.64						
6	**-14	1.00	109.1	3H	4.00	100.00	1.87	34.50	0.63	0.099	0.71	144.21
				14C	14.00	53.45	18.97	17.68	73.75			
				WIDE	29.00	37.14						
7	**-15	1.00	123.0	3H	8.00	70.71	17.89	31.45	0.65	1.323	1.06	145.85
				14C	10.00	63.25	13.51	17.58	73.14			
				WIDE	21.00	43.64						
8	**-16	1.00	113.2	3H	9.00	66.67	16.87	33.58	0.63	0.893	0.71	147.47
				14C	14.00	53.45	18.88	17.65	73.57			
				WIDE	32.00	35.36						
9	**-17	1.00	114.2	3H	9.00	66.67	20.60	33.36	0.63	1.707	0.86	149.21
				14C	9.00	66.67	12.06	[illegible]	73.52			
				WIDE	25.00	40.00						

?M NO	POS	TIME MIN	H#	ISO	CORRECTED CPM	%ERROR	DPM	EFF-1	EFF-2	RATIO	LUMEX %	ELAPSED TIME
0	**-1[illegible]	1.00	114.3	3H	10.00	63.25	27.22	33.36	0.63	5.229	0.99	150.92
				14C	4.00	100.00	5.21	17.65	73.53			
				WIDE	24.00	40.82						
1	**-1	1.00	113.6	3H	5.00	89.44	6.36	33.50	0.63	0.391	0.73	152.69
				14C	12.00	57.74	16.26	17.65	73.55			
				WIDE	24.00	40.82						
2	**-2	1.00	114.4	3H	8.00	70.71	19.78	33.32	0.63	2.475	0.71	[illegible]
				14C	6.00	81.65	7.99	17.65	73.52			
				WIDE	24.00	40.82						
3	**-3	1.00	119.2	3H	5.00	89.44	8.09	32.27	0.64	0.596	0.75	156.06
				14C	10.00	63.25	13.57	17.51	73.31			
				WIDE	22.00	42.64						
4	**-4	1.00	112.5	3H	13.00	55.47	32.27	33.75	0.63	2.700	0.68	157.78
				14C	9.00	66.67	11.95	17.66	73.60			
				WIDE	25.00	40.00						
5	**-5	1.00	116.2	3H	7.00	75.59	12.56	32.94	0.64	0.774	0.60	159.52
				14C	12.00	57.74	16.23	17.63	73.44			
				WIDE	26.00	39.22						
6	**-6	1.00	115.1	3H	4.00	100.00	4.12	33.18	0.64	0.276	0.70	161.13
				14C	11.00	60.30	14.93	17.64	73.49			
				WIDE	25.00	40.00						
7	**-7	1.00	112.7	3H	6.00	81.65	15.03	33.69	0.63	2.832	1.22	162.88
				14C	4.00	100.00	5.31	17.66	73.59			
				WIDE	16.00	50.00						
8	**-8	1.00	120.2	3H	6.00	81.65	7.51	32.05	0.64	0.368	0.59	164.61
				14C	15.00	51.64	20.41	17.60	73.26			
				WIDE	30.00	36.51						
9	**-9	1.00	115.1	3H	5.00	89.44	10.78	33.18	0.63	1.335	0.98	166.34
				14C	6.00	81.65	8.07	17.64	73.49			
				WIDE	17.00	48.51						
0	**-10	1.00	112.9	3H	4.00	100.00	1.91	33.67	0.63	0.101	0.56	168.08
				14C	14.00	53.45	19.01	17.66	73.54			
				WIDE	28.00	37.80						
MISSING SAMPLE												
2	**-12	1.00	130.6	3H	8.00	70.71	17.26	29.80	0.66	1.057	1.54	169.72
				14C	12.00	57.74	16.33	17.49	72.79			
				WIDE	28.00	37.80						
3	**-13	1.00	116.2	3H	8.00	70.71	13.42	32.94	0.64	0.661	0.86	171.35
				14C	15.00	51.64	20.31	17.63	73.44			
				WIDE	31.00	35.92						
4	**-14	1.00	121.3	3H	8.00	70.71	20.72	31.81	0.64	2.586	0.84	173.09
				14C	6.00	81.65	8.01	17.59	73.22			
				WIDE	21.00	43.64						
5	**-15	1.00	163.9	3H	4.00	100.00	5.08	22.92	0.72	0.302	1.10	174.70
				14C	12.00	57.74	16.85	16.83	[illegible]			
				WIDE	25.00	40.00						
6	**-16	1.00	112.2	3H	10.00	63.25	23.30	33.81	0.63	1.937	0.69	176.46
				14C	9.00	66.67	12.03	17.66	73.61			
				WIDE	29.00	37.14						
7	**-17	1.00	133.3	3H	8.00	70.71	18.43	29.22	0.66	1.231	0.70	178.09
				14C	11.00	60.30	14.97	17.46	72.66			
				WIDE	24.00	40.82						
8	**-18	1.00	112.8	3H	9.00	66.67	21.84	33.67	0.63	2.342	0.60	179.83
				14C	7.00	75.59	9.32	17.66	73.59			
				WIDE	25.00	40.00						

MISSING SAMPLE

M IO	POS	TIME MIN	H#	ISO	CORRECTED CPM	%ERROR	DPM	EFF-1	EFF-2	RATIO	LUMEX %	ELAPSED TIME
0	**-2	1.00	125.8	3H	11.00	60.30	**30.38**	30.82	0.65	3.260	0.58	181.68
				14C	7.00	75.59	**9.32**	17.55	73.01			
				WIDE	30.00	36.51						
1	**-3	1.00	120.3	3H	[illegible]	38.49	**34.96**	32.03	0.64	0.389	0.29	183.43
				14C	66.00	24.62	**89.78**	17.60	73.26			
				WIDE	121.00	18.18						
2	**-4	1.00	120.7	3H	7.00	75.59	**18.24**	31.95	0.64	2.736	0.71	185.16
				14C	5.00	89.44	**6.67**	17.60	73.24			
				WIDE	25.00	40.00						
3	**-5	1.00	122.1	3H	7.00	75.59	**13.84**	[illegible]	[illegible]	0.928	0.59	186.7[illegible]
				14C	11.00	60.30	**14.91**	17.58	73.18			
				WIDE	34.00	34.30						
4	**-6	1.00	119.1	3H	2.00	141.42	**0.24**	32.20	0.64	0.022	0.97	188.42
				14C	8.00	70.71	**10.91**	17.61	73.32			
				WIDE	18.00	47.14						
MISSING SAMPLE												
6	**-8	1.00	112.8	3H	13.00	55.47	**32.33**	33.69	0.63	2.705	0.49	190.07
				14C	9.00	66.67	**11.95**	17.66	73.59			
				WIDE	35.00	33.81						

- **Appendix C –Instrument Calibration Certificates and Quality Control Sheets**

162850 2224/43-32
161685

RADIATION DETECTOR QUALITY CONTROL SHEET

H_2 { 187275
216244

} 2224-1/43-68

H_1 { 187244
216252

Meter Model: ____________ Meter Serial #: ____________

Detector Model: ____________ Detector Serial #: ____________

Operating Voltage (V): 500 Background (cpm): 100/350 Check Source (cpm): 4200

Calibration Date: 2/16/05

	Date	Battery	Audio	Background (cpm)	Check Source (cpm)	Initials	Comments
H_1	10/18	✓	✓	β 133 / 1 α	4243	MT	Hand-held
H_2	10/18	✓	✓	β 107 / 2 α	4197	MT	Hand-held
F	10/18	✓	✓	β 345 / 4 α	4235	MT	Floor Monitor

Designer and Manufacturer of Scientific and Industrial Instruments

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.
POST OFFICE BOX 810 PH. 325-235-5494
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

CUSTOMER RADIATION SAFETY ACADEMY ORDER NO. 230061

Mfg. Ludlum Measurements, Inc. Model 2224 Serial No. 162850

Mfg. Ludlum Measurements, Inc. Model 43-37 Serial No. PR161685

Cal. Date 16-Feb-05 Cal Due Date 16-Feb-06 Cal. Interval 1 Year Meterface 202-783

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 70 °F RH 29 % Alt 706.8 mm Hg

☑ New Instrument Instrument Received ☐ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☑ Mechanical ck. ☑ Meter Zeroed ☐ Background Subtract ☐ Input Sens. Linearity
☑ F/S Resp. ck ☑ Reset ck. ☑ Window Operation ☑ Geotropism
☑ Audio ck. ☐ Alarm Setting ck. ☑ Batt. ck. (Min. Volt) 2.2 VDC

☐ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89. ☑ Calibrated in accordance with LMI SOP 14.9 rev 02/07/97.

Instrument Volt Set 1675 V Input Sens. Comment mV Det. Oper. 1675 V at Comment mV Threshold Dial Ratio ______ = ______ mV

☑ HV Readout (2 points) Ref./Inst. 500 / 509 V Ref./Inst. 2000 / 1996 V

COMMENTS:

```
Alpha sensitivity = 120mV
 Beta sensitivity =   4mV
     Beta window =  40mV
  Firmware number = 390063
Calibrated using 6 ft. cable.
Overload function was checked but not set.
```

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
X1000	400 K cpm		400
X1000	100 K cpm		100
X100	40 K cpm		400
X100	10 K cpm		100
X10	4 K cpm		400
X10	1 K cpm		100
X1	400cpm		400
X1	100cpm		100

*Uncertainty within ± 10% C.F. within ± 20% ALL Range(s) Calibrated Electronically

	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout	400 K cpm		40050 (1D)
	40 K cpm		4005
	4 K cpm		400
	400 cpm		40
	40 cpm		4

	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Log Scale			

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978. State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources:

Cs-137 Gamma S/N ☐ 1162 ☐ G112 ☐ M565 ☐ 5105 ☐ T1008 ☐ T879 ☐ E552 ☐ E551 ☐ 720 ☐ 734 ☐ 1616 ☐ Neutron Am-241 Be S/N T-304

☑ Alpha S/N #4337,Pu239 ☑ Beta S/N #918,Sr90y90*635/83,Tc99 ☐ Other

☑ m 500 S/N 196745 ☐ Oscilloscope S/N ☐ ☑ Multimeter S/N 82840194

Calibrated By: Eliot Chavez Date 16-FEB-05

Reviewed By: Gloria Orozco Date 17 Feb 05

FORM C22A 11/26/2003

AC Inst. Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed:

Designer and Manufacturer of Scientific and Industrial Instruments

LUDLUM MEASUREMENTS, INC.
POST OFFICE BOX 810 PH. 325-235-5494
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

Bench Test Data For Detector

Detector 43-37 Serial No. ~~PR 2~~ PR 161685 Order #. 230061

Customer RADIATION SAFETY ACADEMY Alpha Input Sensitivity 120 mV

Counter 2224 Serial No. 162850 Beta Input Sensitivity 4 mV

Count Time 1 Minute Beta Window 40 mV

Other Plateau w/ 6ft. cable. Distance Source to Detector Surface

High Voltage	Background Alpha	Background Beta	Isotope Pu239, Size 30,900 dpm Alpha	Pu239 Beta	Isotope Sr90/Y90, Size 109,165 dpm Alpha	Sr90/Y90 Beta	Isotope Tc99, Size 22,900 dpm Alpha	Tc99 Beta
1625	1	319	5485	867	2	22246	4	6794
1650	1	442	5808	959	3	27099	2	7518
1675	3	564	6071	1073	6	31178	7	7960
1700	1	624	6574	1193	33	34519	10	7861
1725	3	731	6899	1302	160	35897	40	7391

☐ Gas Proportional detector count rate decreased ≤ 10% after 15 hour static test using 39" cable.

☑ Gas proportional detector count rate decreased ≤ 10% after 5 hour static test using 39" cable and alpha/beta counter.

Signature Elias Chavez Date 16-FEB-05

FORM 04F 04/07/03

Designer and Manufacturer of Scientific and Industrial Instruments

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.
POST OFFICE BOX 810 PH. 325-235-5494
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

CUSTOMER RADIATION SAFETY ACADEMY ORDER NO. 230061

Mfg. Ludlum Measurements, Inc. Model 2224-1 Serial No. 187244

Mfg. Ludlum Measurements, Inc. Model 43-68 Serial No. PR190289

Cal. Date 16-Feb-05 Cal Due Date 16-Feb-06 Cal. Interval 1 Year Meterface 202-783

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 70 °F RH 29 % Alt 706.8 mm Hg

☑ New Instrument Instrument Received ☐ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☑ Mechanical ck. ☑ Meter Zeroed ☐ Background Subtract ☐ Input Sens. Linearity
☐ F/S Resp. ck ☑ Reset ck. ☑ Window Operation ☑ Geotropism
☑ Audio ck. ☐ Alarm Setting ck. ☑ Batt. ck. (Min. Volt) 2.2 VDC

☑ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89. ☐ Calibrated in accordance with LMI SOP 14.9 rev 02/07/97.

Instrument Volt Set 1575 V Input Sens. Comment mV Det. Oper. 1575 V at Comment mV Threshold Dial Ratio ____ = ____ mV

☑ HV Readout (2 points) Ref./Inst. 500 / ~~EL 420~~ 503 V Ref./Inst. 2000 / 1996 V

COMMENTS:

```
Alpha sensitivity = 120mV
 Beta sensitivity = 3.5mV
      Beta window =  40mV
  Firmware number = 390092
Overload function was checked but not set.
```

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
X1000	400kcpm		400
X1000	100kcpm		100
X100	40kcpm		400
X100	10kcpm		100
X10	4kcpm		400
X10	1kcpm		100
X1	400cpm		400
X1	100cpm		100

*Uncertainty within ± 10% C.F. within ± 20% ALL Range(s) Calibrated Electronically

	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*		REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
Digital Readout	400kcpm		40017 (0)	Log Scale			
	40kcpm		40020				
	4kcpm		4006				
	400cpm		40				
	40cpm		40				

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978. State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources:

Cs-137 Gamma S/N ☐ 1162 ☐ G112 ☐ M565 ☐ 5105 ☐ T1008 ☐ T879 ☐ E552 ☐ E551 ☐ 720 ☐ 734 ☐ 1616 ☐ Neutron Am-241 Be S/N T-304

☑ Alpha S/N 4337,Pu239 ☑ Beta S/N #918,Sr90y90*635/83,Tc99 ☐ Other

☑ m 500 S/N 196745 ☐ Oscilloscope S/N ☑ Multimeter S/N 82840194

Calibrated By: Eliso Chavez Date 16 FEB 05

Reviewed By: Gloria Orozco Date 17 Feb 05

FORM C22A 11/26/2003

AC Inst. Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed:

Designer and Manufacturer of Scientific and Industrial Instruments

LUDLUM MEASUREMENTS, INC.
POST OFFICE BOX 810 PH. 325-235-5494
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

Bench Test Data For Detector

Detector 43-68 Serial No. PR190289 Order #. 230061

Customer RADIATION SAFETY ACADEMY Alpha Input Sensitivity 120 mV

Counter 2224-1 Serial No. 187244 Beta Input Sensitivity 3.5 mV

Count Time 1 Minute Beta Window 40 mV

Other Distance Source to Detector Surface

High Voltage	Background Alpha	Background Beta	Isotope Pu239 Size 30,900 dpm Alpha	Beta	Isotope Sr90/Y90 Size 109,165 dpm Alpha	Beta	Isotope Tc99 Size 22,900 dpm Alpha	Beta
1525	2	139	6045	651	2	25808	5	7253
1550	2	168	6357	693	4	29646	6	7332
1525	2	167	6647	758	3	31882	7	7113
1600	2	172	7088	756	83	32732	38	6504
1625	5	174	7236	710	431	30430	188	5455

31 %

☐ Gas Proportional detector count rate decreased ≤ 10% after 15 hour static test using 39" cable.

☑ Gas proportional detector count rate decreased ≤ 10% after 5 hour static test using 39" cable and alpha/beta counter.

Signature Elvis Chaney Date 16 FEB 05

FORM C48 04/09/2003

of
Scientific and Industrial
Instruments

CERTIFICATE OF CALIBRATION

LUDLUM MEASUREMENTS, INC.
POST OFFICE BOX 810 PH. 325-235-5494
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

CUSTOMER RADIATION SAFETY ACADEMY ORDER NO. 230061

Mfg. Ludlum Measurements, Inc. Model 2224-1 Serial No. 187275
Mfg. Ludlum Measurements, Inc. Model 43-68 Serial No. PR216252
Cal. Date 16-Feb-05 Cal Due Date 16-Feb-06 Cal. Interval 1 Year Meterface 202-783

heck mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 70 °F RH 29 % Alt 706.8 mm Hg

☑ New Instrument Instrument Received ☐ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair ☐ Other-See comments

☑ Mechanical ck. ☑ Meter Zeroed ☐ Background Subtract ☐ Input Sens. Linearity
☐ F/S Resp. ck ☑ Reset ck. ☑ Window Operation ☑ Geotropism
☑ Audio ck. ☐ Alarm Setting ck. ☑ Batt. ck. (Min. Volt) 2.2 VDC
☑ Calibrated in accordance with LMI SOP 14.8 rev 12/05/89. ☐ Calibrated in accordance with LMI SOP 14.9 rev 02/07/97.

ıstrument Volt Set 1550 V Input Sens. Comment mV Det. Oper. 1550 V at Comment mV Threshold Dial Ratio ______ = ______ mV

☑ HV Readout (2 points) Ref./Inst. 500 / 508 V Ref./Inst. 2000 / 2007 V

COMMENTS:

```
Alpha sensitivity = 120mV
 Beta sensitivity = 3.5mV
      Beta window =  40mV
  Firmware number = 390092
Overload function was checked but not set.
```

amma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
X1000	400kcpm		400
X1000	100kcpm		100
X100	40kcpm		400
X100	10kcpm		100
X10	4kcpm		400
X10	1kcpm		100
X1	400cpm		400
X1	100cpm		100

*Uncertainty within ± 10% C.F. within ± 20% ALL Range(s) Calibrated Electronically

ıigital eadout	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
	400kcpm		40045 (D)
	40kcpm		4004
	4kcpm		400
	400cpm		40
	40cpm		4

Log Scale	REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*

ıdlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of ther International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques ıe calibration system conforms to the requirements of ANSI/NCSL Z540-1-1994 and ANSI N323-1978 State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources:
Cs-137 Gamma S/N ☐ 1162 ☐ G112 ☐ M565 ☐ 5105 ☐ T1008 ☐ T879 ☐ E552 ☐ E551 ☐ 720 ☐ 734 ☐ 1616 ☐ Neutron Am-241 Be S/N T-304
☑ Alpha S/N 4337,Pu239 ☑ Beta S/N #918,Sr90y90*635/83,Tc99 ☐ Other
☑ m 500 S/N 196745 ☐ Oscilloscope S/N ☑ Multimeter S/N 82840194

Calibrated By: Elias Chavez Date 16-FEB-05
Reviewed By: Gloria Orozco Date 17 Feb 05

FORM C22A 11/26/2003

AC Inst. Only ☐ Passed Dielectric (Hi-Pot) and Continuity Test ☐ Failed:

Designer and Manufacturer of Scientific and Industrial Instruments

LUDLUM MEASUREMENTS, INC.
POST OFFICE BOX 810 PH. 325-235-5494
501 OAK STREET FAX NO. 325-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

Bench Test Data For Detector

Detector 43-68 Serial No. PR216252 Order #. 230061

Customer RADIATION SAFETY ACADEMY Alpha Input Sensitivity 120 mV

Counter 2224-1 Serial No. 187275 Beta Input Sensitivity 3.5 mV

Count Time 1 Minute Beta Window 40 mV

Other Distance Source to Detector Surface

High Voltage	Background Alpha	Background Beta	Isotope Pu239, Size 30,900dpm Alpha	Isotope Pu239, Size 30,900dpm Beta	Isotope Sr 90/Y90, Size 109,165dpm Alpha	Isotope Sr 90/Y90, Size 109,165dpm Beta	Isotope Tc99, Size 22,900dpm Alpha	Isotope Tc99, Size 22,900dpm Beta	
1500	2	96	5855	662	1	21211	4	6346	
1525	2	120	6287	665	1	26081	4	7007	
1550	1	131	6589	700	3	30663	4	7648	34 %
1575	0	172	7017	778	3	33019	5	7695	
1600	1	186	7150	920	27	35444	9	7410	

☐ Gas Proportional detector count rate decreased ≤ 10% after 15 hour static test using 39" cable.

☑ Gas proportional detector count rate decreased ≤ 10% after 5 hour static test using 39" cable and alpha/beta counter.

Signature Elias Chavez Date 16-FEB-05

FORM C4B 04/09/2003