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1.0 INTRODUCTION

All use of radioactive material at Woods Hole Oceanographic Institution (WHOI), or under the authority of WHOI’s radioactive material licenses, is subject to the review and approval of the Radiation Safety Committee. This Committee is appointed by the Executive V.P. & Director of Research and consists of members of the Scientific, Technical and Graded staff, the Radiation Safety Officer, and the Assistant Radiation Safety Officer. In accordance with the Radiation Safety Manual, the Committee has the authority to approve, disapprove, revoke, or request modifications to any proposed or current uses of radioactive material and radiation generating devices.

The primary responsibility for radiation safety rests with those individuals authorized by the WHOI Radiation Safety Committee (RSC) to use radioactive material or radiation generating devices (RGDs). This Radiation Safety Manual (RSM) is an integral part of the Institution’s radioactive materials licenses, which have been issued by the Massachusetts Department of Public Health, Radiation Control Program and the U.S Nuclear Regulatory Commission (NRC). The requirements of this manual apply to both the use of radioisotopes in research and the use of radiation generating devices. The manual supersedes the Isotope Users Manual. The procedures and practices detailed in this manual have been established for the following purposes:

• To ensure that employee exposure to ionizing radiation is maintained As Low As Reasonably Achievable (ALARA).
• To provide for the protection of the WHOI community and the general public against hazards associated with possession, use, transport, and disposal of radioactive materials used by WHOI.
• To ensure WHOI’s compliance with all applicable regulations promulgated by Federal, State, and local agencies.

Therefore, each user, or prospective user, of radioactive material or RGDs at WHOI must become familiar with and follow all applicable requirements delineated in this manual. In circumstances where a researcher persistently fails to follow the applicable rules and regulations, the Committee and/or Radiation Safety Officer is responsible for recommending to the Director of Research that a current Authorization be suspended or revoked.

1.1 Government Regulations

The WHOI Radiation Protection Program is regulated by several government agencies. The pertinent portions of applicable regulations are described throughout this manual and the appendices. The Radiation Protection Program governing the licensed radioactive material work activities conducted on Woods Hole Oceanographic Institution property must meet standards established by Massachusetts regulations. The Radiation Protection Program governing licensed radioactive material work activities conducted on WHOI research vessels or in field activities outside of Massachusetts must meet the standards established by NRC regulations. The Massachusetts license authorizes activities on WHOI property located in Massachusetts and provides authorizations for WHOI to:

• Receive, acquire, possess, and transfer radioactive materials designated within the scope of the license.
• Use such licensed material for the purpose(s) and at the place(s) designated by the license; and
• Deliver or transfer such material to persons authorized to receive it in accordance with the regulations in 105 CMR 120.

A copy of the Massachusetts Radioactive Material License is maintained on file at the WHOI Radiation Safety Office. The NRC license allows use of licensed material in research vessels at sea in national and international waters, and in ponds, lakes, bays, and coastal waters located anywhere where the NRC maintains jurisdiction for regulating the use of licensed material, including areas of exclusive Federal jurisdiction within Agreement States. The NRC license which authorizes WHOI to:

• Receive acquire, possess, and transfer byproduct, source, and special nuclear material as designated by the license;
• Use such material for the purpose(s) and at the places designated by the license; and
• Deliver or transfer such material to persons authorized to receive it in accordance with the regulations of the applicable Part(s) of Title 10, Code of Federal Regulations, Chapter 1, parts 19, 20, 30, 31, 32, 33, 34, 35, 36, 39, 40, and 71.

A copy of the NRC license is also maintained on file at the WHOI Radiation Safety Office. Both licenses stipulate that the Institution’s licensed material shall only be used by, or under the supervision of, individuals designated, in writing, by the Radiation Safety Committee. The NRC license also states that the Institution is authorized to transport any licensed material only if it follows the provisions of 10 CFR Part 71, “Packaging and Transportation of Radioactive Material”. Part 71 requires that licensees who transport licensed material or who may offer such material to a carrier for transport must comply with the applicable requirements of the U.S. Department of Transportation (DOT) that are found in 49 CFR Part 171 through 173.

This Radiation Safety Manual and its protocols have been written to facilitate and ensure WHOI’s compliance with the all applicable Federal and State regulatory requirements.

1.2 Occupational Dose Limits

1.2.1 Massachusetts Regulatory Limits

It is a regulatory requirement and an Institution policy that every effort be made to maintain exposures to ionizing radiation As Low As Reasonably Achievable (ALARA). The Institution must control the annual occupational dose to individual adults, except for planned special exposures, to the most limiting of the following limits:

• A Total Effective Dose Equivalent (TEDE) of 5 rems, or
• The sum of the Deep-Dose Equivalent (DDE) and the Committed Dose Equivalent (CDE) to any individual organ or tissue other than the lens of the eye of 50 rems
• An Eye Dose Equivalent (EDE) of 15 rems
• A Shallow Dose Equivalent (SDE) of 50 rems to the skin or to any extremity

1.2.2 WHOI Administrative Limits

To comply with the ALARA requirements, the Institution has established administrative personnel exposure limits that are 20% of the regulatory limits. These limits are established to ensure that the Radiation Safety Officer can stop, or limit, a worker’s activities until the radiation controls for the project can be adequately reviewed and modified to ensure that the worker does not exceed any of the regulatory limits. These administrative limits are the most limiting of the following:

• A Total Effective Dose Equivalent (TEDE) of 1 rems, or
• The sum of the Deep-Dose Equivalent (DDE) and the Committed Dose Equivalent (CDE) to any individual organ or tissue other than the lens of the eye of 10 rems
• An Eye Dose Equivalent (EDE) of 3 rems, and
• A Shallow Dose Equivalent (SDE) of 10 rems to the skin or to any extremity
• A Declared Pregnant Worker TEDE of 0.1 rems to the embryo/fetus during the entire term of the pregnancy

1.2.3 Declared Pregnant Worker Dose Limits

A Declared Pregnant Worker is a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception. If a woman chooses to declare her pregnancy, it is the responsibility of the pregnant worker to notify the Radiation Safety Office as soon as possible after pregnancy is confirmed. Refer to Protocol 1, “Declared Pregnant Women”. This form can be found at http://ehs.whoi.edu/ under Radiation Safety tab. The dose equivalent to an embryo/fetus during the entire pregnancy, due to occupational exposure of a declared pregnant worker, shall not exceed 0.5 rems. The
dose equivalent to the embryo/fetus is the sum of the deep dose equivalent to the declared pregnant worker and the dose equivalent resulting from any intakes of radionuclides.

1.2.4 Minors (less than 18 years old)
Massachusetts labor law prohibits minors (less than 18 years old) from working with carcinogens, which includes radioactive materials and radiation.

1.3 Public Dose Limits
105 CMR 120 requires that the Institution must also restrict licensed or registered operations such that:
- The total effective dose equivalent to individual members of the public does not exceed 0.1 rems in a year,
- The dose rate in any unrestricted area from external sources of radiation does not exceed 2 mrems in one hour, and
- The total effective dose equivalent to individual members of the public from infrequent exposure to radiation from radiation generating devices does not exceed 0.5 rems per year.

In accordance with 105 CMR 120, the Institution shall maintain records sufficient to demonstrate compliance with the dose limit for individual members of the public. These records shall be maintained until the State terminates each pertinent license requiring the record.

1.4 Radiation Protection Training
Before working with licensed material all workers who have the potential to receive an occupational exposure in excess of 100 mrems in a year must receive radiation safety training commensurate with their assigned duties. Section 105 CMR 120 defines the topics that should be covered as a minimum to meet the training requirement and outlines the worker’s responsibility to adhere to the instructions provided and report conditions that could be unsafe and/or lead to a violation of a regulatory requirement. The training can take any form, but the person conducting the training shall be a qualified individual who is familiar with the Institution’s radiation protection program and authorized by the RSO. Annual refresher training must be performed to ensure that all radiation workers understand applicable requirements of the WHOI Radiation Safety Manual and its protocols. It is the policy of WHOI and a license condition to require initial and annual refresher training for all employees who work with radioactive material regardless of the anticipated annual occupational exposure. All training is documented and filed.

2.0 RADIATION SAFETY ORGANIZATION
The radiation safety organization for WHOI consists of the Radiation Safety Committee (RSC), Radiation Safety Officer (RSO), Assistant Radiation Safety Officer (ARSO), Authorized Users, and Radiation Workers. The RSO and ARSO can be contacted at x2242, x3347, or x3788 for assistance.

2.1 Radiation Safety Committee
The Radiation Safety Committee (RSC) has been established by the President and Director. The Director of Research appoints members to the RSC. The membership, responsibilities, and Committee meeting requirements are detailed below.

2.1.1 RSC Membership
Membership of the RSC shall be drawn from the WHOI research and research support community and consist of the Chair, at least three additional members from the Scientific, Technical and Graded Staff, the RSO, and the ARSO.

2.1.2 RSC Responsibilities
- Oversee the radiation protection program and ensure compliance with license conditions and applicable regulations.
• Provide advice and assistance as required for radiation protection and compliance with regulations.
• Review and approve all new requests for Authorized Users and specify modifications to research protocols and radiological work practices as needed to provide maximum protection.
• Review qualifications of persons applying to become a new Authorized User of radioactive material.
• Review and approve all amendment requests for Authorized Users that includes increases in isotope(s), activity limits, and/or changes to use and storage locations.

2.1.3 Recommend appropriate action to the Director of Research for any individual who persistently fails to observe the rules and regulations related to the safe use of radioactive material.

2.1.4 Meetings

The WHOI RSC has established a schedule to ensure that, at a minimum, there shall be approximately three meetings per year. Additional meetings may be held at the discretion of the RSO or RSC Chair. Committee members should provide the RSO and RSC Chair with topics for the meeting agenda prior to the scheduled meeting. The RSO is responsible for ensuring that meeting minutes are recorded and distributed to all committee members.

All members of the RSC shall make note of the established meeting dates and, to the extent possible, maintain a clear schedule for that date in order to attend the meeting. Should urgent business arise when the RSC Chair is unavailable, the RSO or any other Committee member may convene the RSC.

2.2 Radiation Safety Officer

The Radiation Safety Officer (RSO) is responsible for the implementation and maintenance of the Radiation Safety Program. The specific responsibilities of the RSO are as follows:
• Provide consultation/advice to the WHOI community on all matters involving radiation safety.
• Ensure that rules and regulations promulgated by governmental agencies and policies and procedures established by the RSC are followed.
• Stop any operation that may endanger health or cause contamination problems. In these instances, details of the situation must be reported to the RSC as soon as possible.
• Arrange for the calibration of survey and monitoring equipment annually (or as needed) and maintain associated records.
• Arrange for or conduct semi-annual surveys, leak tests, and inventories (as applicable) of sealed sources of ionizing radiation.
• Arrange for or conduct inspections of facilities and equipment where sources of ionizing radiation are used or stored, at least semi-annually.
• Review all requests for new Authorized Users of radioactive material and requests for amendments to existing Authorizations. After any necessary clarification of information on the request has been made, the RSO will submit the request to the Radiation Safety Committee for review and approval. NOTE: only requests for new authorized users, new isotopes, increases activity levels, or new isotope use/storage locations will require Radiation Safety Committee review.
• Review and approve all requests for new Radiation Worker authorizations that are not part of a new Authorized User request.
• Review and approve all requisitions for radioactive material and maintain a file of the radioactive material receipt records.
• Maintain a record of all isotopes purchased and used by Authorized Users to ensure Institution isotope activity limits are not exceeded. Maintain the radioactive materials inventory system.
• Manage the Low-Level Radioactive Waste (LLRW) disposal program.
• Periodically review and revise, as needed, the Radiation Safety Manual (RSM). Any major revisions will have the approval of the RSC prior to implementation and RSM distribution. Minor revisions to the RSM and protocols do not require RSC review and can be made with page changes.
• Provide Radiation Safety Training to all Authorized Users and Radiation Workers.
• Maintain a reference library of radiation safety materials and pertinent government regulations.
• Conduct semi-annual or more frequent audits of all Authorized Users to confirm compliance with the requirements governing the use of radioisotopes at WHOI.
• Coordinate an annual radiation safety program review (should not be conducted by the RSO or member of the RSC).

2.3 Assistant Radiation Safety Officer

The Assistant Radiation Safety Officer (ARSO) provides assistance to the RSO, as necessary, to perform the above duties.

2.4 Authorized User Responsibilities

Each individual authorized to use radioactive material is responsible for complying with the procedures, applicable protocols, conditions of authorization and this manual. Non-compliance could result in a recommendation to the Director of Research that the authorization be revoked.

Authorized User responsibilities:
• Comply with all applicable regulations and provisions of this manual.
• Maintain a current listing of all rooms in which radioactive material is handled or stored.
• Allow only qualified Radiation Workers who are listed on the user’s Authorization to work with radioactive material using established and approved protocols.
• Provide training or arrange for Radiation Safety training of personnel as required.
• Maintain an accurate inventory of the isotopes and associated activities possessed and ensure that authorized limits are not exceeded. Refer to Protocol 2, “Radioactive Material Procurement, Receipt and Accountability”.
• Allow only authorized personnel to work in areas that are designated as restricted areas for reasons of radiation protection.
• Submit to the RSO and/or RSC, for approval, any proposed new use of radioactive material, changes in radionuclides used, or changes that may increase the potential for personnel exposure.
• Ensure that survey measurements to establish that radiation and contamination levels are within permissible limits. Refer to Protocol 11, “Radiation and Contamination Surveys”.
• Ensure that radioactive materials are properly labeled and secured.
• Ensure that experiments after normal working hours are properly attended.
• Ensure that laboratories are secured against unauthorized access.
• Inform all Radiation Workers and other laboratory personnel of the existence of the WHOI Declared Pregnant Worker Policy (Protocol 1) and their right to declare their pregnancy if they so choose.
• Conduct area surveys and wipe tests to verify that there are no contaminated areas in the laboratory. Refer to Protocol 11.
• Secure radioactive material from unauthorized access or removal. Maintain constant surveillance of radioactive material that is in use to prevent unauthorized removal or use. Refer to Section 5, “Control and Security of Radioactive Material”.
• Minimize the generation of radioactive waste and mixed waste. Mixed waste is both radioactive and hazardous and can be very expensive to dispose.
• The Authorized User and Radiation Worker share the responsibility for informing visitors to the isotope use laboratory of the potential hazards existing in the lab and the related safety rules and precautions. Additionally, they are responsible for the proper signage and labeling of chemicals, other research material and wastes containing radioisotopes.
2.5 Radiation Worker Responsibilities

Each individual who has been approved as a Radiation Worker is responsible for complying with the procedures, protocols, conditions of authorization and precautions contained in this manual. Radiation Worker responsibilities:

- Follow established and approved protocols developed for isotope use.
- Comply with all applicable regulations and provisions of this manual.
- Be aware of hazards associated with the isotopes and chemicals used in the laboratory, and keeping radiation exposure As Low as Reasonably Achievable.
- Wear the prescribed radiation monitoring device (dosimetry badge) and/or participate in a bioassay program, if required.
- A female radiation worker who knows that she is pregnant should review the WHOI Declared Pregnant Worker policy. If a declaration of pregnancy is made, the pregnant worker needs to be aware that the exposure to the fetus, during the entire term of pregnancy, must not exceed 0.5 rems (1/10th of the allowable exposure to an adult radiation worker). For this reason, it is prudent for this individual to notify and consult with the RSO as soon as possible. Refer to Protocol 1. Utilizing appropriate personal protective measures to limit radiation exposure to embryo/fetus is required, e.g., wearing protective clothing and laboratory gloves, and utilizing protective barriers for isotopes requiring shielding.
- Develop good personal radiological and chemical hygiene work habits, such as: keeping the laboratory neat and clean; keeping isotope work surfaces covered with absorbent material; and performing isotope work only in approved and properly labeled areas.
- Perform personal contamination monitoring after using isotopes, using appropriate survey instruments. Refer to Protocol 11.
- Perform contamination surveys of isotope use areas using appropriate survey instruments and methods per Protocol 11. Contact the RSO if you need a survey instrument or have questions.
- Perform decontamination of workspace and equipment when necessary, based on the results of the contamination surveys. Refer to Protocol 12, “Decontamination Techniques”.
- Properly label and isolate radioactive waste that is generated in the laboratory. Refer to Protocol 6, “Posting and Labeling of Radioactive Material”.
- Reporting unsafe conditions and accidents/incidents to the supervisor and the RSO.
- Secure radioactive material from unauthorized access or removal.
- Maintain constant surveillance of radioactive material in use to prevent unauthorized removal or use of material. Refer to Section 5 “Control and Security of Radioactive Material”.
- The Authorized User and Radiation Worker share the responsibility for informing visitors to the isotope use laboratory of the potential hazards existing in the lab and the related safety rules and precautions. Additionally, they are responsible for the proper signage and labeling of chemicals, other research material and wastes containing radioisotopes.

3.0 REQUEST FOR RADIOACTIVE MATERIAL USE AUTHORIZATION AT WHOI

All applications for authorization to use radioactive material should be submitted at least 30 days in advance of the proposed time of isotope use in order to provide adequate time for thorough review by the RSO. New authorizations, at-sea/field use authorizations (see Section 16.0) and significant modifications to existing authorizations (i.e., new isotopes and use/storage locations) will require a full RSC review/approval. All other authorizations will only require RSO review/approval.

Initial Radioactive Material Authorized User request forms for At-Sea, Field and WHOI use are found at http://ehs.whoi.edu/. Authorization Amendments to existing Authorizations are requested using the applicable Radioactive Material Amendment Request form found at http://ehs.whoi.edu/. The RSO can assist with this process. As applicable, the items listed below may need to be addressed in the authorization request and/or protocol.
3.1 Qualifications and Experience of the Applicant

The training and experience of the Authorized User and other radiation workers named in the application must be included. If the training was not received at WHOI, documentation of completed training from the RSO or designee of the facility where the training was received is required.

3.2 Radionuclides and Protocols

All radionuclides proposed for use must be listed, including the name of the radionuclide (e.g., carbon-14), maximum activity to be on hand, physical and chemical form, and typical amounts to be used for each experiment. The amount requested must be justified and kept as low as possible. If the request is for a sealed source, the source description, radionuclide name and activity must be provided.

The laboratory protocols that will be used when working with the radioactive material must be described. Controls that will be used to ensure safe operations, security, and waste management must be described. Refer to Section 9, "Radiological Work and Safety Practices".

3.3 Radiation Detection Instruments

Radiation detection instruments must be appropriate for the radionuclides and radiological quantities of interest. If the instrument is shared with other researchers, the arrangement and availability of the instrument should also be included. Section 15, “Radiation Detection Instruments”, lists the monitoring applications for instruments used at WHOI.

3.4 Laboratory Facilities and Security

The following information must be provided with a description or diagram of the proposed use and storage areas:

- The building and room number(s) where the isotopes will be used and stored.
- Applicable radiological controls (e.g., lab hoods, shielding, containment, etc.) must be identified and described.
- All security measures for use and storage of radioactive material must be described. Refer to Protocol 6.

NOTE: 105 CMR 120, Security and Control of Licensed Sources of Radiation, states: a) the licensee shall secure licensed radioactive material from unauthorized removal or access, and b) the licensee shall maintain constant surveillance and use devices or administrative procedures to prevent unauthorized use of licensed radioactive material that is not in storage.

3.5 External Radiation Dosimetry

Dosimetry may be issued to workers exposed to x-rays or if the isotopes used are gamma emitters or beta emitters with energies greater than 150 keV. Dosimetry will not be issued to workers for the use of H-3, S-35, C-14, and/or alpha emitters. These isotopes emit beta radiation with energies less than 150 keV and are not detectable by dosimetry badges. Finger ring dosimeters may be issued to workers using high energy beta emitters (e.g., P-32). Refer to Section 7, “Radiation Dosimetry” for specific dosimetry requirements.

Request forms for radiation dosimeters are available at http://ehs.whoi.edu/. A signed completed application must be submitted for each individual named on the Application for Authorization.

3.6 Contamination Controls

If dispersible radioisotopes are to be used, the appropriate contamination controls must be used and described. Contamination controls may include lab hoods, storage/containment devices, personal protective equipment, contamination monitoring, etc.

Procedures involving volatile substances (e.g., volatile forms of radioiodines) require special controls. The use of filtered hoods (e.g., charcoal filter for iodine), sealed reaction vials, glove boxes, or other special containment devices may be required. Refer to Section 9, “Radiological Work and Safety Practices”.

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3.7 Radioactive Waste

The request for authorization must list the methods planned for handling radioactive wastes that are generated, minimizing waste volumes, and avoiding or minimizing mixed waste. The Radiation Safety Office will provide appropriate containers for the accumulation of all radioactive waste. Refer to Section 10, “Low Level Radioactive Waste”, for radioactive waste procedures.

3.8 Emergency Plan

Each request for authorization must include a plan for responding to various emergency situations that might arise, such as spills, injuries, or fire. Refer to “Section 17, “Emergency Procedures”.

4.0 PROCUREMENT, RECEIPT, AND STORAGE OF RADIOACTIVE MATERIAL

4.1 Authorized Limits

The radioactive material licenses issued to WHOI by Massachusetts and the U.S. Nuclear Regulatory Commission restrict the Institution to activity limits specific to the isotope in use. The radioactive material procurement and inventory control process prevents these activity limits from being exceeded.

In addition, each Authorized User of radioactive material is assigned a limit for the isotopes, which they use in their respective labs (refer to each User’s Authorization for specific isotope activity limits). Requests to purchase isotopes that would result in exceeding a specific Authorized User’s limit require an Amendment to the User’s Authorization and approval by the RSC.

4.2 Inventory Control

The radioactive material inventory database is used to track radioisotopes at the individual lab and Institution levels. It lists all isotopes by lab, Authorized User, and by specific isotope. The Radiation Safety Office is responsible for maintaining the radioactive material inventory database. As isotopes are received, used and disposed, the RSO or designee updates this information. Authorized Users are responsible for tracking and controlling isotope amounts during use and informing the RSO when isotopes can be disposed.

4.3 Procurement of Radioactive Material

To ensure that the purchase of radioactive material does not result in exceeding any licensed limits, the Radiation Safety Office must be involved in the requisition of all radioactive material prior to the placement of the order with a vendor/supplier or other licensee. Refer to Protocol 2 for instructions on procurement of radioactive material.

- Purchase requisitions must be approved by the RSO before being executed by the Procurement Office. If the RSO is not available, a Radiation Safety Committee member (preferably the Chair) may approve the purchase requisition. In the case of transfer of isotopes from another licensee, the RSO from the originating licensee must provide WHOI with the isotope, activity, and form of radioactive material.
- Requisitions will be checked to ensure that the acquisition of the material will not cause the Institution or field location to exceed the licensed possession limits.
- Requisitions shall be limited to the radionuclides and quantities specified in the User’s Authorization.
- Requests for isotopes different from those specified in the Authorization, or in quantities in excess of the original authorization, require an amendment to the Authorized User’s radioactive material Authorization. Amendment requests must be submitted to the RSO and RSC, and approved, prior to placing an order for the material.

4.4 Receipt of Radioactive Material (RAM) and Opening Packages

All licensed radioactive material must be approved by the RSO prior to being purchased, ordered, or shipped to WHOI. In general and unless pre-approved by the RSO, all radioactive material shipments are delivered to Distribution. If not visibly damaged and in coordination with the RSO, Distribution delivers the unopened
shipment to the authorized user, the RSO, or a hot lab in Clark, Redfield, or Watson. The package must be either secured or under direct control by authorized personnel at all times.

Prior to shipment, this delivery process must be coordinated with the RSO, the Authorized User or their designated radiation worker, and Distribution personnel. The receiving record shall be completed and maintained in the Radiation Safety Office files. Refer to Protocol 2 for a copy of Form 2.1 and for additional RAM receipt and accountability instructions.

The general radiation and contamination monitoring procedures for received packages are as follows:

- All Type A packages which are received and bearing White I, Yellow II, or Yellow III labels must be monitored for surface contamination within 3 hours after receipt if received during normal working hours or within 3 hours of the start of the next working day if received after normal working hours. Packages that are received after normal working hours must be secured. With the exception of some Pa-233 sources, most of our routine radioactive material shipments are not labeled and, thus, will not require surface contamination monitoring.

- Type A packages with evidence of damage (e.g., leaking) must also be monitored to determine external radiation dose rates, i.e., both external dose rates and contamination monitoring must be performed on the damaged package. All damaged packages should not be moved and must be immediately reported to the RSO (x2242, x3347).

- Excepted (unlabeled) and exempt packages do not require any monitoring unless damaged, in which case, monitoring for external surface contamination and external dose rates is required. Most of our radioactive material shipments are exempt or excepted and will not require contamination monitoring unless damaged.

- Immediately notify the RSO about any damaged or leaking package (x2242, x3347).

**NOTE:** Packages designated as containing H-3, Tritium, Tritiated Water, or Hydrogen-3 are not permitted in the Clark Laboratory. No dispersible radiocarbon sources (e.g., C-14) are permitted in McLean or Fye Laboratories.

### 4.5 Storage of Radioactive Material

All radioactive material will be kept or stored in a manner that provides adequate containment, radiation shielding, protection against breakage of primary containers, and protection against unauthorized removal. While not in use, all radioactive material must remain in a locked and posted storage area/unit.

### 5.0 CONTROL AND SECURITY OF RADIOACTIVE MATERIAL

Licensed radioactive materials must be secured or under the direct control of authorized personnel. The regulatory agencies governing the possession and use of radioactive material have strongly urged all licensees to establish and maintain a heightened level of awareness with regard to security of their radioactive materials.

In order to control unrestricted or unauthorized access and or use of licensed radioactive material, it is the responsibility of the last radiation worker exiting a radioactive material use laboratory to ensure that all radioactive material is secured within a locked cabinet, locked refrigerator, or a locked inner room and that laboratory door is closed and locked.

The RSO must be immediately notified if any licensed radioactive material is suspected or found to be missing from the designated Radiation Material Areas at WHOI.

Specific requirements for security and control of radioactive materials are listed below:
5.1 Massachusetts Regulations

105 CMR 120; Security and Control of Licensed or Registered Sources of Radiation:

- The licensee shall secure licensed radioactive material from unauthorized removal or access;
- The licensee shall maintain constant surveillance, and use devices or administrative procedures to prevent unauthorized use of licensed radioactive material that is in an unrestricted area and that is not in storage;
- The registrant shall secure registered radiation generating devices from unauthorized removal; and
- The registrant shall use devices or administrative procedures to prevent unauthorized use of registered radiation generating devices.

5.2 U. S. Nuclear Regulatory Commission Regulations

10 CFR 20; Security of Stored Material: The licensee shall secure from unauthorized removal or access licensed materials that are stored in controlled or unrestricted areas.

10 CFR 20; Control of Material Not In Storage: The licensee shall control and maintain constant surveillance of licensed material that is in a controlled or unrestricted area and that is not in storage.

6.0 TRANSPORTATION OF RADIOACTIVE MATERIAL

6.1 Pedestrian Transport Within WHOI Property Boundaries

Radioactive material may be hand carried or hand trucked by RSO-authorized personnel from one laboratory to another in the same building, and between laboratory buildings on the same campus, provided that the following conditions are met:

- The material is enclosed in a leak-proof, shatter-resistant container that is properly labeled.
- The inner package of radioactive material is double-bagged or in an equivalent type of packaging.
- The emitted dose rate at the surface of the container does not exceed 2 mrems/hr.
- There is no removable contamination on the surface of the container, as determined by a removable contamination wipe test.

6.2 Pedestrian Transport Outside WHOI Property Boundaries

NOTE: Motorized vehicle transportation of radioactive material between WHOI campuses must follow all U.S. Department of Transportation and Massachusetts regulations.

Radioactive material may be hand-carried directly between WHOI buildings when necessary, over routes that include public streets and sidewalks, provided that:

- The conditions under “6.1” above are met.
- The container conforms to Department of Transportation specifications. (These specifications may be obtained from the RSO or Protocol 4, “Shipping Radioactive Material between WHOI Campuses or to Another Licensee”.)
- The emitted dose rate at the surface of the container does not exceed 2 mrems/hr.
- The transportation route and time are planned such that pedestrian traffic encountered will be as low as practical.

6.3 Transport of Radioactive Material Between Campuses or Off-Site

Anytime public roads are used to transport radioactive material by motorized vehicle, U.S. Mail, or other commercial transport vendor, U.S. Postal Service and U.S DOT regulations must be followed.

Within Massachusetts, an exclusive-use vehicle or a commercial carrier must be used, and this requires specific prior approval from the RSO.
Outside of Massachusetts, a commercial carrier or an approved and properly trained WHOI Radiation Worker in a WHOI vehicle must be used. The RSO must be notified in advance of transport by WHOI personnel to insure that required procedures and documentation are used between WHOI campuses, to field research locations, or to another licensee, U.S. Department of Transportation and Massachusetts regulations must be followed. Refer to Protocol 4 for specific instructions.

7.0 RADIATION DOSIMETRY

7.1 External Dosimetry

- In general, individuals handling or working near radioactive materials that are gamma emitters and high energy beta emitters or using X-ray generating devices are required to wear whole body and/or extremity dosimeter badges. For each new project, the RSO may complete an External/Internal Dosimetry Worksheet required by Protocol 5 or an equivalent assessment. Based on this assessment, worker dosimetry requirements will be established.
- If a worker’s calculated Deep Dose Equivalent (DDE) expected from research work is likely to exceed 500 mrems/year, the worker will be required to wear external whole body dosimeter badges.
- If a worker’s calculated Shallow Dose Equivalent (SDE) expected from research work is likely to exceed 5000 mrems/year, the worker will be required to wear extremity dosimeter badges.
- External dosimeter badges may be issued to workers by the RSO even though the above DDE or SDE limits are not exceeded. In general, external dosimeter badges will be issued to radiation workers who use gamma emitters and high energy (>150 keV) beta emitters.

External dosimeters are not required or provided to workers that are ONLY working with low energy beta emitters (e.g., H-3, C-14, S-35) or alpha emitters. These isotopes decay by emitting low energy beta radiation that do not contribute to external whole body dose and do not have enough energy to be detected by dosimeter badges.

Under certain circumstances (e.g., lost badges, anomalous external dosimeter badge results, etc), the RSO may adjust or estimate personnel doses. In these instances, doses may be calculated from radiation survey data, personnel stay time estimates, and other factors, as appropriate.

Whole body or extremity dosimeter badges integrate personnel dose over a period of time and must be returned to and exchanged through the Radiation Safety Office quarterly unless otherwise specified.

All external dosimeter badge suppliers are accredited through the National Voluntary Laboratory Accreditation Program (NVLAP) to ensure quality control.

7.1.1 Travel Radiation Dosimeters

Radiation workers traveling by air and bringing a personal radiation dosimeter to field locations must contact the Radiation Safety Office (x2242) one month before the trip to obtain a spare dosimeter to be used as a control badge for the trip. Airport x-ray machines will cause non-occupational dose that must be properly subtracted with a control badge. The following steps must be followed when using travel radiation dosimeters:

- When traveling with the personal dosimeter and a control dosimeter, pack the two dosimeters together in a Ziploc plastic bag (or equivalent) for the trip.
- At the field location, the control dosimeter must be left with your luggage and not stored with the personal dosimeter (which will be worn during radioactive material work).
- During the return trip, both dosimeters must be placed together in a Ziploc plastic bag for traveling.
- After returning to WHOI, the control dosimeter must be immediately returned to the Radiation Safety Office where it will be stored for the remainder of the quarter.
• If two or more radiation workers are traveling to and from a destination together, then only one control dosimeter is needed. If travel will not be together in either direction, each person needs their own control dosimeter and to follow the above steps.

7.2 Internal Dosimetry

All individuals handling or working near radioactive materials may be required to participate in a bioassay or internal dose assessment program. The Institution has implemented an internal dose screening process based on a “Hazard Index” as defined by Regulatory Guide 8.25.

From the approved radioactive material protocols, the RSO will calculate the Hazard Index with the types and quantities of radioisotopes to be used, expected use periods, source containment and release factors, and radioisotope Annual Limits of Intake (ALI) values for each radioisotope. If the calculated “Hazard Index” is greater than 10, the Radiation Safety Office will establish a specific worker bioassay and internal assessment program. Internal dose evaluations may be required by the RSO, even though the “Hazard Index” limit is not exceeded.

The frequency and type of internal dose assessments will be defined by the RSO. Bioassay requirements may be established for specific isotopes and activity limits, or the Hazard Index limit may be reduced when the RSO or the RSC believes that an experiment has a high potential for creating internal exposure.

In general, bioassay and internal assessments may be conducted as follows: 1) as baseline and/or termination monitoring, 2) to identify and quantify intakes of radioisotopes by workers performing routine work at the Institution, and 3) after an unplanned incident involving a possible intake of a radioisotope(s).

Two types of measurements used to quantify intakes of radioisotopes are described below:

- **In vivo** measurements are performed using whole body or organ counters that provide quantitative and qualitative results of suspected internal radioactivity.
- **In vitro** measurements normally are obtained using representative samples of urine or feces from a worker and analyzing the samples with a suitable counting system.

In general, sample containers for urinalysis are available from the Radiation Safety Office. These bioassay measurements are preformed by a contract laboratory that is approved by the RSO.

7.3 Selection of Bioassay Analysis Techniques

Both **in vitro** analysis of urine and **in vivo** thyroid analysis are acceptable bioassay techniques for estimating intakes of radioactive iodine. In most cases, the **in vivo** thyroid analysis provides an adequate evaluation. However, it may be prudent to confirm significant intakes measured by a thyroid assay by performing a separate urinalysis assay. General internal dosimetry requirements are provided below:

- Workers must be scheduled for an initial **in vivo** thyroid analysis prior to the initial iodination procedure when using activities greater than Table 1 and routine samples either on the day following each iodination or on a weekly basis. The RSO may require periodic urinalysis screening for iodine users.

<table>
<thead>
<tr>
<th>Table 1, Recommended bioassay action levels for I-125 and I-131 (From Reg Guide 8.20)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bioassay action level</strong></td>
</tr>
<tr>
<td><strong>Type of operation</strong></td>
</tr>
<tr>
<td>Processes in open room or bench, with possible escape of iodine from process vessels.</td>
</tr>
<tr>
<td>Processes with possible escape of iodine carried out within a fume hood of adequate design, face velocity, and performance reliability.</td>
</tr>
<tr>
<td>Processes carried out within glove boxes, ordinarily</td>
</tr>
</tbody>
</table>

RSM 15 Rev. 5
closed, but with possible release of iodine from process and occasional exposure to contamination. | 100 mCi | 1000 mCi

- **In vitro** bioassay of H-3, S-35, C-14, and P-32 intake is generally done rather than **in vivo** bioassays because these isotopes do not have detectable photon emissions associated with their decay.
- Any worker handling activities of tritium greater than Table 2 must submit urine samples to the RSO for analysis. Samples must be submitted before research at the Institution begins and either following each experiment or on a weekly schedule.
- Although P-32 produces measurable bremsstrahlung radiation, a urinalysis bioassay is the preferred method of evaluating a P-32 uptake because a significant fraction of phosphorous is excreted in the urine.
- Workers conducting experiments involving **10 mCi or more of P-32** that pose a significant risk of producing airborne activity must undergo routine (e.g., weekly) urinalysis.
- NRC Regulatory Guide 8.20 includes guidelines on deciding when to perform **in vitro** bioassay, the frequency of bioassay, and the actions to pursue based on the bioassay results. Table 1 summarizes additional bioassay action levels for both unbound and bound forms of I-125 and I-131. Table 2 summarizes the bioassay action levels for tritium in three different forms: a tritiated compound, tritium gas in a sealed container and for tritiated compounds mixed with more than 10 kg of water.
- The RSO may impose more frequent and/or more restrictive bioassay requirements than specified above.

<table>
<thead>
<tr>
<th>Type of operation</th>
<th>Bioassay action level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processes in open room or bench, with possible escape of tritium from process vessels.</td>
<td>0.1 Ci</td>
</tr>
<tr>
<td>Processes with possible escape of tritium carried out within a fume hood of adequate design, face velocity, and performance reliability.</td>
<td>1 Ci</td>
</tr>
<tr>
<td>Processes carried out within glove boxes, ordinarily closed, but with possible release of tritium from process and occasional exposure to contaminated box and box leakage.</td>
<td>10 Ci</td>
</tr>
</tbody>
</table>

## 7.4 Dosimetry Reporting

### 7.4.1 Reports to workers

Radiation exposure data for an individual and the results of any measurements, analyses, and calculations of radioactive material deposited or retained in the body of an individual shall be reported to the individual by the RSO as listed below:

- Provide annually, to each worker required to be monitored, a written report of the worker's exposure to radiation.
- Provide a written report of the worker's exposure at the request of a worker formerly engaged in activities controlled by the Institution. The report shall include the dose record for each year the worker was required to be monitored. The report shall be furnished within 30 days from the date of the request, or within 30 days after the dose of the individual has been determined by the licensee or registrant, whichever is later.
At the request of a worker who is terminating employment, provide to the worker or to the worker's designee, a written report regarding the radiation dose received during the current year. If the most recent individual monitoring results are not available at that time, a written estimate of the dose shall be provided together with a clear indication that this is an estimate.

When required to report to the Agency any exposure of an individual listed in Protocol 3, “Emergency Procedures”, provide the individual a written report of the exposure data included. The reports shall be transmitted at a time not later than the transmittal to the Agency. Each report shall contain the following statement: “This report is furnished to you under the provisions of 105 CMR 120. You should preserve this report for future reference”.

7.4.2 Reports to Massachusetts

Reports of incidents and exceeding exposure limits are required as described in Protocol 3.

8.0 POSTING AND LABELING OF RADIOACTIVE MATERIAL AREAS (RMAs) AND CONTAINERS

Each laboratory storing or using licensed radioactive material will be designated as a Radioactive Material Area (RMA) and must be posted in accordance with the requirements of 105 CMR 120.

The RSO is responsible for maintaining a list of all WHOI RMAs. RMA signs shall not be removed without approval from the RSO. Supervisors shall not establish a new RMA or change the radioactive materials assigned to a specific RMA without approval from the RSO.

Each lab must have a Space Hazard Placard posting that documents the names and contact numbers of primary WHOI personnel to be called in an emergency. The Principal Investigator/Supervisor is responsible for keeping his/her lab Space Hazard Placard updated with current information. Refer to the EH&S website for further information at http://ehs.whoi.edu/.

Each container of radioactive material must comply with the regulations stated in 105 CMR 120 and 120.297, Appendix C. Protocol 6 provides guidance for workers concerning compliance with posting and labeling requirements.

8.1 Posting Of Areas

It is a WHOI policy that all rooms containing any amount of licensed radioactive material will be designated as a RMA and must be posted accordingly. This is more stringent than the regulatory requirements and occasional deviations from this policy may be approved by the RSO on a case-by-case basis. Only approved postings that conform to 105 CMR 120 may be used.

8.2 Labeling Containers

It is a WHOI policy that all containers of radioactive material, both licensed and exempt, will be labeled regardless of the total radioactivity of the contents. This is more stringent than the regulatory requirements and occasional deviations from this policy may be approved by the RSO on a case-by-case basis, (e.g., labeling secondary containment rather than each small container). Certain manufactured instruments and articles may be exempt from labeling requirements. Some examples of these exempt items include: polonium static dischargers, smoke detectors and thorium lantern mantles. Refer to Protocol 6 for guidance.

9.0 RADIOLOGICAL WORK AND SAFETY PRACTICES

9.1 General Criteria

There will be no eating, drinking, smoking, or storage of foods or beverages in any area where unsealed, unpacked, or otherwise dispersible radioactive materials are present.
• A paper copy of the Radiation Safety Manual (current version) shall be readily available to all personnel authorized to use radioactive material or radiation generating devices.
• Gloves, lab coat, and eye protection will be the minimum personal protective equipment requirement when working in laboratory areas where dispersible radioactive materials are used. The use of hazardous chemicals may require additional controls.
• If required, all authorized users and radiation workers must wear dosimeters while working with radioactive materials or radiation generating devices.
• After handling radioactive materials, radiation workers must conduct a personnel contamination survey of exposed skin, hair, and clothing prior to leaving the laboratory.
• Any potentially contaminated equipment/materials must be surveyed prior to removal from the radiological work area.
• There will be no mouth pipetting of radioactive solutions.
• All radioactive solutions must be stored in clearly labeled containers. Place containers too small for such labels in larger labeled containers.
• Handle radioactive solutions in trays large enough to contain the material in the event of a spill.
• Dispose of radioactive waste only in approved and properly labeled containers.
• Secure all licensed radioactive material when it is not in use.
• Whenever possible, new procedures and handling techniques should be practiced using non-radioactive/non-hazardous material.
• When laboratory operations are expected to produce airborne radiation levels (e.g., evaporations, sanding, grinding, transfer of powdery material, volatile liquids or gases), adequate exhaust ventilation or lab hoods must be used. All radioactive material hoods must be properly labeled and flow checked by Facilities. The RSO may require that certain radiological work with dispersible materials be restricted to an enclosed system with filtered exhaust.
• Maintain your occupational exposure to radiation As Low As Reasonably Achievable (ALARA).
• Ensure all persons handling radioactive material are trained, authorized, and listed on an approved protocol.
• Review the nuclide characteristics prior to working with that nuclide. Review the protocol(s) authorizing the procedure to be performed and follow any additional precautions in the protocol. Contact the RSO to view the protocol information.
• Plan experiments to minimize external exposure by reducing exposure time, using shielding and increasing your distance from the radiation source. Reduce the potential for intakes and internal dose by conducting personal contamination monitoring and work area monitoring after each use of radioactive materials and promptly cleaning up any contamination. Use the smallest amount of radioisotope possible to minimize potential radiation exposures and radioactive waste.
• Keep an accurate inventory of radioactive material, including records of all receipts, transfers & disposal.
• Provide for safe disposal of radioactive waste by following Protocol 8. Avoid generating mixed waste (mixtures of radioactive, biological, and chemical waste).
• NOTE: Lab staff is not permitted to pour measurable quantities of radioactive material down the drain.
• Never store food and beverages in refrigerators/freezers used for storing radioisotopes.
• Prevent skin contact with skin-absorbable solvents containing radioactive material.
• Use sealed containers and appropriate secondary containment (leak proof) to carry radioactive material between rooms. Notify Radiation Safety Office before taking any radioactive material off site.

9.2 As Low As Reasonably Achievable (ALARA)
The Institution shall implement an effective ALARA program to ensure radiation exposure is minimized

9.2.1 Limit Exposure Time
• Preplan the job and select the proper tools and equipment.
• Practice research protocol without the radiation source.
• Store the radiation source(s) in a secure area when not in use.

9.2.2 Work Area Controls
• Maximize the distance from radiation sources.
• Establish engineered safeguards (i.e., ventilation, etc), as necessary.
• Work at an arm’s length from the source(s) or use long handled tools.
• Work behind temporary shielding.
• Decontaminate work areas, as necessary.
• Line source dose rate (R) reduces directly with distance (D) from the radiation source: \( R_1D_1 = R_2D_2 \).
• Point source dose rate reduces inversely as the square of the distance from the source: \( R_1D_1^2 = R_2D_2^2 \).

9.2.3 Shielding
• Use low atomic number materials (e.g., Lucite, plastic, etc) to shield beta radiation sources.
• Use lead or concrete for shielding gamma or x-ray radiation.
• Estimate the proper amount of shielding based on the photon energy and material type. Consult the RSO for assistance.

9.3 Commonly Used Isotopes
The majority of the Institution’s radiological work involves low activity levels of H-3, C-14, S-35, P-32, and P-33. Refer to the EH&S website for Isotope Safety Date Sheets and other information: [http://ehs.whoi.edu](http://ehs.whoi.edu).

9.4 Using Radioiodine in Research
Protocol 9 (Using Radioactive Iodine in Research) identifies specific requirements for the use of radioiodines, such as I-131 and I-125.

10.0 RADIOACTIVE WASTE
In order to comply with strict waste management regulations, WHOI must maintain control of all radioactive waste. The Low Level Radioactive Waste (LLRW) generated at WHOI will fall into one of two classifications, either LLRW to be held for decay-in-storage (waste containing only radioisotopes whose half-life is less than 120 days) or LLRW for commercial disposal (waste containing all other radioisotopes).

10.1 Radioactive Waste Minimization and Segregation
10.1.1 Minimization
Waste minimization is an important part of research using radioactive materials. Because of the limited availability of radioactive material disposal facilities, the disposal of radioactive waste is expensive. In addition, while working in a research environment, hazardous chemicals are also used together with the radioactive material. The combination of radioactive and hazardous waste results in the formation of mixed waste, which is regulated as both hazardous and radioactive waste. Mixed waste requires special care and results in relatively higher disposal costs. Examples of laboratory practices that minimize the generation of radioactive and mixed waste are:
• Substitute non-radioactive and non-hazardous materials in research protocols when possible.
• Order only the minimum quantity of material needed.
• Avoid generating mixed waste, which is both hazardous waste and radioactive waste.
• Minimize both the volume and weight of radioactive liquid and dry active waste.
• Avoid mixing radioactive liquid and dry active waste.
• Where possible, minimize the radioactive sample size that you prepare and analyze.
• Maximize the use of short-lived radionuclides (half-lives less than 120 days), which we can decay in storage in our hot labs.
• Minimize the use of long-lived radionuclides (half-lives longer than 120 days).
• Avoid mixing short-lived and long-lived radionuclides.
• Do not mix solid (non-radioactive) waste and radioactive waste (e.g., monitor your gloves, equipment, etc., before discarding as radioactive waste). Gloves and equipment that are not radioactive (i.e., indistinguishable from background radiation levels with a survey meter) should not be mixed with radioactive waste.
• Use non-hazardous liquid scintillation media (e.g., Scintiverse) that are readily soluble in water and avoid using toluene, benzene, or xylene based media since they must be disposed of as mixed waste.
• If a paper laboratory bench cover has some contamination on it, cut that area out and put only the piece that is contaminated in the radioactive trash.
• Share ideas concerning waste minimization with the Radiation Safety Office and coworkers, so that others may benefit.
• Reduce frequency with which laboratory bench paper is changed.
• When possible, use non-porous equipment that can be easily decontaminated.

10.1.2 Segregation

Long-lived (>120 day half-life) and short-lived (<120 day half-life) LLRW should not be mixed in the same waste container. In addition to this separation by half-life, LLRW must also be segregated by its physical characteristics as indicated below. Store sealed sources separately. Refer to Protocol 8, Radioactive Waste.
• Dry Active Waste (DAW): This is LLRW that commonly consists of paper, cloth, plastics, tape, etc. (compactable). DAW may also consist of contaminated glassware, razor blades, metal items, needles, etc. (non-compactable). Sharps must be segregated, into approved sharps containers to prevent possible puncture injuries. DAW must not include hazardous waste or sealed sources.
• Liquid Waste: Any liquid LLRW generated from research protocols, other than that which is in liquid scintillation vials, must be placed into an approved liquid waste container. Care must be taken to insure that the chemical constituents of liquid waste streams, being placed into the same waste container, are compatible, and will not cause an adverse chemical reaction.
• Liquid Scintillation Vials (LSV): This LLRW consists of liquid scintillation vials (up to 20 ml maximum volume) and their contents. LSV waste must be segregated from the other types of LLRW.
• Segregate mixed, biohazardous, and radioactive waste. Refer to the Biosafety Manual for biohazardous waste requirements. Refer to Hazardous Waste Generator Guideline for hazardous waste requirements.

10.2 Release of Radioactive Material to the Environment

10.2.1 Release of Radioactive Material into Ventilation Systems.

Any release of radioactive material, via the laboratory ventilation systems, is not allowed unless reviewed and authorized by the RSO.

10.2.2 Disposal into the Sewer System.

No sink disposal by Authorized Users and Radiation Workers is permitted. Any accidental release of radioactive material into the sewer system must be reported to the RSO.

10.2.3 Release of Radioactive Material Into the Environment.

Disposal or abandonment of licensed radioactive material into the environment (water, soil, etc) is forbidden.

10.3 Waste Collection Containers

All radioactive waste will be put into approved containers according to the following guidelines:
• All DAW articles put into containers for decay in storage must have all radioactive labels and symbols removed or defaced.
• Lab radioactive waste containers may include plastic bags or cardboard boxes for dry waste and plastic bottles for liquids. Size is dependant on the amount of waste generated. Generally, the smallest
appropriate container will be provided. All waste must be placed in DOT approved packaging prior to disposal shipments. Containers will be approved and provided by the Radiation Safety Office.

- The total amount of radioactive material put into any waste container must be controlled to ensure that the radiation level at 1 foot is less than 2 mrems/hr and ALARA. In addition, containers packaged for shipping must meet Department of Transportation radiation level limits.

- Material must not be put into waste containers if there is any possibility of a chemical reaction during storage that might cause fire, explosion, or the release of toxic or radioactive gases. Incompatible chemicals must be segregated.

- Materials containing animals, animal tissue, excreta, or biohazardous materials must not be put into a waste container unless it has been specifically approved by the RSO and Biosafety Officer (BSO). Special disposal procedures must be arranged with the RSO and BSO prior to the start of work that will generate this type of waste.

- A record must be kept of the quantity and kinds of waste placed in each LLRW container. This inventory is to be kept current and attached to the specific LLRW container. Refer to Protocol 8 for an example of Form 8.2.

- A yellow Radioactive Waste tag must be attached to the container, and the date marked when the container is full.

- When a container is full, or radiation levels are nearing the limits specified above, the RSO shall be notified.

- **Pickup Notification:**
  1) Before adding radioactive waste, attach a yellow radioactive waste tag to the waste collection container. When the container is full, submit a Radioactive Waste Pickup Notification to alert the RSO that a pick up is required. If the waste is hazardous as well, attach a red hazardous waste tag to the container and list the hazardous constituents. Refer to Protocol 8 for an example of the radioactive waste tag.
  2) If necessary, a generator may request the removal of a container before it is full.
  3) The generator shall utilize the on-line WHOI Radioactive Waste Pick Up Notification Form. This form is found online at [http://ehs.whoi.edu/](http://ehs.whoi.edu/).
  4) All fields of the Waste Pickup Notification Form must be completed.

- Do not put solid objects, such as paper, test tubes or pipettes, into a liquid waste container.

- Do not put liquids into a container designated for solid waste. Bottles or other objects must be completely drained before being placed into a solid waste container.

- Put powdery material into a sealed metal or plastic container.

- Put hypodermic needles, pipettes, and other sharp objects into approved sharps containers, which will be provided by the Radiation Safety Office and properly labeled.

Non-conforming waste items may not be collected by the Radiation Safety Office until the issues are resolved. The RSO must be consulted prior to the start of work that will generate radioactive wastes not covered by the above requirements.

### 10.4 Storage of Radioactive Waste for Decay

The Massachusetts Radioactive Material License allows the Radiation Safety Office to dispose of radionuclides with a half-life less than 120 days by holding for sufficient decay and then disposing as non-radioactive waste. This requires about seven half-lives and monitoring to ensure the waste materials are indistinguishable from background. Wastes containing these short half-lived isotopes should be kept separate from other radioactive waste. Refer to Protocol 8 for instructions.

### 10.5 Storage of Radioactive Waste for Commercial Disposal

The hot labs at the Quissett (Clark and Watson) and Village (Redfield) campuses may be used to store radioactive waste until commercial disposal can be arranged. Radioactive waste can only be placed in the hot labs by the RSO, ARSO or person authorized by the RSO. Refer to Protocol 8 for instructions.
11.0 RADIATION GENERATING DEVICES (RGDs)

Massachusetts regulates the use of radiation generating devices. WHOI’s policies for the use of radiation generating devices are designed to meet the applicable requirements of the Massachusetts regulations in 105 CMR 120 and to ensure the safety of users and other personnel.

Unless specifically exempted, radiation generating devices must be registered with Massachusetts and a registration fee paid. Registration will be in the name of the Institution, with the Radiation Safety Office as point of contact. The Radiation Safety Office must be notified of the acquisition, transfer, or disposal of any radiation generating device. User authorizations are established for all RGDs and include authorized personnel, locations and requirements. Only authorized and trained personnel are allowed to use RGDs and must follow all applicable requirements.

11.1 General Requirements for Radiation Generating Devices

- Authorized Users: Principal Investigators are responsible for ensuring that only trained and authorized users are allowed to operate their devices and that Radiation Safety Manual and 105 CMR 120 requirements are implemented. The RGD User Authorization should be posted at the machine.
- Training Requirements: New personnel must be trained by the Principal Investigator (or an experienced qualified operator designated by the PI) and must satisfactorily demonstrate knowledge of the operating and safety procedures before independently operating a radiation generating device. All personnel are required to attend RGD radiation safety training provided by the Radiation Safety Office.
- Posting: A sign bearing the radiation symbol and the words “CAUTION - X-RAY EQUIPMENT”, or words having similar intent, must be posted at the entrance to each laboratory containing a radiation generating device. A label with “CAUTION – RADIATION - THIS EQUIPMENT PRODUCES RADIATION WHEN ENERGIZED” or similar wording must be posted at the control panel.
- Access Control: All radiation generating devices shall be secured to prevent unauthorized removal or operation. In addition, devices or administrative procedures shall be used to prevent unauthorized use of radiation generating devices.
- Operating Procedures: Operating procedures for each device must be available at or near the device.
- Dosimetry: The Radiation Safety Officer will establish dosimetry requirements after completing a review of each facility. When applicable, users of radiation generating devices will be issued a personnel dosimeter. This dosimeter shall be worn while in the facility when the device is in operation. Refer to Section 7, “Radiation Dosimetry” for individual dosimetry requirements.
- The Radiation Safety Officer may also post dosimeters at various locations in the facility. Laboratory personnel should not move these area dosimeters.
- Radiation Surveys: The Radiation Safety Office performs inspections of radiation-producing devices when first installed, periodically after they are installed, and whenever significant changes to the device, facility, or operating procedures are made. In some cases, these surveys are performed by facility personnel.

11.2 National Ocean Sciences Accelerator Mass Spectrometry (AMS) Facility

The AMS Facility is located in McLean Laboratory. The Facility Director shall ensure that all applicable radiation safety requirements are implemented for this facility. AMS system operators shall be trained in and demonstrate competence of radiation safety, radiation survey instruments, and the operating and emergency procedures for the Facility.

The AMS system shall be secured to prevent unauthorized use when not in operation. A copy of the operating and emergency procedures shall be maintained at the accelerator control panel. All operators and direct support staff are required to wear dosimeters when the AMS system is operating. A radiation survey shall be performed and documented when changes have been made in shielding, operation, equipment, or occupancy of adjacent areas.
Visitors and casual workers (those who spend less than 80 hours per year in the accelerator room) do not need dosimeters. They must stay on the “visitor side” of the yellow and black tape on the floor demarcating the area within the AMS system, which is off limits to visitors and casual workers. They must also remain outside of any restricted areas, as indicated by the AMS personnel.

Qualified AMS personnel shall perform routine radiation surveys to identify and characterize any areas of ionizing radiation around the AMS system. These quarterly surveys should occur when the facility is operating and follow the requirements listed below.

- Check the meter in accordance with Protocol 7 "Radiation Detection Instruments".
- Survey readings shall be taken at designated station numbers that are marked on the survey diagram located in the logbook.
- Survey results shall be recorded on a data-log sheet in the Radiation Survey Logbook.
- Any unusual radiation levels should be brought to the attention of the Facility Director and RSO.

It is the responsibility of the Authorized User or Principal Investigator to inform the RSO of any changes that may increase radiation doses to radiation workers or unrestricted locations that are occupied.

### 11.3 CT Scanner

The CT scanner is installed in the Marine Research Facility Laboratory and is to be used for scanning inanimate objects and live or dead animals for research purposes only and is not permitted to be used for scanning live humans.

Shielding has been installed to limit exposures in unrestricted areas. The doors leading into the CT exam room are installed with interlock switches that will de-energize the x-ray tube if opened. A warning light is located near each entrance to warn against entry when the x-ray tube is energized. A radiation protection survey and/or area monitoring shall be performed by the RSO when significant changes have been made in shielding, operation, equipment, or occupancy of adjacent areas. It is the responsibility of the Authorized User or designee to inform the RSO of any changes that may increase radiation doses to radiation workers or unrestricted locations that may be occupied.

The Authorized User or designee shall ensure that all applicable radiation safety requirements are implemented for this device and that it is operated in accordance with applicable permits, registrations, and licenses. Additional requirements are listed in the User Authorization and below:

- A copy of the User Authorization shall be posted in the control room of the CT scanner and followed by all operators.
- All applicable requirements of the Radiation Safety Manual must be followed.
- All operators and visiting personnel classified as radiation workers must receive Radiation Generating Device Training prior to operation. Visitors must be appropriately classified as either Radiation Workers or members of the public. Only Radiation Workers who are properly trained by authorized personnel are authorized to work in the restricted area (interlocked room). All required training events must be documented in the log.
- Operators and visitors must be made aware of the declared pregnant women program.
- A copy of 105 CMR 120.400, which relates to healing arts radiographic systems, must be available in the control room and all applicable requirements must be followed by all operators, including all applicable Quality Assurance Program requirements.
- The CT scanner facility must meet all applicable performance criteria specified in 105 CMR 120.400, including applicable parts of the annual physics survey.
- Sufficient shielding and/or access controls are required to limit doses (<100 mrem/year uncontrolled areas, <2 mrem/hour uncontrolled areas).
- Safety interlocks must be checked annually. This test must be documented in the log.
• Interlocks must not be bypassed without a written program and approval of the RSO.
• The CT Scanner area must be secured when not in operation and/or under control of authorized personnel.
• A copy of the operating procedures and the emergency protocol must be available to all operators.
• ALARA requirements must be followed to minimize dose to operators and Radiation Workers, including: minimizing exposure time, increasing distance from x-ray source, and using proper shielding.
• Strict adherence to the dosimetry program is required by all operators and radiation workers.
• Visitor dosimeter badges will be used sequentially (not shared) and those badges receiving dose will be retired. Dosimeters shall be worn on the outside of the lead apron at the collar. Dosimeter issuance shall be documented in the log by authorized personnel.
• Personnel within the restricted area shall wear a protective apron of not less than 0.25mm lead equivalent and throat shields.
• Leaded gloves and a finger dosimeter shall be worn by operators and radiation workers who have the potential for an extremity radiation dose, e.g., holding live animals during CT Scanner operation.
• Aprons, throat shields, and gloves must be routinely inspected for defects in shielding via a documented scan.
• All Radiation Workers must be over the age of 18.
• The CT X-ray system shall be operated only by individuals who have been specifically trained in its operation and only after the approval of the scanner Facility director.

11.4 X-Ray Diffraction (XRD) Machine

Regulations for the X-Ray Diffraction unit are found in 105 CMR 120. The Principal Investigator shall ensure that all applicable radiation safety requirements are implemented for this device.

A Philips Model 1830 X-Ray Diffraction (XRD) unit is located in McLean Laboratory. It is a cabinet x-ray device and is shielded to limit exposure to the other occupants of the building. The XRD normally operates at 40 keV.

The XRD has a built-in light which will warn of the unit’s on/off operational status. The x-ray beam housing is labeled with a warning of a high intensity x-ray beam inside. The door leading into the room shall be posted and shall be secured during unattended operation of the XRD.

A written operating procedure shall be kept near the XRD for use by all operators. All operators will receive annual training on hazards of operation, significance of warning and safety devices, operating procedures, recognition of symptoms of acute localized exposure, and proper procedures for reporting a suspected or actual exposure. All operators may be required to wear dosimetry while working in the room when the XRD is operating.

A radiation protection survey shall be performed by the RSO and documented when changes have been made in shielding, operation, equipment, or occupancy of adjacent areas. It is the responsibility of the Authorized User or Principal Investigator to inform the RSO of any changes that may increase radiation doses to radiation workers or unrestricted locations that are occupied.

11.5 GeoTek Core Logger

The GeoTek Core Logger is used on Research Vessels and certain shore-side labs. The Authorized User or designee shall ensure that all applicable radiation safety requirements are implemented for this device. Only authorized personnel can use this device. The radiation source for this device is a 10 mCi Cesium-137 capsule, which is securely housed inside of a 150 mm diameter lead cylinder. (The source activity will be less due to radioactive decay.) The source may be stored in one of the hot labs.

A written operating procedure or operator manual shall be kept near the Core Logger for use by all operators. Protocol 10 and the applicable Shore-Side or At-Sea Authorization shall be kept with this device. All
operators will receive training in hazards of operation, significance of warning and safety devices, operating procedures and emergency procedures.

The GeoTek Core Logger must be secured or under the direct control of authorized personnel when it is stored or being used. When the Core Logger is taken on board a Research Vessel, all security measures listed in the At-Sea Authorization must be implemented and the At-Sea Authorization and procedures must be present. The RSO will determine the area and/or personal dosimetry requirements. The radiation source of the Core Logger must be leak tested every 6 months and these results must be kept on file for the RSO to review.

11.6 X-Ray Fluorescence (XRF) Machine

An Itrax Core Scanner X-Ray Fluorescence (XRF) machine is located in McLean Laboratory. The Principal Investigator or Authorized User shall ensure that all applicable radiation safety requirements are implemented for this device. The Itrax Core Scanner is a cabinet x-ray device and is shielded to limit exposure to the other occupants of the building. When running the instrument and using the X-Ray Fluorescence for measurements, the instrument is typically run at 30 keV. When using the instrument for X-Ray Micro Radiography, the instrument is run at 60 keV.

The X-Ray Fluorescence Unit has a key operated start-up switch. The x-ray beam housing is labeled with a warning of an x-ray beam inside. The door leading into the room shall be posted and shall be secured during unattended operation of the X-Ray Fluorescence Unit. There is a written Lock Out/ Tag Out procedure that should be followed for all maintenance or repair work done on this instrument.

A written operating procedure shall be kept near the X-Ray Fluorescence Unit for use by all operators. All operators will receive training in hazards of operation, significance of warning and safety devices, operating procedures, recognition of symptoms of acute localized exposure, and proper procedures for reporting a suspected or actual exposure.

A radiation protection survey shall be performed by the RSO and documented when changes have been made in shielding, operation, equipment, or occupancy of adjacent areas. It is the responsibility of the Authorized User or Principal Investigator to inform the RSO of any changes that may increase x-ray exposures to radiation workers or unrestricted locations that are occupied.

11.7 Devices with Generally Licensed Radioactive Material

Generally licensed material is radioactive material contained in certain devices distributed by licensed facilities to individuals or institutions that do not have to obtain a license in order to possess the material. This material is regulated and must be properly controlled. Example devices with generally licensed radioactive material are gas chromatographs with electron capture detectors (Ni-63), liquid scintillation counters with internal sources (Cs-137, Ba-133, Ra-226) and static eliminators with Po-210.

REGULATORY AUTHORITY

When an instrument containing a generally licensed source is purchased, a general license is issued to the purchaser. The Principal Investigator or WHOI may be recorded as the owner. Regardless of the owner, WHOI’s RSO has oversight of this radioactive material while it is used in WHOI facilities and projects.

MANUFACTURER RESPONSIBILITIES

It is the manufacturer's responsibility to provide the purchaser/owner with the requirements for properly controlling the radioactive material, including proper disposal.

LEAK TESTING

Devices containing 100 microcuries or more of beta-gamma emitting material or 10 microcuries or more of alpha-emitting material require testing for leakage every six months. The purpose of this test is to ensure that the source has not lost its integrity and is not releasing radioactive material. At WHOI, the Radiation Safety
Office maintains an inventory of all known sources and performs the required leak tests every six months. Therefore, the device owner/user must contact the Radiation Safety Office immediately upon receiving a device containing a generally licensed source.

REGISTRATION OF DEVICES

Certain generally licensed devices must be registered with Massachusetts RCP when they are purchased or ownership is transferred. To properly evaluate the registration requirements, the RSO must be contacted prior to transfer of ownership or purchasing generally licensed devices.

DISPOSAL OR DISPOSITION OF DEVICES

Improper disposal of generally licensed devices with radioactive material is forbidden. The RSO must be contacted to coordinate proper disposal or disposition of generally licensed devices. This may require a modification to the registration with Massachusetts RCP. In general, only a qualified vendor can safely remove the radioactive source (often the manufacturer's service technician) from the device. There may be a fee for source removal. The department or principal investigator is responsible for paying this fee.

12.0 CONTAMINATION SURVEYS AND DECONTAMINATION TECHNIQUES

Radioactive contamination is the presence of radioactive material in any location where it is not desired. Contamination monitoring may include surveys with a hand held survey meter and/or smear surveys. The direct frisk can identify fixed and removable contamination for certain radionuclides. The goal of a smear survey or removable contamination survey is to identify any removable radioactive contamination that might be present. Note: direct frisks are not appropriate for all radionuclides (e.g., tritium). Protocol 11 provides further instruction for contamination surveys. Protocol 12 provides decontamination instructions.

12.1 Contamination Limits and Surveys

12.1.1 Personnel

The Institution has established an administrative limit for skin contamination of no detectable counts above background levels. Proper use, removal, and disposal of protective clothing will generally ensure that workers avoid personnel contamination events. Workers are expected to minimize the spread of contamination and conduct personal contamination checks after each work period involving radioactive material. Survey meters that can adequately measure the contamination levels identified in Table 3 must be used for these surveys. Workers shall check their clothes, hands, and feet for contamination.

In the event that a worker identifies contamination on their skin or clothing, the worker should notify the Radiation Safety Office (x2242, x3347, or 3788). The event will be documented using Form 11.1 of Protocol 11 or equivalent form and appropriate decontamination measures will be initiated in accordance with Protocol 12. It is the Institution’s position that every effort will be taken to decontaminate the worker to background levels. If a contaminated worker is also injured or ill, the medical condition takes priority.

<table>
<thead>
<tr>
<th>Types of surface</th>
<th>Alpha emitters</th>
<th>Beta or X-ray emitters</th>
<th>Low–risk Beta or X-ray emitters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protective clothing worn only in restricted areas</td>
<td>220</td>
<td>2,200</td>
<td>22,000</td>
</tr>
<tr>
<td>Unrestricted areas</td>
<td>22</td>
<td>220</td>
<td>2,200</td>
</tr>
<tr>
<td>Restricted Areas</td>
<td>220</td>
<td>2,200</td>
<td>22,000</td>
</tr>
</tbody>
</table>

1 Averaging is acceptable over non-living areas of up to 300 cm² or, for floors, walls, and ceiling, 100 cm². Averaging is also acceptable over 100 cm² for skin or, for the hands, over the whole area of the hand, nominally 300 cm².
2 Low-risk radioisotopes include C\(^{14}\), H\(^3\), S\(^{35}\), Tc\(^{99m}\), and others whose beta energies are less than 0.2 MeV maximum, whose gamma or X-ray emission is less than 0.1 R/hr at 1 meter per curie, and whose permissible concentration in air is greater than \(10^{-6}\) \(\mu\text{Ci/ml}\).

12.1.2 Facilities and Equipment

Prior to the release of equipment or facilities for unrestricted use, a thorough surface contamination survey must be conducted for fixed and removable contamination. Fixed contamination is contamination that cannot be removed after successive levels of decontamination. Contamination found in unrestricted areas or equipment should be immediately decontaminated to background levels and shall not exceed the levels in Table 3 or 4, as applicable. Select a survey meter and/or smear method that is appropriate for the survey.

Authorized Users and Radiation Workers are expected to minimize contamination levels and to routinely monitor their work areas for contamination. For survey instructions, refer to Protocol 11. No covering should be applied to radioactive surfaces of equipment or structures by paint, plating, or other covering material until it is known that contamination levels are below the applicable limits.

### Table 4. Acceptable Surface Contamination Levels For Unrestricted Release of Equipment (From Regulatory Guide 8.23)

<table>
<thead>
<tr>
<th>Radioisotope(^5)</th>
<th>Average(^1,2) (dpm/100 cm(^2))</th>
<th>Maximum(^1,3) (dpm/100 cm(^2))</th>
<th>Removable(^1,4) (dpm/100 cm(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-nat, U-235, U-238, and associated decay products</td>
<td>5,000</td>
<td>15,000</td>
<td>1,000</td>
</tr>
<tr>
<td>Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129</td>
<td>100</td>
<td>300</td>
<td>20</td>
</tr>
<tr>
<td>Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133</td>
<td>1,000</td>
<td>3000</td>
<td>200</td>
</tr>
<tr>
<td>Beta–gamma emitters except Sr-90 and others noted above</td>
<td>5,000</td>
<td>15,000</td>
<td>1,000</td>
</tr>
</tbody>
</table>

1 As used in this table, dpm (disintegration per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

2 Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such object.

3 The maximum fixed contamination level applies to an area of not more than 100 cm\(^2\).

4 The amount of removable radioactive material per 100 cm\(^2\) of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionately and the entire surface should be wiped.

5 Where surface contamination by both alpha and beta-gamma emitting nuclides exists, the limits established for alpha and beta-gamma emitting nuclides should apply independently.

12.1.3 Sealed Sources

The Radiation Safety Office is responsible for performing leak tests. Sealed sources shall be tested for leakage and/or contamination at intervals not to exceed 6 months, or at more frequent intervals as specified by the manufacturer. Sealed sources which emit alpha particles must be tested for leakage at intervals not to exceed 3 months.

Each sealed source fabricated by the Institution or transferred to the Institution shall be inspected and tested for construction defects, leakage, and contamination prior to any use or transfer as a sealed source.

Sealed sources and detector cells need not be leak tested if:
- The source(s) contain tritium; or
- The source(s) are radioactive gas; or
• The half-life of the radioisotope is 30 days or less; or
• The source’s beta and/or gamma activity does not exceed 100 μCi or 10 μCi of alpha activity; or
• The source is storage and not in use.

No sealed source or detector cell shall be stored for a period of more than 10 years without being tested for leakage and/or contamination. If a sealed source is stored for more than 6 months since it was last leak tested, it must be leak tested when taken out of storage. The leak test shall be capable of detecting the presence of 0.005 μCi of radioactive material on the test sample. Records of the leak test results shall be kept in units of μCi and available for inspection. If the test results reveal the presence of removable contamination of greater or equal to 0.005 μCi then a report must be filed with the Agency and the source shall be decontaminated, repaired or removed from service and disposed. Certain sealed sources are exempt from leak testing, e.g., static eliminator bars, smoke detectors, etc.

12.2 Decontamination Techniques

12.2.1 Personnel
Workers are expected to perform general decontamination by gently washing a contaminated skin area in accordance with Protocol 12.

12.2.2 Facilities and Equipment
Workers are expected to perform general decontamination of work areas by in accordance with Protocol 12. If a laboratory is to be deactivated, Protocol 13 must be followed.

13.0 RADIATION DOSE RATE SURVEYS
Protocol 11 provides instructions for performing radiation dose rate surveys to determine and document dose rates in work areas with gamma and x-ray radiation sources. At a minimum, radiation dose rate measurements will be performed in the following areas:

• Where workers or members of the public may be exposed to radiation levels that exceed the administrative and regulatory limits established in Section 1 of this manual, or
• Where workers are using radioactive material or radiation generation devices that can produce radiation levels greater than 1 mrem/hr.

All measurements will be performed using a calibrated survey meter that is appropriate for measuring the radiation of interest. Protocol 7 provides survey instrument instructions. The background readings should be taken in an area outside of the radioactive material use area(s) being surveyed. The readings obtained will be recorded as the background for that particular survey. Authorized Users or their designees are expected to perform surveys as required by the authorization and/or this manual. The results of all external area surveys will be recorded in mrem per hour on Form 11.2, or an equivalent form. Any area indicating an exposure level of greater than 1 mrem/hr and/or unusually high will be brought to the attention of the RSO. Radiation exposures must be kept as low as reasonably achievable (ALARA).

14.0 DEACTIVATION OF FACILITIES
Should an Authorized User foresee a period of time in which he/she does not plan on using radioactive material in a lab, the affected laboratory(s) may be either temporarily or permanently deactivated.

14.1 Temporary Deactivation
Temporary deactivation of a lab or work area allows an Authorized User to remove all radiological posting and labeling when radiological work is discontinued for a period of time. This time period is normally for greater than six months. In the case of Authorized Users with multiple work areas and labs, this deactivation only applies to the requested lab or work area. Labs and work areas may be reactivated when radioactive material use is anticipated to recommence and required training is current.
The RSO must be informed by the Authorized User about the plan for temporary deactivation. The deactivation process includes detailed surveys of the area by the RSO or designee to ensure no radioactive contamination exists. When this is completed, radiological postings, labeling and work area boundaries may be removed. Radioactive material may still be stored in a deactivated lab or work area. In this case, Radioactive Material Area postings and radioactive material storage container labeling must remain in place and the radioactive material must be secured. Refer to Protocol 13.

14.2 Permanent Deactivation

Permanent deactivation results in the lab or area being removed from the user’s authorization. The RSO must be informed by the Authorized User about the plan for permanent deactivation. Refer to Protocol 13.

15.0 RADIATION DETECTION INSTRUMENTS

Every laboratory using radioactive materials must possess, or have available for immediate use, appropriate radiation monitoring equipment. Refer to Table 5 for a listing of most instruments used at WHOI. This equipment must be in good working order and must be calibrated annually. Equipment that is beyond the calibration date must be removed from service until it is repaired or replaced. For questions about your equipment, contact the Radiation Safety Office (x2242). Monitoring instruments must be capable of detecting the radioisotope being monitored at or below the contamination limits listed in Protocol 11.

There are several types of monitoring instruments commonly used in research laboratories. The most widely used instrument is the Geiger counter. The Geiger counter is the least expensive and generally the most reliable means of detecting and measuring radioactive contamination from a wide variety of radionuclides. The pancake detector used with the Geiger counter will detect all beta emitting radioisotopes (except H-3) and alpha emitters greater than 2.5 MeV. The beta energy associated with H-3 is too low to be detected by the pancake detector. Radioisotopes which may be detected reliably with the pancake detector include: C-14, S-35, P-32, and P-33. While the Geiger counter can detect higher energy alpha emitters (>2.5 MeV), the zinc sulphide (ZnS) alpha scintillation detector is much more sensitive for detecting alpha contamination and is preferred for alpha contamination surveys.

Another instrument in common use is the liquid scintillation counter, which is ideally suited for contamination surveys of H-3, other low energy beta emitters, alpha emitters, and very low energy photons (Fe-55). This method requires the use of smear/swipe surveys. If the contamination is not removable (i.e., it is fixed to the surface), the smear/wipe survey will not pick it up and contamination will not be detected.

Dose rate meters are used in locations such as the AMS Facility, Hot Labs, RGDs, and other areas where gamma and x-ray radiation may be present.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Detector</th>
<th>Radiation Detected</th>
<th>Survey Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ludlum Model 3 with GM probe</td>
<td>External Pancake GM (1.7 mg/cm² window)</td>
<td>Beta &gt; 28 keV Gamma &gt; 30 keV Alpha &gt; 2.5 MeV</td>
<td>Contamination Surveys</td>
</tr>
<tr>
<td>Ludlum Model 3 with ZnS probe</td>
<td>ZnS alpha scintillation probe</td>
<td>Alpha particles (30% efficient). Will not detect Beta and Gammas</td>
<td>Alpha contamination surveys only</td>
</tr>
<tr>
<td>Ludlum Model 2401-P</td>
<td>Internal Pancake GM (1.7 mg/cm² window)</td>
<td>Beta &gt; 28 keV Gamma &gt; 30 keV Alpha &gt; 2.5 MeV</td>
<td>Contamination Surveys</td>
</tr>
<tr>
<td>ND2001ID (Research Vessels)</td>
<td>Internal Pancake GM</td>
<td>Beta &gt; 35 keV Gamma &gt; 6 keV Alpha &gt; 3.5 MeV</td>
<td>Contamination Surveys</td>
</tr>
<tr>
<td>Instrument/Counter Type</td>
<td>Description</td>
<td>Gamma/Alpha/Beta Levels</td>
<td>Survey Type</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>--------------------------------------------------</td>
<td>--------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>Victoreen Model 451P Pressurized Ion Chamber</td>
<td>Gamma &gt; 20 keV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ludlum Model 2401-EW Internal End Window GM</td>
<td>Gamma, Beta</td>
<td></td>
<td>Radiation Surveys</td>
</tr>
<tr>
<td>Bicron MicroRem Internal Tissue Equivalent Scintillator</td>
<td>Gamma &gt; 40 keV</td>
<td></td>
<td>Radiation Surveys</td>
</tr>
<tr>
<td>Beckman Coulter LS 6500 Liquid Scintillation Counter</td>
<td>Liquid Scintillation</td>
<td>Alpha, Beta (H-3), I-125, Fe-55</td>
<td>Contamination Surveys</td>
</tr>
<tr>
<td>Ludlum Model 3030 Alpha-Beta Swipe Counter</td>
<td>Alpha, Beta</td>
<td></td>
<td>Contamination Surveys</td>
</tr>
<tr>
<td>Triathler Portable Liquid Scintillation Counter</td>
<td>Liquid Scintillation</td>
<td>Alpha, Beta, I-125</td>
<td>Contamination Surveys</td>
</tr>
</tbody>
</table>

### 16.0 RADIOACTIVE MATERIAL AT FIELD LOCATIONS AND ON RESEARCH VESSELS

For WHOI research personnel, prior approval by the RSO and Radiation Safety Committee is required for all work involving the use of sealed sources and/or radioactive material on board research vessels or at field locations outside of WHOI’s properties in Woods Hole, MA.

For Non-WHOI research personnel who wish to conduct research under WHOI’s radioactive material license, prior approval by the RSO and Radiation Safety Committee is required for all work involving the use of sealed sources and/or radioactive material on board WHOI research vessels or at WHOI owned or controlled locations within Massachusetts.

Coordination and approval from local, state, federal and/or international authorities at the research location may be necessary prior to the initiation of the research. These additional approvals will require a longer lead-time. It is the responsibility of the researcher to apply for these approvals. The RSO should be contacted as soon as possible (at least 60 days) prior to departing for the research location to ensure that all necessary coordination with out-of-state institutions or agencies is completed. Refer to Appendix C (At-Sea/Field Use of Radioactive Material) for additional instructions.

### 17.0 EMERGENCY PROCEDURES

#### 17.1 Spills

Workers should follow the procedure defined in Protocol 3 when responding to a radioactive material spill. The acronym, SWIMN, identifies keys actions:

- **Stop** or contain the spill or leak, if this can be done safely.
- **Warn** other occupants of the laboratory of the spill or leak
- **Isolate** the area.
- **Minimize** your exposure to the radiation hazard.
- **Notify** the RSO (x2242, x3347, x3788) about the incident. Call 2911 after hours.

Unless injured or it is otherwise unsafe to remain, workers should not leave the area until someone from the Radiation Safety Office has determined that you are not contaminated or have been successfully decontaminated. Protocol 11 and Protocol 12 may need to be implemented. Depending on the radioactive material involved, the RSO will evaluate whether or not an internal or skin dose assessment is required.

#### 17.2 Minor Contaminated Injury

To minimize internal contamination, workers are expected to notify the RSO of any open wounds, protect any open wounds with appropriate bandages, and immediately report any cut or abrasion received while working with radioactive materials. The RSO may prohibit continuation of worker activities with radioactive material depending on the severity of the wound or the quality/integrity of the protective covering.
Depending on the radioactive material involved, the RSO will evaluate whether or not an internal dose assessment is required.

### 17.3 Fire, Explosion or Major Injury

Workers are expected to immediately notify 2911 (cell 508 289-2911) about any fire, explosion, and/or major injury occurring in a radioactive material use or storage area. The following information must be provided to the emergency response contact:

- Name and contact number of caller
- The nature of the accident
- The location of the accident
- The number and type of injuries involved
- Whether radioactive material contamination and/or other hazardous substance is involved

If safe to do so, radiation workers should remain available to help maintain initial area controls, to provide incident information, and to prevent the spread of contamination until the RSO or designee arrives at the incident scene. The RSO will be responsible for assisting with decontamination activities and related surveys. Depending on the radioactive material involved, the RSO will evaluate whether or not an internal dose assessment is required. Additional emergency procedures are provided in Protocol 3.
APPENDIX A
DEFINITIONS

ACCELERATOR: Any device capable of accelerating electrons, protons, deuterons, or other charged particles in a vacuum and of discharging the resultant particulate or other radiation into a medium at energies usually in excess of 1 MeV. For purposes of this definition, "particle accelerator" is an equivalent term.

ACCELERATOR-PRODUCED MATERIAL: Any material made radioactive by a particle accelerator.

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 or more years of age.

AGREEMENT STATE: Any State with which the U.S. Nuclear Regulatory Commission or the U.S. Atomic Energy Commission has entered into an effective agreement under §274b of the Atomic Energy Act of 1954, as amended (St. 1973, c. 689).

AIRBORNE RADIOACTIVE MATERIAL: Any radioactive material dispersed in the air in the form of dusts, fumes, particulates, mists, vapors, or gases.

AIRBORNE RADIOACTIVITY AREA: A room, enclosure, or area in which airborne radioactive materials exist in concentrations in excess of the derived air concentrations specified in the 105 CMR 120; or 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% of the annual limit on intake (ALI) or 12 DAC-hours.

ALARA (As Low as Reasonably Achievable): Making every reasonable effort to maintain exposures to radiation as far below the MRCP/NRC specified dose limits as is practical consistent with the purpose for which the licensed activity is undertaken. It may take into account the state of technology, the economics of improvements in relation to 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 ionizing radiation and licensed or registered sources of radiation in the public interest.

ALI (Annual Limit on Intake): The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year that would result in a committed effective dose equivalent of 5 rems (0.05Sv) or a committed dose equivalent of 50 rems (0.5Sv) to any individual organ or tissue.

ALPHA PARTICLE: A strongly ionizing particle emitted from the nucleus during radioactive decay having a mass and charge equal in magnitude to a helium nucleus, consisting of 2 protons and 2 neutrons with a double positive charge.

ATOM: Smallest particle of an element which is capable of entering into a chemical reaction.

BACKGROUND RADIATION: Ionizing radiation from cosmic sources; naturally occurring radioactive material, including radon (except as a decay product of source or special nuclear material); and global fallout as it exists in the environment from the testing of nuclear explosive devices or from past nuclear accidents such as Chernobyl that contribute to background radiation and are not under the control of the licensee. “Background radiation” does not include radiation from source, byproduct, or special nuclear materials regulated by Massachusetts or the NRC.

BEQUEREL (Bq): The SI unit of activity equivalent to disintegrations per second (1 Ci=3.7x10¹⁰ Bq).

BETA PARTICLE: A charged particle emitted from the nucleus of an atom, having a mass equal in magnitude to that of the electron, and a single positive or negative charge.
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 \((\text{in vivo}\) counting), or by analysis and evaluation of materials excreted or removed from the human body \((\text{in vitro}\) analysis).

BREMSSTRAHLUNG: Electromagnetic (X-ray) radiation associated with the deceleration of negative electrons passing through matter (more pronounced with energetic beta emitters such as P-32).

CALIBRATION: The process of determining the relation between the output (or response) of a measuring instrument and the value of the input quantity or attribute, a measurement standard. Calibration is often regarded as the process of adjusting the output on a measurement instrument to agree with value of the applied standard, within a specified accuracy. National Institute of Standards and Technology, maintains standards and is considered the arbiter and ultimate (in the U.S.) authority for values of units and industrial standards. Calibration standards should be NIST-traceable, or equivalent.


CMR: Code of Massachusetts Regulations.

COMMITTED DOSE EQUIVALENT: The dose equivalent to tissue or organs 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: The sum of the products of the weighting factors applicable to the body organs or tissues that are irradiated and the committed dose equivalent to the tissues or organs.

CONTAMINATION, RADIOACTIVE: Deposition of radioactive material in any place where it is not desired, and in any place where its presence may be harmful. Contamination may negate the validity of an experiment, as well as being a source of internal or external radiation exposure.

COUNT (RADIATION MEASUREMENTS): The external indication of a device designed to enumerate ionizing events. It may refer to a single detected event or to the total registered in a given period of time. The term is often erroneously used to designate a disintegration, ionizing event, or voltage pulse. (See Efficiency).

CRITICAL ORGAN: The organ or tissue, the irradiation of which will result in the greatest hazard to health of the individual or his descendants.

CURIE: The quantity of any radioactive material in which the number of disintegrations is \(3.7000 \times 10^{10}\) per second. Abbreviated Ci.

DAC: (Derived Air Concentration) The concentration of a given radionuclide in air which, if breathed by the reference man for a working year of 2000 hours under conditions of light work, results in an intake of one ALI.

DAC-HOUR (Derived Air Concentration-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 may take 2,000 DAC-hours to represent one ALI, equivalent to a committed effective dose equivalent of 5 rems \((0.05\) sievert).

DECAY, RADIOACTIVE: Disintegration of the nucleus of an unstable nuclide by the spontaneous emission of charged particles and/or photons.

DECLARED PREGNANT WORKER: A woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception or her expectation to become pregnant.

DECOMMISSION: To remove safely from service and reduce residual radioactivity to a level that permits release of the property for unrestricted use and/or termination of license/permit.
DEEP DOSE EQUIVALENT: External whole body exposure, the dose equivalent at a tissue depth of 1 cm (1000 mg/cm²).

DOSE: A general term denoting the quantity of radiation or energy absorbed in a specified mass.

DOSE, ABSORBED: The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. The unit of absorbed dose is the rad (6.24x10⁷ MeV/g).

DOSE EQUIVALENT: A quantity used in radiation protection expressing all radiation on a common scale for calculating the effective absorbed dose. The unit of dose equivalent is the rems, which is numerically equal to the absorbed dose in rads multiplied by certain modifying factors such as the quality factor, the distribution factor, etc. (See Sievert)

EFFICIENCY (Counters): A measure of the probability that a count will be recorded when radiation is incident on a detector. Typically expressed as a % or in counts per decay. Efficiency varies considerably by instrument and radiation type so it is critical to know the specific factors involved for each situation (radiation type, detection method, window thickness/material, energy dependence, etc.).

ELECTRON: Negatively charged elementary particle, which is a constituent of every neutral atom. Its quantity of negative charge equals 1.6 x 10⁻¹⁹ coulombs. Its mass is 0.000549 atomic mass units.

ELECTRON CAPTURE: A mode of radioactive decay involving the capture of an orbital electron by its nucleus. Capture from a particular electron shell is designated a "K-electron capture," "L-electron capture," etc.

ELECTRON VOLT: A unit of energy equivalent to the amount of energy gained by an electron in passing through a potential difference of 1 volt. Abbreviated eV. Larger multiple units of the electron volt frequently used are: keV for thousand electron volts and MeV for million electron volts.

ERYTHEMA: An abnormal reddening of the skin due to distention of the capillaries with blood. Many different agents, such as heat, drugs, ultra-violet rays, and ionizing radiation, can cause erythema.

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 centimeter (300 mg/cm²).

GAMMA RAY: Very penetrating electromagnetic radiation of nuclear origin. Except for their origin, gamma rays are identical to X-rays. (See Photon)

GEIGER-MUELLER (GM) COUNTER: An instrument with a gas-filled detector and associated circuitry used for radiation detection and measurement.

GRAY (Gy): The SI unit of absorbed dose equal to 100 rads.

HALF-LIFE, BIOLOGICAL: The time required for the body to eliminate one-half of an administered dose of any substance by the regular processes of elimination.

HALF-LIFE, EFFECTIVE: Time required for a radionuclide contained in a biological system to be diminished 50% as a result of the combined action of radioactive decay and biological elimination. Effective half-life=(Biological half-life x Radioactive half-life) / (Biological half-life + Radioactive half-life)

HALF-LIFE, RADIOACTIVE: Time required for a radioactive substance to lose 50% of its activity by decay. Each radionuclide has a unique half-life.
HALF-VALUE LAYER (Half thickness): The thickness of any specified material necessary to reduce the intensity of an X-ray or gamma ray beam to one-half its original value.

HIGH RADIATION AREA: An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 1 mSv (0.1 rems) in 1 hour at 30 centimeters from any source of radiation or from any surface that the radiation penetrates.

INVERSE SQUARE LAW: The intensity of radiation at any distance from a point source varies inversely as the square of the distance. For example, if the radiation exposure is 100 mrems/hr at 1 foot from the source, the exposure will be 1 mrems/hr at 10 feet.

ION: An atom that has too many or too few electrons, causing it to be chemically active. Also an electron that is not associated (in orbit) with a nucleus.

IONIZATION: The process by which a neutral atom or molecule acquires either a positive or a negative charge (i.e., creating ions), by addition or removal of one or more electrons.

IONIZATION CHAMBER: An instrument designed to measure the quantity of ionizing radiation in terms of the current flow between two electrodes associated with ions produced within a defined volume.

IONIZING RADIATION: Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter.

LABELLED COMPOUND: A compound consisting, in part, of labeled molecules or atoms. By radioactivity observations the compound or its fragments may be followed through physical, chemical or biological processes.

LEAD EQUIVALENT: The thickness of the material in question affording the same attenuation, under specified conditions, as lead.

LET (Linear Energy Transfer): Used in radiation biology and radiation effects studies to describe the linear rate of energy absorption in the absorbing medium. It is usually expressed in units of keV/micron. Generally, the higher the rate of LET of the radiation, the more effective it is in damaging the organism.

MEMBER OF THE PUBLIC: An individual except when that individual is receiving an occupational dose.

MINOR: An individual less than 18 years of age.

MONITORING, AREA: Routine monitoring for contamination of any particular area, building, room, or equipment.

MONITORING, PERSONNEL: Monitoring any part of an individual, breath, excretion, or any part of the clothing. (See Radiological Survey)

MONITORING, RADIOLOGICAL: Periodic or continuous determination of the amount of ionizing radiation or radioactive contamination present in an occupied region as a safety measure for purposes of health protection.

NEUTRON: Elementary particles found in nucleus of atom that are electrically neutral and have a mass approximately the same as that of a proton.

NUCLEAR REGULATORY COMMISSION (NRC): The U.S. Nuclear Regulatory Commission or its duly authorized representatives.

NUCLIDE: A species of atom characterized by its mass number, atomic number, and energy state of its nucleus.

OCCUPATIONAL DOSE: The dose received by an individual in the course of employment in which the assigned duties involve exposure to radiation and radioactive materials from licensed and unlicensed sources.
Occupational dose does not include dose from background radiation, as a patient from medical practices, or as a member of the general public.

**OPTICALLY STIMULATED LUMINESCENCE (OSL):** A dosimeter with a thin strip of aluminum oxide crystalline material that measures radiation exposure due to gamma and beta radiation by stimulating the aluminum oxide strip with selected frequencies of laser light causing it to luminesce in proportion to the amount of radiation exposure.

**PLANNED SPECIAL EXPOSURE:** An infrequent exposure to radiation, separate from and in addition to the annual dose. Planned Special Exposures must be approved by the MRCP/NRC and the RSC.

**PHOTON:** A quantity of electromagnetic energy (E) whose value is the product of its frequency (f) and Planck's constant (h). The equation is: \( E = hf \).

**PROTECTIVE BARRIERS:** Barriers of radiation absorbing material, such as lead, concrete, plaster, and plastic that are used to reduce radiation exposure.

**PROTECTIVE BARRIERS, PRIMARY:** Barriers sufficient to attenuate the useful beam to the required degree.

**PROTECTIVE BARRIERS, SECONDARY:** Barriers sufficient to attenuate stray or scattered radiation to the required degree.

**QUALITY FACTOR (Q):** A modifying factor that is used to derive dose equivalent from absorbed dose.

**RAD:** The absorbed dose, or amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material.

**RADIATION:** Alpha particles, beta particles, gamma rays, x rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. Ionizing radiation does not include non-ionizing radiation, such as radio waves or microwaves, visible, infrared, or ultraviolet light.

**RADIATION AREA:** Any area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 5 mrem in one hour at 30 centimeters from the source of radiation or from any surface that the radiation penetrates.

**RADIATION DETECTOR:** A device, which, in the presence of radiation, provides by either direct or indirect means a signal or other indication suitable for use in measuring one or more quantities of incident radiation.

**RADIATION GENERATING DEVICE:** Any device capable of producing radiation except, those devices with radioactive material as the only source of radiation.

**RADIATION SAFETY OFFICER (RSO):** An individual who has the knowledge and responsibility to apply appropriate radiation protection regulations, and who is identified on the WHOI license as the RSO.

**RADIATION WORKER:** An individual that is at least 18 years old with the potential to receive a dose of 100 mrem or greater Total Effective Dose Equivalent.

**RADIOACTIVE MATERIAL:** Any solid, liquid, or gas, which emits radiation spontaneously.

**RADIOACTIVITY:** The transformation of unstable atomic nuclei with the emission of radiation.

**RADIONUCLIDE:** A nuclide with an unstable ratio of neutrons to protons, placing the nucleus in a state of stress. In an attempt to reorganize to a more stable state, it may undergo various types of rearrangement that involve the release of radiation.

**RADIOTOXICITY:** Term referring to the potential of an isotope to cause damage to living tissue by absorption of energy from the disintegration of the radioactive material introduced into the body.
REM: The special unit of dose equivalent. The dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the quality factor, distribution factor, and other necessary modifying factors. (See Sievert)

RESTRICTED AREA: An area, access to which is limited by the licensee or registrant for the purpose of protecting individuals against undue risks from exposure to sources of radiation. Equivalent to a controlled area.

SEALED SOURCE: Any radioactive material that is used as a source of radiation and is encased in a capsule designed to prevent leakage or escape of the radioactive material.

SHALLOW DOSE EQUIVALENT: The dose equivalent for external exposure of the skin or extremities measured at a tissue depth of 0.007 cm (7 mg/cm²) averaged over an area of 10 cm².

SHIELDING MATERIAL: Any material, which is used to absorb radiation and thus effectively reduce the intensity of radiation, and in some cases eliminate it. Lead, concrete, aluminum, water, and plastic are examples of commonly used shielding material.

SI: The abbreviation for the International System of Units.

SIEVERT (Sv): The SI unit of dose equivalent equal to 1 J/kg when modified by quality factors and uniformity of radiation. 1Sv = 100 rems.

SOURCE TRACEABILITY: The ability to show that a radioactive source has been calibrated either by the national standards laboratory of the National Institute of Standards and Technology (NIST), or by a laboratory which participates in a continuing measurement quality assurance program with NIST or other equivalent national or international program.

SPECIFIC ACTIVITY: Total radioactivity of a given nuclide per unit mass or volume of a compound, element or radioactive nuclide.

STOCHASTIC EFFECTS: Health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancers are stochastic effects.

TOTAL EFFECTIVE DOSE EQUIVALENT: (TEDE) The sum of the deep dose equivalent for external exposure and the committed effective dose equivalent for internal exposure.

TRACER, ISOTOPIC: The isotope or non-natural mixture of isotopes of an element which may be incorporated into a sample to make possible observation of the course of that element, alone or in combination, through a chemical, biological, or physical process. The observations may be made by measurement of radioactivity or of isotopic abundance.

UNRESTRICTED or UNCONTROLLED AREA: An area that access is neither restricted nor controlled for radiation protection purposes.

VERY HIGH RADIATION AREA: An area, accessible to individuals, in which radiation levels could result in and individual receiving an absorbed dose in excess of 500 rads in one hour at one meter from a source of radiation or any surface that the radiation penetrates.

WHOLE BODY: For purposes of external exposure, the whole body is defined as the head, trunk (including male gonads), arms above the elbow, or legs above the knee.

X-RAYS: Penetrating electromagnetic radiation having wavelengths shorter than those of visible light. They are usually produced by bombarding a metallic target with high energy electrons in a high vacuum (see Bremsstrahlung). In the nuclear reactions, photons originating in the nucleus are gamma rays and those originating in the extra nuclear part of the atom (electron cloud) are X-rays.
1.0 OBJECTIVE:
This protocol provides guidelines and methods for controlling the radiation exposure to the embryo/fetus. This protocol includes the processes for declaring pregnancy as well as for rescinding a pregnancy declaration and applies to female workers.

2.0 SCOPE:
105 CMR 120 requires that lower exposure limits be imposed on declared pregnant women to control the dose to the embryo/fetus. These lower limits must be applied to workers who voluntarily declare pregnancy in writing to the Institution. This notification must include the estimated date of conception. Upon declaration, the following administrative limits apply:

- 50 mrems per month, not to exceed 100 mrems per pregnancy period.
- If the dose to the embryo/fetus has already exceeded 450 mrems at the time of declaration, then the limit for the duration of the pregnancy is 50 mrems.

105 CMR 120 further requires monitoring of occupational exposure to radiation and to require the use of individual monitoring devices by declared pregnant women. If necessary, occupational intakes of radioactive material must also be monitored and the dose to the embryo/fetus from the intakes to declared pregnant worker must be assessed. Refer to Protocol 5 for additional instructions.

Although it is unlikely that employees will receive a significant dose of radiation, WHOI female employees who are authorized to use radioactive material may choose to declare their pregnancy, if they so desire. The WHOI Declared Pregnant Worker policy allows a woman to declare that she is pregnant or attempting to become pregnant. This declaration must be in writing to either her supervisor or the RSO. Confidentiality shall be maintained. WHOI personnel involved in the process of implementing this procedure shall maintain the confidentiality of the woman.

Although not required by 105 CMR 120 or necessary based on the potential for radiation exposure, WHOI may reassign the individual, if possible, to activities that do not involve working with, or in the vicinity of, licensed or unlicensed sources of radiation, if requested by the Declared Pregnant Worker.

Information concerning biological risks should be obtained from the RSO or designee. It is the responsibility of the woman to notify WHOI of the pregnancy, if desired. The declaration may be rescinded at any time and for any reason. A female employee, who expects to become pregnant within the next 30 to 60 days, may request placement into the "Expected Pregnant" category. This category restricts radiation exposure to the limits stated above. Notification of the woman’s supervisor is required every sixty days in order to continue in this category.

3.0 INSTRUCTIONS:

3.1 Worker Process for Declaring Pregnancy
Notify the RSO or Supervisor of the desire to declare pregnancy.
Complete Form 1.1, found at [http://ehs.whoi.edu/](http://ehs.whoi.edu/), sign and forward to the RSO.

3.2 RSO Post-Declaration Requirements
Arrange for a meeting with the woman to discuss the radiological risks and the declaration process. A copy of U.S. NRC Regulatory Guides 8.13 and 8.29 or equivalent should be given to the woman.

Perform a prospective radiation dose assessment and determine the appropriate exposure controls needed for the woman, if any, and ensure that the woman acknowledges these controls in writing.

To monitor monthly external exposures to X-rays, gamma rays, or high energy beta particles, issue a fetal dosimeter and arrange for monthly processing. Fetal dosimeter should be worn over abdomen, if possible, and should be worn in addition to the worker’s whole body dosimeter.

If the exposure controls impede the woman’s normal functions, then notify the woman’s supervisor of the restrictions.

Complete Form 1.1. Maintain the completed form in the RSO file. Provide a copy of the completed form to the woman. This information must remain confidential.

3.3 Worker Process for Rescinding Pregnancy Declaration

Notify the RSO of the desire to rescind the pregnancy declaration, obtain original Form 1.1 from the RSO and complete Section II.

3.4 RSO Responsibilities for Rescinding the Pregnancy Declaration

Meet with the woman and ensure that she completes Section II of Form 1.1. Maintain the completed form on file. Provide a copy of the completed form to the woman. This information must remain confidential.
Form 1.1
Declaring and Rescinding Pregnancy

Section 1 - Pregnancy Declaration:
I, __________________________, voluntarily declare that I (check which applies):

[ ] am pregnant; the estimated month and year of conception is ________________.

[ ] am expecting to become pregnant.

I have been informed of the potential risks of radiation exposure to the unborn, exposure limits and controls, and the WHOI policy on radiation exposure to the unborn. I have been given the opportunity to ask questions concerning this information. Understanding these risks and the impact on my employment, I voluntarily declare my pregnancy.

I understand that my exposure limits have been reduced to no more than 50 mrems in any one month and 100 mrems for the pregnancy period. Or, if my declaration has occurred after receiving 450 mrems, my limit for the remainder of the pregnancy period is 50 mrems.

____________________________________________ __________________
Declared Pregnant Worker Signature    Date

Briefing Provided By: ___________________________ __________________
Radiation Safety Officer  Date

Section II. Rescinding Pregnancy Declaration

I, ____________________________, declare that I no longer wish to be considered a Declared Pregnant Worker.

____________________________________________ __________________
Signature of Formerly Declared Pregnant Worker    Date
1.0 PURPOSE:
This protocol provides guidelines and methods for procurement, receipt, and accountability of radioactive material.

2.0 SCOPE:
The radioactive material purchase, receipt and accountability program at WHOI is designed to physically and administratively track all licensed radioactive materials from the point of purchase to final disposition. This protocol applies to all personnel involved in this processes, including Shipping and Receiving Department personnel.

3.0 PURCHASE OF RADIOACTIVE MATERIAL:
- The authorized user must submit a Radioactive Material Use Authorization Request and be approved by the RSC, before the radioactive material is procured.
- The Authorized User or approved Radiation Worker prepares the WHOI Purchase Requisition Form(s). An Authorized User must approve all requests.
- The completed Purchase Requisition Form is forwarded to the Radiation Safety Office (MS#48 or fax: 508-457-2015).
- The Radiation Safety Office reviews each request for the purchase or transfer of radioactive material. The request is compared against the isotope inventory to ensure that the isotope and activity are authorized under the Radioactive Material License, to verify the user is authorized to posess and use the requested material, and to ensure that the requested activity does not cause the user to exceed their authorized limit. After reviewing and approving the request, the RSO will sign and forward the request for processing to Procurement. If the RSO is not available, a Radiation Safety Committee member may approve the purchase requisition.

4.0 RECEIVING RADIOACTIVE MATERIAL:
4.1 Most packages containing radioactive material are initially received by the WHOI Shipping and Receiving Department, a.k.a, Distribution. Upon receipt of a shipment of radioactive material during working hours, the WHOI Shipping and Receiving Department will notify the Radiation Safety Office (x2242, x3347) or the RSO’s designee of its arrival. Delivery of the package is then arranged to the authorized lab. If delivery to the authorized lab is not possible, delivery will be made to the Clark or Watson Hot Lab (if the Authorized User is working at the Quissett Campus), Redfield Hot Lab (if the Authorized User is at the Village Campus), or the EH&S office if the Radiation Safety Office representative is available. The Radiation Safety Office representative, Authorized User, or RSO-authorized radiation worker must be available to inspect, survey (if required) and secure the package upon delivery. If delivery of the package was made to a Hot Lab, the RSO or designee will make arrangements for delivery to the authorized lab at a time when the authorized user or their designee is available to accept and secure the package.
NOTE: Packages designated as containing H-3, Tritium, Tritiated Water, or Hydrogen-3 are not permitted in the Clark Laboratory. No radiocarbon, e.g., C-14, is permitted in McLean or Fye Laboratories.

4.2 After normal working hours, packages received shall be stored in the designated refrigerator/freezer/storage area in Shipping and Receiving area until proper delivery can be accomplished. Packages must be stored under conditions that will preserve perishable items, e.g., –80°C freezer for items shipped on dry ice. This refrigerator/freezer/storage area must be locked and posted as a Radioactive Material Area.

4.3 The general radiation and contamination survey procedures for received packages are as follows:
   • All Type A packages which are received and bearing White I, Yellow II, or Yellow III labels must be monitored for surface contamination within 3 hours after receipt if received during normal working hours or within 3 hours of the start of the next working day if received after normal working hours. Packages that are received after normal working hours must be secured. With the exception of some Pa-233 sources, most of our routine radioactive material shipments are not labeled and, thus, will not require monitoring.
   • Type A packages with evidence of damage (e.g., leaking, crushed, wet) must also be monitored to determine external radiation dose rates, i.e., both external dose rates and contamination monitoring must be performed on the damaged package. All damaged packages should not be moved and must be immediately reported to the RSO (x2242, x3347).
   • Excepted (unlabeled) packages do not require any monitoring unless damaged, in which case, monitoring for external surface contamination and external dose rates is required. Most of our routine radioactive material shipments are exempt or excepted and will not require contamination monitoring unless damaged.
   • Immediately notify the RSO about any damaged or leaking package (x2242, x3347).

4.4 The inspection and survey results (if performed per above steps) must be documented on Form 2.1 or equivalent form.

4.5 Upon delivery of the package, the Authorized User, or an approved Radiation Worker, will sign Form 2.1 or equivalent form, acknowledging receipt of the shipment. The RSO will retain the original copy of this form, with the second and third copies being issued to the Authorized User.

5.0 Accountability and Inventory Database:

5.1 Based on the information from the Receipt and Accountability forms, the RSO enters the delivery into the Inventory Database. This database, maintained by the Radiation Safety Office, provides a running inventory of radioactive material, with an entry for each isotope approved for each of the various Authorized Users at WHOI. It also maintains a total inventory of each isotope for the Institution.

5.2 The Authorized User and the Radiation Worker(s) are responsible for entering the 'Materials Use' information into the 'Accountability' portion of Form 2.1. Other forms are acceptable, as long as they capture the same information as Form 2.1. When all of the radioactive material from an individual purchase has been used and documented, the form must be signed and dated by the Authorized User or an approved Radiation Worker and one copy returned to the Radiation Safety Office.

5.3 Whenever an Authorized User completes a Receipt and Accountability form and returns it to the Radiation Safety Office, an entry is made into the database by the RSO or designee indicating the disposition of the isotope.
FORM 2.1

WOODS HOLE
OCEANOGRAPHIC INSTITUTION
RADIOACTIVE MATERIAL ACCOUNTABILITY RECORD

RECEIVING RECORD

AUTHORIZED USER : SIGNATURE

ISO TOPE ORDERED

ACTIVITY ORDERED mCi

REFERENCE/PO No.

DATE RECEIVED

PACKAGE CONDITION

OUTER PACKAGING MATERIAL CONDITION □ GOOD □ FAIR □ POOR

PRIMARY VIAL & SEALS □ VIAL INTACT □ VIAL BROKEN □ SEALS INTACT □ SEALS BROKEN

RADIATION READINGS

EXTERNAL EXPOSURE READINGS (mR/hr) BKG PKG Surface

REMOVABLE CONTAMINATION: BKG= OP= IP= PV= dpm/100cm²

REMARKS & SPECIAL INSTRUCTIONS

1. Always wear disposable gloves when handling RadioActive Material (RAM).
2. Perform contamination surveys on yourself and your work area after each use of RAM.
3. Eating, Drinking & Smoking are prohibited in ALL laboratory and RAM storage areas.

ACCOUNTABILITY RECORD

Indicate the amount, in millicuries, of each aliquot used out of this purchase, and the date of that use. For each entry, indicate what the final disposition of the RAM was [Final Disposition Code:

<table>
<thead>
<tr>
<th>Aliquot Used: mCi</th>
<th>Date:</th>
<th>Disposition:</th>
</tr>
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<tbody>
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</table>

Sign and date this form after the total activity of this shipment has been expended. Return a copy of this form to the Radiation Safety Office. Retain a copy of this form for your files.

SIGNATURE OF AUTHORIZED USER

DATE COMPLETED

RSM-Appendix B-Protocol 2 43 Rev. 5
1.0 SCOPE:
This protocol provides instructions to Institution radiation workers when responding to radioisotope spills or emergency conditions having the potential to produce potentially contaminated and injured personnel. Table 3.1 provides NRC and Massachusetts Radiation Control Program notification requirements.

2.0 DEFINITIONS:
Minor injury: wound or abrasion that does not require medical care.
Major injury: wound, burn, or bone break or fracture requiring onsite or offsite medical care.
Major Spill: A spill is considered major if it results in any of the following:
- Known or suspected internal radiation dose to personnel (inhalation/ingestion of radioactive material)
- Excessive external radiation dose to personnel or contamination of personnel
- Contamination of large areas or multiple areas or associated with other hazardous materials
- Considerable delay in work

Incidental Spill: A spill can generally be considered incidental if it contaminates small areas or equipment, is not otherwise hazardous, and:
- No external or internal contamination of personnel.
- No excessive external radiation dose to personnel.
- No serious delay in work; and
- Can be safely cleaned and decontaminated by qualified radiation workers.

3.0 Notification Requirements:
Incidental Spills – No formal notification is required. Let others in the lab know about the spill to prevent possible spread of contamination. Contact the RSO if you are unsure about what to do or require assistance.
Major Spills - Immediately notify the RSO (X 2242, X 3877 or X 3347) and follow this protocol.
Minor injury while working with radioisotopes - Notify the RSO and follow this protocol.
Fire/explosion/major injuries in RMA storage areas – Dial X 2911 (cell 508 289-2911) and describe the emergency situation, location and contact names/numbers.
Missing Radioactive Material - Notify the RSO.

4.0 Radiation Safety Office Actions
Incidental Spills – No action is required unless requested.
Major Spills – Respond to the scene to evaluate the level of personnel and area contamination in accordance with Protocol 11, “Radiation and Contamination Surveys”, and initiate any required decontamination measures in accordance with Protocol 12, “Decontamination Techniques”. If necessary, bring Radiological Emergency Response Kit to the incident scene, which should include the items listed below.
### RADIOLOGICAL RESPONSE KIT

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QUANTITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suitable survey meters</td>
<td>1 each</td>
</tr>
<tr>
<td>Decontamination Spray</td>
<td>1 container</td>
</tr>
<tr>
<td>Tyvek Suits (XXL, XL)</td>
<td>2 each size</td>
</tr>
<tr>
<td>Goggles</td>
<td>2 pair</td>
</tr>
<tr>
<td>Shoe Covers</td>
<td>2 pair</td>
</tr>
<tr>
<td>Nitrile Gloves</td>
<td>2 pair</td>
</tr>
<tr>
<td>Warning Tape</td>
<td>1 - 150’ roll</td>
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<tr>
<td>Radiological Warning Signs</td>
<td>4</td>
</tr>
<tr>
<td>Radiological Tape</td>
<td>1 roll</td>
</tr>
<tr>
<td>Duct Tape</td>
<td>1 roll</td>
</tr>
<tr>
<td>Sample Bags</td>
<td>1 pkg</td>
</tr>
<tr>
<td>Radiological Waste Bags</td>
<td>4</td>
</tr>
</tbody>
</table>

The kit is stored in the EHS Trailer adjacent to the L’Hirondelle Building at the Village Campus.

Minor injury while working with radioisotopes – Review the worker injury and personnel contamination report form, and recommend appropriate protective measures and internal dose evaluation, as necessary.

Fire/explosion/major injuries in RMA storage areas – Follow this protocol.

Missing radioactive material or significant exposures - Notify Massachusetts Radiation Control Program and the NRC as required. Initiate search for any missing material. Refer to Table 3.1.

### 4.1 Worker Actions for Radioactive Spills

**Stop** or contain the spill or leak, if this can be done safely.

**NOTE:** Do not attempt to stop the spill or leak, if inadequate protective clothing is being worn or you are unfamiliar with the operation.

- Put on proper protective clothing before starting containment and clean up of the spill.
- Cover the spill with absorbent material as quickly and as completely as possible to prevent spreading. To contain the contamination, begin at the outer edge of the contaminated area and wipe inward toward the center of the spill. Do not wipe back and forth or in a random fashion.

**Warn** other occupants of the laboratory of the spill or leak.

**Isolate** the area.

- Restrict access to the immediate spill area until it has been cleaned, decontaminated and surveyed for contamination.

**Minimize** your exposure to the radiation hazard.

- Having contained the spill, remove any protective clothing, and segregate as radioactive waste.
- Wash all contaminated areas of skin thoroughly, **without vigorous scrubbing**, with warm (98°F) water and mild soap as soon as possible after the event. Refer to Protocol 12.

**Notify** either the RSO or the Radiation Safety Office if the spill is considered major. Have someone who is not contaminated call the RSO immediately.

- If possible/safe, do not leave the area until someone from the Radiation Safety Office has determined that you are not contaminated or have been successfully decontaminated. Protocol 11 will be
implemented to determine the extent of the problem and to assist in determining the measures to be taken. Depending on the radioactive material involved, the RSO will evaluate whether or not an internal dose assessment is required.

4.2 Worker Actions for Minor Injury While Working With Radioisotopes

Notify the RSO of any open wounds prior to initiating any work with radioisotopes.

Protect any open wounds with appropriate bandages.

Report any cut or abrasion received while working with radioactive materials immediately to the Radiation Safety Office.

Monitor wound site for contamination.

Decontaminate the wound in accordance with Protocol 12 as directed.

NOTE: The RSO may prohibit continuation of worker activities with radioactive material depending on the severity of the wound or the quality/integrity of the protective covering. Depending on the radioactive material involved, the RSO will evaluate if an internal dose assessment is required.

Review wound and survey results with the RSO following decontamination.

Implement protective measures directed by the RSO.

4.3 Worker Actions for fires, explosions, or major injuries in RMAs

Evacuate the area of the fire or explosion, if possible, and move to a safe location. Call 2911 immediately and provide the following information to the emergency response contact:

- Name, phone number and location of the caller
- The nature of the accident
- The location of the accident
- The number and type of injuries involved

4.4 RSO Actions for fires, explosions, or major injuries in RMAs

As applicable to the emergency scenario, the RSO or designee should consider the following actions:

- Respond to location of the injured worker with the Radiological Response Kit.
- Evaluate the area radiological conditions and extent of personnel injury.
  - If time permits, prepare area for arrival of offsite medical personnel by implementing controls to minimize the spread of contamination.
- Supply appropriate protective clothing to responders.
- As necessary, supply dosimeters for offsite medical personnel.
- Monitor dose rates in areas occupied by offsite medical personnel, as necessary.
- Document names, survey results, and stay times, as necessary.
- If appropriate, prepare the ambulance to receive a contaminated worker by placing a sheet or blanket over the gurney and establishing a contaminated waste bag.
- Brief offsite medical personnel on radiological conditions and recommend radiological controls.
- Provide direction to all first aid providers, including ambulance response personnel, concerning appropriate contamination control measures.
- If requested, provide assistance to medical personnel transporting the injured person from accident site.
- If permitted by medical personnel, survey the injured worker for contamination levels.
- If the individual is significantly contaminated, perform the following:
Consult medical personnel.
If permitted by medical services personnel, decontaminate injured worker, perform contamination survey, and document results on Form 11.1.
Brief medical personnel on results of decontamination action and consider isolating contamination, e.g., Tyvek suit, wraps, etc, if approved by medical personnel.
- Maintain control over all potentially contaminated clothing or biological material from injured worker.
- If necessary, report to offsite medical facilities and implement this protocol.

4.5 Ambulance Transport Of Contaminated Injured Worker
- Accompany the injured worker in the ambulance, if possible, and bring Radiological Response Kit with survey meters.
- Maintain control over contamination, contaminated clothing and contaminated biological material from injured worker.
- Direct the ambulance staff to relay radiological data and contamination control procedures to the emergency room.

5.0 Hospital Response to a Contaminated Injured Worker

NOTE: All questions by media or other persons not directly involved in treatment of the injured individual should be referred to the WHOI Public Information Officer or designee.
- Request that the ambulance crew and medical response personnel remain with the ambulance or other appropriate location until they can be surveyed for possible contamination. If ambulance response personnel and ambulance are not contaminated, release them. Otherwise, decontaminate and release.
- If the emergency room is unable to initiate contamination control measures prior to arrival, consider the following – as appropriate for the situation:
  - Don disposable gloves and hospital scrubs and provide additional supplies in the emergency room
  - Use plastic sheeting to cover the floor under the patient treatment area.
  - Drape hospital sheets over the work counters, placing only required medical equipment out for use by the staff.
  - Obtain a large supply of absorbent pads to control fluid collection processes.
  - If additional WHOI Radiation Safety Office personnel are available, assign them to conduct personnel contamination surveys of the ambulance crew and release of the ambulance and entrance pathway.
  - Ensure immediate and appropriate removal and disposal of any contaminated clothing that the worker may have been wearing, unless it interferes with immediate medical care.
  - Monitor the contaminated worker.
  - Decontaminate the worker as directed by Protocol 12 if appropriate.
  - If injured worker must be moved to an operating room or other treatment room not in the emergency room, assist emergency room staff in posting and controlling the area.
  - Document all information that may be useful in making a complete radiological assessment of the response efforts.

- Request that emergency room staff not leave the area until a personnel contamination survey has been completed and personnel decontamination has been successful or efforts to reduce contamination are no longer effective.
- When the injured worker is transferred out of the emergency room, perform the following:
  - Survey the emergency room and document the results in accordance with Protocol 11.
  - Supervise decontamination of the emergency room in accordance with Protocol 12.
  - Provide assistance to emergency room staff in removing and disposing of protective clothing, whole body frisk, and personnel decontamination activities.
Control and store any contaminated clothing or biological material from injured worker(s) until arrangements can be made for proper shipment to the Institution.

6.0 Recovery Phase

- Update WHOI Senior Management Official(s) on the health and radiological status of the worker and the hospital, ambulance and response personnel.
- Document all personnel and equipment contamination and radiation surveys in accordance with Protocol 11.

<table>
<thead>
<tr>
<th>Table 3.1, NRC/Massachusetts Notification Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lost, stolen or missing RAM</td>
</tr>
<tr>
<td>Immediate (by phone)</td>
</tr>
<tr>
<td>&gt; 1000 times Appendix C quantity</td>
</tr>
<tr>
<td>Incidents involving RAM</td>
</tr>
<tr>
<td>Caused or threatens to cause dose &gt; 5 times any limit</td>
</tr>
<tr>
<td>Excess exposure, radiation levels or concentrations of RAM</td>
</tr>
<tr>
<td>Caused or threatens to cause dose &gt; 5 times any limit</td>
</tr>
<tr>
<td>Sealed source leak test &gt; 0.005 μCi</td>
</tr>
<tr>
<td>Any occurrence</td>
</tr>
<tr>
<td>Notify MA/RCP and final carrier immediately for exceeding DOT radiation and contamination limits when receiving packages</td>
</tr>
</tbody>
</table>

RSM-Appendix B-Protocol 3  48  Rev. 5
1.0 PURPOSE AND SCOPE

The purpose of this protocol is to define the procedures to be followed at WHOI to comply with federal and state regulations for shipping radioactive material from one campus to another or to another licensee. This protocol is applicable to all WHOI employees and contractors who prepare and ship radioactive materials. This protocol does not include shipments of Type B or fissile radioactive material.

NOTE: This protocol is provided as a general reference. Only trained personnel that are approved by the RSO can ship or prepare packages of radioactive materials for shipment. As the regulations change, current shipping regulations shall be reviewed prior to each shipment.

2.0 ROLES AND RESPONSIBILITIES

2.1 Lab/Area Supervisor

Notify the Radiation Safety Office (x2242, x3347, x3788) when a shipment of radioactive material is required. Provide as much advance notice as possible to allow evaluation of the feasibility, logistics and regulations associated with your shipping request. In some cases, alternative shipping arrangements may be required.

2.2 Radiation Safety Officer (RSO) and Assistant RSO (ARSO)

Oversee and provide assistance with all shipments of radioactive material.

3.0 DEFINITIONS AND TRAINING

3.1 Definitions

**A₁ Value** – Based on external radiation hazards, the maximum activity of special form material permitted in a Type A package. The escape from the packaging would present only a direct radiation hazard. A₁ values are found in 49 CFR173.435

**A₂ Value** - Based on radiotoxicity, the maximum activity of normal form material permitted in a Type A package. The escape from the packaging would present both a direct radiation and contamination hazard. A₂ values are found in 49 CFR173.435

**Consignee** - one to whom something is consigned or shipped.

**Hazardous Material** – A substance which has been determined by the DOT to be capable of posing an unreasonable risk to health, safety and property when transported in commerce.

**Hazardous Substance** – A quantity, in one package, which equals or exceeds the reportable quantity (RQ) listed in the appendix A to 49 CFR 172.101. For packages containing a hazardous substance, RQ must be noted before or after the basic description name on the shipping papers and a “RQ” marking must be placed on the package.
Limited Quantity of Radioactive Material – A quantity of radioactive material not exceeding the limits in Appendix C, Limited Quantity Activity Limits. Most of the radioactive material shipped from WHOI falls into this category. Also known as excepted quantity.

Low Specific Activity – Radioactive material with limited specific activities which satisfies the description and limits of 49 CFR 173.403 for LSA-1, LSA-2 and LSA-3.

Normal Form Radioactive Material – Radioactive material which has not been demonstrated to qualify as "special form radioactive material." Also referred to as Other Form or Other Than Special Form.

Package - The packaging together with its radioactive contents as presented for transport.

Packaging - The assembly of components necessary to ensure compliance with the packaging requirements. It may consist of one or more receptacles, absorbent materials, spacing structures, thermal insulation, radiation shielding, etc.

Radioactive Instrument/Article - Any manufactured instrument or article such as an instrument, clock, electronic tube or apparatus, or similar instrument or article having radioactive material in gaseous or non-dispersible solid form as a component part.

Special Form Radioactive Material - radioactive material which satisfies the following conditions:
- It is either a single solid piece or is contained in a sealed capsule that can be opened only by destroying the capsule
- The piece or capsule has at least one dimension not less than 5 millimeters (0.2 inch); and
- It satisfies the test requirements of 49 CFR 173.469
- At WHOI, special form material would be sealed sources that are accompanied by a special form certification. Most radioactive materials shipped by WHOI are Normal Form and does not qualify as special form.

Specific Activity - The activity of the radionuclide per unit mass of that nuclide. The specific activity of a material in which the radionuclide is essentially uniformly distributed is the activity per unit mass of the material.

Surface Contaminated Objects (SCO) – A solid object which is not itself radioactive but which has Class 7 (radioactive) material distributed on any of its surfaces. An object can be SCO I or SCO II depending on the fixed and non-fixed activity present.

Transport Index – A dimensionless number (rounded up to the next tenth) placed on the label of a package to designate the degree of control to be exercised by the carrier during transportation. For nonfissile material packages, the transport index is determined as the maximum radiation level in mrems per hour at one meter from the external surface of the package.

Type A Package – Packaging designed to retain the integrity of containment and shielding required under normal conditions as demonstrated by specific performance based tests.

Type A Quantity – A quantity of radioactive material, the aggregate radioactivity of which does not exceed $A_1$ for special form or $A_2$ for normal form radioactive materials.
3.2 Training

Before shipping radioactive materials, all WHOI employees and contractors involved with the packaging and shipping of radioactive materials will be trained on the requirements of this job function. Employees and contractors shall receive this required training at least once every three years. DOT training is required to ship radioactive materials by ground, and IATA training is required to ship by air.

4.0 Exempt Shipment Evaluation

In accordance with the table in 49 CFR 173.436, determine if the radioactive material is exempt from DOT hazardous materials regulations and this protocol – check against the limits for total activity or activity concentration.

5.0 CONSIGNEE LICENSE

5.1 Consignee license current

Before transferring licensed radioactive material to anyone, verify their authority to receive the type, form, and quantity of material being shipped. Obtain a copy of their current license or written certification that they are authorized to receive the material.

6.0 MATERIAL FORM

Determine the form based on the following:

6.1 Special Form (A₁ Values)

6.1.1 It is either a single solid piece or is contained in a sealed capsule that can be opened only by destroying the capsule.

6.1.2 The piece or capsule has at least one dimension not less than 5 millimeters (0.197 inch), and

6.1.3 It satisfies the test requirements of 49 CFR 173.469

6.2 Normal Form (A₂ Values)

Class 7 (radioactive) material which has not been demonstrated to qualify as Special Form is considered Normal Form.

7.0 MATERIAL CLASSIFICATION

Prior to shipment, all material that is not EXEMPT must be properly classified to ensure that proper packaging and shipping procedures are used. This classification should be documented on Form 4.1 or an equivalent form and filed.

7.1 Excepted Packages - Limited Quantities of Radioactive Materials

Most of the radioactive material shipments shipped from WHOI are limited quantity shipments. A Class 7 (radioactive) material whose activity per package does not exceed the limits specified in 49 CFR 173.425 (Table 4.1 below) may be shipped in accordance with the following requirements:
7.1.1 The package must meet the general design requirements (49 CFR 173.410). A good, sturdy cardboard box that is properly closed and sealed may meet the general design requirements.

7.1.2 The radiation level at any point on the external surface of the package does not exceed 0.005 mSv/hr (0.5 mrem/hr).

7.1.3 The nonfixed (removable) radioactive surface contamination on the external surface of the package does not exceed the limits of 0.4 Bq/cm² (220 dpm/cm²) beta-gamma or low-toxicity alpha emitter (natural uranium, depleted uranium, natural thorium; uranium-235, uranium-238, thorium-232, thorium-228 or thorium-230 when contained in ores or physical or chemical concentrates or tailings; or alpha emitters with a half-life of less than 10 days) and 0.04 Bq/cm² (22 dpm/cm²) other alpha emitting radionuclides. Note: take a 300 cm² swipe, count swipe, divide net counts by 300, and compare to above limits.

7.1.4 The outside of the inner packaging or, if there is no inner packaging, the outside of the packaging itself bears the marking "Radioactive."

7.1.5 The outside of the packaging bears the proper marking: UN2910.

7.1.6 The package does not contain fissile materials, unless excepted by §173.453.

7.1.7 Complete the Straight Bill of Lading, FedEx Airbill, or equivalent. A Shipper’s Declaration for Dangerous Goods is not required for Excepted Packages (Limited Quantity, Instruments, and Articles) unless it is greater than the reportable quantity (RQ).

7.1.8 If the radioactivity exceeds the limits specified in Table 1, the package may not be shipped as an excepted package, limited quantity radioactive material. Stop here and notify the RSO.

7.2 Excepted Packages – Radioactive Instruments and Articles

Instruments and manufactured articles such as an instrument, clock, electronic tube or apparatus, or similar instrument and article having Class 7 (radioactive) materials in gaseous or non-dispersible solid form as a component part may be shipped in accordance with the following:

7.2.1 Each package meets the general design requirements of 49 CFR 173.410.

7.2.2 The activity of the instrument or article does not exceed the relevant limit listed in Table 4.1.

7.2.3 The total activity per package does not exceed the relevant limit listed in Table 4.1.

7.2.4 The radiation level at 10 centimeters (4 inches) from any point on the external surface of any unpackaged instrument or article does not exceed 0.1 mSv/hr (10 mrem/hr).

7.2.5 The radiation level at any point on the external surface of a package bearing the article or instrument must not exceed 0.005 mSv/hr (0.5 mrem/hr), or, for exclusive use domestic shipments, 0.02 mSv/hr (2 mrem/hr).

7.2.6 The non-fixed (removable) radioactive surface contamination on the external surface of the package must not exceed the limits of 0.4 Bq/cm² (220 dpm/cm²) beta-gamma or low-toxicity alpha emitter (natural uranium, depleted uranium, natural thorium; uranium-235, uranium-238, thorium-232, thorium-228 or thorium-230 when contained in ores or physical or chemical concentrates or tailings; or alpha emitters with a half-life of less than 10 days) and 0.04 Bq/cm² (22 dpm/cm²) other alpha emitting radionuclides. Note: take a 300 cm² swipe, count swipe, divide net counts by 300, and compare to above limits.
alpha emitters with a half-life of less than 10 days) and 0.04 Bq/cm² (22 dpm/cm²) other alpha emitting radionuclides. Note: take a 300 cm² swipe, count swipe, divide net counts by 300, and compare to above limits.

7.2.7 The outside of the packaging bears the proper marking: UN2911.

7.2.8 The package does not contain more than 15 grams of uranium-235.

7.2.9 Complete Straight Bill of Lading, FedEx Airbill, or equivalent shipping papers. A Shipper’s Declaration for Dangerous Goods is not required for Excepted Packages (Limited Quantity, Instruments, and Articles) unless it is greater than the RQ.

7.2.10 If the radioactivity exceeds the limits specified in Table 4.1, the package may not be shipped as excepted package, radioactive instruments or articles. Stop and notify the RSO.

| Table 4.1 Activity Limits for Limited Quantities, Instruments and Articles From 49 CFR 173.425 |
|---------------------------------|---------------------------------|---------------------------------|
| Nature of Contents | Instruments and Articles | Limited Quantity Package Limits |
| Solids: Special Form | $10^{2}A_{1}$ | $A_{1}$ | $10^{3}A_{1}$ |
| Solids: Normal Forms | $10^{2}A_{2}$ | $A_{2}$ | $10^{3}A_{2}$ |
| Liquids: Tritiated water | $10^{3}A_{2}$ | $10^{3}A_{2}$ | $10^{4}A_{2}$ |
| Gases: Tritium | $20$ Ci | $200$ Ci | $0.02 A_{2}$ |
| Gases: Special form | $10^{3}A_{1}$ | $10^{2}A_{1}$ | $10^{3}A_{1}$ |
| Gases: Normal forms | $10^{3}A_{2}$ | $10^{2}A_{2}$ | $10^{3}A_{2}$ |

7.3 Low Specific Activity

Low specific activity (LSA) material means Class 7 (radioactive) material with limited specific activity which satisfies the descriptions and limits listed below. LSA shipments are not expected at WHOI. LSA material must be in one of three groups:

7.3.1 LSA-I

(i) Uranium and thorium ores, concentrates of uranium and thorium ores, and other ores containing naturally occurring radionuclides which are intended to be processed for the use of these radionuclides; or

(ii) Solid unirradiated natural uranium or depleted uranium or natural thorium or their solid or liquid compounds or mixtures; or

(iii) Radioactive material other than fissile material, for which the $A_{2}$ value is unlimited; or

(iv) Other radioactive material, excluding fissile material in quantities not excepted under §173.453, in which the activity is distributed throughout and the estimated average specific activity does not exceed 30 times the
values for activity concentration specified in §173.436, or 30 times the default values listed in Table 8 of §173.433.

7.3.2 LSA-II

(i) Water with tritium concentration up to 0.8 TBq/L (20.0 Ci/L); or

(ii) Other radioactive material in which the activity is distributed throughout and the average specific activity does not exceed $10^{-4} \text{ A}_2/\text{g}$ for solids and gases, and $10^{-5} \text{ A}_2/\text{g}$ for liquids.

7.3.3 LSA-III Solids (e.g., consolidated wastes, activated materials), excluding powders that meet the requirements of §173.468 and in which:

(i) The radioactive material is distributed throughout a solid or a collection of solid objects, or is essentially uniformly distributed in a solid compact binding agent (such as concrete, bitumen, ceramic, etc.);

(ii) The radioactive material is relatively insoluble, or it is intrinsically contained in a relatively insoluble material, so that, even under loss of packaging, the loss of Class 7 (radioactive) material per package by leaching when placed in water for seven days would not exceed 0.1 \text{ A}_2; and

(iii) The estimated average specific activity of the solid, excluding any shielding material, does not exceed $2 \times 10^{-3} \text{ A}_2/\text{g}$.

7.4 Surface Contaminated Objects (SCO)

Surface contaminated objects means a solid object, which is not itself radioactive, but which has Class 7 material distributed on any of its surfaces. SCO must be in one of two groups, SCO I or SCO II, depending on the activity levels of fixed and/or non-fixed contamination. In the unlikely event that WHOI will need to ship SCO material, refer to 49 CFR 173.427.

7.5 Type A Quantities

Type A quantity means a quantity of Class 7 (radioactive) material, the aggregate radioactivity which does not exceed $A_1$ for special form or $A_2$ for normal form material, where $A_1$ and $A_2$ values are given in 49 CFR 173.435 or are determined in accordance with 49 CFR 173.433.

8.0 PACKAGING CRITERIA

After material classification, proper packaging must be chosen.

8.1 Limited Quantities

8.1.1 The packaging shall meet the requirements of 49 CFR 173.410, General Design Requirements.

8.1.2 Package liquids in unbreakable bottles if possible. Place the bottle in a plastic bag into the outer packaging (cardboard box, metal can) with a poly bag and add enough absorbent material to absorb twice the liquid content.
8.2 Low Specific Activity

8.2.1 Non-exclusive use shipment packaging shall be DOT specification 7A (49 CFR 178.350) Type A package or an industrial package (IP-1, IP-2 or IP-3; 49 CFR 173.411) subject to the limitations of Table 8 of 49 CFR 173.427

Except for IP-1 packaging, records generated from certified vendor documentation that each package used as an industrial packaging has been evaluated and meets the requirements of 49CFR173.411 shall be maintained on file for a period of 1 year after the latest shipment.

8.2.2 LSA material required to be consigned as exclusive use shall either be in accordance with the above or shall comply with the following, in which case they are excepted from marking and labeling:
- Materials may be packaged in a package that meets DOT’s general design requirements §173.410 that prevents leakage of the radioactive content under normal conditions of transport provided the quantity of Class 7 (radioactive) material in each packaging does not exceed an A₂ quantity.
- Shipments must be loaded by the consignor and unloaded by the consignee from the conveyance or freight container in which originally loaded.
- There must be no loose Class 7 (radioactive) material in the conveyance, however, when the conveyance is the packaging there must be no leakage of Class 7 radioactive) material from the conveyance.
- Packages must be braced so as to prevent shifting of lading under conditions normally incident to transportation.
- Specific instructions for maintenance of exclusive use shipment controls must be provided by the offeror to the carrier. Such instructions must be included with the shipping papers.
- Except when transported in an industrial package in accordance with Table 8 of 49CFR173.427, transportation by aircraft is prohibited.

8.3 Type A Packages

Type A packaging shall be used when shipments of non LSA material in quantities less than the A₁/A₂ values given in 49CFR173.435 are being made.
- All the general design requirements of 49CFR173.410 and 173.412 shall apply.
- Records generated from certified vendor test reports that each package used as Type A packaging has been tested to meet the applicable requirements of 49CFR178.350 shall be maintained on file for a period of 1 year after the latest shipment.

9.0 PACKAGING LOADING

9.1 Ensure that the packaging is appropriate for the size, weight, physical form, and chemical form of the material.

9.2 Drain, to the extent practicable, all pumps, hoses, piping, or other equipment that may contain liquids. Cap, plug or seal all connections and openings. If it cannot be ensured that all liquid has been removed, add absorbent material to the package. Add enough absorbent material to absorb twice the estimated liquid content.

9.3 Inspect the packaging to ensure that:
- It contains no foreign material.
- It contains no standing liquid.
- Other than superficial marks, there is no apparent physical damage.
- All required closure devices are available for use and free of defects that could prevent proper closure.
• All required gaskets are installed or available and free of damage or defects that could prevent sealing. Gasket sealing surfaces are unobstructed.

9.4 Place material in the packaging in such a way as to prevent movement or shifting during transport. Install dunnage, shoring, or bracing as necessary.

9.5 Securely close the package.

9.6 For greater than limited quantity non-exclusive use shipments, install a tamper indicating seal between the package and package lid.

9.7 Perform exposure rate and contamination survey on the package as described below.

10.0 PACKAGE RADIATION LEVEL LIMITATIONS

These limits only apply to shipments of LSA material and Type A packages.

10.1 Non-Exclusive use

Each package of radioactive materials offered for non-exclusive use transportation shall be designed and prepared for shipment so that under conditions normally incident to transportation the radiation level does not exceed 2.0 mSv/hr (200 mrems/hr) at any point on the external surface of the package, and the transport index does not exceed 10.

Measure the dose rate of the package at the package surface and if applicable, the dose rate 10 cm (4 inches) from the unpackaged surface of the instrument or article and record the results on Form 4.1, or equivalent.

10.2 Exclusive Use

A shipment that exceeds the radiation level limits specified above may be transported on the ground as an exclusive use shipment if the radiation level does not exceed any of the following at any time during transportation:

2.0 mSv/hr (200 mrems/hr) on the accessible external surface of the package unless the following conditions are met, in which case the limit is 10 mSv/hr (1000 mrems/hr):
• The shipment is made in a closed transport vehicle;
• Provisions are made to secure the package so that its position within the vehicle remains fixed during transportation; and
• There are no loading or unloading operations between the beginning and end of the transportation.
• 2.0 mSv/hr (200 mrems/hr) at any point on the outer surface of the vehicle, including the upper and lower surfaces, or, in the case of a flat bed style vehicle, at any point on the vertical planes projected from the outer edges of the vehicle, on the upper surface of the load, and on the lower external surface of the vehicle.
• 0.10 mSv/hr (10 mrems/hr) at any point 2 meters (6.6 ft) from the vertical planes represented by the outer lateral surfaces of the vehicle; or, in the case of a flat bed style vehicle, at any point 2 meters (6.6 ft) from the vertical planes projected from the outer edges of the conveyance; and 0.02 mSv/h (2 mrem/h) in any normally occupied space, except that this provision does not apply to carriers if they operate under the provisions of a State or federally regulated radiation protection program and if personnel under their control who are in such an occupied space wear radiation dosimetry devices.
• For shipments made under the provisions of step 8.2.2, the shipper shall provide specific written instructions for maintenance of the exclusive use shipment controls using Form 4.2, or equivalent. The instructions shall be included with the shipping paper information.
11.0 PACKAGE CONTAMINATION LEVEL LIMITATIONS

Perform a removable contamination survey with the following steps: take a 300 cm² swipe, count swipe, divide net counts by 300, and record the dpm/cm². The removal efficiency of the swipe sample may be assumed to be 10%. The non-fixed (removable) radioactive surface contamination on the external surface of the package must not exceed the limits of 0.4 Bq/cm² (220 dpm/cm²) beta-gamma or low-toxicity alpha emitter (natural uranium, depleted uranium, natural thorium; uranium-235, uranium-238, thorium-232, thorium-228 or thorium-230 when contained in ores or physical or chemical concentrates or tailings; or alpha emitters with a half-life of less than 10 days) and 0.04 Bq/cm² (22 dpm/cm²) other alpha emitting radionuclides.

12.0 PACKAGE MARKING AND LABELING

12.1 Limited quantity excepted packages shall bear the marking “RADIOACTIVE” on the outside of the inner packaging. If there is no inner package, the outside of the package shall bear the marking "RADIOACTIVE". Mark outside of package with proper UN number (e.g., UN2910, UN2911, etc).

12.2 For combination packaging having an inner packaging containing liquid radioactive materials, the words "THIS END UP" with double arrows pointing to the upright orientation of the inner packaging closure shall be affixed to the outside package.

12.3 For air shipments, ensure the required markings are applied to the package. Type A, Type B, SCO, and LSA shipments must include two “Cargo Aircraft Only” labels on same sides as White I, Yellow II, or Yellow III labels.

12.4 Each package weighing more than 50 Kilograms (110 pounds) must have its gross weight plainly and durably marked on the outside of the package.

12.5 When labels are required, there must be two on opposite sides of package, not on top and bottom.

12.6 All non LSA packages, e.g. Type A packages, excluding excepted packages, shall be labeled in accordance with Table 4.2.

12.7 Ensure that Low Specific Activity (LSA) packages being shipped as exclusive use have been stenciled or marked "RADIOACTIVE-LSA" on each package 180 degrees apart in letters at least 13 mm (1/2") high in contrasting color.

<table>
<thead>
<tr>
<th>Label Category</th>
<th>Package Surface Radiation Level</th>
<th>Transport Index (TI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White - I</td>
<td>≤ 0.5 mrem/h to ≤ 200 mrem/h</td>
<td>N/A</td>
</tr>
<tr>
<td>Yellow - II</td>
<td>&gt; 0.5 mrem/h to ≤ 50 mrem/h</td>
<td>≤ 1</td>
</tr>
<tr>
<td>Yellow – III</td>
<td>&gt; 50 mrem/h to ≤ 200 mrem/h</td>
<td>&gt; 1 and ≤ 10</td>
</tr>
</tbody>
</table>

12.8 As applicable, the following information must be entered in the blank spaces on the "RADIOACTIVE" label (must be legible and durable/weather resistant):

- **Contents** - The name of radionuclides as taken from 49CFR173.435 A₁ - A₂ values. For mixtures of radionuclides, with consideration of space available on the label, the radionuclides that must be shown must be determined in accordance with 49CFR173.433(f).

- **Activity** - Units shall be expressed in appropriate SI units, (e.g., Becquerels (Bq), Terabecquerels (TBq), etc.). Curie units or multiples thereof may also be indicated on the label, but must be shown in (parentheses) after the primary units, Bq.
• Transport Index - The dimensionless number (rounded up to the next tenth) shall be placed on the label of a package to designate the degree of control to be exercised by the carrier during transportation. The TI is determined by multiplying the maximum radiation level in milliSieverts per hour at 1 meter (3.3 ft) from the external surface of the package by 100 (equivalent to the maximum radiation level in mrems per hour at one meter)

12.9 Nonbulk packages marked "RADIOACTIVE-LSA" that contain a hazardous substance or Reportable Quantity (49CFR171.8 and 172.101 Appendix A), must be stenciled or otherwise marked with the letters "RQ".

12.10 All packages shipped, which bear “RADIOACTIVE- Class 7” labels, must be at least Type A.

12.11 Each package of Class 7 (radioactive) materials which conforms to the requirements for Type A packaging must be plainly and durably marked on the outside of the package in letters at least 13 mm (1/2 inch) high, with the words "TYPE A". A packaging that is not in compliance with these requirements may not be so marked.

12.12 Each package of Class 7 (radioactive) materials which conforms to the requirements for Industrial Packaging Type 1, Industrial Packaging Type 2, Industrial Packaging Type 3 must be plainly and durably marked on the outside of the package in letters at least 13 mm (1/2 inch) high, with the words "TYPE IP-1", "TYPE IP-2", or "TYPE IP-3" as appropriate. A packaging that is not in compliance with these requirements may not be so marked.

12.13 Type A packages shall be designed so that the outside of the packaging incorporates a feature, such as a seal, that is not readily breakable, and that, while intact, is evidence that the package has not been opened. In the case of packages shipped in exclusive use closed transport vehicles, the cargo compartment may be sealed instead of the individual packages.

12.14 Complete all required shipping papers, such as Straight Bill of Lading, FedEx Airbill, and Shipper’s Declaration For Dangerous Goods. A Uniform Low Level Radioactive Manifest may be required for radioactive waste shipments. Ensure that the RSO’s emergency contact numbers are listed on the required shipping papers for all Type A or radioactive waste shipments.

12.15 Each package of radioactive waste must be clearly labeled as Class A, B, or C stable/unstable (10 CFR 61) when being shipped directly to an approved disposal site.

13.0 VEHICLE PLACARDING

13.1 All radioactive materials shipment shall be placarded in accordance with the following:

• Radioactive placards as described in 49CFR172.500 Subpart F shall be applied to all four sides of a trailer and the front of the tractor when making a placard required shipment with a tractor/trailer system.

• Placards shall be applied to both sides, front and rear of a non-tractor/trailer system shipment requiring placards.

13.2 Radioactive placards shall be used as described above when making the following shipments:

• Low Specific Activity or Surface Contaminated Objects sent by exclusive use vehicles.

• Radioactive Materials packages bearing Yellow III labels.
14.0 EMERGENCY RESPONSE INFORMATION

14.1 Emergency response information is required to be provided as part of the shipping papers for Type A and radioactive waste shipments. Ensure that the RSO’s or other appropriate emergency contact numbers are listed on the required shipping papers for all Type A shipments and radioactive waste.

14.2 Emergency response information must be immediately available for use at all times the hazardous material is present.

14.3 Emergency response information, including the emergency response telephone number(s), must be immediately available to any person who, as a representative of a federal, state or local government agency, responds to an incident involving a hazardous material or is conducting an investigation which involves a hazardous material.

14.4 Example emergency response information is presented in Form 4.3

15.0 CONSIGNEE NOTIFICATION

Notify the consignee of the shipment and record the notification on Form 4.1, or equivalent record.
Form 4.1  
Radioactive Material Shipment Record

To: ___________________________  Date: ________________

_____________________________  Shipment #: ______________________

_____________________________  Carrier: _________________________

_____________________________

Off-Site Use by WHOI Personnel: ___________________ Yes ______________ No

Expected Date of Return: _______________ Transferee’s Licensee’s #: _______________________

Radioactive Material Description: _______________________________________________________


<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Activity (Ci)</th>
<th>Materials Package Limit (Ci)</th>
<th>Fraction of Package Limit</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

**Sum of Fractions of Materials Package Limits**

☐ Excepted  ☐ A1 Special Form  ☐ A2 Normal Form  ☐ Type A

**Radiation Measurements**

Exposure Rate Meter Type: ___________________________ Serial #: __________ Calibration Date: __________

Survey Meter Type: ___________________________ Serial #: __________ Calibration Date: __________

Maximum Exposure Rate @ Package Surface: ___________________________ mrems/hr

Maximum Exposure Rate @ 1 Meter from Surface: ___________________________ mrems/hr

Max. Exp. Rate @ 10 cm Unpackaged Instruments and Manufactured Articles Only: ___________________________ mrems/hr

Background: ___________________________ dpm/100cm²  Smear Survey: ___________________________ dpm/300cm²

Radiation Measurements Performed By: ___________________________ Date: ___________________________

Cconsignee Notified of Shipment By: ___________________________ Date: ___________________________

Approved By RSO or designee: ___________________________ Date: ___________________________
Form 4.2
Driver’s Instructions for Exclusive Use

Shipment Date __________________
Number of Packages ______________________ Tractor/Trailer_________________
Carrier   ______________________
Contents_______________________________________________________________

To the Driver _________________________________________
1. This transport vehicle is consigned to the exclusive use of the Woods Hole Oceanographic Institution. There shall be no additions or deletions to the cargo, alterations to the loading arrangement or changes in the fifth wheel placement without the prior approval of the Woods Hole Oceanographic Institution. The transport vehicle shall only be unloaded by__________________ personnel upon arrival at the disposal site/facility.

2. You have been provided with or offered two replacement radioactive placards and labels (if applicable). Should any of the placards or labels affixed to the truck cab or trailer, become lost or damaged, they shall be replaced as soon as practicable. Periodically inspect placards (and labels) during transport and maintain as in condition of departure from the Woods Hole Oceanographic Institution.

3. The routing to ________________ is prescribed as follows:________________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
The Woods Hole Oceanographic Institution requests that this shipment leave Massachusetts directly. Should a change in the above routing instructions occur, the Woods Hole Oceanographic Institution must be notified as soon as possible.

4. If you are involved in an accident or delayed beyond your expected arrival date, notify the Woods Hole Oceanographic Institution RSO: 508.962.2260 or 508.289.3788

5. Additional Instructions:
________________________________________________________________________________
________________________________________________________________________________

I approve of the loading arrangement and placement of packages for this shipment and have been verbally briefed and understand the preceding instructions.

_____________________________________  Date  ____________
Driver

The driver has been verbally briefed on the preceding instructions.

_____________________________________  Date  ____________
Shipper
Form 4.3
Emergency Response Information
Radioactive Material – LSA

Description of Shipment:

POTENTIAL HEALTH HAZARDS:
Radiation presents minimal risk to transport workers, emergency response personnel, and the public during transportation accidents. Packaging durability increases as potential hazard of radioactive content increases. Undamaged packages are safe - low radiation hazard when material is inside container. Contents of damaged packages may cause higher external radiation exposure or both external and internal radiation exposure if contents are released.

If material is released from package or bulk container, hazard will vary from low to moderate. Level of hazard will depend on the type and amount of radioactivity, the kind of material it is in, and/or the surfaces it is on. Some material may be released from packages during accidents of moderate severity but risks to people are not great.

Released radioactive materials or contaminated objects usually will be visible if packaging fails. Some exclusive use shipments of bulk and packaged materials will not have “RADIOACTIVE” labels. Placards, markings, and shipping papers provide identification.

Some packages may have a “RADIOACTIVE” label and a second hazard label. The second hazard is usually greater than the radiation hazard; so follow this Guide as well as the response guide for the second hazard class label.

Some radioactive materials cannot be detected by commonly available instruments. Runoff from control of cargo fire may cause low-level pollution.

POTENTIAL FIRE OR EXPLOSION HAZARDS:
Some of these materials may burn, but most do not ignite readily. Uranium and thorium metal cuttings may ignite spontaneously if exposed to air. Nitrates are oxidizers and may ignite other combustibles.

PUBLIC SAFETY:
Call emergency response telephone number on shipping paper. Priorities for rescue, life-saving, first aid, and control of fire and other hazards are higher than the priority for measuring radiation levels. The radiation authority must be notified of accident conditions. The radiation authority is usually responsible for decisions about radiological consequences and closure of emergencies. Isolate spill or leak area immediately for at least 25 to 50 meters (80 to 160 feet) in all directions. Stay upwind. Keep unauthorized personnel away. Detain or isolate uninjured persons or equipment suspected to be contaminated and delay decontamination and cleanup until instructions are received from the radiation authority.

PROTECTIVE CLOTHING:
Positive pressure self-contained breathing apparatus (SCBA) and structural firefighters’ protective clothing will provide adequate protection.

EVACUATION:
Large Spill: Consider initial downwind evacuation for at least 100 meters (330 feet) for potential airborne hazard.
Fire: When a large quantity of this material is involved in a major fire, consider an initial evacuation distance of 300 meters (1000 feet) in all directions.

FIRE EMERGENCY RESPONSE:
Presence of radioactive material will not influence the fire control processes and should not influence selection of techniques. Move containers from fire area if you can do it without risk. Do not move damaged packages - only move undamaged packages out of fire zone. Small fires: Dry chemical, CO2, water spray or regular foam. Large fires: Water spray, fog (flooding amounts). If feasible, collect fire-control water for proper disposal.

SPILL OR LEAK EMERGENCY RESPONSE:
Do not touch damaged packages or spilled material. Cover liquid spill with sand, earth or other noncombustible absorbent material. Dike to collect large liquid spills. Cover powder spill with plastic sheet or tarp to minimize spreading.

FIRST AID EMERGENCY RESPONSE:
Medical problems take priority over radiological contamination concerns. Use first aid treatment according to the nature of the injury. Do not delay care and transport of a seriously injured person. Apply artificial respiration if victim is not breathing. Administer oxygen if breathing is difficult. In case of contact with substance, immediately wipe or rinse from skin, and flush skin or eyes with running water for at least 20 minutes. Injured persons contaminated by contact with released material are not a serious hazard to health care personnel, equipment or facilities. Ensure that medical personnel are aware of the material(s) involved, take precautions to protect themselves and prevent spread of contamination.
Form 4.3
Emergency Response Information
Radioactive Material – TYPE A or RADIOACTIVE WASTE

Description of Shipment:_____________________________________________________________________

POTENTIAL HEALTH HAZARDS:
Radiation presents minimal risk to transport workers, emergency response personnel, and the public during transportation accidents. Packaging durability increases as potential hazard of radioactive content increases. Undamaged packages are safe. Contents of damaged packages may cause higher external radiation exposure or both external and internal radiation exposure if contents are released. Type A packages (cartons, boxes, drums, articles, etc.) identified as “Type A” by marking on packages or by shipping papers contain non-life endangering amounts. Partial releases might be expected if “Type A” packages are damaged in moderately severe accidents. Radioactive White-I labels indicate radiation levels outside single, isolated, undamaged packages are very low (<0.5 mrems/h). Radioactive Yellow-II and Yellow-III labeled packages have higher radiation levels. The transport index (TI) on the label identifies the maximum radiation level in mrems/h one meter from a single, isolated, undamaged package. Some radioactive materials cannot be detected by commonly available instruments. Water from cargo fire control may cause pollution.

POTENTIAL FIRE OR EXPLOSION HAZARDS:
Some of these materials may burn, but most do not ignite readily. Radioactivity does not change flammability or other properties of materials.

PUBLIC SAFETY:
Call emergency response telephone number on shipping paper. Priorities for rescue, life-saving, first aid, and control of fire and other hazards are higher than the priority for measuring radiation levels. The radiation authority must be notified of accident conditions. The radiation authority is usually responsible for decisions about radiological consequences and closure of emergencies. Isolate spill or leak area immediately for at least 25 to 50 meters (80 to 160 feet) in all directions. Stay upwind. Keep unauthorized personnel away. Detain or isolate uninjured persons or equipment suspected to be contaminated and delay decontamination and cleanup until instructions are received from radiation authority.

PROTECTIVE CLOTHING:
Positive pressure self-contained breathing apparatus (SCBA) and structural firefighters’ protective clothing will provide adequate protection against internal radiation exposure, but not external radiation exposure.

EVACUATION:
Large Spill: Consider initial downwind evacuation for at least 100 meters (330 feet) for potential airborne hazard. Fire: When a large quantity of this material is involved in a major fire, consider an initial evacuation distance of 300 meters (1000 feet) in all directions.

FIRE EMERGENCY RESPONSE:
Presence of radioactive material will not influence the fire control processes and should not influence selection of techniques. Move containers from fire area if you can do it without risk. Do not move damaged packages - move undamaged packages out of fire zone. Small fires: Dry chemical, CO 2, water spray or regular foam. Large fires: Water spray, fog (flooding amounts). If feasible, collect fire-control water for proper disposal.

SPILL OR LEAK EMERGENCY RESPONSE:
Do not touch damaged packages or spilled material. Damp surfaces on undamaged or slightly damaged packages are seldom an indication of packaging failure. Most packaging for liquid content have inner containers and/or inner absorbent materials. Cover liquid spill with sand, earth or other noncombustible absorbent material.

FIRST AID EMERGENCY REPSONE:
Medical problems take priority over radiological concerns. Use first aid treatment according to the nature of the injury. Do not delay care and transport of a seriously injured person. Apply artificial respiration if victim is not breathing. Administer oxygen if breathing is difficult. In case of contact with substance, immediately wipe or rinse from skin, and flush skin or eyes with running water for at least 20 minutes. Injured persons contaminated by contact with released material are not a serious hazard to health care personnel, equipment or facilities. Ensure that medical personnel are aware of the material(s) involved, take precautions to protect themselves and prevent spread of contamination.
Woods Hole Oceanographic Institution

PROTOCOL 5

External/Internal Dosimetry Worksheet

External/Internal Dosimetry Worksheet
Dosimetry Requested For: ___________________________ Dept.: ___________________

<table>
<thead>
<tr>
<th>Required</th>
<th>Provided But Not Required</th>
<th>Not Required Not Provided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Body Dosimeter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extremity Dosimeter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bioassay Sampling</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EXTERNAL DOSIMETRY - ISOTOPES

NOTE: External dosimeters are not required/provided if personnel are ONLY working with low energy beta emitters (e.g., H-3, C-14, S-35) or alpha emitters.

<table>
<thead>
<tr>
<th>Source</th>
<th>Source</th>
<th>Source</th>
<th>Source</th>
<th>*Source</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Isotope</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Maximum Activity Used (mCi)</td>
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</tr>
<tr>
<td>3</td>
<td>**Dose Rate @ 1 cm (mrem/ hr)</td>
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<tr>
<td>4</td>
<td>**Dose Rate @ 30 cm (mrem/hr)</td>
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<tr>
<td>5</td>
<td>Hours/ Year with source</td>
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<td></td>
</tr>
<tr>
<td>6</td>
<td>DDE = (#4) x (#5)</td>
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<td></td>
</tr>
<tr>
<td>7</td>
<td>SDE = (#3) x (#5)</td>
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</tbody>
</table>

*Use additional pages if necessary.

**Apply any shielding factors, if applicable, and attach supporting documents if necessary.

EXTERNAL DOSIMETRY – RADIATION GENERATING EQUIPMENT

<table>
<thead>
<tr>
<th>Device</th>
<th>Device</th>
<th>*Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Type of Equipment</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Device Operating Current/ Voltage</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>**Dose Rate @ 1 cm (mrem/hr)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>**Dose Rate @ 30 cm (mrem/hr)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Hours/ Year with device</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>DDE = (#4) x (#5)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>SDE = (#3) x (#5)</td>
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</tbody>
</table>

*Use additional pages if necessary

**Apply shielding and/or distance factors, if applicable, and attach supporting documents if necessary
ESTIMATED ANNUAL EXTERNAL DOSE

Total of DDE for all Isotopes and Equipment:__________________ mrems

Total of SDE for all Isotopes and Equipment:___________________ mrems

If DDE ≥ 500 mrems/year, external whole body dosimeter is required

If SDE ≥ 5,000 mrems/year, extremity dosimeter is required

INTERNAL MONITORING

The following assessment of internal monitoring, based on the ‘Hazard Index’ determination, is from NUREG/CR-1400, Air Sampling In The Workplace, 1991 and as described in the Radiological Health Handbook, 1998. The calculation has been modified by addition of the Inhalation Factor (#4).

<table>
<thead>
<tr>
<th>Source</th>
<th>Isotope</th>
<th>Activity Used /Procedure (µCi)</th>
<th>Number of Procedures/Year</th>
<th>Inhalation Factor (see below)</th>
<th>Containment Factor (see below)</th>
<th>Release Factor (see below)</th>
<th>Annual Limit on Intake (µCi)</th>
<th>Hazard Index (see below)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
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</tbody>
</table>

*Use additional pages if necessary

Inhalation Factor: A modifying factor that the RSO can apply as appropriate and based on consideration of the guidance from NUREG 1400 (≥ 1x10^-6).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glovebox</td>
<td>10</td>
</tr>
<tr>
<td>Well Ventilated Hood</td>
<td>1</td>
</tr>
<tr>
<td>Open Bench</td>
<td>0.1</td>
</tr>
<tr>
<td>Non-routine or special job: unknown ventilation</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Release Factors

<table>
<thead>
<tr>
<th>Condition</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gases or volatile material</td>
<td>1</td>
</tr>
<tr>
<td>Nonvolatile powders (beta/gamma)</td>
<td>0.01</td>
</tr>
<tr>
<td>Nonvolatile powders (alpha)</td>
<td>0.001</td>
</tr>
<tr>
<td>Solids (i.e. metals)</td>
<td>0.001</td>
</tr>
<tr>
<td>Liquid</td>
<td>0.01</td>
</tr>
<tr>
<td>Surface contamination (beta/gamma)</td>
<td>0.001</td>
</tr>
<tr>
<td>Surface contamination (alpha)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Encapsulated material</td>
<td>0</td>
</tr>
</tbody>
</table>

Hazard Index (HI) = \( \frac{(\#2 \times \#3 \times \#4 \times \#6)}{(\#7 \times \#5)} \times 100 \)

Total of HI for all sources = ________________

If HI total ≥ 10, bioassay sampling is required.

Worksheet Completed By:_________________________ Date:______________

Reviewed By:_________________________ Date:______________
1.0 SCOPE:

The Institution shall meet the laboratory posting and container labeling requirements established under 105 CMR 120. Examples of approved postings and labels are provided below. Approved postings and labels should be obtained from the Radiation Safety Office.

2.0 LABORATORY POSTING

It is a WHOI policy that a room containing any amount of licensed radioactive material is a Radioactive Materials Area (RMA).

- Each room where radioactive materials are stored or used must prominently display an 8” X 10” “Caution Radioactive Materials” sign.
- In addition to caution signs, all rooms must be posted with a Space Hazard Placard with emergency contact names and phone numbers.
- All fume hoods used for radioactive materials shall be clearly labeled with a “Caution Radioactive Materials” sign or tape and a current hood flow test certification.
- Any area where the airborne concentration for a particular isotope exceeds the DAC or where an individual could take in 0.6% of the ALI shall be posted as an “Airborne Radioactivity Area”.
- All radioactive material work bench areas shall be clearly identified using “Caution Radioactive Materials” tape as a boundary.
- All signs shall use the colors magenta, purple or black on yellow background.
- All storage containers that are not located in secured laboratories shall be individually posted with their stored inventories and be locked.

3.0 CONTAINER LABELING

Although the regulations in 105 CMR 120 require labeling only containers above the limits in 105 CMR 120, it is a WHOI policy that all containers be labeled regardless of the total radioactivity of the contents.

- Each container that holds radioactive materials must have a durable, clearly visible, label bearing the radiation warning symbol and the words “Caution Radioactive Material.”
- All labels must indicate the contents of the container including the nuclide, the amount of activity and the date.
- All labels shall use the colors magenta, purple or black on yellow background.
- Containers used temporarily during laboratory procedures (e.g. pipettes) do not require labeling provided the user is present and the room is properly posted.
- All refrigerators, freezers, and cabinets used for storage of radioactive materials shall be clearly marked with a “Caution Radioactive Materials” label.
- All storage containers that are not located in secured laboratories shall be individually labeled with their stored inventories.
- Tape appropriate for labeling containers is available from the RSO. Under no circumstances should the tape be used for any purpose other than for proper labeling of radioactive items.
- Remove or black out all radioactive material labels prior to disposing containers as waste.
Examples of Radioactive Postings and Labels
This protocol contains specific instructions for operation of the radiation survey instruments listed below. Refer to the operational manuals for more detailed instructions.

Ludlum Model 3 Survey Meter with GM Probe or ZnS (Alpha) Probe

Note: The ZnS probe is used only for alpha contamination surveys and the GM (pancake) probe is used for all other contamination surveys, except tritium (H-3). The GM probe is not sufficiently sensitive for routine alpha contamination surveys. Tritium contamination must be detected with liquid scintillation.

Ludlum Model 2401-EW Pocket Ratemeter

Ludlum Model 2401-P Pocket Ratemeter

ND 200ID Ratemeter

ThermoElectron Micro Rem Survey Meter

Victoreen Model 451P Survey Meter

Beckman Coulter Scintillation System Model LS 6500

Ludlum Model 3030 Alpha-Beta Swipe Counter
Protocol for Use of the
Ludlum Model 3 Survey Meter with GM Probe or ZnS

The Ludlum Model 3 equipped with a pancake GM probe/detector is a portable ratemeter used to measure fixed or removable (smears) contamination. The meter has an audible monitoring system and a selector switch for fast or slow response. A Reset button rapidly returns meter readings to zero. The ZnS probe is used only for alpha radiation and the GM (pancake) probe is used for all other radiation, except tritium (H-3). The GM probe is not sufficiently sensitive for routine alpha contamination surveys.

Pre-operational Checks:

1. Turn switch to BAT position. The meter should read in the indicated BAT TEST zone. Replace batteries with batteries with two D-cells if needed. Do not use instrument if BAT indication is not within BAT TEST zone.
2. Inspect for physical damage. Do not use if damaged.
3. Check calibration due date on sticker. Do not use if past due.
4. Contact EH&S Office for instrument repair or calibration (508-289-2242).
5. If available, test the meter’s response using a check source for this instrument. It should respond within +/- 20% of the correct value or within the response range. Do not use if source check fails.

CAUTION: Do not set the probe/detector down on any projection which may puncture the delicate detector window. Ensure the protective probe cover is in place when instrument is not in use.

Battery Replacement:

1. Ensure instrument is turned off before changing batteries.
2. Open the battery compartment lid by twisting the latch counterclockwise ¼ turn.
3. Replace batteries. Note (-) and (+) marks on inside of the lid. Match battery polarity to these marks.
4. Close the battery compartment lid by pressing down and turning the latch ¼ turn clockwise until it latches.

Operational Instructions:

1. Perform all pre-operational checks.
2. Flip fast/slow response switch to SLOW position.
3. Place audible response switch to the ON position.
4. Turn selector switch to X 0.1 position. This multiplies the top CPM scale reading by 0.1.
5. Remove red protective cover from probe/detector.
6. Determine background count rate. Do not use in areas where background counts are greater than 300 counts per minute. Move to an area of lower background to count removable contamination smears.
7. Keep probe/detector as close to the surface as possible without touching the probe and move 1-2 inches per second while listening for increased count rate.
8. Stop when count rate increases and determine amount of contamination present. Turn selector switch to correct scale multiplier if reading on the X 0.1 position is off scale.
9. When monitoring is completed, ensure the selector and audio switches are turned off. Replace the red protective cover on the probe/detector.
Protocol for Use of the
Ludlum Model 2401-EW Portable (Pocket) Ratemeter

The Ludlum Model 2401-EW is a sensitive, portable (pocket) ratemeter used to measure fixed or removable (smears) contamination. The meter has an audible monitoring system that should be used when monitoring for radioactive contamination. This meter may be used for monitoring all isotopes, except Tritium, and is not very sensitive for alpha emitters.

Pre-operational Checks:
1. Turn power switch to BAT CHECK position. The meter should read in the indicated BAT OK zone. Replace battery with one 9-volt cell if needed. Do not use instrument if BAT CHECK indication is not within BAT OK zone.
2. Inspect for physical damage. Do not use if damaged.
3. Check calibration due date on sticker. Do not use if past due.
4. Contact EH&S Office for instrument repair or calibration (508-289-2242).
5. If available, test the meter’s response using a check source for this instrument. It should respond within +/- 20% of the correct value or within the response range. Do not use if source check fails.

Battery Replacement:
1. Ensure instrument is turned off before opening instrument case for any reason.
2. Place meter upside down on flat surface. Remove the four screws and carefully lift the bottom case off of the top section. Be careful not to disconnect or damage wiring inside case.
3. Replace battery.
4. Replace the bottom portion of the case and tighten the four screws until the top and bottom meet securely.

Operational Instructions:
1. Perform all pre-operational checks.
2. Place power switch to NORMAL position for an audible response.
3. Turn scale selector switch to X 1 position. This multiplies the bottom CPM scale reading by 1.
4. Determine background count rate. Do not use in areas where background counts are greater than 300 counts per minute. Move to an area of lower background to count removable contamination smears.
5. Keep detector approximately one-half inch above surface and move two to three inches per second while listening for increased count rate.
6. Stop when count rate increases and determine amount of contamination present. Turn scale selector switch to correct scale multiplier if reading on the X 1 position is off scale.
7. When monitoring is completed, ensure the power switch is turned off.
Protocol for Use of the
Ludlum Model 2401-P Portable (Pocket) Ratemeter

The Ludlum Model 2401-P is a sensitive, portable (pocket) ratemeter used to measure fixed or removable (smears) contamination. The meter has an audible monitoring system that should be used when monitoring for radioactive contamination. This meter may be used for monitoring all isotopes, except Tritium, and is not very sensitive for alpha emitters.

Pre-operational Checks:

1. Turn power switch to BAT CHECK position. The meter should read in the indicated BAT OK zone. Replace battery with one 9 volt cell if needed. Do not use instrument if BAT CHECK indication is not within BAT OK zone.
2. Inspect for physical damage. Do not use if damaged.
3. Check calibration due date on sticker. Do not use if past due.
4. Contact EH&S Office for instrument repair or calibration (508-289-2242).
5. If available, test the meter’s response using a check source for this instrument. It should respond within +/- 20% of the correct value or within the response range. Do not use if source check fails.

Battery Replacement:

- Ensure instrument is turned off before opening instrument case for any reason.
- Place meter upside down on flat surface. Remove the four screws and carefully lift the bottom case off of the top section. Be careful not to disconnect or damage wiring inside case. Replace battery.
- Replace the bottom portion of the case and tighten the four screws until the top and bottom meet securely.

Operational Instructions:

1. Perform all pre-operational checks.
2. Place power switch to NORMAL position for an audible response.
3. Turn scale selector switch to X 1 position. This multiplies the top CPM scale reading by 1.
4. Determine background count rate. Do not use in areas where background counts are greater than 300 counts per minute. Move to an area of lower background to count removable contamination smears.
5. Keep detector approximately one-half inch above surface and move two to three inches per second while listening for increased count rate.
6. Stop when count rate increases and determine amount of contamination present. Turn scale selector switch to correct scale multiplier if reading on the X 1 position is off scale.
7. When monitoring is completed, ensure the power switch is turned off.
Protocol for Use of the
ND200ID Portable Ratemeter

The Model ND200ID is a sensitive, portable ratemeter used to measure fixed or removable (smears) contamination. The meter has an audible monitoring system and a selector switch for fast or slow response. This meter may be used for monitoring all isotopes, except Tritium, and is not very sensitive for alpha emitters.

Pre-operational Checks:
1. Turn switch to BATT position. The meter should read in the indicated BATT zone. Replace batteries with 2 D-cells if needed. Do not use instrument if BATT indication is not within BATT zone.
2. Inspect for physical damage. Do not use if damaged.
3. Check calibration due date on sticker. Do not use if past due.
4. Contact EH&S Office for instrument repair or calibration (508-289-2242).
5. If available, test the meter’s response using a check source for this instrument. It should respond within +/- 20% of the correct value or within the response range. Do not use if source check fails.

Battery Replacement:
1. Ensure instrument is turned off before opening instrument case for any reason.
2. Remove the four screws and carefully lift the top out of the meter case. Be careful not to disconnect or damage detector wiring inside case.
3. Replace batteries.
4. When securing the survey meter lid to the case, clean the case gasket to ensure a proper seal. Tighten the four screws until the top and bottom meet securely.

Operational Instructions:
1. Perform all pre-operational checks.
2. Place fast/slow response switch in SLOW position.
3. Turn on audible response.
4. Turn selector switch to X .1 position. This multiplies the top CPM scale reading by 0.1.
5. Determine background count rate. Do not use in areas where background counts are greater than 300 counts per minute. Move to an area of lower background to count removable contamination smears.
6. Keep detector approximately one-half inch above surface and move two to three inches per second while listening for increased count rate.
7. Stop when count rate increases and determine amount of contamination present. Turn selector switch to correct scale multiplier if reading on the X .1 position is off scale.
8. When monitoring is completed, ensure the selector and audio switches are turned off.
Protocol for Use of the
Thermo Electron Micro Rem Survey Meter

The Thermo Electron Micro Rem Survey Meter is a sensitive, portable dose rate meter that is used to measure dose rates from gamma and x-rays above 40 keV. A Reset button rapidly returns meter readings to zero.

Pre-operational Checks:
1. Turn switch to BAT position. The meter should read in the indicated BAT OK zone. Replace batteries with two 9 volt cells if needed. Do not use instrument if BAT indication is not within BAT OK zone.
2. Turn switch to HV (high voltage) position. The meter should read in the indicated HV zone. If not, take the meter out of service and call the EH&S Office for corrective action.
3. Inspect for physical damage. Do not use if damaged.
4. Check calibration due date on sticker. Do not use if past due.
5. Contact EH&S Office for instrument repair or calibration (508-289-2242).
6. If available, test the meter’s response using a check source for this instrument. It should respond within +/- 20% of the correct value or within the response range. Do not use if source check fails.

Battery Replacement:
1. Ensure instrument is turned off before changing batteries.
2. Open the battery compartment lid by opening latches on each end of meter.
3. Pull up meter top using the handle.
4. Replace batteries.
5. Close the battery compartment lid by inserting the top of the instrument into the bottom and closing latches.

Operational Instructions:
1. Perform all pre-operational checks.
2. There is no audible response.
3. Turn selector switch to X 0.1 position. This multiplies the μrems/h scale reading by 0.1.
4. Determine background exposure rate. Look for an increase in exposure rate as meter is pointed in the direction of interest and moved around. Detector is located in the front of the meter.
5. Stop when exposure rate increases and determine the maximum exposure rate for the article or area being surveyed. Turn selector switch to correct scale multiplier if reading on the X 0.1 position is off scale.
6. When monitoring is completed, ensure the selector switch is turned off.
Protocol for Use of the
Victoreen Model 451P Survey Meter

The Victoreen Model 451P survey meter is a sensitive, portable pressurized ion chamber used to measure dose rates from gamma and x-ray radiation above 25 keV. The meter is equipped with a digital readout and an analog bar graph which will auto adjust to the correct range. This meter will not measure beta radiation dose rates.

Pre-operational Checks:
1. Press On-Off switch until the digital display is visible. The meter will run through the elements of a self test process. Replace batteries with two 9 volt cells and two AA cells if needed. Do not use instrument if LO BAT message stays on. The batteries must be replaced with 1 hour of the LO BAT message appearing or meter will not operate.
2. If the meter fails the self test process, it will remain locked in the self test mode. Do not use and call the EH&S office for corrective action.
3. Inspect for physical damage. Do not use if damaged.
4. Check calibration due date on sticker. Do not use if past due.
5. If available, test the meter’s response using a check source for this instrument. It should respond within +/- 20% of the correct value or within the response range. Do not use if source check fails.
6. Contact EH&S Office for instrument repair or calibration (508-289-2242).

Battery Replacement:
1. Ensure instrument is turned off before changing batteries.
2. Slide top of handle back to expose batteries.
3. Replace batteries
4. Slide top of handle back on.

Operational Instructions:
1. Perform all pre-operational checks.
2. Place Mode in mR/h position.
3. Let meter warm up for five minutes and check that display has stabilized to less than 0.5 mrems/h
4. There is no audible response.
5. Determine background exposure rate.
6. Look for an increase in exposure rate as meter is pointed in the direction of interest and moved around.
7. Stop when exposure rate increases and determine maximum exposure rate for the article or area being surveyed.
8. When monitoring is completed, ensure the On-Off switch is turned to off.
SCOPE: This protocol outlines the steps required to operate the Beckman Coulter Model LS 6500 liquid scintillation counter in Redfield to count swipes for low energy beta emitters (e.g., H-3), alpha emitters, and some low energy x-ray emitters, e.g., Fe-55. The parameters given here will result in Minimum Detection Concentrations for carbon 14 and tritium as required by Table 3 in the WHOI Radiation Safety Manual. All release criteria are based on a 100 cm² swipe test.

EQUIPMENT:
Beckman Coulter LS 6500 liquid scintillation counter
Glass fiber filters 4.25 cm, cut in halves
Brinkmann Dispenser -1 to 10 ml capacity
Glass scintillation vials with screw cap - 7 ml capacity

REAGENTS:
Liquid Scintillation Cocktail –Fisher Scintisafe 30% or equivalent

SAMPLE PREPARATION:
1.) Samples should consist of swipes.
2.) Each swipe should be kept separate from all other swipes by using wax sample paper or plastic bags.
3.) A blank sample should be created using an unused ½ piece of filter paper wetted with deionized water.
4.) Place the blank sample in the first glass scintillation vial in position 1 of the sample rack.
5.) Place all other samples individually into glass scintillation vials filling up the sample rack.
6.) Add 5 ml of liquid scintillation cocktail to each sample using the Brinkmann Dispenser.
7.) Put the screw caps on each sample and shake to completely mix sample with liquid scintillation cocktail.
8.) Attach the user program card #4, for H-3 and C-14 counting protocol, to the card slot on the back of the sample rack with the squares of the program card facing away from you. User program #4 is a preset program specifically designed for use counting H-3 and C-14 samples. Sample racks are located in the drawer beneath the instrument.
9.) A calibration rack with H-3 and C-14 standards is provided inside the sample area of the instrument.
10.) A halt rack is provided inside the sample area of the instrument.
AUTOMATIC COUNTING:

1.) The first rack to be positioned at the back of the sample area of the instrument is the calibration rack.
2.) Place the sample rack in front of the calibration rack.
3.) Place the halt rack closest to you in front of the sample rack.
4.) Select the “Main Menu” button on the instrument.
5.) Select “Automatic Counting” from this menu by using the arrow keys on the instrument to the “Automatic Counting” selection on the screen and then using the “Select” button.
6.) Depress the “Start” button on the instrument.
7.) The instrument will start running the calibration procedure and then the samples. Only use the counting results from the printout if the words “Calibration Successful” are printed on the results.
8.) After counting is complete, the samples should be disposed of in the Liquid Scintillation waste drum located to the left of the sink in Redfield 3-04.

ANALYZING RESULTS:

1.) The efficiencies for H-3 and C-14 are noted on the sample results printout. The efficiency for H-3 is about 57% and the efficiency for C-14 is about 75%. The efficiencies are used in user program #4 to calculate the dpm for each sample for you.
2.) The printout will display cpm for H-3 and C-14, and in the center columns, the dpm for H-3 and C-14 will be calculated for you.
3.) Refer to Protocol 13 in the Radiation Safety Manual for specific instructions and action levels for removable surface contamination.
Protocol for Use of the Ludlum Model 3030
Alpha-Beta Swipe/Smear Counter

The Ludlum Model 3030 is a dual-channel counter designed for simultaneous alpha and beta sample measurement. An integral scintillation detector features a shielded chamber and chrome-plated brass sample tray that can accept a maximum sample size of 2 inches in diameter. The unit is powered by 110 VAC or can be operated on the internal gel-cell battery for a period of 8 hours. An internal trickle-charger replenishes the battery whenever the counter is plugged into an AC power source. The Model 3030 has adjustable count time periods, a click-per-event audio with adjustable audio level and two independent liquid crystal displays (LCDs). This system may be used to evaluate all alpha and beta emitting isotope wipes except Tritium.

Pre-operation Checks:
1. Inspect for physical damage. Do not use if damaged
2. Check calibration due date on sticker. Do not use if past due.
3. Turn power switch to the on position. Verify that the QC, OL, αAL, βAL all illuminate red with the CPM and DPM illuminating green momentarily. Both LCDs should also flash 8.8:8:8:8.8 then each display will read zero after a few seconds.
4. Perform a daily QC (≤ 24 hrs.) as described below.

Manual QC Check:
1. Position the tray switch to TRAY UNLATCH each time to open the sample tray and TRAY LATCHED to lock the tray and enable count mode.
2. Select the 1 minute count time using the rotary switch
3. Open the tray and insert the ALPHA source, close the tray and press COUNT (Colons on displays indicate count in progress). When the count is finished, remove the source and record the value.
4. Count the BETA source as above.
5. Close the tray, press COUNT to collect a background. When the count is finished, record the values.
6. Determine a pass/fail by subtracting the alpha and beta background from the respective source readings and then comparing the net counts to the criteria posted on the Model 3030. If the test fails repeat the test. Tag the unit out of service if unable to pass the QC test.

Manual Operational Instructions:
1. Adjust the audio output volume control to the desired level.
2. Position the tray switch to TRAY UNLATCH each time to open the sample tray and TRAY LATCHED to lock the tray and enable count mode.
3. Select the desired count time using the rotary switch, normally 1 minute.
4. Press the COUNT button to obtain background counts. Record the values when counts complete.
5. Open the tray and insert the sample to be measured, close the tray.
6. Press the COUNT button to initiate the count.
7. Open the tray when the count is complete and remove the sample. Record the CPM on the appropriate form.
8. Repeat steps 2 through 6 until all samples are counted.
PROTOCOL 8
Radioactive Waste

1.0 OBJECTIVE
This protocol provides instructions for properly managing radioactive and mixed waste that is both hazardous and radioactive.

2.0 DECAY-IN-STOREAGE
The WHOI radioactive material license allows the Institution to use decay-in-storage (DIS) as a method of waste disposal. Radioactive material with a physical half-life of less than 120 days may be included in this program and should be held for at least 7 half-lives. The primary locations for DIS waste are the Clark, Watson and Redfield Hot Labs.

2.1 All waste must be properly labeled and identified prior to transfer to a hot lab. The yellow radioactive waste tag (Figure 1) must be attached to the waste container. Form 8.2 or equivalent must be completed by the generator and included with the container, if additional information is needed. If the container holds mixed waste, a red hazardous waste tag identifying the hazardous component must also be attached.

2.2 Log the waste into the storage log Form 8.1 upon arrival at the Redfield hot lab. Issue the next consecutive storage number to the container and complete the rest of the required information. The estimated disposal date can be estimated as follows: [(7)(isotope’s half-life in days) + (date received or date last isotope was added to the container)]. For containers with more than one isotope, the longest half-life is used in this calculation. Update the Radioactive Material Inventory Database as necessary.

2.3 Ensure the yellow radioactive waste tag is properly completed.

2.4 Place container in decay-in-storage section of hot lab.

2.5 If necessary, add shielding to maintain doses ALARA.

2.6 Prior to disposal, perform the following:

- Use a survey instrument and method that is appropriate for the type and energy of the radiation being measured.
- Check the radiation detection survey meter for proper operation and current calibration status.
- Survey in a low background area away from all sources of radioactive material, if possible.
- Discard as non-radioactive waste, only those containers that have been held for about 7 half-lives and whose radiation levels at the surface of waste are indistinguishable from background radiation levels. Evaluate the non-radioactive waste materials for other hazardous waste materials (e.g., hazardous chemicals, biohazardous items) and ensure proper disposal procedures are followed.
- Remove or deface any radioactive material labels prior to discarding the container.
- Record the disposal date in the storage log for each container. Update the Radioactive Material Inventory Database, as necessary.
- Initiate a survey record to include: container identification number, date the container was put in storage, date of disposal, radionuclide(s) disposed, survey instrument used, background measurement, measurement at the surface of each waste container, and the name of the individual who performed the disposal. The record of each disposal must be kept for three years.
- Regardless of how long the container has been in storage, any containers with radiation levels at the surface that are higher than background radiation levels must be returned to the storage area for further decay or disposed of as low level radioactive waste (LLRW).
2.7 For decayed mixed waste disposal, ensure that a red Hazardous Waste tag is attached identifying the hazardous component remaining.

3.0 STORAGE OF RADIOACTIVE WASTE FOR COMMERCIAL DISPOSAL

Radioactive waste not treated as decay-in-storage must be disposed as LLRW via a commercial vendor or waste broker.

3.1 All waste must be properly labeled and identified prior to transfer to a hot lab. The Radioactive Waste tag must be attached to the container. If the container holds mixed waste, attach and complete a red Hazardous Waste tag that identifies the hazardous component. NOTE: mixed waste must comply with both radioactive, hazardous waste regulations, and/or other applicable regulations.

3.2 Log the waste into the waste storage log-book (Form 8.1) upon arrival at the Clark, Watson or Redfield hot labs. Issue the next consecutive storage number to the container or waste tag and complete the rest of the required information. The Estimated Date of Disposal should be N/A. Update the Radioactive Material Inventory Database as necessary.

3.3 Add the following information to the Radioactive Waste tag: storage number and date placed in storage. Place the container in the LLRW section of the hot lab.

3.4 Consolidate waste into proper DOT-approved shipping containers. Ensure that LLRW streams are properly segregated: dry active waste (DAW) for compaction, DAW for incineration, non-compactable DAW, liquid scintillation vials, bulk liquids, mixed flammables, mixed oxidizers, etc. Sealed sources must be stored separately and cannot be comingled with the above LLRW streams.

General Waste Acceptance Criteria:

- Separate mixed waste and radioactive waste with different shipping containers.
- Ensure that incompatible mixed waste items, such as oxidizers and flammables, are separated. Material must not be put into shipping containers if there is any possibility of a chemical reaction during storage that might cause fire, explosion, or the release of toxic or radioactive gases.
- Record the quantity and types of waste placed in each shipping container on Form 8.2. This inventory must be kept current and attached or referenced to the specific container.
- Ensure waste containers remain properly tagged while stored in the hot lab (yellow tag, red tag, etc).
- Ensure that drum lid gaskets are in place and that lid is sealed tightly before off-site shipment.
- Before off-site shipment, ensure container dose rates and surface contamination levels are ALARA and below DOT criteria.
- Ensure that waste containers are properly labeled by the waste broker before off-site shipment.

DAW for Compaction:

- This includes solid dry waste, such as paper, gloves, personnel protective equipment, cardboard, etc. Place steel bars or rods horizontally not vertically in drum.
- This cannot include: pourable liquids, powders, animal carcasses, biohazardous waste, hazardous waste, cylinders, large non-compactable items (rocks), etc.
- Place this waste in 55-gallon or 30-gallon steel or ploy drums that is lined with 4-6 mil poly drum liner.
- When drum is full, twist and fold over top of bag and j-lock with duct tape. Mark container as compactable.
- Nuclides and activity shall not exceed limits for Class A waste.

DAW Non-compactable:

- This includes solid dry waste that is non-compactable, such as rocks, contaminated soil, large solid items, etc.
• This cannot include: pourable liquids, powders, animal carcasses, biohazardous waste, hazardous waste, large non-compactable items (rocks), etc.
• Place this waste in 55-gallon or 30-gallon steel or poly drums that is lined with 4-6 mil poly drum liner.
• When drum is full, twist and fold over top of bag and j-lock with duct tape. Mark container as non-compactable.
• Nuclides and activity shall not exceed limits for Class A waste.

DAW for Incineration:
• This includes solid dry waste that is combustible, such as paper, gloves, plastic, etc
• This cannot include: non-combustible items (metal, glass), pourable liquids, powders, animal carcasses, biohazardous waste, hazardous waste, large non-compactable items (rocks), etc.
• Place this waste in fiberboard or poly drums that are lined with 4-6 mil poly drum liner.
• When drum is full, twist and fold over top of bag and j-lock with duct tape. Mark container for incineration.
• Nuclides and activity shall not exceed limits for Class A waste.

Biohazardous Waste:
• Biohazardous waste that is radioactive must be made non-infectious by approved methods before being packaged with radioactive waste. Refer to the Biosafety Manual for the approved methods.
• Double bag biohazardous waste with two 4 mil clear poly bags. When bag is full, twist and fold over top of bag and j-lock with duct tape.
• For biohazardous waste that will be incinerated, place the bagged items in to fiberboard or ploy drums.

Liquid Scintillation Vials (LSV):
• LSV should be placed in steel or poly drums that are lined with 4-6 mil poly bags. No other waste items are permitted. Note: steel drums are preferred for LSV waste.
• Before adding the poly liner to the drums, add sufficient absorbent to the bottom of drum.
• When bag is full, twist and fold over top of bag and j-lock with duct tape.

Bulk Liquids:
• Liquids shall be placed in non-leaking containers that are compatible with the waste liquid.
• The primary containers shall be placed in over pack drums. Sufficient absorbent shall be added to the over pack drum such that it can absorb the total volume in the primary waste containers.
• Incompatible liquids shall be placed in separate over pack drums.

3.5 Based on space and cost considerations, periodically arrange for vendor pickup and disposal of waste. As waste is shipped for disposal, update the Radioactive Material Inventory Database.
FORM 8.1
Radioactive Waste Storage Log

<table>
<thead>
<tr>
<th>Waste number</th>
<th>Type: DAW, Liquid, LSC</th>
<th>Isotope</th>
<th>Activity (uCi)</th>
<th>Authorized User</th>
<th>Date received</th>
<th>Date disposed</th>
<th>Bkg. dose rate urem/hr</th>
<th>Waste container dose rate urem/hr</th>
<th>Survey meter used</th>
<th>Person who disposed of waste</th>
</tr>
</thead>
</table>

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**FORM 8.2**

Radioactive Waste Container Inventory

WASTE TYPE: [ ] LIQUID [ ] DAW [ ] LSC VIALS [ ] MIXED/OTHER

LOCATION: _______________________

AUTHORIZED USER: ___________________________

<table>
<thead>
<tr>
<th>Date Added</th>
<th>Isotope</th>
<th>Activity (uCi)</th>
<th>Chemical Form</th>
<th>Initials</th>
</tr>
</thead>
<tbody>
<tr>
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</table>
FIGURE 1
Radioactive Waste Tag
The control of radioiodine can present numerous problems due to its volatility and low permissible concentrations in air. The following worker actions are required when radioiodines are utilized in the research lab.

- Radioiodine work must be reviewed and approved by the RSO and Radiation Safety Committee (RSC) prior to procurement of radioiodine.
- Always refer to the Radioactive Material User's Authorization for specific directions for the work you are performing.
- Ensure that the workers assigned to the project comply with all dosimetry, monitoring, detection, and special precautions noted and are properly trained in working with radioactive iodine.
- When working with volatile forms of radioiodine, the work must be conducted in a properly functioning lab hood that has been authorized for use with radioactive materials. Use of a fume hood is also strongly recommended even if the radioiodine is in a non-volatile form.
- Radioiodines may volatilize in an acidic solution. Take special precautions when working with volatile isotopes, e.g., vapor trapping devices, activated carbon filtration, etc.
- Cap these containers tightly when they are not in use. Do not leave vials containing radioiodine open any longer than is necessary.
- Always open vials and containers of radioiodine well within a fume hood.
- Separate and double bag all radioiodine-contaminated wastes generated and store in fume hood or adequately ventilated location.
- The venting of vials through a charcoal trap is strongly recommended before opening of the vial. A simple trap can be constructed by placing charcoal in a hypodermic syringe sandwiched between two wads of glass wool. The syringe is then fitted with an 18 to 20 gauge needle, which is used to penetrate the septum of the vial.
- All volatile, gaseous, or aerosolized radioactive material shall only be used in an approved lab hood with a Caution Airborne Radioactivity hood label, unless otherwise specified in writing by the Radiation Safety Officer. In particular, radioactive iodination must be performed only in these specially designed fume hoods. The Radiation Safety Officer (through a protocol) must approve all such use.
- Radioiodine contamination should be monitored with a thin (low background) sodium iodide detector, liquid scintillation counter, or other sufficiently sensitive method.
- Both radiation dose and contamination surveys are required prior to handling or initiating any operations using radioiodines and are required at the completion of the lab operations. Protocol 11 “Radiation and Contamination Surveys” provides the details of the surveys required and the documentation to be provided to the RSO.
- It is strongly recommended that “dry runs” be conducted prior to any actual work involving radioiodine. This practice allows the worker to become familiar with the procedures to be used, while eliminating the risk of unnecessary exposure to radioiodine.
- Any worker involved with an iodination procedure must wear a lab coat, safety glasses, dosimetry, and impermeable gloves. Latex gloves should not be used. Double gloving may be prudent.
• Workers should never handle stock vials containing millicurie quantities of radioiodines directly. In these cases, tongs should be used when removing a vial from a lead pig and remote-handling devices should be used when possible.
• All personnel working with significant radioiodine quantities must comply with Protocol 5, “External/Internal Dosimetry Worksheet” requirements.
• Extremity dosimeters may be required by the RSO.
• If an internal intake of iodine is suspected, workers must contact the Radiation Safety Office immediately for possible bioassay monitoring and emergency treatment.
• Use sealed containers and appropriate secondary containment to carry radioactive material between rooms. Notify Radiation Safety Office before attempting to take radioactive material off site.
Operational Guidelines

The radiation source for this device is a 10 mCi Cesium-137 capsule, which is securely housed inside of a 150 mm diameter lead shielded cylinder. The Principal Investigator shall ensure that all applicable radiation safety requirements are implemented for this device. Only authorized and trained operators shall use this device. All operators of this device shall be trained in radiation safety, safe operating procedures, and emergency actions. As necessary, the Principal Investigator shall develop and implement safe operating procedures for this device.

If required by the Radiation Safety Officer, all approved operators must wear whole body dosimeters during operation or use an area dosimeter(s). All areas where the device is set up for use or stored shall be properly posted and labeled. Refer to Protocol 6.

When not in use, the device shall be stored in “stand down” mode, with the safety plug in place. This device must be secured so that general access by unauthorized individuals is prevented. When the device is scheduled to be used in the field, it will be transferred to the field in accordance with applicable DOT shipping regulations.

The operational “window” for the device has two principle configurations: 1) during storage and transport, a cylindrical lead safety plug is located in, and secured over, the “window” by means of two retaining screws; and 2) during operational use, the safety plug is rotated away from the “window” and is replaced by a lead collimating plug.

Emergency Actions

In the unlikely event that the Cesium capsule should become dislodged or dislocated from the operational housing, the following steps shall be immediately initiated:

(1) If the device is located in a WHOI Shore-Side Laboratory:

- All operations shall be immediately suspended by the operator and all personnel shall be evacuated from the vicinity of the device.
- The RSO shall be immediately notified (x3788, x2242, x3347).
- The area shall be secured from access until the RSO has arrived on the scene.
- The RSO shall survey the area and verify the location of the source capsule.
- The RSO shall recover the source capsule and place it in a shielded storage container. A remote handling device may be needed.
- After the storage container has been sealed, the RSO shall perform a confirmation survey to verify that radiation levels have been reduced to acceptable levels.
- The RSO shall perform a leak test to verify source integrity.

(2) If the device is located in the field:

- All operations shall be immediately suspended by the operator, and all personnel shall be evacuated from the vicinity of the device. (Keep back at least 10 feet.)
- The area shall be secured from access by the device operator.
- The operator shall survey the area with the ND200ID meter or equivalent and verify the location of the source capsule.
- The operator shall recover the source capsule and place it in a shielded storage container.
• After the storage container has been sealed, the operator shall perform a confirmation survey to verify that radiation levels have been reduced acceptable levels.
• Once recovery and safe storage of the source has been verified, the operator shall notify the WHOI Radiation Safety Officer.

(3) In the event of a fire on a research vessel:

• Evacuate area and immediately report the fire to marine crew member.

  Note: Due to the ceramic source matrix and steel containment, dispersal of radioactive contamination from this source is unlikely during a fire.

• Fire should be extinguished using normal fire fighting procedures.

• Prevent access to the Cs-137 core logger. Do not move or handle the Cs-137 source or its housing. Maintain security of the source.

• After the fire is extinguished and it is safe to enter the space, a qualified person (e.g., Chief Mate, SSSG, or authorized user) should perform radiation and contamination survey measurements with the ND 200ID Ratemeter or equivalent survey meter. Visually inspect the Cs-137 source container housing, without touching it. Note: If elevated radiation or contamination readings are detected (>3x ambient background levels) and/or the source container housing is visibly damaged, stop the survey, prevent access to the Cs-137 core logger, and contact the Radiation Safety Officer for instructions (508.289.3788 or 508.962.2660).

• Immediately report the incident and the above measurement and inspection results to Radiation Safety Officer.

• The RSO or designee will verify the Cs-137 source containment and shielding integrity. If the integrity was compromised by the fire, the Cs-137 source will be removed from service and secured. The RSO will coordinate with Marine Operations on recovery actions and regulatory reporting.
1.0 PURPOSE:
This protocol provides instructions for conducting radiation dose rate and radioactive contamination monitoring and surveys.

2.0 Personal Contamination Surveys
Personal contamination monitoring should be performed after using dispersible radioactive materials. Select the appropriate survey meter to evaluate the contamination. Ensure that you know the meter’s counting efficiency for the isotope to be evaluated. Record the type of meter being used, its serial number, and counting efficiency. Refer to Protocol 7, “Radiation Detection Instruments” for instrument operating instructions.

The Institution has established an administrative limit for skin contamination of no detectable counts above background levels. Survey slowly (e.g. 1-2” per second), starting at the head/face area proceeding downward, keeping the detector probe as close to the surface as possible without contaminating the probe, and record any observed levels above background.

Provide adequate waste containers to control the contaminated materials. Provide gloves, smears, and nasal swabs to assist the evaluation process. Use Form 11.1 to document the survey. Record the worker’s name, work location where the contamination event occurred, the time and date of the event, and a description of the contaminating event.

<table>
<thead>
<tr>
<th>Types of surface</th>
<th>Alpha emitters</th>
<th>Beta or X-ray emitters</th>
<th>Low-risk Beta or X-ray emitters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protective clothing worn only in restricted areas</td>
<td>220</td>
<td>2,200</td>
<td>22,000</td>
</tr>
<tr>
<td>Unrestricted areas</td>
<td>22</td>
<td>220</td>
<td>2,200</td>
</tr>
<tr>
<td>Restricted Areas</td>
<td>220</td>
<td>2,200</td>
<td>22,000</td>
</tr>
</tbody>
</table>

1 Averaging is acceptable over non-living areas of up to 300 cm² or, for floors, walls, and ceiling, 100 cm². Averaging is also acceptable over 100 cm² for skin or, for the hands, over the whole area of the hand, nominally 300 cm².
2 Low-risk radioisotopes include C¹⁴, H³, S³⁵, Tc⁹⁹m, and others whose beta energies are less than 0.2 MeV maximum, whose gamma or X-ray emission is less than 0.1 R/hr at 1 meter per curie, and whose permissible concentration in air is greater than 10⁻⁶ μCi/ml.

If the contamination is on the clothing, note this condition on Form 11.1 and implement the following:
• Record the contaminated clothing locations, as necessary.
• Provide the worker with replacement clothing (e.g., disposable coveralls), as necessary.
• Remove all personnel clothing from the contamination site.
• Check each piece individually and separate contaminated and uncontaminated articles by slowly moving the meter over the contaminated surface at a distance of approximately ½ inch from the surface.
• If the worker’s clothes are contaminated: 1) record the maximum net count rate level on the clothing, 2) check the worker’s skin beneath the contaminated clothes and record the result, and 3) attempt to decontaminate any articles in accordance with Protocol 12.
• Dispose of any clothing that cannot be decontaminated to the levels identified in Table 11.1 or store the contaminated clothing for decay of the short-lived isotopes.
• If no skin contamination is detected, the dose evaluation section is recorded as “NA”.
• Ask the worker to identify the reason(s) for the contamination event.
• Document the probable cause of the event using the categories noted on Form 11.1.
• Document and share any actions that should be implemented to prevent future events from occurring.

If the contamination is on the skin, note this condition on Form 11.1 and implement the following actions:
• Check all suspected contaminated skin areas with the survey meter. Record the corrected count rate for the maximum skin contamination level that was first measured prior to each decontamination attempt on Form 11.1.
• Use the continuation sheet of Form 11.1 to document all other noted contaminated skin sites.
• If facial contamination is found, obtain nasal smears. Frisk the smears and place them in separate envelopes for later analysis. If nasal smears indicate positive results above background levels, direct the individual to blow their nose. Check the tissue for contamination, and record the result.
• If internal contamination is suspected, check for whole body count or bioassay requirements in accordance with Section 7, “Radiation Dosimetry”.
• Initiate decontamination actions in accordance with Protocol 12.
• Survey the individual after each decontamination attempt, recording post-decontamination corrected count rate results and time on Form 11.1.
• Use the dose conversion factor for the pancake probe listed on Form 11.1 to estimate the SDE contribution from each measured contamination result and the estimated contamination period. This action should be completed by the RSO. This action is not necessary for tritium contamination.
• Ask the worker to identify the reason(s) for the contamination event
• Document the probable cause of the event using the categories noted on Form 11.1.
• Document and share any actions that should be implemented to prevent future events from occurring.

Provide copies of any skin contamination reports to the Radiation Safety Committee for review.

3.0 Facility and Equipment Contamination Survey

The User’s Authorization records should be reviewed to ascertain the types and amounts of radioactive materials that might be used in the area(s) to be surveyed.

A general diagram of the work area(s) should be created on Form 11.2, or equivalent. Depending on the isotope in use, select a survey meter that is sufficiently sensitive to detect the applicable contamination limits. Refer to Table 11.1 and Table 11.2 for requirements.

Record the meter type, serial number and the counting efficiency of the meter for the isotopic contamination being evaluated on Form 11.2.

A slow deliberate direct frisk survey of the general work area using an appropriate survey meter will identify the contaminated areas requiring a more detailed survey using contamination smears. Direct frisk results should be noted on Form 11.2. Direct frisk results are useful in defining total (fixed plus removable) contamination sites.

A generalized sequence of 'smear survey' locations should be annotated on the diagram.
A sufficient supply of smear media (i.e., filter paper, absorbent smears, etc.) should be obtained to support the level of survey to be conducted.

Disposable gloves should be worn when conducting the survey.

Tritium contamination surveys should be conducted using smears which are counted using a Liquid Scintillation Counter (LSC).

Using a smear, wipe a surface area of approximately 100 cm².

**NOTE:** Care must be taken when using a wet smear. The liquid used, whether it is water or an organic solvent, may assist the process by dissolving and picking up dry contamination. However, a wet smear may also attenuate low-energy beta particles from tritium and carbon-14 and alpha emitters. Wet smears should be allowed to dry prior to analysis, unless analyzed by liquid scintillation.

Number each smear location and record the contact survey reading on Form 11.2. Make sure that the survey result is converted to dpm/100 cm² by dividing the measured net cpm by the meter counting efficiency for the isotope involved. Dispose of any contaminated smears as radioactive waste once the survey results have been recorded. Compare the final survey results against Table 11.1 for removable contamination levels and Table 11.2 for release limits. Contamination found in unrestricted areas should be immediately decontaminated to background levels and must never exceed level given in Table 11.2.

<table>
<thead>
<tr>
<th>Radioisotope</th>
<th>Average (dpm/100 cm²)</th>
<th>Maximum (dpm/100 cm²)</th>
<th>Removable (dpm/100 cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-nat, U-235, U-238, and associated decay products</td>
<td>5000</td>
<td>15,000</td>
<td>1000</td>
</tr>
<tr>
<td>Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129</td>
<td>100</td>
<td>300</td>
<td>20</td>
</tr>
<tr>
<td>Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133</td>
<td>1000</td>
<td>3000</td>
<td>200</td>
</tr>
<tr>
<td>Beta–gamma emitters except Sr-90 and other noted above</td>
<td>5000</td>
<td>15,000</td>
<td>1000</td>
</tr>
</tbody>
</table>

1. As used in Table 2, dpm (disintegration per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.
2. Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such object.
3. The maximum fixed contamination level applies to an area of not more than 100 cm².
4. The amount of removable radioactive material per 100 cm² of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionately and the entire surface should be wiped.
5. Where surface contamination by both alpha and beta-gamma emitting nuclides exists, the limits established for alpha and beta-gamma emitting nuclides should apply independently.
4.0 Contamination Survey Frequency for Work Areas

Table 11.3 should be used to establish the proper contamination survey frequency for work areas. NOTE: personal contamination surveys should be performed after each use of dispersible radioactive materials (see above instructions).

- Multiply the number of millicuries of isotope that will be used by the appropriate Operational Condition Multiplier (OCM) for the procedure involved and compare it to the table’s activity range (A) to determine an appropriate surveillance frequency.
- Example calculation: A protein is to be labeled with 1.5 mCi of I-125. An OCM factor of 10 would be multiplied by 1.5 mCi since the operations would be classified as a complex wet operation with volatile radioactive compounds. The calculated activity range equals 15 mCi with the activity range > 1 mCi; therefore, the laboratory should be surveyed immediately after the labeling procedure.
- NOTE: If isotopes are in storage and not being used, the minimum survey frequency is every 6 months and only the storage location/area needs to be surveyed.

<table>
<thead>
<tr>
<th>Survey Category</th>
<th>Activity Range (A)</th>
<th>Survey Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>&lt;0.01 mCi</td>
<td>Once a month</td>
</tr>
<tr>
<td>Medium</td>
<td>0.01 mCi to 1 mCi</td>
<td>Every 2 weeks</td>
</tr>
<tr>
<td>High</td>
<td>&gt;1 mCi</td>
<td>After each operation</td>
</tr>
</tbody>
</table>

5.0 Survey Process

The direct radiation or area survey is conducted using a calibrated survey meter that is appropriate for detecting the type of radiation emitted from the radioactive material(s) used in the laboratory. At a minimum, swipe surveys should be conducted at all direct survey locations.

The results of laboratory surveys must be recorded on Form 11.2. A diagram of the laboratory should be made showing benches, desks, sinks, and hoods.

Background readings should be taken in an area outside of the radioactive material work area(s) being surveyed. These readings will be recorded as the background for that particular survey.

General area dose rates should be measured in each space that contains significant gamma-emitters or x-ray sources. Record the results using the convention directed by Table 11.4. General area readings should include: background dose rate, lab benches, fume hoods, and radioactive material storage locations. A general area radiation survey is taken with the survey meter between head and waist level and approximately 30 cm (12 inches) from any lab bench, hood area, or storage locations. Any area indicating an exposure level
of greater than 1 mrem/hr will be placed temporarily off limits until the source of the exposure has been identified, evaluated, and properly controlled.

<table>
<thead>
<tr>
<th>Table 11.4, Standard Survey Conventions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dose Rates</strong></td>
</tr>
<tr>
<td><strong>Smears</strong></td>
</tr>
<tr>
<td><strong>Contact</strong></td>
</tr>
<tr>
<td><strong>RAM Posting</strong></td>
</tr>
<tr>
<td><strong>Radiation Area Posting</strong></td>
</tr>
<tr>
<td><strong>Contaminated Area Boundaries</strong></td>
</tr>
</tbody>
</table>
Form 11.1 Personnel Contamination Report

<table>
<thead>
<tr>
<th>Classification:</th>
<th>Skin</th>
<th>Personal Clothing</th>
</tr>
</thead>
</table>

Name: ____________________________ Location of the Contamination Event: ____________________________

Time/Date: ____________________________ Description of Contamination Event: ____________________________

Clothing/Skin Location(s): ____________________________

Classification: Skin

Skin

Rad Survey Inst: ____________________________ Serial #: ____________________________ Calibration Due Date: ____________________________

Survey Inst Counting Efficiency for the Isotope: ____________________________ dpm/cpm

<table>
<thead>
<tr>
<th>Maximum Measured Value (net cpm)</th>
<th>X</th>
<th>Dose Conversion Factor(s)</th>
<th>X</th>
<th>Total Time contaminated at the listed level (hrs)</th>
<th>mrems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial survey</td>
<td></td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st decon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd decon (if necessary) **</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd decon (if necessary) **</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Maximum Measured Value (net cpm) X 0.001 X

Total mrems Shallow Dose

**ATTACH additional sheets as necessary.**

Action Levels for “Total” above 500 mrems Shallow Dose.

• RESTRICT individual from RMA work area until full event investigation by the RSO is completed.

Contaminated Worker Comment on Cause/Event:

Signature:

Probable Cause (to be completed by worker)

☐ Spill or Accident ☐ Improper PC use ☐ Protective Clothing Removal ☐ Failure to follow authorization instructions

☐ Poor work practices

Comments:

WBC or bioassay may be required for any of the following:

• radioactive material detected on a nasal smear or
• facial contamination

WBC or bioassay required? ☐ Y ☐ N

Immediate Actions: ____________________________

Radiation Safety Committee Review Follow-Up Action/Comments:

RSO Signature:
*NOTE Indicate on drawing each location that is contaminated (skin or clothing) with its associated contamination level
Form 11.2, Radiological Survey

<table>
<thead>
<tr>
<th>#</th>
<th>Instrument</th>
<th>Serial No.</th>
<th>Cal Due Date</th>
<th>Background</th>
<th>Efficiency α / β</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Insert swipe/survey map of lab

**Surface Contamination Measurements** (results in dpm/100cm² unless otherwise noted) (ND = Not Distinguishable from Background)

<table>
<thead>
<tr>
<th>#</th>
<th>cpm/100cm² α / β</th>
<th>dpm/100cm² α / β</th>
<th>Inst #</th>
<th>#</th>
<th>cpm/100cm² α / β</th>
<th>dpm/100cm² α / β</th>
<th>Inst #</th>
<th>#</th>
<th>cpm/100cm² α / β</th>
<th>dpm/100cm² α / β</th>
<th>Inst #</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1.0 Personnel Decontamination Limits

Decontamination should be initiated for any measurable skin or personal clothing contamination levels above background. For contaminated wounds and body orifices, medical personnel should be consulted.

1.1 General Instructions for Personnel Decontamination

The immediate actions in case of skin contamination can be remembered as “CCC”.

- **CONTACT** the RSO to inform him/her about the skin contamination.
- **COUNT** the amount of contamination on the skin with an appropriate detector and write this number down. This will later be used to help evaluate skin dose and/or possible intake.
- **CLEAN** the contaminated area by going to the nearest sink and washing with mild soap and warm (98°F) water. While cleaning, a general rule is to not take any actions that are painful or uncomfortable. In most cases, the skin acts as a barrier to keep contamination on the outside of the body and it is important not to breach this barrier.

Remove clothing, jewelry, etc. from contaminated area and decontaminate as necessary.

In general, decontamination is performed with the simplest procedure that is effective (e.g., soap and water) and then using more complicated procedures as necessary. Qualified medical personnel should be consulted for decontamination of body orifices and significant (open) wounds.

Inspect wounds and determine if decontamination can wait until medical treatment is completed. Survey the affected area initially and after each decontamination attempt to determine effectiveness. Record the contamination levels on Form 11.1. (Use additional sheets as necessary.)

1.2 Decontamination of wounds

Decontamination of a wound should only be performed by qualified medical personnel. Review Table 12.1 recommendations prior to commencing decontamination actions.
Table 12.1. Decontamination of Wounds by Qualified Medical Personnel

<table>
<thead>
<tr>
<th>Type Of Wound</th>
<th>Actions</th>
<th>Comment</th>
</tr>
</thead>
</table>
| Broken Skin            | 1. Copious, but gentle, irrigation with water, aqueous saline or a 3% aqueous solution of hydrogen peroxide will remove a major portion of the contaminants from the wound area.  
2. Irrigation is continued until a survey of the area being decontaminated indicates normal or background levels | If the wound is contaminated, it’s possible that systemic absorption from the site will have occurred. Therefore, an internal contamination assessment should be initiated by RSO. |
| Embedded Fragment      | 1. If visible, these fragments may be removed by means of forceps or a pulsating water jet.  
2. Place all removed fragments in separate containers, label appropriately and retain for analysis. |                                                                                               |
| Puncture wounds        | Scrubbing then inducing bleeding is the best treatment for a puncture wound, especially the finger. | The location of the wound will determine the best course of action.                          |
| Chemical or Thermal Burns | The radioisotope contaminant usually will be contained in the burn tissue that sloughs off.  
Change dressing frequently and be certain to dispose of the dressings properly. | Treat these as you would treat a non-contaminated burn.                                        |

Use sterile drapes to isolate the contaminated wound site. Decontaminate skin adjacent to the wound. Depending on the surface and depth of the wound, irrigate with sterile saline, dab with gauze pads and sterile saline, or use applicators to cleanse the wound.

Collect all materials used and place in labeled containers, e.g., Biohazard, Radioactive, etc.

Monitor wound, record results on the personnel contamination survey form in Protocol 11, “Radiation and Contamination Surveys”.

1.3 Decontamination of Body Orifices:

Decontamination or sampling of an orifice should be performed by qualified medical personnel. Take sample of activity in nose, ear canals and other orifices prior to decontamination. Decontaminate areas surrounding the orifice. Gently clean the orifice using wet swabs. Check the swab with a contamination survey meter.

If nose swab indicates significant radioactivity in the nasal cavity, irrigate with sterile saline and syringe. Encourage vigorous blowing of nose and save tissues for contamination survey.

Collect all materials used, and label container as to location where sample was taken.

1.4 Decontamination of Unbroken Skin:

Review Table 2 for the types of decontamination techniques that can be used for unbroken skin. Try the most gentle and effective methods first (mild soap and water). Only attempt more aggressive decontamination methods if necessary.
Table 12.2, Decontamination Of Unbroken Skin (Other Than Face/Head)

<table>
<thead>
<tr>
<th>TECHNIQUE</th>
<th>INSTRUCTIONS</th>
<th>CAUTIONS</th>
</tr>
</thead>
</table>
| Wash                           | 1. Wash area with mild soap and water or dilute hydrogen peroxide.  
  2. Blot dry.                   | Ensure water temperature is not higher than body temperature. |
| Wash and brush                 | 3. Wash area with mild soap and water.                 | Ensure water temperature is not higher than body temperature. |
|                                | 4. Use a soft brush. Blot dry.                         |                                               |
| Wash with abrasive soap        | 5. Wash area with a mildly abrasive soap (LAVA).       | Take care not to abrade the skin.             |
|                                | 6. Use a soft brush.                                   |                                               |
|                                | 7. Blot dry.                                           |                                               |
| Scrub with a paste             | 8. Make a paste of detergent, such as Tide and water.  | Take care not to abrade the skin.             |
|                                | 9. Use a mild scrubbing action.                        |                                               |
|                                | 10. Rinse with water.                                 |                                               |
| Induce sweating                | 11. Enclose the contaminated area with tape and plastic or rubber over a cotton glove or liner.  
  12. Place near a heat source for 10-15 minutes to induce sweating.  
  13. Wash with warm water.     | Ensure water is not cold, as this may lodge the contamination more deeply. |
| Wash with a chemical rinse      | 14. Mix equal volumes of saturated solution of potassium permanganate (6.4g KMNO4 per 100 ml H2O) and 0.2N sulfuric acid (H2SO4).  
  15. Pour mixture over wet skin.  
  16. RUB skin with a hand brush for not more than two minutes.  
  17. RINSE with water.         | Contact longer than two minutes will remove skin. |
| RSO AND MEDICAL APPROVALS REQUIRED | 18. DRY the skin.                                    |                                               |
|                                | 19. APPLY a freshly prepared solution of sodium acid sulfite (5g NaHSO3 per 100 ml H2O) to remove permanganate stain.  
  20. APPLY lanolin or hand cream to skin surface. |                                               |

1.5 Decontamination of Other Body Parts:

Review Table 12.3 for details.

Table 12.3, Miscellaneous Decontamination Techniques

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>INSTRUCTIONS</th>
<th>CAUTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAIR</td>
<td>1. Wash using mild soap and water.</td>
<td>Clip or Shave only under medical supervision.</td>
</tr>
<tr>
<td></td>
<td>2. Clip or Shave if washing is not effective.</td>
<td></td>
</tr>
<tr>
<td>MOUTH</td>
<td>Flush or Rinse the mouth with potable water.</td>
<td>Caution the individual not to swallow or inhale the water.</td>
</tr>
<tr>
<td>FINGERNAILS</td>
<td>1. Wash using mild soap and water.</td>
<td>Save nail clippings</td>
</tr>
<tr>
<td></td>
<td>2. Use a soft brush to scrub.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Clip if washing is not effective.</td>
<td></td>
</tr>
</tbody>
</table>

2.0 DECONTAMINATION TECHNIQUES FOR FACILITY AND EQUIPMENT:

Use the safest method that is effective and minimizes the generation of hazardous waste.
1.0 OBJECTIVE:
This protocol provides instructions for temporary and permanent deactivation of equipment or a space for unrestricted use. All shore-side and field-use spaces, vans, and equipment are covered by the protocol.

2.0 SCOPE:
This protocol is only intended for releasing equipment and spaces for unrestricted use by WHOI or as designated by the RSO or designee. It does not include the formal decommissioning requirements for termination of the Institution license, which are found in 105 CMR 120.

Prior to the release for unrestricted use, a thorough surface contamination survey must be conducted by the RSO or designee for both total (fixed plus removable) and removable contamination. Residual contamination levels must be below applicable clearance limits and ALARA. The radiation survey instrument’s minimum detectable activity (sensitivity) should be well below the limits in Tables 13.1 and 13.2. If contamination is detected, the equipment and facility must be decontaminated to acceptable levels prior to its unconditional release. Refer to Protocol 11, “Radiation and Contamination Surveys”.

Table 13.1, Recommended Action Levels for Removable Surface Contamination
(From Regulatory Guide 8.23)

<table>
<thead>
<tr>
<th>Area</th>
<th>Alpha emitters dpm/100cm²</th>
<th>Beta or X-ray emitters dpm/100cm²</th>
<th>Low–risk Beta or X-ray emitters dpm/100cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unrestricted areas</td>
<td>22</td>
<td>220</td>
<td>2,200</td>
</tr>
<tr>
<td>Restricted Areas</td>
<td>220</td>
<td>2,200</td>
<td>22,000</td>
</tr>
</tbody>
</table>

1 Averaging is acceptable over non-living areas of up to 300 cm² or, for floors, walls, and ceiling, 100 cm². Averaging is also acceptable over 100 cm² for skin or, for the hands, over the whole area of the hand, nominally 300 cm².

2 Low–risk radioisotopes include C¹⁴, H³, S³⁵, Tc99m, and others whose beta energies are less than 0.2 MeV maximum, whose gamma or X-ray emission is less than 0.1 R/hr at 1 meter per curie, and whose permissible concentration in air is greater than 10⁻⁶ μCi/ml.
Table 13.2, Acceptable Surface Contamination Levels For Unrestricted Release of Equipment
(From Regulatory Guide 8.23)

<table>
<thead>
<tr>
<th>Radioisotope5</th>
<th>Average1,2 (dpm/100 cm²)</th>
<th>Maximum1,3 (dpm/100 cm²)</th>
<th>Removable1,4 (dpm/100 cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-nat, U-235, U-238, and associated decay products</td>
<td>5000</td>
<td>15,000</td>
<td>100</td>
</tr>
<tr>
<td>Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129</td>
<td>100</td>
<td>300</td>
<td>20</td>
</tr>
<tr>
<td>Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133</td>
<td>1000</td>
<td>3000</td>
<td>200</td>
</tr>
<tr>
<td>Beta–gamma emitters except Sr-90 and others noted above</td>
<td>5000</td>
<td>15,000</td>
<td>1000</td>
</tr>
</tbody>
</table>

1 As used in this table, dpm (disintegration per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.
2 Measurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such object.
3 The maximum fixed contamination level applies to an area of not more than 100 cm².
4 The amount of removable radioactive material per 100 cm² of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionately and the entire surface should be wiped.
5 Where surface contamination by both alpha and beta-gamma emitting nuclides exists, the limits established for alpha and beta-gamma emitting nuclides should apply independently.

3.0 TEMPORARY DEACTIVATION AND REACTIVATION

3.1 Temporary Deactivation may be requested by submitting the Radioactive Material Use Amendment Authorization Request found at http://ehs.whoi.edu/. The following information is required:

- The building and room number and a description of the laboratory or area to be deactivated.
- A statement describing the disposition of all radioactive materials used or stored in the affected laboratory (i.e., disposed of, transferred to another Authorized User, or stored).

3.2 Upon receipt of the Amendment Request, the RSO shall perform removable and direct frisk contamination surveys. The selected radiation detection equipment shall be used only if the detection limits are below the limits in Tables 13.1 and 13.2. If contamination is found, the contaminated areas and/or equipment must be decontaminated and re-surveyed until levels are below the allowable limits and ALARA.

3.3 Upon deactivation, all signs and labels, indicating that the laboratory was an Authorized radioactive material use area must be removed. Radioactive material may still be stored in a deactivated lab or work area; in which this case, radioactive material area postings and radioactive material storage container labeling must remain in place and the radioactive material must be secured. Alternatively, the radioactive material can be stored in a hot lab. At this point, the laboratory or area is released for unrestricted use. Further use of radioactive material in this laboratory or area is prohibited. The duration of deactivation shall be until the Authorized User wishes to once again use radioactive material.

3.4 Reactivation may be requested by notifying the RSO. The notification must indicate the location to be reactivated and that there will be no changes in the use of radioactive material from the previous authorization. If changes are required, an Authorization Amendment must be submitted.
4.0 PERMANENT DEACTIVATION

4.1 Permanent Deactivation may be requested by submitting the Radioactive Material Use Authorization Amendment Request found at http://ehs.whoi.edu/. The following information is required:
- The building and room number and a description of the laboratory or area to be deactivated.
- A statement that all radioactive materials used or stored in the affected laboratory(s) have been removed, and the method of their disposition (i.e., disposed of as LLRW, transferred to another Authorized User, stored).

4.2 Upon receipt of the Amendment Request, the RSO shall perform removable and direct frisk contamination surveys. If contamination is found, the contaminated areas and/or equipment must be decontaminated and re-surveyed until levels are below the applicable limits and ALARA.

4.3 The RSO must determine if this deactivation is considered a decommissioning which could require different decontamination criteria and regulatory reviews. Requirements for decommissioning are found in 105 CMR 120.

4.4 Upon deactivation, all signs and labels, indicating that the laboratory(s) was an Authorized radioactive material use area, must be removed. At this point, the laboratory or area is released for unrestricted use. Further use of radioactive material in this laboratory or area is prohibited.
1.0 OBJECTIVE & SCOPE:
This protocol defines swipe procedures and contamination levels for work in isotope vans and other authorized areas onboard WHOI research vessels. Please note that the contamination levels that are protective of human health may be unacceptable for natural radiotracer research. Authorized users may be responsible for all costs associated with significant decontamination efforts.

UNOLS expects that research vessels and isotope vans are kept free of contamination that could impact natural radiotracer research: http://yyv.rsmas.miami.edu/groups/tritium/SWAB-comments-reports.html

2.0 ROLES AND RESPONSIBILITIES

2.1 Chief Mate

- The Chief Mate, or designee, shall ensure that this protocol is implemented by the Principal Investigator (PI) and/or Authorized Users of radioactive materials and that Forms 14.1 and 14.2 are completed and submitted prior to end of voyage.
- Report radioactive spills to the Port Office.
- Provide copies of completed Form 14.2 (contamination survey records) to the Port Office.

2.2 Port Office

- Report radioactive spills to the Radiation Safety Officer (RSO) and the SSSG Manager.
- Provide completed survey records to RSO (MS#48 or fax: 508-457-2015).

2.3 Principal Investigator and Authorized Users

The Principal Investigator and/or Authorized Users that are using licensed radioactive materials on WHOI research vessels are responsible for:

- Implementing this protocol and submitting survey forms to the Chief Mate;
- Immediately reporting all radioactive spills to the Chief Mate;
- Ensuring that all radioactive materials work areas are properly decontaminated; and
- Following all applicable requirements in the Radiation Safety Manual.

2.4 Shipboard Scientific Services Group (SSSG)

- Ensure that the isotope vans are equipped with a functional and calibrated liquid scintillation counter, scintillation fluid, and sample vials.
- Ensure that operating instructions are available with each liquid scintillation counter.
- Provide assistance to radioactive material users concerning the operation of the liquid scintillation counter and the applicable requirements of the Radiation Safety Manual, including Protocol 14 and other key requirements.
- Report radioactive spills to the Chief Mate.
3.0 SWIPE PROCEDURE:

- Swipe surveys shall be conducted before and after radioisotope work in the isotope van, in other approved locations, and in any spill locations. Swipes are collected and analyzed after a spill of radioactive material to determine if the decontamination procedure was effective.

- Ensure that you have an adequate supply of swipe counting materials, including filter papers for wipe samples (55 mm diameter, cellulose filter paper preferred), deionized water for wetting the filter paper before swiping surface, permanent ink marker, counting vials, and scintillation fluid. In general, Authorized Users are responsible for supplying these materials.

- Obtain copies of Form 14.2 (or equivalent survey form) to record information and counting results.

- Don appropriate personal protective equipment (such as disposable nitrile gloves, lab coat, safety glasses, etc) to protect yourself from any potential radiological contamination and hazardous chemicals.

- Number each filter paper swipe and vial lid to correspond with the swipe location. Using Form 14.2, mark the swipe locations on the isotope van map with a circle and the swipe number inside. Mark any other equipment that is present in the isotope van on Form 14.2 diagram box, e.g., hoods, frig, counters, door, etc.

- At a minimum, all numbered swipe locations that are listed on Form 14.2 shall be swiped. At each swipe sample location, swipe the filter paper (pre-wetted with deionized water) over approximately 100 cm² surface area (about size of dollar bill) with sufficient pressure to collect any removable contamination. Fold swipes in half, with contaminated side in and place in the corresponding counting vial to avoid cross contaminating other swipes. NOTE: As necessary, change your gloves to avoid cross-contaminating subsequent swipes.

- Add sufficient scintillation fluid to the vials containing the vials and secure the cap. Count the swipes on a calibrated and properly functioning liquid scintillation counter. All swipes and one blank must be counted for 5 minutes. Contact the SSSG for operating procedures. If there is no liquid scintillation counter onboard the research vessel, the samples shall be counted immediately upon return to WHOI or other institution and results reported to the WHOI RSO in accordance with this protocol.

- Record the counting results on Form 14.2 and attach any available instrument printouts. If available, record both gross counts per minute (cpm) and net counts per minute (dpm). Net dpm is calculated by dividing the net cpm results, (gross counts – background counts) by the efficiency of the instrument. The background counts are obtained from the blank count. All counts must be for 5 minutes. Some liquid scintillation counters may automatically perform some or all of the above calculations – check with the SSSG.

- Compare the swipe results to the contamination limits below. All areas above category B levels and all spill locations must be decontaminated by the Authorized Users before work with radioisotopes may proceed.

<table>
<thead>
<tr>
<th>Category</th>
<th>Tritium (dpm/100cm²)</th>
<th>C14 (dpm/100cm²)</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&lt; 5</td>
<td>&lt; 0.5</td>
<td>No action</td>
</tr>
<tr>
<td>B</td>
<td>5 – 100</td>
<td>0.5 - 100</td>
<td>Needs cleaning before radiotracer work</td>
</tr>
<tr>
<td>C</td>
<td>100 – 1000</td>
<td>100 – 500</td>
<td>Must be cleaned before any use</td>
</tr>
<tr>
<td>D</td>
<td>&gt; 1000</td>
<td>&gt; 500</td>
<td>May be a health hazard, notify RSO</td>
</tr>
</tbody>
</table>

Notes:

1) C-14 and S-35 have peak energies of 156 and 167 KeV, respectively; thus S-35 will be registered as C-14 with standard liquid scintillation counting methods.

2) Multiply dpm/cm² by 100 to get dpm/m² to allow comparison of above limits to SWAB criteria.
4.0 DECONTAMINATION PROCEDURES

4.1 While wearing gloves, lab coat and protective eyewear, conduct applicable decon step:

- **Tritium**: Wash and scrub with radioactive cleanup detergent such as COUNT-OFF (50 ml or 1/4 cup COUNT-OFF to 1 gallon of water), using sponges to distribute solution and reabsorb it.

- **C-14**: Wash with 1% sulfuric or 2% hydrochloric (muriatic) acid with \textbf{good ventilation} (acid will dissolve carbonates, releasing $^{14}\text{CO}_2$). Follow up with wash/scrub that is indicated for tritium.

4.2 Swipe the decontaminated surfaces and repeat above decontamination procedure as necessary.
Form 14.1

Woods Hole Oceanographic Institution

Isotope Van Record of SWIPE Tests

Voyage # ________________________________

Dates: ________________________________

The undersigned individuals accept full responsibility for the proper pre and post cruise swipe tests of the Isotope Van, the proper handling and removal of any radioactive materials and wastes from the vessel and the proper cleaning and decontamination of the Isotope Van before departing the vessel at the end of the voyage.

Please note that the contamination levels that are protective of human health may be unacceptable for natural radiotracer research. Authorized users may be responsible for all costs associated with significant decontamination efforts.

UNOLS expects that research vessels and isotope vans are kept free of contamination that could impact natural radiotracer research: http://yy.rsmas.miami.edu/groups/tritium/SWAB-comments-reports.html.

Use of Radioactive Material aboard ship is governed by the WHOI Radiation Safety Manual and the approved At-Sea Radioactive Materials Authorization.

____________________________________
Isotope User’s Signature / Date

____________________________________
Chief Scientist Signature / Date

This document with the attached results of the pre and post cruise swipe test shall be given to the Chief Mate, or designee, before departing the vessel. A copy must be provided to the WHOI Radiation Safety Officer.
**Form 14.2**

**WOODS HOLE OCEANOGRAPHIC INSTITUTION**

**Record of Swipe Tests in Isotope Vans**

R/V and Cruise No.:_______________________________________________________ Date:__________

Pl/Supervisor: ______________________________ Affiliation:___________________________________

**Instructions:** Mark swipe location with number inside circle and draw major equipment (hood, sink, frig, counter, cabinets) that are inside isotope van and van door in the diagram box below. Swipe all locations listed in table below and record counting results in table below. Swipe more locations as needed or if spills have occurred. Conduct swipes before and after radioisotope work and after spill decontamination.

<table>
<thead>
<tr>
<th>Location</th>
<th>Location</th>
<th>H3 cpm/100 cm²</th>
<th>H3 dpm/100cm²</th>
<th>C14 cpm/100cm²</th>
<th>C14 dpm/100cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLANK</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Floor at door</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Floor at counter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Floor at hood</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Countertop</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Countertop</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Countertop</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Hood inside</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Hood apron</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Hood sash handle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Phone</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>LSC counter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Frig handle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Door handle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX C

At-Sea/Field Use of Radioactive Material

1.0 AUTHORIZATION

For WHOI research personnel, prior approval by the RSO and Radiation Safety Committee is required for all work involving the use of sealed sources and/or radioactive material on board research vessels or at field locations outside of WHOI’s properties in Woods Hole, MA.

For all personnel who wish to conduct research under WHOI’s radioactive material license, prior approval by the RSO and Radiation Safety Committee is required for all work involving the use of sealed sources and/or radioactive material on board WHOI research vessels or at WHOI owned or controlled locations at Woods Hole, MA.

A “Radioactive Material Use Authorization Request” must be completed and submitted well in advance (a minimum of 60 days is requested) of the intended field use to allow adequate time for evaluation and processing. The forms and checklists are available at http://ehs.whoi.edu/. The name of the ship or the field location (the State and geographical location), and the expected dates of use must be included in the request. Requests must be submitted for each cruise or field use. It is the responsibility of the researcher requesting the authorization to inform the Chief Scientist and the WHOI RSO of the proposed use of isotopes or sources of ionizing radiation. This must include the specific isotope, activity and physical form.

Coordination and approval from local, state, federal and/or international authorities at the research location may be necessary prior to the initiation of the research involving radioisotopes. These additional approvals will require a longer lead-time. It is the responsibility of the researcher to apply for these approvals.

A summary of the research protocol(s) to be used must be submitted with the request and must include:

- A description of the laboratory techniques and procedures that will be used when working with the radioactive material. If the material is also in a hazardous form (e.g., readily dispersible, volatile, etc.), a description of the controls that will be used to ensure safe operations must be indicated. Refer to Manual Section 9.
- The quantities of radioactive material requested. The activities requested must be justified and should be the minimum amount necessary to accomplish the research being conducted.
- The planned location for work. Work at sea involving radioactive materials will be limited to the isotope van, unless an alternate work location has been requested and approved.
- Special considerations for the type(s) and quantity of waste generated by the research and the method of waste handling.
- Disposal at sea is not permitted and facilities for storage of waste onboard the research vessels are very limited.
- Explanatory figures and diagrams, if they will be helpful in the evaluation process.
- The security procedures must be identified.
- The names of all individuals who will handle radioactive material, along with a summary of their training and experience in the safe use of radioactive material must also be included.

The authorized users must provide their own consumable supplies, including protective clothing, gloves, workbench absorbent blotters, scintillation fluid, swipes, secondary containment, decontamination supplies, etc. The research vessels do not carry these supplies or emergency materials, such as absorbent spill pillows, or decontamination materials, such as "Radiac Wash" or "Scrubbing Bubbles".

2.0 CONTAMINATION CONTROL
Control of contamination aboard the research vessels and at field sites is of vital importance. Please note that the contamination levels that are protective of human health may be unacceptable for natural radiotracer research. Authorized users will be responsible for all costs associated with significant decontamination efforts. UNOLS expects that research vessels and isotope vans are kept free of contamination that could impact natural radiotracer research:

http://yyv.rsmas.miami.edu/groups/tritium/SWAB-comments-reports.html.

2.1 Contamination Surveys

- For work with dispersible radioactive materials in Isotope Vans or other approved areas onboard WHOI Research Vessels, Protocol 14 must be followed.
- It will be the responsibility of the authorized users who are using the radioactive materials to perform contamination surveys and, as necessary, decontaminate work areas.
- The SSSG should equip the isotope vans with a functional and calibrated liquid scintillation counter that can be used for obtaining immediate results. Counting supplies must be provided by the researcher.
- Any radioactive contamination detected by smear/swipe tests requires immediate decontamination. Refer to Protocol 14 and 12 for the most appropriate decontamination method.
- Any major spills or accidents involving radionuclides must be reported immediately to the Chief Scientist, Chief Mate or designee, and WHOI RSO (508.289.3788). Upon completion of the cruise or fieldwork, the Authorized User or designee must submit a detailed report of the incident to the WHOI RSO that includes the corrective measures taken. Refer to Protocol 3 for emergency procedures.

2.2 Close Down Procedures

Specially designed and equipped isotope vans are provided for use on board WHOI research vessels.

- In general, use of radioactive material on these vessels will be restricted to the isotope van.
- Upon completion of the cruise, the van must be surveyed for residual isotope contamination, and must be decontaminated (if necessary) and otherwise cleaned. This includes removal of duct tape and tie-down materials, scouring of sinks, radioactive waste, hazardous waste and cleaning of refrigerators.
- The Chief Mate or designee will inspect the van for cleanliness before the authorized user is given permission to leave the ship.
- Scientists are responsible for providing their own consumable supplies, including gloves, lab coats, absorbent paper, wipes, secondary containment devices, LSC cocktail, vials, etc.

3.0 MONITORING EXPOSURE TO IONIZING RADIATION

If required, WHOI personnel shall wear dosimeters during at-sea or field use of radioactive materials or radiation generating devices. Authorized users from other organizations that will be using radioactive materials or radiation generating devices that present an external dose hazard, are responsible for providing and maintaining their own radiation dosimeters and should coordinate with their organization’s RSO.

4.0 SEALED SOURCES & RADIATION GENERATING DEVICES

All sealed sources must successfully pass an approved leak test (<0.005 microcuries) within the previous 6 months. The results of the leak test must be provided to the WHOI RSO for review and approval, prior to the at-sea or field use. Only trained and authorized personnel shall be allowed to operate or use sealed sources or radiation generating devices, such as, core loggers, density gauges, electron capture detectors, x-ray scanners, etc. If applicable, the operating procedure must be present with the device or sealed source and readily available to all operators. The location and orientation of the sealed source or radiation generating device must be selected to minimize potential radiation exposures to operators (restricted areas) and preclude the potential exposure to individuals in unrestricted areas. For example, the primary and secondary beams of an x-ray generating device should be oriented toward restricted or controlled areas that are unoccupied. This
location and orientation should be approved by the WHOI RSO or designee. The security of the sealed source or radiation generating device must be maintained at all times by the authorized user.

5.0 WASTE DISPOSAL

Specific arrangements must be made before the cruise or fieldwork regarding the storage and ultimate disposal of radioactive and hazardous waste that is generated from WHOI Research Vessels and field locations. WHOI's NRC license specifically forbids disposal of radioactive materials into waterways.

It is the responsibility of the authorized user to arrange for the removal and disposal of all radioactive waste that was generated. Unless pre-approved by the WHOI RSO, the cost for disposal is the responsibility of the authorized user.

The volume of radioactive waste should be minimized. The combination of radioactive and hazardous waste results in the formation of mixed waste. Mixed waste requires special procedures and results in higher disposal costs and should be avoided.

Refer to Section 10 additional waste management requirements and examples of laboratory practices that minimize the generation of radioactive and mixed waste.