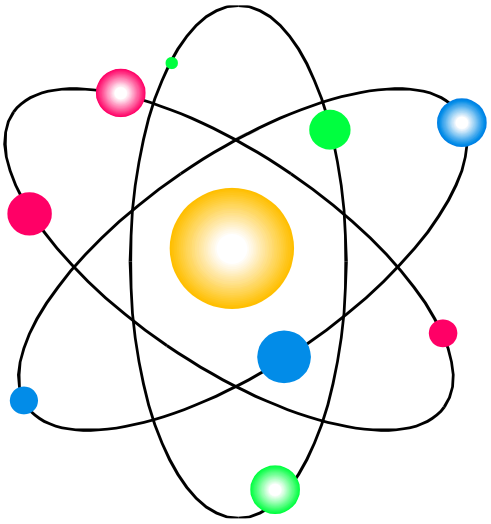
James Madison University



Radiation Safety Manual

Rev. 3 Approved by RSC December 7th, 2022

INTRODUCTION

This revision of the Radiation Safety Manual was approved by the Radiation Safety Committee and supersedes all other revisions. It also supersedes and takes precedence over any memoranda, notices or condensed versions issued prior to the date of issuance of this manual.

In this manual are the policies and standards for work with radiation and radioactive materials at James Madison University. These policies and standards shall govern all work at University locations involving the use of radionuclides, particle accelerators, X-ray machines, and other sources of ionizing radiation.

These radiation safety policies meet all regulatory requirements of the Nuclear Regulatory Commission (NRC) and the Virginia Department of Health (VDH).

The requirements of this document apply to **all** personnel working with radiation or radioactive materials at James Madison University or under the cognizance of the James Madison University's radioactive materials license at any off-site location.

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SECTION 1: ADMINISTRATION AND OVERSIGHT OF THE RADIATION SAFETY PROGRAM

The James Madison University Radiation Safety Committee (RSC) is chartered to provide proper and continuing oversight relating to all potential radiation hazards resulting from the activities of the University. The Committee is further charged with establishing and maintaining appropriate procedures for the procurement, use, and care of all radioactive sources and radiation-producing machines within the entire University. This is to ensure compliance with existing state and federal requirements and is to afford a maximum degree of protection to University personnel, students, visitors, and the general public from radiation hazards arising out of the use of radiation-producing sources and machines. The duties and responsibilities of the Committee are regulatory as well as oversight and reporting and are listed in Section 2 of this manual.

Procedures developed by the Committee are published in the Radiation Safety Manual and are presented to the Office of the Vice Provost for Research and Scholarship. The Standing RSC meets at least quarterly. Additional ad-hoc members of the committee may be added at the discretion of the Chairman of the RSC.

The responsibility for ensuring that approved procedures are carried out, including the rules and regulations of the University and the governing public agencies regarding radiation safety, is assigned to the Radiation Safety Officer (RSO). The RSO reports to the University Director of Emergency Services Management, who does not use or supervise the use of radiation or radioactive materials. The RSO is responsible for identifying radiation safety problems or areas of non-compliance; initiating, recommending, or providing corrective actions; and verifying implementation of corrective actions. Other duties of the RSO are enumerated in Section 3 of this manual.

Violations of legal requirements or standards for safe work with radiation and radioactive materials will be handled according to the process detailed in Section 5 of this manual.

ORGANIZATION FOR RADIATION SAFETY

Board of Visitors
Office of the President
Office of the Vice Provost for Research and Scholarship
Radiation Safety Officer

STANDING COMMITTEE ON RADIATION SAFETY

Chair, Radiation Safety Committee (appointed by the Vice Provost for Research and Scholarship)
Radiation Safety Officer (non-voting member)
At least three representatives from academic departments utilizing radiation or radiation generating devices
One representative from outside the university

(Persons specified above may name representatives to take their place on the Committee with the exception of the RSC Chair and the RSO.)

SECTION 2: DUTIES AND RESPONSIBILITIES OF THE RADIATION SAFETY COMMITTEE

The Radiation Safety Committee (RSC) meets at least quarterly to review the performance of the Radiation Safety Program and discuss issues relating to the safe and regulatory-compliant use of radiation and radioactive materials at James Madison University. A quorum consists of not less than one half of the voting RSC members and must include the committee Chairman and the non-voting RSO. Issues discussed may include, but are not limited to, activities of the RSO, program issues or changes, violations, proposed changes in policy, and reports of radiological issues. Other items are discussed as necessary. The RSC has an oversight and reporting function as well as a regulatory function because this manual supports the university's license application. Members serve terms of three years unless terminated earlier as provided below.
Members are eligible for reappointment and may serve additional terms. Members are asked to recommend alternates, who must be approved by the Vice Provost for Research and Scholarship (or his/her designee). The appointment year runs from September through August.

Members are appointed by, and serve at the discretion of, James Madison University's Vice Provost for Research and Scholarship (or his/her designee) and may be removed from membership by the Vice Provost for Research and Scholarship (or his/her designee) at any time by written notice from the Vice Provost for Research and Scholarship (or his/her designee).

The Radiation Safety Committee Chairperson is appointed by the Vice Provost for Research and Scholarship (or his/her designee) to serve a four year term, unless terminated earlier as provided below. The Chairperson is eligible for reappointment and may serve additional terms, but none consecutive as the Chairperson. The Committee Chairperson may be consecutively appointed to the committee as a member

Committee Chairpersons are appointed by, and serve at the discretion of, James Madison University's Vice Provost for Research and Scholarship (or his/her designee) and may be removed from membership by the Vice Provost for Research and Scholarship (or his/her designee) at any time by written notice from the Vice Provost for Research and Scholarship (or his/her designee).
Duties and responsibilities of the RSC are listed below.

Responsibilities

The Radiation Safety Committee shall

1. Ensure procedures for the procurement, use, and care of radioactive materials and radiation-producing machines within the University are established and maintained and that these procedures are in accordance with Virginia Department of Health (VDH) regulations and conditions of the license.
2. Ensure that the RSO and Authorized Users effectively administer the University's Radiation Safety program to ensure that all use of radioactive materials and the operation of radiation-producing machines is accomplished safely and in accordance with all federal and state regulations and the conditions of the radioactive material license.

Duties

The Radiation Safety Committee shall

1. Be familiar with all pertinent VDH and NRC regulations, the terms of the radioactive materials license, and the information submitted in support of the request for the license and its amendments.
2. Ensure the training, experience, and qualifications of all prospective radioactive materials Authorized Users are sufficient to enable them to perform their duties safely and responsibly.
3. Monitor the university's program to ensure individual and collective doses as low as reasonably achievable (ALARA).
4. Establish a table of investigation levels for occupational radiation exposure, which when exceeded will initiate an investigation and consideration of action by the Radiation Safety Officer.
5. Approve the program that ensures that all individuals whose duties may require them to work in the vicinity of radioactive material (e.g. maintenance, housekeeping personnel) are properly instructed.
6. Review the radiation safety program annually to determine that activities are being conducted safely and in accordance with federal and state regulations and the university's radioactive material license. The review shall include an examination of records, reports from the Radiation Safety Officer, inspection results from VDH and others, written safety procedures, and adequacy of the university's management control system.
7. Review and determine the adequacy of remedial action to correct any deficiencies identified in the radiation safety program or quality assurance programs.
8. Review and determine the adequacy of corrective or disciplinary actions for Authorized Users with an excessive number of, or repetitive, violations noted during laboratory visits.
9. Maintain written records of all committee meetings (including members present), documenting votes, action, recommendations, decisions as well as any dissenting opinions from committee members.
10. Ensure that the radioactive materials license is amended, when necessary, prior to any changes in facilities, equipment, policies, procedures, radioactive material, possession limits, and personnel, as specified in the license.
11. Commission an annual program review by external expert. Upon completion of the external program review, it will be immediately communicated to the RSC.
12. The RSC will formally issue the report to the affected departments' chair and dean along with a request for the department, within 30 days, to provide the RSC with an action plan that addresses each of the audit observations and corresponding completion dates. The RSC will then either approve the plan or respond to the department and dean that modification are needed. The department then has seven days to address the required modifications and resubmit the action plan to the RSC for approval.
13. Once approved, the RSO will track that the approved action plan is implemented according to the agreed upon timeline. If a milestone is missed or any part of the action plan is not

implemented as agreed, the RSO will notify the RSC, who will issue a warning letter to the affected department chair.

14. If compliance with the action plan is not achieved by the department five days after issuance of the warning letter, a second warning letter will be sent by the RSC to the department dean. If compliance with the action plan is not achieved five days after issuance of the second warning letter to the dean, the RSC will notify the Vice President for Research and Scholarship with a recommendation to shut the lab down.

SECTION 3: DUTIES AND RESPONSIBILITIES OF THE RADIATION SAFETY OFFICER

Responsibilities

The Radiation Safety Officer shall

1. Ensure that safe radiological working conditions are established and maintained for all University personnel, students, visitors, and the general public.
2. Ensure compliance with all pertinent federal, state, and local regulations.
3. Fulfill the duties of the Radiation Safety Officer specified in the NRC NUREG-1556 Vol.7 (Program-Specific Guidance About Academic Research and Development, and Other Licenses of Limited Scope). The manner in which each of these responsibilities is carried out is described in other sections of this manual.

Duties

The specific duties of the Radiation Safety Officer include the following:

1. Perform general surveillance over all activities involving radioactive material and radiation-producing machines including routine monitoring, inspection, and special surveys of areas in which radioactive material is used or radiation-producing machines are operated.
2. Enforce compliance with rules and regulations, license conditions, and policies specified by the RSC.
3. Monitor and maintain systems and documentation associated with the use, storage, or disposal of radioactive material.
4. Furnish consulting services on all aspects of radiation safety to personnel upon request.
5. Ensure proper receipt, unpacking, and delivery to point-of-use of radioactive material shipments arriving at James Madison University and ensure outgoing shipments are processed in accordance with state and federal regulations. This responsibility may be delegated provided that training in the applicable regulations is completed and the individual agrees to assume this added responsibility. Any transfer of radioactive material, whether from RSO/designee to PI/designee or the reverse, must be acknowledged with a signature as well as the time and date.
6. Distribute and process personnel-monitoring devices, determine the need for bioassays, maintain personnel exposure and bioassay records, and notify individuals and their supervisors of exposures.
7. Conduct training programs and otherwise instruct personnel in the proper procedures for the use of radioactive material prior to use, annually (refresher training), and as required by changes in procedures, equipment, regulations, etc.
8. Supervise and coordinate the radioactive waste disposal program, including maintaining waste storage and disposal records and monitoring effluents.
9. Ensure proper storage of radioactive materials not in current use, including wastes.
10. Perform leak tests on sealed sources as required by state and federal regulations.

11. Maintain an inventory of all radioisotopes and limit the quantity of radionuclides to the amounts authorized by the license.
12. Terminate any work or project that is found to be an immediate threat to health or property.
13. Maintain other records not specifically designated above (e.g., receipt, transfer, and survey records).
14. Provide periodic inspections of x-ray-generating equipment, including, but not limited to, x-ray machines, electron microscopes, x-ray diffraction devices, and other machines that emit x-radiation by design.
15. Review and approve purchases, transfers, and loans of radioactive material prior to the order or request being made.
16. At a minimum, perform quarterly formal inspections of all areas where radioactive sources are in use.
17. Coordinate annual audit by an external consultant.

SECTION 4: RESPONSIBILITY OF RADIOACTIVE MATERIALS AUTHORIZED USERS

A radioactive materials authorized user (AU) is defined as any person whose training and experience have been reviewed by VDH, who is named on the license, and who uses or directly supervises the use of licensed material. The AU's primary responsibility is to ensure that the radioactive materials used in his or her particular lab or area are used safely and according to regulatory requirements. The AU is also responsible to ensure that procedures and engineering controls are used to keep occupational doses and doses to members of the public ALARA.

AUs must have adequate and appropriate training to provide reasonable assurance that they will use licensed material safely, including maintaining security of, and access to, licensed material, and respond appropriately to events or accidents involving licensed material to prevent the spread of contamination.

AUs are responsible for the safe use of all radioactive materials used under their direction and/or in their laboratory space and for ensuring that all applicable regulations and University policies are followed at all times.

It is the responsibility of **all** Authorized Users to

1. Notify the RSO of the need to amend the Radioactive Materials License for any changes in laboratory space, nuclide(s) to be used, in maximum possession limits, in the chemical form of radioisotopes to be used prior to commencing a new experimental protocol, or upon completion of experiments or protocols using radioactive materials.
2. Notify the RSO of the need for a permit amendment before planning to terminate the use of radioactive materials at James Madison University. Such notification must be made at least four weeks in advance.

3. Ensure that surveys for radioactive contamination are performed and documented weekly when radioactive materials are in use and that these surveys are performed with the appropriate instrumentation that has been calibrated at least annually. Documentation of the instrument calibration must be maintained for the life of the instrument. The weekly surveys must be done legibly, in ink and the RSO must review and approve them as well as maintain a copy.

4. Administer and enforce radiation safety rules and regulations in all areas within the scope of their authority. Ensure that each experimenter properly controls any contamination in his/her work area and that appropriate surveys are performed when work has been completed. If routine contamination above regulatory limits is detected, the RSO must be notified and the area decontaminated.

5. Inform all employees and students of potential health hazards and the safeguards that are established to ensure safe exposures and thoroughly document the communication.

6. Ensure that all employees and students working with, or in the vicinity of, radionuclides or radiation-producing equipment are properly monitored in accordance with the established personnel-monitoring programs. This includes the timely exchange of dosimeters and other personnel-monitoring devices according to the schedule provided and the performance of bioassays subsequent to the use of greater than 1mCi of I-125 or I-131, 20mCi of C-14, 40 mCi of tritium or if inhalation, ingestion, skin contamination, or contamination of open cuts or scrapes has occurred.

7. Maintain control over radioactive materials by proper inventory, receipt, collection of contaminated materials and disposal. Ensure that the written inventory is accurate by tracking all radioactive materials from cradle to grave. This includes checking the source or stock vial in and out of inventory and logging all amounts dispensed from a stock container, tracking secondary solutions, any amounts that are identified and segregated as waste.

8. Ensure that all radioactive waste is collected and segregated for disposal. All waste shall be in sealed containers and labeled with a waste tag or sheet containing the following information: date; isotope and decay-corrected activity of each isotope (in microcuries or millicuries); chemicals present in the waste container; stock vial number(s) from which the waste originated; and the laboratory in which the waste originated. The radioactive waste must be added to the radioactive waste log. Radioactive waste is **NEVER** to be left unattended in hallways. Radioactive waste may **NOT** be disposed of via laboratory sinks.

9. Ensure safe and secure storage of all radioactive materials. Unless the storage area is in a Radiation Area, the radiation field produced by such storage shall not exceed 0.5 milliroentgens per hour at 30 cm from the source of radiation.

10. Notify the RSO prior to the purchase or acquisition of any radiation-producing equipment including, but not limited to, x-ray machines, electron microscopes, and x-ray diffraction equipment.

11. Notify the RSO of the acquisition of any equipment containing radioactive sealed sources. Examples of such equipment are analytical balances, liquid scintillation counters, and gas chromatographs.

12. Review and develop procedures to ensure that all radiological work is conducted safely including proper posting of the rooms and accurate labeling of all containers.

13. Inform the RSO of all instances of radioactive contamination in excess of 500 dpm/100 cm^2 of beta/gamma on fixed surfaces outside a controlled surface contamination area. Fixed surfaces include floors, walls, bench tops (on the bench itself, not on removable materials placed on the bench top), and fume hood walls.
14. Notify the RSO immediately in the event of any radiological emergencies such as spills of radioactive materials, contamination of laboratory personnel, or the loss of radioactive materials.
15. Ensure all radioactive materials users have received radiation safety training prior to commencing work with radioactive materials and that annual refresher training is completed including a quiz or other documented measure of competency. The training records must be maintained and readily accessible for a minimum of 5 years.

Noncompliance with above responsibilities is in violation of University regulations and state and federal laws. Noncompliance also jeopardizes personnel safety and the University's license to use radioactive material. Failure to comply with the requirements specified in this manual will be addressed according to the procedures outlined in Section 5 of this manual. Failure to comply within seven days following department head notification, will result in notification to the RSC Chair and relevant college dean. If compliance is not achieved within seven days following RSC Chair and college dean notification will result in the responsible party being denied access to the radiation area and the suspension or revocation of permission to use radioactive materials or radiation producing equipment. These policies are described in Section 5 of this manual.

SECTION 5: POLICY FOR ADDRESSING VIOLATIONS OF REGULATORY REQUIREMENTS OR STANDARDS FOR SAFE WORK WITH RADIATION AND RADIOACTIVE MATERIALS

Laboratory inspections are performed to ensure compliance with the applicable state and federal regulations and with the policies set forth in this manual. Violations of requirements will be addressed by the policies of this manual. This policy recognizes that specific circumstances and severity of violations call for different corrective or, if necessary, disciplinary actions.

This policy applies to all personnel using radiation-producing machines or radioactive materials at James Madison University and to all personnel using radiation-producing devices or radioactive materials at off-site locations under the auspices of James Madison University's radioactive materials license.

Policy

1. Violations may be noted at any time. Reporting of violations is not limited to formal inspections.
2. Violations will be initially reported to the RSC Chair, who will issue a formal letter to the PI.

3. Violations may be corrected on the spot by the person noting them, if appropriate, or by the PI. The violation will still be reported and noted as corrected.
4. If the violation was not corrected during the inspection, seven days after the date of the violation letter to the PI, a re-inspection will be performed.
5. If repeat or on-going violations are noted, a violation letter will be issued by the RSC Chair to the PI's or responsible party's department head.
6. Seven days after the violation letter to the PI's department head, a re-inspection will be performed.
7. If repeat or on-going violations are noted, a violation letter will be issued by the RSC Chair to the dean of the affected college and the Vice Provost for Research and Scholarship.
8. Seven days after the violation letter to the college dean and Vice Provost for Research and Scholarship, another re-inspection will be performed.
9. If repeat or on-going violations are noted, the PI or responsible party will be denied access to the radiation suite and will not be permitted to work with radioactive sources or radiation-producing equipment. The Vice Provost for Research and Scholarship will notify the Provost and Senior Vice President that the PI's radiation work privileges and access to radiation areas have been suspended.
10. In the case of particularly willful, flagrant, or egregious violations of regulatory requirements, radiological safety requirements, or health and safety practices, the RSO may immediately suspend the use of Radioactive Materials and all work in the space if there is an immediate threat to health and safety. Such suspensions will be immediately referred to the RSC Chair and Vice Provost for Research and Scholarship.
11. The PI may appeal the violation to the RSC after he or she receives the initial violation letter. If the committee votes for the violation to stand, subsequent appeals are only available at the discretion of the Provost and Senior Vice President once access to radiation areas or equipment has been denied.
12. Upon completion of all corrective or disciplinary actions, the RSO will perform a follow-up inspection of all spaces in question to verify compliance with all required actions, regulations, and standards. Following this inspection, the RSO will recommend restoration and resumption of radiological work to the RSC.
13. At a minimum inspections will be performed quarterly. Inspection frequency can be increased during times of increased use or if there are reasons to believe issues are developing (i.e. concerns raised by other faculty or staff members or incidents).

While not exhaustive, a list of potential violations is included for reference below.

Potential Violations

1. Loss of security for any radioactive materials.
2. Eating, drinking, or food storage or evidence thereof in radiologically posted laboratory space.
3. Use of radioactive materials by untrained personnel.
4. Use of radioactive materials in an unposted lab or room, if regulations require posting.

5. Radioactive contamination in excess of 1,000 dpm/100 cm^2 in a **posted** area
6. Presence of detectable radioactive contamination in any **unposted** area
7. Unauthorized receipt, transfer, or shipping of radioactive materials
8. Loss of radioactive materials
9. Evidence of internal exposure of radioactive materials resulting from abnormal incidents
10. Failure to wear required radiation dosimetry
11. Radioactive materials in nonradioactive waste containers
12. Evidence of liquid radioactive waste disposal into laboratory sinks
13. Persons using radioactive materials while person or laboratory is under suspension
14. Unlabeled contaminated laboratory equipment
15. Failure to post correct signage or procedures
16. Failure to wear proper personal protective equipment (safety glasses, lab coat, gloves, etc.)
17. Failure to participate in required bioassay programs (if appropriate)
18. Failure to perform and appropriately document weekly radioactive contamination surveys when radioactive materials were used
19. Pipetting by mouth
20. Survey meter out of calibration or use of inoperable survey meter
21. Radioactive check source not available for contamination survey meter
22. Improper waste segregation
23. Incorrect documentation of radioactive materials inventory (i.e., no decay corrections; total activity present in waste plus stock vials does not agree with activity received and not disposed)
24. Failure to demonstrate proper radiological survey techniques
25. Poor radiological housekeeping
26. Improper use of a fume hood, absorbent pads, or bench covers not used in radiological work or storage areas
27. Failure to post VDH notice to workers
28. Failure to remove or obliterate radiological symbols from empty containers
29. Failure to report a radiological incident (spill, skin contamination, loss of radioactive material, etc.) to the RSO within 2 hours of its occurrence
30. Failure to take appropriate immediate actions in the event of radiological emergencies such as spills or skin contamination incidents
31. Failure to investigate and document any laboratory safety incidents or near-misses that occur in an area where radiological work occurs.
32. Any other activities that violate Virginia State regulations or the provisions of the referenced documents.

Examples of Possible Recommended Corrective or Disciplinary Actions

1. Temporary suspension of an individual's authorization to use radioactive materials pending refresher training
2. Permanent suspension of a specific individual's authorization to use radioactive materials at James Madison University
3. Mandatory refresher training for all personnel affiliated with a particular lab or experiment
4. Suspension of authorization to order radioactive materials for a specified period of time up to one year.
5. Complete revocation of Radioactive Materials permissions and the ability of specific individuals to use radioactive materials anywhere at James Madison University

SECTION 6: RADIATION SAFETY STANDARDS – REFERENCES AND DEFINITIONS

The following references are used in formulating the basis for the radiation safety within the University. All documents referenced in this manual are available online.

6.1 Legal Codes

1. U.S. Nuclear Regulatory Commission Code of Federal Regulations, Title 10, Atomic Energy, Part 20, *Standards for Protection Against Radiation*.
2. Virginia Department of Health, Title 12, Agency 5, Chapter 481, *Radiation Protection Regulations.*
3. Virginia Regulatory Guide *"ORH-720-F Academic, R&D and Other Licenses of Limited Scope"*

6.2 Definitions

Absorbed dose – the energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are the gray (Gy) and the rad.

Activity – the rate of disintegration or transformation or decay of radioactive material. The units of activity are the becquerel (Bq) and the curie (Ci).

Adult – an individual 18 years, or more, of age.

Airborne radioactive material – any radioactive material dispersed in the form of dusts, fumes, particulates, mists, vapors, or gases.

Airborne radioactive area – a room, enclosure, or area in which airborne radioactive materials exist in concentrations

(i) in excess of the derived air concentrations (DACs) specified in Appendix B to 10 CFR Part 20 https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-appb.html

(ii) to such a degree that an individual present in the area without respiratory protective equipment could exceed, during the hours an individual is present in a week, an intake of 0.6 percent of the annual limit of intake (ALI) or 12 DAC-hours.

Annual limit of intake (ALI) – the derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the reference man that would result in a committed effective dose equivalent of 0.05 Sv (5 rem) or a committed dose equivalent of 0.5 Sv (50 rem) to any individual organ or tissue. ALI values for radionuclides are given in Appendix B to 10 CFR Part 20.

As low as reasonably achievable (ALARA) –making every reasonable effort to maintain exposures to radiation as far below the regulatory dose limits as is practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to the state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of licensed or registered sources of radiation in the public interest.

Authorized User (AU) –any person authorized to use radioactive materials at James Madison University. Authorized users must be identified on the permit.

Background radiation –radiation from cosmic sources; naturally occurring radioactive materials, including radon, except as a decay product of source or special nuclear material, and including global fallout as it exists in the environment from the testing of nuclear explosive devices. *Background radiation* does not include sources of radiation from radioactive materials regulated by the VDH/NRC.

Becquerel (Bq) –equal to one disintegration or transformation per second (s^{-1}).

Bioassay – the determination of kinds, quantities or concentrations, and, in some cases, the locations of radioactive material in the human body, whether by direct measurement, in vivo counting, or by analysis and evaluation of materials excreted or removed from the body.

Calendar quarter – not less than 12 consecutive weeks nor more than 14 consecutive weeks. The first calendar quarter of each year shall begin in January, and subsequent calendar quarters shall be so arranged that no such day is included in more than one calendar quarter and no day in any one year is omitted from inclusion within a calendar quarter.

Calibration – the determination of

(i) the response or reading of an instrument relative to a series of known radiation values over the range of the instrument, or

(ii) the strength of a source of radiation relative to a standard.

Class – a classification scheme for inhaled material according to its rate of clearance from the pulmonary region of the lung. Materials are classified as D, W, or Y, which applies to a range of clearance half-times: for Class D (days), of less than 10 days; for Class W (weeks), from 10 to 100 days; and for Class Y (years), of greater than 100 days.

Committed dose equivalent ($H_{T,50}$) – the dose equivalent to organs or tissues of reference (T) that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

Committed effective dose equivalent ($H_{E,50}$) –the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to each of these organs or tissues ($H_{E,50} = w_T H_{T,50}$).

Contamination –the deposition of radioactive material in any place where it is not desired (units = dpm/100 cm^2).

Controlled area – any area where access is controlled for the purpose of protecting individuals from exposure to radiation and radioactive material, but shall not mean any area used as residential quarters. "Controlled area" is synonymous with "restricted area."

Curie (Ci) – a unit of activity. One curie is that quantity of radioactive material that decays at the rate of 3.7×10^{10} transformations per second.

Decay chain (Series) – a series of isotopes resulting from the decay of a parent nuclide and its subsequent radioactive daughters to an ultimate stable form.

Decay constant –the fraction of the number of atoms that will decay in a unit period of time.

DC = ln(2)/t ½

ln(2) = natural logarithm of 2 ~ 0.693…

t ½ = isotope half-life

Declared pregnant woman – a woman who has voluntarily informed her employer, in writing, of her pregnancy.

Deep dose equivalent (H_d) –the dose exposure at a tissue depth of 1 centimeter (applies to external whole body exposure).

Derived air concentration (DAC) – the concentration of a given radionuclide in air, which, if breathed by the reference man for a working year of 2,000 hours under conditions of light work, results in an intake of one ALI. For purposes of this manual, the condition of light work is an inhalation rate of 1.2 cubic meters of air per hour for 2,000 hours in a year. DAC values for radionuclides are given in Appendix B to 10 CFR Part 20.

Derived air concentration-hour (DAC-hour) – the product of the concentration of radioactive material in air, expressed as a fraction or multiple of the derived air concentration for each radionuclide, and the time of exposure to that radionuclide in hours. A licensee or registrant may use 2000 DAC-hours to represent one ALI, equivalent to a committed effective dose equivalent of 0.05 Sv (5 rem).

Dose –a generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, effective dose equivalent, or total effective dose equivalent.

Dose equivalent (H_T) – the product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the sievert (Sv) and rem.

Dose limits – the permissible upper bounds of radiation doses established in accordance with these regulations. For purposes of these regulations, "limits" is an equivalent term.

Dose meter –an instrument designed to measure the dose rate of ionizing radiation—usually displayed in mR/hr.

Dose rate – absorbed dose delivered per unit time (mr/hr).

Dosimeter –an instrument used to detect and measure accumulated radiation exposure.

Dosimetry –the theory and application of the principles and techniques involved in the measurement and recording of radiation doses. Its practical aspect is concerned with the use of various types of radiation instruments with which measurements are made.

Effective dose equivalent (H_E) – the sum of the products of the dose equivalent to each organ or tissue (H_T) and the weighting factor (w_T) applicable to each of the body organs or tissues that are irradiated ($H_E = w_T H_T$).

Element – a category of atoms having the same number of protons and the same chemical properties.

Exposure –

(i) being exposed to ionizing radiation or to radioactive material; or

(ii) the quotient of dQ by dm, where "dQ" is the absolute value of the total charge of the ions of one sign produced in air when all the electrons (negatrons and positrons) liberated by photons in a volume of air having a mass "dm" are completely stopped in air. The special unit of exposure is the roentgen. One roentgen is equal to 2.58×10^{-4} coulomb per kilogram of air.

Exposure rate – the exposure per unit of time, such as roentgen per minute and milliroentgen per hour.

External dose – that portion of the dose equivalent received from any source of radiation outside the body.

Extremity – hand, elbow, arm below the elbow, foot, knee, and leg below the knee.

Eye dose equivalent – the external dose equivalent to the lens of the eye at a tissue depth of 0.3 cm.

Gray (Gy) – the SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 joule/kilogram. One gray is equal to 100 rad.

Half-life (biological) – the amount of time required for ½ of an ingested, inhaled, or administered substance to be eliminated from the body.

Half-life (effective) – the amount of time required for radioactive material in the body to have its activity reduced by 50% by a combination of radioactive decay and elimination.

Half-life (radiological) –the amount of time that is required for a radioactive substance to lose ½ of its activity.

Half-value layer (HVL) – the amount of material required to reduce the dose rate from a radiation source by a factor of 2.

High-radiation area – any area, accessible to individuals, in which radiation levels could result in an individual receiving in excess of 1 mSv (0.1 rem) in 1 hour at 30 centimeters from any source of radiation or from any surface that the radiation penetrates.

Human use – the internal or external administration of radiation or radioactive material to human beings.

Incident – any unexpected event involving radiation or radioactivity with the potential for the spread of radioactive contamination, skin contamination, uptake of radioactive materials, exposure to elevated radiation levels, loss of radioactive material, and so forth.

Individual monitoring – the assessment of

(i) Dose equivalent

(a) by the use of individual monitoring devices, or

(b) by the use of survey data; or

(ii) Committed effective dose equivalent

(a) by bioassay, or

(b) by determination of the time-weighted air concentrations to which an individual has been exposed, that is, DAC-hours.

Individual monitoring devices – devices designed to be worn by a single individual for the assessment of dose equivalent. Individual monitoring equipment and personnel monitoring equipment are equivalent terms. Examples of individual monitoring devices are film badges, dosimeters, thermoluminescent dosimeters (TLDs), pocket dosimeters, and personal air sampling devices.

Internal dose – that portion of the dose equivalent received from radioactive material taken into the body.

Isotope – an atom of the same atomic number (containing the same number of protons) but with a different number of neutrons in the nucleus (different atomic mass) – can be stable or radioactive.

License – a radioactive material license issued by the Virginia Department of Health in accordance with the regulations adopted by that department.

Licensed material – radioactive material received, possessed, used, transferred, or disposed of under a general license or specific license issued by the Virginia Department of Health.

Monitoring – the measurement of radiation, radioactive material concentrations, surface area activities, or quantities of radioactive material, and the use of the results of these measurements to evaluate potential exposures and doses.

Narm – a Naturally occurring or Accelerator-produced Radioactive Material—material that is either naturally radioactive or has been made radioactive by bombardment with high-energy particles or ions in an accelerator.

Norm – a Naturally Occurring Radioactive Material—material that is naturally radioactive due to containing naturally occurring radioactive isotopes.

Nuclide –a species of atom characterized by the constitution of its nucleus and capable of more than a transient existence.

Nuclide (daughter) –an atom characterized by the number of protons in its nucleus AND its energy level [ex: Tc-99m is a different nuclide than Tc-99, exhibiting a different half-life and different decay energies due to its existing in a different nuclear excitation (metastable) state].

Nuclide (parent) –the nuclide that exists prior to radioactive decay, decaying to form the daughter nuclide.

Occupational dose – the dose received by an individual in the course of employment in which the individual's assigned duties involve exposure to sources of radiation, whether in the possession of the licensee, registrant, or other person. Occupational dose does not include doses received from natural background radiation, as a patient from medical practices, from voluntary participation in medical research programs, or as a member of the public.

Quality factor (Q) – the conversion factor used to derive dose equivalent from absorbed dose. The quality factors for converting absorbed dose to dose equivalent are shown in Table 1 at the end of this section.

Rad – the special unit of absorbed dose. One rad is equal to an absorbed dose of 100 erg/gram or 0.01 joule/kilogram (0.01 Gy). One millirad equals 0.001 rad.

Radiation – alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. For purposes of this manual, ionizing radiation is an equivalent term.

Radiation area – any area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.05 mSv (0.005 rem) in 1 hour at 30 centimeters from the source of radiation or from any surface that the radiation penetrates.

Radiation equipment – any equipment or device that can emit radiation through several means. Such equipment includes x-ray units, linear accelerators, and irradiators.

Radiation source – any radioactive material or any radiation equipment.

Radioactive material – any solid, liquid, or gas that emits radiation spontaneously.

Radiation worker – any person who, because of their work, has the potential to receive a dose of 100 mrem or greater in one year from working with or around radiation or radioactive materials. All radiation workers must receive training prior to commencing work with radiation-producing equipment or radioactive materials.

Radioactivity – the property of certain nuclides of spontaneously emitting particles or gamma radiation following orbital electron capture, electron emission, isometric transition, nuclear rearrangement, or spontaneous fission.

Radionuclide – a radioactive nuclide.

Rem – the special unit of any of the quantities expressed as dose equivalent. The dose equivalent in rem is equal to the absorbed dose in rad multiplied by the quality factor (1 rem = 0.01 Sv).

Respiratory protective equipment – an apparatus, such as a respirator, used to reduce an individual's intake of airborne radioactive material.

Restricted area – any area, access to which is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to sources of radiation.

Roentgen – the special unit of exposure. One roentgen equals 2.58×10^{-4} coulomb/kilogram of air (See Exposure).

Sanitary sewerage – a system of public sewers for carrying off waste and refuse, but excluding sewage treatment facilities, septic tanks, and leach fields owned or operated by the licensee or registrant.

Sealed source – radioactive material that is permanently bonded or fixed in a capsule or matrix designed to prevent release and dispersal of the radioactive material under the most severe conditions that are likely to be encountered in normal use and handling.

Shallow dose equivalent (H_s) – the dose equivalent at a tissue depth of 0.007 centimeter averaged over an area of 1 square centimeter (applies to the external exposure of the skin or an extremity).

SI – an abbreviation of the International System of Units.

Sievert – the SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sievert is equal to the absorbed dose in gray multiplied by the quality factor (1 Sv = 100 rem).

State – State of Virginia.

Stochastic effect – a health effect that occurs randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects.

Survey – an evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of sources of radiation. When appropriate, such evaluation includes, but it is not limited to, tests, physical examinations, and measurements of levels of radiation or concentrations of radioactive material present.

Total effective dose equivalent (TEDE) – the sum of the deep dose equivalent for external exposures and the committed effective dose equivalent for internal exposures.

Uranium (natural) –uranium containing the relative abundance of isotopes found in nature (U-238, 99.275%; U-234, 0.005%).

Uranium (depleted) – uranium containing less than 0.720% U-235.

Uranium (enriched) – uranium containing more than 0.720% U-235.

Very high radiation area – an area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 5 Gy (500 rad) in 1 hour at 1 meter from a source of radiation or from any surface that the radiation penetrates.

Weighting factor (w_T) – for an organ or tissue (T) means the proportion of the risk of stochastic effects resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly. For calculating the effective dose equivalent, the values of w_T are

Organ or Tissue	Organ Dose Weighting Factors W_T
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	0.30[a]
Whole body	1.00[b]

[a] 0.30 results from 0.06 for each of five "remainder" organs, excluding the skin and the lens of the eye, that receive the highest doses.

[b] For purposes of weighting the external whole body dose, for adding it to the internal dose, a single weighting factor, $w_T = 1.0$, has been specified. The use of other weighting factors for external exposure will be approved on a case-by-case basis until such time as specified guidance is issued.

Whole body – for purposes of external exposure, head, trunk (including male gonads), arms above the elbow, or legs above the knee.

Table 1: Table of Radiation Quality Factors

Type of Radiation	Quality Factor (Q)	Absorbed Dose Equal to a Unit Dose Equivalent[a]
X, gamma, beta radiation, high-speed electrons	1	1
Alpha particles and other heavy charged particles	20	0.05
Neutrons of unknown energy	10	0.01
High-energy protons	10	0.01

[a]Absorbed dose in rad equal to 1 rem or the absorbed dose in gray equal to 1 Sv.

SECTION 7: USER TRAINING PROGRAMS

7.1 General

It may not be assumed that radiation safety instruction has been adequately covered by prior professional or occupational training or by board certification. In addition to radiation workers, ancillary personnel (e.g., nursing, clerical, housekeeping, security) whose duties may require them to work in the vicinity of radioactive material need to be informed about radiation hazards and appropriate precautions.

Personnel will be instructed

1. before assuming duties with, or in the vicinity of, radioactive materials;

2. during annual refresher training; and
3. whenever there is a significant change in duties, regulations, or the terms of the University's Radioactive Material License.

7.2 Training for Non-Medical Uses of Radioactive Material

Instruction will be provided initially and as annual refresher training. Initial training shall consist of attending a radiation safety class, either in-person or on-line, and passing an examination with a score of 80% or greater. The class requirement may be waived by the RSO for personnel who have previously worked with radioactive materials and are unable to attend the scheduled class. All personnel, however, must pass the examination in order to become authorized radiation workers. Areas to be covered during training will include, but are not limited to

1. Applicable regulations and license conditions
2. Areas where radioactive material is used or stored
3. Potential hazards associated with radioactive material in each area where the employees will work
4. Appropriate radiation safety procedures
5. University radiation safety procedures and policies
6. Each individual's obligation to report unsafe conditions to the Radiation Safety Officer
7. Appropriate response to emergencies or unsafe conditions
8. Worker's right to be informed of occupational radiation exposure and bioassay results
9. Locations where notices, pertinent regulations, and copies of pertinent licenses and license conditions are maintained (including applications and applicable correspondence).

7.3 Training for Operators of X-ray Generating Machines

Operators of radiation-generating devices must have initial and annual radiation safety training that includes definition of ionizing radiation, acute and chronic health effects, restricted vs. non restricted areas, definition and units for dose, dose limits, ALARA and details of the radiation-safety, lights, interlocks and protection mechanisms associated with the device.

7.4 Refresher Training

All radiation workers are required to receive annual refresher training. This training may include any of the following:

1. Taking an on-line refresher training class that includes the above information and a final quiz or examination.
2. Training administered by an Authorized User, after which an examination is given. A training syllabus, attendance sheet, and examination grades from such training shall be forwarded to the RSO.

SECTION 8: OCCUPATIONAL DOSE LIMITS

The Nuclear Regulatory Commission (NRC) and Virginia Department of Health (VDH) specifies dose limits for radiation workers and the general public. These dose limits do not apply to medical x-ray examinations or radiation therapy.

8.1 Occupational Dose Limits for Adults

1. The annual limit is the more limiting of
    - the total effective dose equivalent being equal to 5 rem; or
    - the sum of the deep dose equivalent and the committed dose equivalent to any individual organ or tissue (other than the lens of the eye) being equal to 50 rem.
2. The annual limits to the lens of the eye, to the skin, and to the extremities are
    - an eye dose equivalent of 15 rem, and
    - a shallow dose equivalent of 50 rem to the skin or to any extremity.

The determination of deep, shallow, and internal dose is estimated by procedures presented in 10 CFR 20.1202

These limits must be reduced by the amount of the occupational dose that an employee may have received at a previous place of employment.

8.2 Radiation Exposure During Pregnancy

The dose to an embryo/fetus during the entire pregnancy, due to occupational exposure of a declared pregnant woman, shall not exceed 500 millirem. When a woman voluntarily declares pregnancy, in writing, Radiation Safety shall review past exposure history and provide exposure counseling. When necessary, the pregnant worker's supervisor may have to adjust working conditions so as to avoid a monthly dose rate of greater than 50 millirem. Declaration of pregnancy is a voluntary act. Declaration of Pregnancy Form can be found in the Appendix to this manual. Potential hazards will be communicated to the pregnant worker and she will be required to sign indicating that she has received and understood the communication.

It is the policy of this institution to assure that the unborn children of its employees be protected to the greatest extent possible from possibly harmful effects of the work environment. When a worker becomes pregnant, special provisions may be considered on an individual basis. The Radiation Safety Officer should be consulted for more information and guidance. Also, see NRC Regulatory Guide 8.13 https://www.nrc.gov/docs/ML0037/ML003739505.pdf.

8.3 Occupational Dose Limits for Minors

No minors or animals are to be admitted into radiation use areas or where there is x-ray generating equipment.

8.4 Determination of Internal Doses

The Annual Limit on Intake (ALI) is the basis for estimating the dose of radiation from internally deposited radionuclides. Briefly, an estimate is made of the amount of a given radionuclide in the employee's body by testing urine, or directly monitoring a person with a radiation detector. This process is called bioassay. Based on the bioassay results, a dose is determined. All bioassay results shall be reviewed by the RSO.

The Derived Air Concentration (DAC) is used to determine the committed effective dose equivalent in cases where people are exposed to contaminated atmospheres. These are specified in 10 CFR 20.1203.

In the rare event of an ingestion of a radionuclide, methods will be used, employing the ALI, to determine the dose received.

Bioassays are required for those using more than 1mCi of I-125 or I-131, 20mCi of C-14, 40 mCi of tritium or if inhalation, ingestion, skin contamination, or contamination of open cuts or scrapes has occurred.

8.5 Planned Special Exposures

The University may authorize an adult worker to receive doses in addition to and accounted for separately from the doses received under the limits listed in 7.1 above, provided each of the following conditions are satisfied:

1. Only in an exceptional situation when alternatives that might avoid a higher exposure are unavailable or impractical.
2. The exposure must be authorized in writing by the Radiation Safety Officer before the exposure occurs.
3. Each worker involved is informed of the planned operation, the estimated doses, and associated potential risks and radiation levels, and instructed in measures to keep doses ALARA.
4. The RSO must assess prior dose according to 10 CFR 20.2104(b).
5. The RSO shall not authorize a planned special exposure in excess of 5 REM in a single year. This dose is in addition to the allowable annual exposure of 5 REM in a calendar year.
6. The RSO must document the best estimate of the dose from the planned special exposure and inform the exposed individual within 30 days of the exposure.

8.6 Radiation Dose Limits for Individual Members of the Public

The dose in any area outside of a controlled area shall not exceed 0.02 mSv (2 millirem) in any one hour. The total dose to individual members of the general public shall not exceed 1mSv (100 millirem).

If there is ever a desire to provide tours of radiation spaces to members of the general public, the request must be submitted to the RSO for review and approval.

SECTION 9: PERSONNEL MONITORING

9.1 Dosimeter Requirements

Dosimeters are required for all personnel working with radioactive material or radiation-producing equipment who are likely to receive greater than 10% of the dose limits of Sections 7.1 and 7.2. To ensure that this requirement is met, dosimeters are required for anyone working in the proximity of radioactive material or radiation-producing equipment such that a total effective dose equivalent of 5 millirem or more could be received in one hour.

Generally, no dosimeter is required if the quantity of radioactive material is less than the quantity that requires labeling and this is the only isotope handled (see Appendix C to Part 20 https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/full-text.html#part020-appc). Additionally dosimeters are not required for elements that emit beta radiation of such low energy that it cannot be detected by a dosimeter, e.g., H-3, C-14; S-35; Ca-45. Radiation workers may request to be issued a dosimeter even if this is not required. Such requests must be approved by the RSO before any such dosimeter will be issued.

The University contracts with a vendor dosimeter service that is accredited under National Voluntary Laboratory Accreditation Program (NVLAP), a voluntary program for determining that a dosimetry service meets American National Standards Institute standards.

9.2 How to Obtain a Dosimeter

Employees or students requiring a dosimeter must complete a Dosimeter Request Form and an Unlicensed User Addendum in Appendix A of this manual if they are an unlicensed user.

9.3 Wearing a Dosimeter

Dosimeters are to be clipped to an article of clothing between the waist and shoulder level at the front of the torso (unless otherwise instructed for the type of dosimeter issued). This location should be the area where the body is receiving the greatest exposure.

9.4 Proper Use of Dosimeters

Dosimeters represent a legal and permanent exposure record so they must not be tampered with in any manner. Erroneous exposure readings caused by deliberate exposure may result in investigation by the Department of Health and remain part of a person's permanent exposure record.

Dosimeters issued by the University are to be used to measure radiation exposure at the James Madison University only. They may not be used at any other institution. They must not be worn while receiving medical or dental x rays. Dosimeters are not to be worn home. No person is permitted to wear another's dosimeter at any time for any reason.

9.5 Periodic Exchange

The RSO will periodically collect dosimeters, which will be sent for analysis, and provide a replacement. Any dosimeter that has not been removed from its packet will be sent back and officially recorded as "unused."

9.6 Exposure Results

Exposure results are received from the dosimeter company approximately two weeks after the dosimeters are returned.

Any individual may also obtain his/her dose record by sending a written request to the RSO.

9.7 Radiation Dosimetry Reports

Doses are reported in units of millirem. The minimum dose that is detectable on a dosimeter is 1 millirem for x and gamma rays and about 10 millirem for neutrons and energetic beta particles. The dose is recorded as "M" for minimal if the results are not measurable. Regulations require that records be kept of the deep dose equivalent to the whole body, eye dose equivalent, shallow dose equivalent to the skin, and shallow dose equivalent to the extremities. Various notes explaining

the reports are found on the reverse side of the dosimetry report. If clarification is needed, contact the RSO.

In addition to records of the external dose equivalent, records must be kept of all ingested or inhaled radioactivity. From this information the committed effective dose equivalent will be determined, and added appropriately to the external dose as required by regulations. Examples of internal dose measurements include bioassay of urine or thyroid gland.

9.8 Misuse of Dosimeter

A dosimeter that has been assigned to an individual may not be used by any other person. The participant number is a lifetime assignment and is not transferable to another person. If a dosimeter is lost or misplaced, a new dosimeter will be issued upon request. Any abnormal occurrence should be reported, and a new dosimeter should be issued if the old dosimeter is damaged or misused in any way. Dosimeters should be kept away from heat and radiation when not in use. Control dosimeters should be used only where the unused dosimeters are kept. Dosimeters should not be left on lab coats where they could be accidentally contaminated with radioactivity, or left in rooms where they could be exposed to radiation.

9.9 Notification and Investigation of Exposures

The annual dose limit is a total effective dose equivalent equal to 0.05 Sv (5 rem). This corresponds to 400 millirem per month for a full-time employee. Any dosimetry reports indicating that the average monthly exposure was over 400millirem will be investigated.

9.10 Other Dosimetry Services

Other types of dosimeters are available for special needs. Ring dosimeters (TLD) and wrist dosimeters are available for monitoring fast neutron dose. Routine analysis for internal exposure to radioactive material must be performed when using more than 1mCi of I-125 or I-131, 20mCi of C-14, 40 mCi of tritium or if inhalation, ingestion, skin contamination, or contamination of open cuts or scrapes has occurred.

9.11 Visitors

The term “visitor” is used to designate all persons for whom personnel-monitoring equipment is not provided on a routine basis, including employees, students, and consultants, as well as visitors from outside.

If visitors, with the exception of building contractor personnel, expect to be in a radiation area from time to time for a period of four consecutive weeks or more, the RSO must be notified so that regularly assigned personnel-monitoring equipment can be issued, if required. This service will be furnished until canceled. The individual or their supervisor shall notify the RSO of the cancelation date when determined. Appropriate radiation safety training will be required for visitors prior to allowing radiation exposures.

Contractors may wear their own dosimetry with the concurrence of the RSO.

9.12 Responsibility for Use of Dosimeters

It shall be the responsibility of all individuals and supervisors to wear personnel-monitoring equipment in accordance with the above policies and procedures. Supervisors shall ensure compliance. It is the responsibility of all persons and supervisors to cooperate with the RSO and Radiation Safety Committee in an investigation of exposures when required. It is the responsibility

of each individual to return his/her personnel-monitoring equipment to the appropriate place at the end of each work day. If a dosimeter is lost or damaged, the RSO must be notified promptly.

If an investigator decides that dosimeters are no longer needed, it is his/her responsibility to notify the RSO in writing. If the RSO agrees, the dosimeter will be terminated promptly. If an employee terminates or transfers, the RSO must be notified, in writing, by the investigator before the dosimeter is withdrawn.

SECTION 10: REQUIREMENTS FOR POSTING/LABELING LABS USING RADIOACTIVE MATERIAL

10.1 Radioactive Material Areas: Posting and Labeling

1. A sign with the words "CAUTION-RADIOACTIVE MATERIAL" shall be placed on each door, refrigerator, or storage locker where radioactive materials exceeding 10 times the quantities specified in Appendix C to 10 CFR Part 20 are used or stored (https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/full-text.html#part020-appc)

   The sign will also be affixed to storage and waste containers, contaminated waste cans, hot sinks, hoods, and work areas. In the event multiple nuclides are present, the "sum of the ratios" shall not exceed a value of 1.

2. Values requiring posting for some commonly used nuclides are included below.

Nuclide	Amount requiring posting
H-3	10 mCi
C-14	1 mCi
P-32	100 μCi
S-35	1 mCi
Ca-45	1 mCi
I-125	10 μCi

3. Laboratory equipment and containers, including beakers, flasks and test tubes, pipetters, centrifuges, and so forth, shall be labeled with a radiation symbol.

4. Containers holding radioactive materials must be labeled with the radiation symbol, the words "Caution, Radioactive Materials," and the isotope(s) and activity contained within and date for which the activity is estimated.

5. Exemptions to these labeling rules include

   - containers with a minor amount of radioactive material that are below the limits for labeling according to 10 CFR Part 20, Appendix C
   - laboratory containers, such as beakers, flasks, and test tubes, used transiently in laboratory procedures (i.e., for a period of a few hours) in the presence of an authorized user; or

- containers when they are in transport and packaged and labeled in accordance with the regulations of the U.S. Department of Transportation.

10.2 Empty Containers

Empty containers that are free of contamination and are to be discarded must have all radioactive materials labels, all radiation symbols, and all markings related to radiation or radioactive materials removed prior to disposal. If this is not possible, the RSO should be contacted for assistance.

10.3 Other Postings

Other postings shall be established as required by 10 CFR 20.1902 to mark radiation areas, high-radiation areas, airborne radioactivity areas, and/or controlled surface contamination areas (CSCA). A CSCA is any area in which loose surface contamination levels exceed 1000 dpm/100 cm. Access to controlled surface contamination areas shall be restricted by a physical barrier posted with a sign noting "Controlled Surface Contamination Area, Do Not Enter."

10.4 Misuse of Caution Signs

Labels and signs required in this section shall not be used for any purpose other than to warn against a radiation hazard.

SECTION 11: CONTAMINATION AND RADIATION SURVEYS OF LABS USING RADIOACTIVE MATERIALS

All laboratories where radionuclides are used in unsealed sources shall be surveyed by laboratory personnel after use of radioactive materials or weekly during the nuclear class. Post-work surveys should concentrate on the areas in which radioactive materials were used and must be documented. Survey reports shall be reviewed/approved by the RSO, retained by the laboratory for a period of three years, and a copy provided to the RSO.

Survey results will be recorded in units of disintegrations per minute (DPM) unless the survey is performed with an ion chamber, micro-R meter, or other dose-rate instrument.

As part of the laboratory inspection program, the RSO may perform a survey of any radiation laboratories. These surveys will be recorded, and a copy will be returned to the laboratory within one week of completing the inspection.

Contamination surveys may be performed with a hand-held instrument if the instrument used has a detection efficiency of 10% or greater for the nuclide(s) in use. Such nuclides are typically P-32 and I-125. Surveys for other nuclides must be performed by taking smear wipes over an area of 100 cm^2 and counting them with a liquid scintillation counter. These survey results will be recorded as dpm/100 cm^2. Such nuclides include H-3, C-14, and S-35.

Routine surveys consist of measurements of

- contamination levels of stored radioactive material (dpm),
- general area radiation levels in laboratories (dpm or mrem), and
- airborne radiation levels either in laboratories or hoods or in effluent streams discharged to the environment (μCi/ml).

Results of such surveys are recorded on a floor plan in their exact locations.

Small amounts of contamination will be unavoidable at times, but the degree of such contamination should be kept as low as possible. Loose contamination on exposed surface, such as bench tops and floors, shall be removed as soon as possible. All loose surface contamination must be reduced to the lowest practical levels; however, cost and time to decontaminate must be considered. **The RSO must be consulted before releasing contaminated materials or facilities for unrestricted use.** Maximum regulatory limits for removable contamination are listed in the following table:

Application	**Alpha (dpm/100 cm^2)**		**Beta/Gamma**[1]	
Controlled Area	Total	Removable	Total (mR/hr)	Removable (dpm/100 cm^2)
Basic Guide	25,000 max	500	1.0	5,000
	5,000 avg			
Clean Area	1,000	100	0.5	1,000
Non-controlled Area				
Skin, personal clothing	500	ND[2]	0.1	ND[2]
Release of material or facilities	2,500 max	100	0.2	1,000
	500 avg			

[1]Measured at 1 cm from the surface.
[2]ND means non-detectable.

SECTION 12: GUIDELINES FOR SAFE USE OF RADIOACTIVE MATERIAL

Good radiological work practices can encompass a wide variety of practices that may vary in some ways between laboratories. The following practices are general in nature and apply to most research uses of radioactive materials:

1. Prior to performing operations with quantities of radioactive material that may produce significant external or internal exposure, attention shall be given by the user to precautionary measures including the use of remote handling devices, hoods, shielding, etc. The RSO must be consulted before beginning any new use of radioactive material.
2. There shall be no eating, smoking, drinking, applying cosmetics, or preparation of food in any laboratory posted with the radiation or radioactive material symbol or in any location where unsealed sources of radioactive materials are used or stored.
3. No food, drink, or personal effects will be stored with radioactive material.
4. Pipetting of radioactive solutions by mouth is prohibited.
5. Segregate and label all laboratory equipment (e.g., pipetting devices, centrifuges, etc.) used with radioactive materials from those used with nonradioactive solutions.

6. Lab coats and disposable gloves shall be worn during operations involving the handling of unsealed sources of radioactive material. The lab coat and gloves should be surveyed for radioactive contamination before leaving the laboratory. Shorts, skirts, open-toed shoes, and other articles of clothing that expose bare skin to possible radioactive contamination may **not** be worn while working with radioactive materials.
7. Care must be taken such that other items (e.g., pens, pencils, notebooks, door knobs, telephones, etc.) are not handled with gloves used while working with radioactive materials.
8. Work that may result in contamination of work surfaces shall be done on plastic-backed absorbent paper or other materials that are approved by the RSO. Trays made of impervious materials (e.g., stainless steel, porcelain-coated, etc.) and lined with absorbent paper provide excellent work arrangements to help prevent the spread of contamination.
9. Work surfaces and personnel shall be monitored after working with radioactive materials.
10. Objects and equipment that may have been contaminated with radioactive material shall be surveyed and demonstrated to be free of contamination prior to their removal from a laboratory. Contaminated items must be controlled and decontaminated as soon as practical.
11. Radiation dosimetry shall be worn (if issued) at all times when working with radioactive materials. Dosimeters should be kept away from radioactive materials when not in use. Section 8 of this manual describes dosimetry policies in greater detail.
12. Radioactive material should be transported in containers that can be sealed to minimize the possibility of causing a spill of radioactive materials. Containers of radioactive liquids being transported shall be capped or sealed and transported in secondary containers to minimize the potential for a spill.
13. Personnel working with radioactive materials should avoid working alone so that, in the event of a radiological emergency, a person is available to provide assistance.
14. Each individual is responsible for contacting the Radiation Safety Unit of any radiological spills, skin contamination, ingestion or inhalation of radioactive materials, or other emergencies.
15. All portable survey instruments shall be calibrated annually. Authorized Users are responsible for ensuring meters in their possession are within calibration before use.
16. Authorized Users are responsible for an inventory of all radionuclides under their purview and present in working spaces assigned to them.
17. State laws require that warning signs be placed on all doors of laboratories where licensable quantities of radionuclides are being used.
18. Radioactive material or waste must be secured from unauthorized removal at all times when not in use.
19. All radioactive waste material must be collected and packaged as described in Section 15 of this manual.
20. Use of more than 1 mCi of any iodine isotope in the laboratory requires the worker to have a thyroid bioassay between 24 and 72 hours after use. The use of more than 20m Ci of C-14 or 40 mCi of tritium requires the worker to submit a urine sample for bioassay within one

week. If inhalation, ingestion, skin contamination, or contamination of open cuts or scrapes has occurred, contact the RSO to determine which bioassays are required.

SECTION 13: SEALED AND UNSEALED RADIOACTIVE SOURCES

13.1 Location

1. Anyone requiring sealed sources must obtain permission for their use from the Radiation Safety Officer.
2. All sealed sources must be registered with the Radiation Safety Officer.
3. Any radioactive material that is not permanently sealed is considered to be an unsealed source. The use of these radionuclides is restricted to qualified experimenters and technicians only.

13.2 Handling

1. A radioactive material label shall be attached to each sealed source. The label information shall state the radionuclide, activity, and date of assay. Lettering shall be legible from a safe distance. Whenever possible, the source capsule itself should have a mark identifying the radionuclide engraved or etched on it. Unsealed sources should be stored in containers that have the same information attached to the container.
2. Remote handling equipment is required for sources having an exposure rate of more than 100 millirem per hour at 1 meter and must be used at all times. Movement of sources from the shielded position to the calibration position should be accomplished by mechanical manipulators or other remote control methods; however, only methods of transfer that do not subject the source to repeated shocks, vibration, or pressure should be used.
3. All sealed sources shall be leak-tested by the RSO for possible surface contamination prior to initial use. Subsequent tests shall be performed at least once every six months.

13.3 Transport of Sources (See also Section 20)

1. **External Transport**
   a. All sealed and unsealed sources of radioactivity shall be transported directly to their building use location by the carrier delivering the order.
2. **Internal Transport**
   a. Transport of sources within a building shall be accomplished with appropriate shielded containers. The shield design must be adequate to reduce personnel exposure as much as practicable. The container must be labeled with the "Caution Radioactive Material" label, the radionuclide, date, and amount.
   b. In cases where the radiation level cannot be shielded below 5 mR/hr at 30 cm, the container must have wheels or be placed on a cart. The cart or device must be posted with a "Caution Radiation Area" sign and handled to minimize exposure.
   c. Sources shall not be left unattended in hallways and shall be secured against unauthorized removal at all times while in storage.

d. Only persons who have completed the Radiation Safety training program at the University may transport sources. In most cases, the person shall be equipped with a monitoring device such as a dosimeter.

13.4 Storage of Radioactive Materials (See also Section 19)

Radioactive materials stored in an unrestricted area shall be secured against unauthorized removal from the place of storage:

1. Access to radioactive materials must be restricted to authorized radiation workers.
2. Methods of restricting access include, but are not limited to, the following:
   a. locking laboratory doors when no personnel are present,
   b. locking a corridor or suite containing several rooms, and
   c. placing radioactive stock vials in a locked refrigerator or a lockbox to prevent removal.

SECTION 14: PROCEDURE FOR OBTAINING RADIONUCLIDES

14.1 Approval to Use Radioactive Material

Principal Investigator: Must notify the RSO of their desire to use radioactive materials and provide documentation of radiation training or an appropriate CV.

Radiation Worker: Must take appropriate training, pass the required exam, and apply for a dosimeter using the dosimeter request form in Appendix A of this manual

14.2 Orders for Radioactive Material

The RSO must be notified of all radioactive materials orders and tracking and receipt must be coordinated with the RSO to ensure timely package survey upon receipt. Only qualified and RSO-approved personnel are allowed to initiate orders for radioactive material.

1. Information that must be sent to the RSO includes name of vendor, delivery location, catalog number, quantity (# of isotopes wanted), measure (amount of millicures wanted), complete description of material
2. The RSO will authorize each order for radioactive materials by ensuring that the requested materials and quantities do not exceed possession limits assigned to that permit. If the permit limit is exceeded, the order will not be placed and the department will be notified.

14.3 Receipt of Incoming Radioactive Material Shipments

1. The RSO must be notified of any pending radioactive shipments and all incoming radioactive shipments to JMU shall be received, inspected, and surveyed by the Authorized User. If there is any visible damage to the exterior package or obvious signs of leaks, THE PACKAGE MUST NOT BE ACCEPTED and the RSO notified. Instead, send it back with the carrier to the supplier. For packages that are received, the documented inspection and survey must be performed within 3 three hours of receipt. Immediately notify the RSO if contamination is found or there is anything unexpected regarding the shipment. The survey documentation must be immediately forwarded to the RSO for review and filing. This includes radioactive materials that are considered exempt quantities or are generally licensed.

2. 12VAC5-481-900 requires that the licensee immediately notify the final delivery carrier and, by telephone and either telegram or facsimile, VDH when removable radioactive surface contamination exceeds the limits of 49 CFR 173.44 or external radiation levels exceed the limits of 12 VAC5-481-3070.

3. Numerous kinds of commercial equipment now contain radioactive materials in such small quantities that labeling or special packaging is not required by governmental shipping regulations. Personnel should be aware, however, that radiation and leakage from these items may cause technical interference with the sensitive radiation measurements made in many University programs.

4. All radioactive materials must be registered with the RSO regardless of the amounts involved or the method or type of fabrication of such material. This specifically includes all radioactive materials received from other-than-commercial vendors, such as other universities, private research organizations, or government laboratories. A strict inventory is required by the University's Radioactive Materials License, which limits the total amount of radioactive material that may be possessed.

SECTION 15: OPENING RADIONUCLIDE CONTAINERS

1. Radioactive packages must have the required radiological surveys performed before opening. If contamination is detected, immediately stop and notify the RSO.

2. Proper personal protective equipment, including impermeable gloves and a laboratory coat, should be used when handling radioactive material containers. In addition, there should be no bare skin exposed that could become inadvertently contaminated; therefore, shorts, skirts, and open-toed shoes may not be worn.

3. The DOT White I, Yellow II, or Yellow III label or packing slip must be verified for activity of contents, so shipment does not exceed license possession limits. If possession limits are exceeded, immediately notify the RSO.

4. Special handling or opening procedures supplied by the vendor should be followed and the integrity of the final source container checked (e.g., inspecting for breakage of seals or vials, loss of liquid, discoloration of packaging material, high count rate on smear). If anything, other than expected is observed, stop and immediately notify the RSO.

5. Stock vials and other radioactive materials containers shall be opened only in properly posted rooms.

6. Extreme caution should be used when opening the inner vial containing the radioisotope. Personnel and area monitoring for possible contamination should be performed after all use or handling of radioactive materials.

7. The container usually includes the liner, shield, absorbent materials, and isotope container, which may be contaminated. Container material should be disposed of as radioactive waste if found by appropriate monitoring techniques to be contaminated. (Any container placed in

regular trash must be surveyed for contamination and have all radioactive labels removed or obliterated.)

8. Problems should be reported to the AU or RSO.

SECTION 16: RADIOACTIVE WASTE DISPOSAL

The treatment and ultimate disposal of radioactive wastes depend on many factors and are strictly regulated by both the Virginia Department of Health and Virginia Department of Environmental Quality. Regardless of the method of disposal, written records must demonstrate that disposal amounts are reasonably balanced against the acquired amounts.

16.1 General Rules

1. Minimization of radioactive and mixed waste is a regulatory requirement and an important University goal to minimize risk and concomitantly reduce costs. An important step in volume reduction is to segregate radioactive waste from nonradioactive waste.
2. Packages that present added hazards may require sorting before they can be disposed of. Such hazards include the presence of sharps (broken glass, hypodermic needles, razor blades, etc.), hazardous chemicals, and overly filled liquid waste containers.
3. All liquid waste shall be accumulated in compatible containers identified with a waste tag and contained by a secondary containment. The primary container should not be filled to more than three-quarters full.
4. Scintillation vials should be stored in separate containers.
5. Tags for labeling radioactive waste for disposal must include
   a. date,
   b. radionuclide(s),
   c. decay-corrected activity in microcuries or millicuries for each radionuclide,
   e. name of the AU and lab room number, and
   f. any additional chemicals that are present
6. Needles, syringes, and sharps of any kind must be collected in a sharps container.
7. Disposal of any high-activity waste will be handled on an individual basis. Contact the RSO to make arrangements.
8. All waste disposals must be recorded. The amounts recorded should agree with the amount written on the waste tag.
9. All radioactive identification labels must be defaced or removed from radioactive containers and packages before disposal in radioactive waste containers. Containers and material that are not contaminated should be discarded as nonradioactive waste.

SECTION 17: ANIMALS CONTAINING RADIOACTIVITY

1. No research involving animals may be conducted without receiving approval from JMU's Institutional Animal Care and Use Committee (IACUC).
2. Any planned use of radioactivity in animal experiments must be reviewed and approved by the RSO before any associated work begins.

SECTION 18: PROCEDURES IN CASE OF RADIOLOGICAL INCIDENTS

18.1 Incident Reporting

All incidents involving the use of radiation-producing machines or radioactive material, no matter how minor the accident, must be reported immediately to the RSO. After hours and during weekends or holidays, call Campus Police at 568-6911. The notification and reporting of incidents is mandatory according to 10 CFR 20.403.

18.2 Radiological Incidents

A radiological incident is any event (defined below) involving radioactive contamination, high radiation levels, or the loss of radioactive materials.

All radiation workers are responsible for reporting incident conditions to the RSO. These reports must be made at the earliest opportunity following discovery of the incident and no later than two hours afterward.

Examples of radiological emergencies are

1. Missing radioactive material
2. Spills of radioactive material that could potentially lead to airborne or surface contamination limits being exceeded
3. Release of radioactive material to the environment that could exceed limits
4. Receiving a dose in excess of administrative limits
5. Unexpected airborne materials that could cause an environmental or safety concern
6. Malfunction of a radiation-producing machine with personnel receiving a dose in excess of 1 rem
7. Personnel contamination
8. Fire or flood involving radioactive material

The general procedure to follow in the event of an incident is as follows:

1. Stop the cause of the incident if this can be accomplished without additional risk to yourself or co-workers.
2. Warn others in the area and notify Radiation Safety and your Supervisor.
3. Isolate the affected areas by closing doors, putting up barriers, and/or guarding the entrances to the area.
4. Minimize your exposure to radiation and/or radioactive materials.
5. If possible, secure local fans if radioactive material could be spread by the fans.

6. If you suspect that you are contaminated, stand fast and call for help. Minimize your movements to prevent the spread of contamination.

Under no circumstances shall any untrained person attempt to examine or clean up any spilled radioactive material. Proper precautions taken immediately will protect the environment and worker health and safety.

Spill of radioactive material

A radioactive material spill is defined as the inadvertent release of radioactive materials to an undesirable location with the potential of exceeding contamination limits. Radioactive spills are rarely a physical hazard in the research environment, but they have the potential to raise significant issues and incur considerable expense in the future to decontaminate university facilities. Spills of radioactive materials may jeopardize ongoing and future research and teaching activities. All spills of radioactive materials shall be reported to the RSO or Campus Police immediately. Research personnel involved in the spill shall take the immediate actions noted below and shall proceed with spill cleanup. The immediate actions to be taken in the event of a radioactive materials spill are outlined below. The acronym used to remember these actions is "SWIMS":

Stop *the spill by capping any open container(s) and placing absorbent materials on top of spilled liquids.* The purpose of this step is to take actions to prevent the spill from worsening. Taking these actions help contain the potential spread of radioactive contamination.

Warn *others of the spill by announcing it to co-workers, posting a notice on the door to the laboratory (if appropriate), and contacting the Radiation Safety Unit or Security.* These actions let others know of the spill so they can take appropriate actions such as rendering assistance, donning protective clothing, evacuating the area, or avoiding walking through the spill area, as appropriate for the specific instance.

Isolate *the area by erecting boundaries, posting warning signs, or taking other actions as appropriate.* This prevents the inadvertent contamination of personnel and limits the spread of contamination away from the spill area. No personnel may enter a spill area unless they don appropriate anti-contamination clothing such as shoe covers, a laboratory coat, and protective gloves. No personnel may leave a spill area until they have been surveyed and found to be free of contamination.

Minimize *personnel exposure by carefully considering the extent of the spill, determining appropriate personal protective equipment, and conducting radiological surveys to delineate the spill area*. This helps to maintain personal exposures as low as reasonably achievable.

Stop *ventilation if possible and appropriate by turning off room or area ventilation, shutting ventilation dampers, or other appropriate measures.* This reduces volatilization of liquid compounds and distribution of powdery solids.

Cleanup of the spill shall commence immediately upon completion of the above immediate actions. Following decontamination, surveys shall be performed using appropriate equipment to verify cleanup to appropriate levels has been accomplished. Copies of these surveys will be maintained by the RSO and by the laboratory involved in the spill. These surveys shall note the exact location and extent of spilled radioactive materials prior to commencing decontamination efforts, the contamination levels noted at the time of the spill, and post-cleanup contamination levels (both fixed and removable). In general, use the following rules of thumb when cleaning up a radioactive spill:

1. Clean from top to bottom on vertical surfaces or when contamination is at several different levels.
2. Clean from the outside to the inside of a spill.
3. Clean from areas of low contamination toward areas of high contamination.

Skin contamination

Skin contamination refers to the presence of radioactive materials in direct contact with a person's skin. Skin contamination is a concern because of the potential for very high localized radiation dose and because of the potential for uptake of radioactive materials attached to compounds that are absorbed through the skin and into the body. Skin contamination is almost entirely preventable through the proper use of protective clothing (gloves, lab coats, closed-toe shoes, wearing pants instead of shorts, and so forth). In the event that skin contamination does occur, the following procedure should be followed.

1. Notify the RSO immediately.
2. Estimate the amount of radioactive material on the skin. This may be done by using an appropriate meter and recording the count rate, type of detector, and isotope.
3. Commence decontamination efforts, beginning with mild soap and cool or warm water. In general, do not take measures that cause pain or that may degrade the skin's natural ability to act as a barrier. Decontamination efforts should continue until the RSO arrives, the decontamination is successful, or it is determined that continued efforts are inadvisable.

In the event of contamination with radioactive isotopes of iodine, a thyroid bioassay is required between 24 and 72 hours after the contamination occurs. In the event of contamination with a beta-emitting nuclide (H-3, C-14, S-35, P-32, for example) a urine bioassay is required between 24 and 48 hours after the contamination occurred. The purpose of these bioassay measurements is to determine if uptake of radioactive materials occurred. Personnel who are exposed to skin contamination shall remain in or near their laboratory area.

Ingestion or inhalation of radioactive materials

Potentially the most serious form of exposure to radioactive materials is via inhalation or ingestion since this brings radioactive materials into direct contact with living tissues and gives these materials a way to directly affect internal organs. Virtually all cases of ingestion or inhalation of radioactive materials can be avoided through the use of proper laboratory safety equipment including the use of fume hoods or face shields (when appropriate) and the elimination of eating and drinking in the laboratory environment. Personnel who may have ingested or inhaled

radioactive materials shall remain in or near their laboratory area. In the event there is a suspected uptake of radioactive materials through inhalation or ingestion, the following actions shall be taken immediately:

1. Stop the source of uptake if possible (for example; leave the room, move into fresh air, spit contaminated liquids out of the mouth, blow your nose, etc.).
2. Notify the RSO or JMUPD at 568-6911 immediately.
3. Estimate the amount of uptake to the best of your ability (save empty or partially empty stock vials, laboratory glassware, etc., that may help in this estimate).
4. Urine samples will be collected between 24 and 48 hours following any uptake of radioactive materials for bioassay. Personnel working with radioactive isotopes of iodine shall have thyroid bioassay measurements performed between 24 and 72 hours following exposure.

Exposure to abnormal and high levels of x-ray, beta, gamma, or neutron radiation

Abnormal levels of x-ray, beta, gamma, or neutron radiation are those levels that exceed 5 mrad/hr or that result in off-scale readings on the highest setting of any survey instrument. Radiation levels of 5 mrad/hr pose no risk to personnel but are indicative of problems that must be investigated. In the event abnormal radiation levels are encountered, personnel shall note the readings on their radiation survey instruments and immediately contact the RSO (or Campus Police after normal working hours). If radiation levels exceed 50 mrad/hr, personnel shall leave the area and assemble in a common area. Depending on the perceived severity of the incident, the RSO may collect or exchange radiation dosimetry at this time to ensure no personnel were exposed to excessive levels of radiation.

Loss of radioactive materials

Radioactive materials are considered lost if they cannot be located within 4 hours. Loss of radioactive materials is a serious concern that may have to be reported to the State of Virginia. If any worker feels they have lost radioactive materials, inform the RSO immediately. Be prepared to provide the following information:

1. The isotope(s) involved and the approximate activity of each
2. The last time that particular stock vial was used
3. The normal storage location
4. Actions taken to locate the missing stock vial

Upon arrival at the scene, the RSO will assist with attempting to locate the missing radioactive materials. If the materials cannot be located, all involved parties will be required to write a report detailing the circumstances surrounding the loss of radioactive materials and describing all actions taken. In addition, the RSO will determine the risk posed by the loss of radioactive materials (if any) and will report the loss to the Virginia Department of Health as required under the provisions of Virginia Radiation Regulations.

Fire or flooding involving radioactivity

If a room containing radioactive materials is involved in fire or flooding, the following actions shall be taken by personnel working in the area or noticing the problem:

1. Exit the area if you feel your life is in danger.
2. Immediately report the emergency to Campus Police (568-6911) including the fact that radioactive material is stored in the room in question.
3. During working hours, notify the RSO of the emergency.
4. DO NOT try to combat a fire yourself unless you are trained, have a clear means of egress and feel comfortable doing so.
5. If it is possible to safely isolate a source of flooding by operating an isolation valve or some other means, or to divert the water away from radioactive materials, try to do so.

Malfunction of radiation-producing machinery

Radiation-producing machinery include x-ray machines, linear accelerators, irradiators, and similar devices designed to produce ionizing radiation. There are specific requirements for operating such machines, including a requirement that all safety alarms and interlocks be working correctly at all times. In the event of any malfunction in any radiation-producing machine or related safety systems, the following actions shall be taken:

1. Exit the room containing the machine immediately.
2. Contact the RSO (8-4959) during normal working hours or Public Safety (8-6911) after hours, on holidays, or weekends.
3. Attempt to determine if the machine is emitting radiation.
4. If the machine is emitting radiation, attempt to disable or secure it without entering the room in which it is located.
5. Monitor radiation levels in the vicinity of the room housing the machine.

SECTION 19: STORAGE OF RADIOACTIVE MATERIALS

Radioactive materials are stored in a variety of forms, but regardless of the form of the radioactive material, certain requirements must be met to fully comply with regulatory requirements and good radiation safety practices. These requirements are enumerated below.

1. All rooms, corridors, or other areas containing radionuclides must be posted with the radiation symbol and the words “Caution, Radioactive Materials” or “Danger, Radioactive Materials”.
2. All storage cabinets, lockers, refrigerators, freezers, or other storage locations shall be marked with the radiation symbol and a list of the nuclide(s) and activity of each nuclide in that storage location.

3. All radioactive materials must be secured against unauthorized removal at all times.
4. Radioactive material storage locations shall be posted as "Radioactive Materials Storage Area" and shielded so that radiation levels are less than 2 mrem per hour at a distance of 1 meter from any accessible surface.
5. Bulk liquids shall be stored in a sealed container. These containers shall be kept in a secondary containment to minimize the potential for contamination in the event the primary container is breached or damaged.

SECTION 20: TRANSPORTATION OF RADIOACTIVE MATERIALS

20.1 Incoming Radioactive Material Shipments (See also Section 13.3)

Upon arrival, the package must be inspected and surveyed as soon as practicable, but not later than 3 hours after receipt of package to ensure that there is no damage and that the radioactive material is not leaking. If packages are received outside of normal working hours, the package must be surveyed within 3 hours of the beginning of the next work day.

20.2 Outgoing Shipments of Radioactive Material

If any shipments of radioactive material need to be made, contact the RSO. Other technical experts will need to be consulted to ensure that the packaging is appropriate, it has been properly surveyed, and that the receiving institution is properly licensed by either the NRC or an agreement state. A copy of the receiving institution's radioactive materials license must be provided to JMU to demonstrate proper licensing and authorization to receive a particular radioactive material.

20.3 Reports of Damaged Shipments

Any report of a damaged radioactive shipment to or from the University shall be promptly referred to the RSO for investigation.

SECTION 21: RADIATION-GENERATING DEVICES

21.1 Hazards from Radiation-Generating Devices

Hazards from radiation-producing equipment are classified into primary beam hazards and scattered radiation. The fact that adequate shielding against either the primary or the secondary radiation can be designed to eliminate such radiation hazards requires, in principle, well-defined rules for the elimination of such hazards.

21.2 Acquisition of Radiation-Generating Devices

1. The RSO must be alerted of the intention to acquire any Radiation-Generating Device and notified prior to the acquisition of any Radiation-Generating Device.
2. The RSO must be notified of any pending Radiation-Generating Device shipments and all incoming Radiation-Generating Device shipments to JMU shall be received, inspected, and surveyed by the Authorized User. All Radiation-Generating Devices must be registered with the RSO.

3. X-ray producing machines must be registered with the Virginia Department of Health and will also be surveyed at a frequency and at the direction of the Virginia Department of Health.

21.3 Rules for Safe Operation

1. Any facility having radiation-generating devices shall be surveyed for possible exposure hazards to the operators.
2. Operators of radiation-generating devices must have initial and annual radiation safety training that includes definition of ionizing radiation, acute and chronic health effects, restricted vs. non restricted areas, definition and units for dose, dose limits, ALARA and details of the radiation-safety, lights, interlocks and protection mechanisms associated with the device.
3. Radiation-generating devices include, but are not limited to, x-ray machines, fluoroscopy units, CT scanners, linear accelerators, x-ray diffraction units, electron microscopes, and other devices that produce ionizing radiation as a result of their normal operation.
4. Consistent with the findings of such surveys, specific operational limitations must be observed, and changes in protection design shall be carried out before the installation is approved for continued operation.
5. Dosimeters shall be worn by operators if exposures greater than 10% of those allowed in Section 7 are likely, or if the equipment is capable of producing greater than 5 millirem in 1 hour in an accessible area at a distance of 30 centimeters from the tube.
6. Radiation-generating devices should be surveyed during the initial operation of such equipment and whenever any change is made in the installation that might change the radiation level to which a person could be exposed. In evaluating the results of the survey, the actual operating conditions, including workload, use factor, occupancy and attenuation of the useful beam by patients or objects, shall be the criteria for recommendations of changes.
7. A written record of all surveys will be presented to the individual responsible for each unit within one week after the survey unless the survey indicates abnormal values in which case the responsible individual should be informed immediately. All serious violations, i.e., those that endanger research subjects, students, or employees must be corrected immediately or the unit must be shut down until such corrections can be made. Other, less serious violations will be handled according to the policy detailed in Section 5.
8. The RSO must be contacted prior to disposing of any radiation producing machines to ensure proper disposal and updating of associated regulatory registrations.

SECTION 22: EXPERIMENTAL AND USE OF IODINE AND VOLATILE COMPOUNDS

Iodine is a volatile element that is part of many compounds. Other radionuclides such as tritium are also used as part of volatile compounds at times. In addition, many compounds are easily absorbed through the skin. Any uptake of radioactive materials, especially iodine, carries with it

increased chance for elevated radiation dose to internal organs. The potential for uptake must be kept as low as reasonably achievable, and, if a person is exposed to possible uptake, it must be determined as quickly as possible so an accurate dose assessment may be performed. Examples of compounds in this category include

- Sodium iodide
- ^{35}S Methionine
- ^{3}H- $NaBH_4$, succinic anhydride, and acetic anhydride
- Compounds that are heated sufficiently that vapors may be released (e.g., heating tritiated water)

22.1 Precautions for Working with All Volatile Compounds (Including Iodine Isotopes)

1. All work shall be performed in a fume hood. Respiratory protection is not normally required if the fume hood is working properly.
2. Fume hoods shall be checked for proper face velocity at least annually.
3. The fume hood opening shall not be obstructed in such a way that airflow is impeded or eddies may form that could result in releasing radioactive materials from the fume hood.
4. Notify the RSO immediately in the event of a spill or failure of a fume hood while working with these compounds. The RSO will determine if a bioassay is necessary.
5. If stock solutions in excess of 5 mCi are to be used, contact the Radiation Safety Officer prior to such use. The Radiation Safety Officer will perform a dose assessment to determine if carbon filtration or other precautions are required.
6. The limits shown in Table 1 may be adjusted by the RSO if a researcher can demonstrate that the physical or chemical form of the compounds they are working with are not volatile.
7. Urine or thyroid bioassay will be required for all personnel who handle stock vials containing more than one Allowable Level for Intake (ALI) of any volatile radionuclide or radionuclide attached to a volatile chemical. Table 1 gives examples of some of these values.

Table 1

Isotope-use limits requiring bioassay. If a worker's isotope usage in a single application exceeds these limits, bioassay will be required. Continuing use of more than 1 ALI in any month also requires a thyroid bioassay. Fume hood filtration requirements are based on the single-use limit.

Nuclide	1 ALI
H-3	80 mCi
C-14	2 mCi
S-35	20 mCi

I-125	1 mCi
I-131	1 mCi

22.2 Additional Precautions for Working with Radioactive Iodine Compounds

1. All work with iodine compounds shall take place in a fume hood.
2. All personnel working with stock solutions containing more than 1 mCi of any iodine isotope shall receive a thyroid bioassay at least 24 hours afterward and no later than 72 hours after such work.
3. All personnel having skin contact with liquids containing iodine isotopes shall receive a thyroid bioassay at least 24 hours afterward and no later than 72 hours after the contact.
4. All personnel involved in decontamination of a spill containing any radioactive isotope of iodine shall receive a thyroid bioassay at least 24 hours afterward and no later than 72 hours after the spill.
5. Personnel working with iodine or volatile radioactive compounds on a regular basis may, with the concurrence of the RSO, receive monthly bioassay measurements.
6. The RSO will review isotope-use records to verify that bioassays are performed as required.

SECTION 23: MAINTENANCE ON CONTAMINATED OR POTENTIALLY CONTAMINATED EQUIPMENT

Many laboratories contain equipment that may be contaminated with radioactivity. Such equipment includes, but is not limited to,

1. Refrigerators and freezers in which radioactive materials are stored
2. Fume hoods in which radioactive materials are used or stored
3. Centrifuges, incubation ovens, and other pieces of large analytical equipment
4. Ventilation ducts, fans, filters, and other equipment downstream of a radioactive fume hood
5. Auto pipettes

Such equipment must be labeled with the radiation symbol if the ***potential*** for contamination levels in excess of 500 dpm/100 cm^2 exists.

When contaminated or potentially contaminated equipment requires repair or calibration, it must be surveyed and cleared by a qualified radiation worker ***prior*** to commencing repairs or (in the case of portable equipment) prior to removal from a posted laboratory. The sequence of operations required in such cases should be as follows:

1. Laboratory notifies the RSO of the need to survey broken equipment. Any qualified radiation worker may perform the equipment survey and decontamination in accordance with this

section; however, all such surveys will be documented and verified by the RSO within one working day.

2. Laboratory requests repair of equipment and notifies Facilities Management that equipment is used for radiological work.
3. Qualified radiation worker performs survey and informs Facilities Management of the results.
4. If the equipment is contaminated, laboratory staff will decontaminate and the decontamination will be verified by the RSO prior to repair work commencing.
5. The equipment will be posted with tag or sticker indicating it has been cleared for maintenance work and the date and time of the survey and Facilities Management will be notified.
6. Facilities Management will perform repair work and inform the RSO upon completion. Once the work is complete, the "cleared for maintenance" tag will be removed and returned to the RSO.

SECTION 24: GENERALLY LICENSED DEVICES

Under NRC regulations, a general licensee using a tritium EXIT sign must:

- NOT remove the labeling or radioactive symbol or abandon the sign;
- Properly dispose of an unwanted sign (see below);
- Report to the NRC or appropriate Agreement State any lost, stolen or broken sign;
- Inform the NRC or Agreement State of changes to the name or address of the general licensee or the person in charge of complying with the regulations;
- NOT give away or sell the sign unless it is to remain in use at its original location; in such a case, the general licensee making the transfer must give the new owner a copy of the regulations and report the transfer to the NRC or Agreement State within 30 days.
- Maintain an inventory of in-use tritium EXIT signs, including installation location, installation date, serial number, activity level.

Tritium EXIT signs must NOT be disposed of as normal trash. To dispose of a sign properly, a general licensee must transfer the sign to a specific licensee—such as a manufacturer, distributor, licensed radioactive waste broker or licensed low-level radioactive waste disposal facility. These facilities may charge a fee for disposing of the sign.

Within 30 days of disposing of a sign, the general licensee must file a report to the NRC or Agreement State. More information about the regulatory requirements for tritium exit signs can be found at 10 CFR Part 31.5.

APPENDIX A: *ADMINISTRATIVE FORMS*

- Dosimeter Request Form
- Unlicensed User Addendum Form
- Declaration of Pregnancy Form
- Physics/chemistry Radiation Suite Floor Plan to Document Surveys (page1)
- Physics/chemistry Radiation Data Page to Document Surveys (page 2)
- Radioactive Waste Label
- Radioactive Material Use Log
- Radioactive Material Receiving Survey Report

JAMES MADISON UNIVERSITY

Request for Dosimeter Service

(* Unlicensed users must also complete and attach the Unlicensed User Addendum.)

Name:_____ _____ _____

(last) (first) (MI)

Last 4 digits of SSN # _____

Student or Employee # _____

Male _____ Female _____

Date of Birth: (month) _____ (day) _____ (year) _____

Email Address: _____

Mailing Address: _____

Type of radiation to which you expect to be exposed:

alpha ____ beta ____ gamma ____ thermal neutron ____ fast neutron ____ x-ray ____

Are there any occupational (including student) radiation exposure records on file for you at any other institution or private company ? Yes ____ No ____

If Yes, please provide the following information below:

(a) Name and mailing address of institution or company
(b) Beginning and ending dates of exposure period

Signature of Applicant: _____Date: _____

Signature of Faculty Advisor: _____ Date: _____

(required for student applicants)

Radiation Safety Officer Approval: _____Date: _____

First Wear Date: _____

JAMES MADISON UNIVERSITY
Request for Dosimeter Service

Unlicensed User Addendum

(Top portion to be completed by unlicensed user).

Name: (last) _____ (first) _____ (MI) _____

Student or Employee Number_____

I understand the importance of maintaining safe laboratory conditions. Therefore, I agree to follow the established guidelines for radiation safety in all work that I conduct with radioactive materials.

I understand that failure to adhere to the established radiation safety guidelines will result in loss of authorization to use radioactive materials.

Signature of Unlicensed User _____Date: _____

(Bottom portion to be completed by licensed users serving as faculty advisors)

The unlicensed user named on this form works under my supervision (or is a student in my class) using radioactive materials. The student is authorized to use radioactive materials under my supervision. This use is to include, but is not limited to sealed sources.

I have reviewed radiation safety guidelines and emergency procedures with the above named user. To the best of my ability, I judge their knowledge of radiation fundamentals and laboratory techniques to be adequate for the work authorized.

The user has been informed concerning proper dosimeter usage, laboratory survey requirements, emergency procedures, and the consequences of improper behavior in regards to the handling of radioactive materials.

Signature of Licensed User _____Date: _____

Approval of Radiation Safety Officer _____Date: _____

JAMES MADISON UNIVERSITY
Exposure Policy and Program for Declared
Pregnant Women

Declaration of Pregnancy

TO: The Radiation Safety Officer and My Supervisor

_____

I am declaring that I am pregnant. I believe I became pregnant in _____,
(only the month and year need to be provided). My Social Security Number is
_____-_____-_____.

I understand that my occupational radiation dose during my entire pregnancy will not be allowed to exceed 500 millirem (unless that dose has already been exceeded between the time of conception and submitting this letter).

I understand that my occupational radiation does during each month cannot exceed 50 millirem (unless that does has already been exceeded between the time of conception and submitting this letter).

I also understand that meeting the lower dose limit may require a change in job or job responsibilities during my pregnancy.

After I have delivered my baby, or if I find that I am not pregnant, or if my pregnancy is terminated, I will inform the Radiation Safety Officer and my supervisor in writing that participation in this Declared Pregnancy Program is no longer required.

_____
(Your Signature)

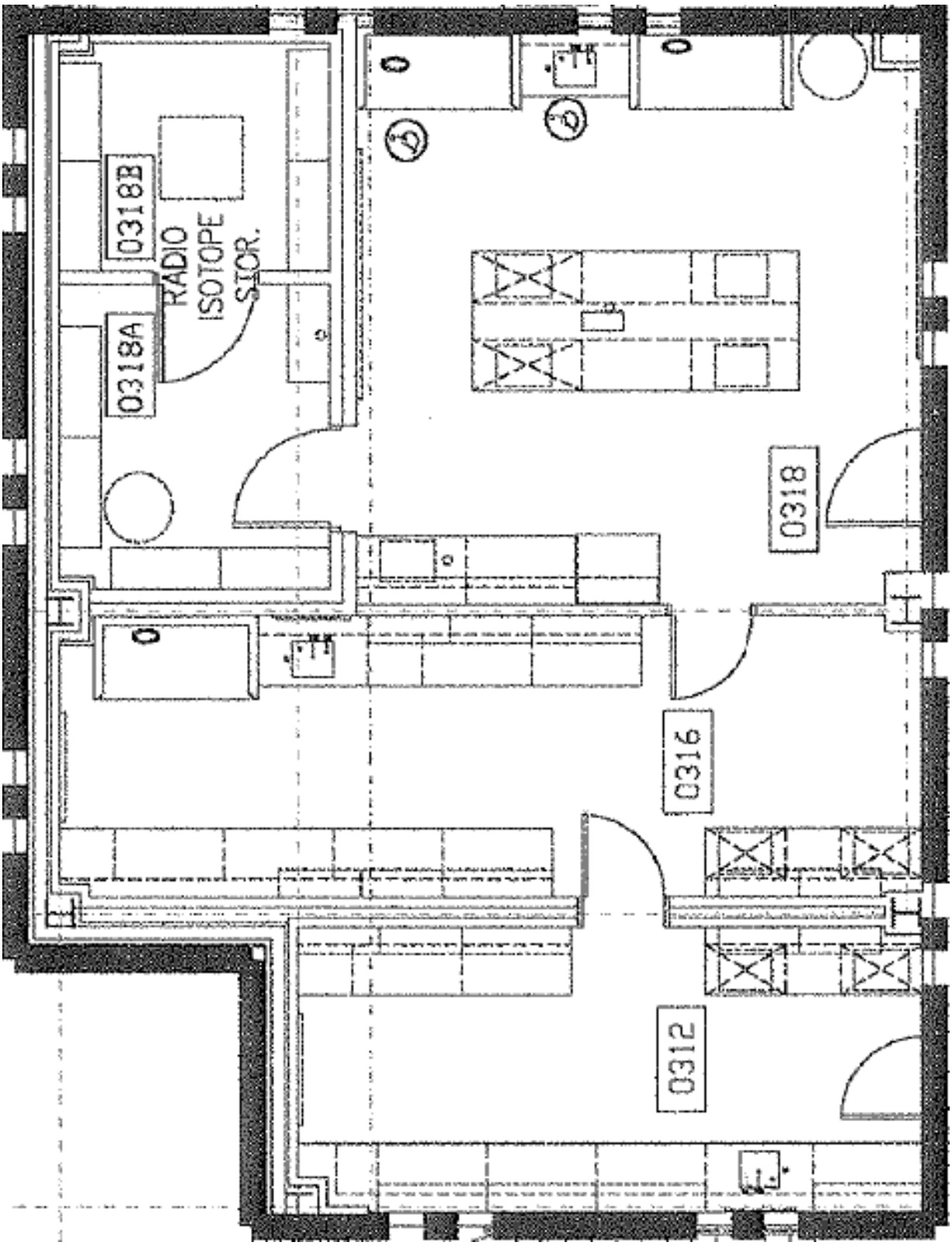
_____
(Your Name Printed)

_____
(Date)

For Radiation Safety Officer Use Only

Date Received: _____ Deletion Date:_____

PHYSICS/CHEMISTRY RADIATION SUITE FLOOR PLAN TO DOCUMENT SURVEYS



JAMES MADISON UNIVERSITY

LABORATORY RADIATION SURVEY REPORT

NOTE: A laboratory radiation survey must be performed at the conclusion of radioactive material usage and must be approved by the RSO. Write legibly in ink.

Building: Physics and Chemistry	
Laboratory Supervisor: Dr. Dan Downey	Phone Number: 540-568-6635
Surveyor:	Survey Date:
Nuclides Used:	
Instrument Used: Perkin Elmer TriCarb Model B281000 Serial #SGTC06150543	**Other ***:(Write Instrument Name and Serial #)

Survey Locations, as numbered on the attached room diagram, and Results

Numbered Location	Survey Results **	Numbered Location	Survey Results **
1		16	
2		17	
3		18	
4		19	
5		20	
6		21	
7		22	
8		23	
9		24	
10		25	
11		26	
12		27	
13		28	
14		29	
15		30	

*Instrument must have been calibrated within last 12months.

**Wipes reported as dpm/100cm2

Comments

RSO Approval:_____ Date: _____

RADIOACTIVE WASTE LABEL

MIXED WASTE ACCUMULATION LOG

Date	Radionuclides	Decay-corrected activity (mCi or µCi) for each nuclide	Name	Room Number	Additional Chemicals Present

RADIOACTIVE MATERIAL USE LOG (Legibly Print ALL Information)							
Date	User	Vial/Container Description	Original Vial Activity	Amount Withdrawn	Activity Withdrawn	Amount Remaining	Comments

JAMES MADISON UNIVERSITY
Radioactive Material Receiving Survey Report

Note: A separate form must be completed for each primary container included in the shipment. Survey must be conducted within three (3) hours of receipt of package (if package was received within normal business hours) or within three (3) hours of beginning of next working day (if package was received after normal business hours).

Date of Arrival of Shipment: _____ Time: _____ AM/PM

Date of Survey of Package: _____ Time: _____ AM/PM

Vendor: _____ JMU DO/PCO # _____

Isotope: _____ Chemical Form: _____

Total Activity: _____ Half-Life: _____

Is there any evidence of damage or leakage of the secondary container? _____
If yes, please describe _____

Is there any evidence of damage or leakage of the primary secondary? _____
If yes, please describe _____

If there is visible damage or leakage of either or both containers, notify the RSO before proceeding.

Dose Rate Measurements:

Survey Instrument Used: _____ S/N: _____

Surface of Secondary Container _____ mrem/hr

Surface of Primary Container _____ mrem/hr

Wipe Test Results:

Instrument Used: _____ S/N: _____

Background Reading: _____

Secondary Container Wipe _____ dpm/100 cm^2

Primary Container Wipe _____ dpm/100 cm^2

If analysis of the wipe indicates contamination, place the primary container back into the secondary container with the original packing material and notify the RSO.

Name of Person Conducting Survey: _____ Signature: _____

Name of Authorized User: _____ Signature: _____