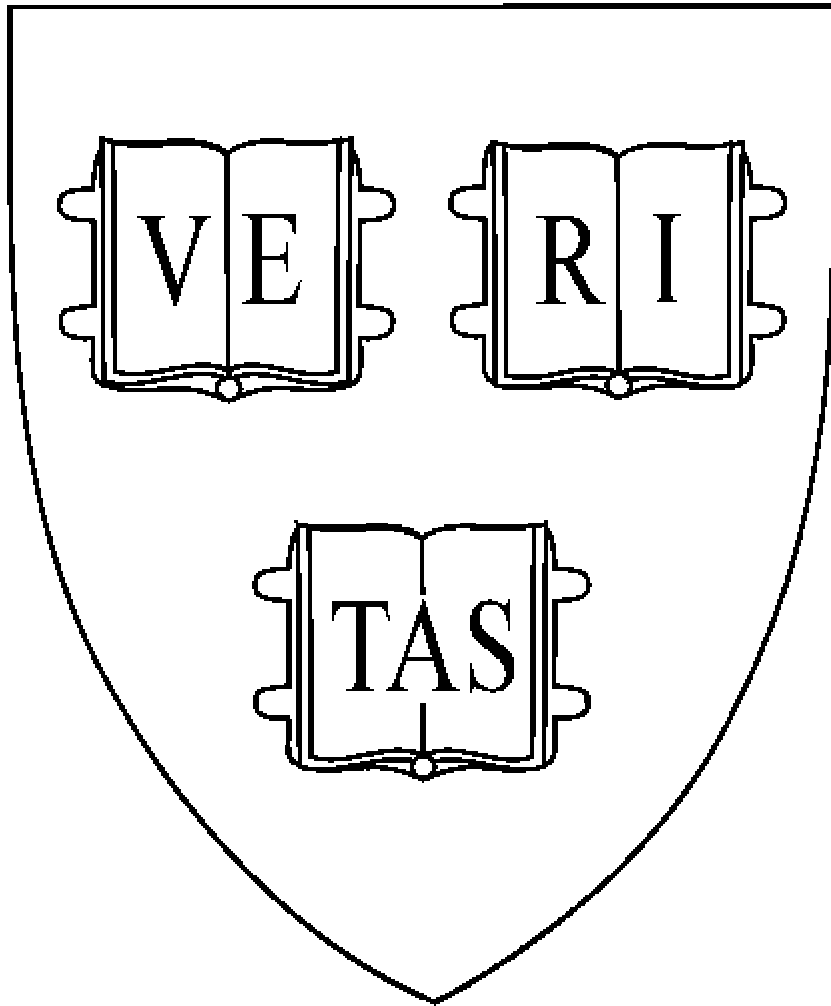


Harvard University
Radiation Safety Manual



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Forward

This revision of the Radiation Safety Manual was approved by the Radiation Safety Committee on September 17, 2002 and supersedes all other issuances or revisions. It also supersedes and includes all other policy, notices, Radiation Alerts current as of September 17, 2002. This manual states the Policies and Standards for work with radiation, radioactive materials, and radiation generating devices at Harvard University to ensure compliance with Federal State and Local governmental agencies.

This Manual provides for the protection of the University Community and the members of the general public against radiation hazards associated with the University's possession, use, transportation, storage and disposal of radioactive materials and radiation generating devices.

Radiation Protection Office Mission

The mission of the Radiation Protection Office is to implement a program committed to the safe and proper use of radioactive materials and radiation generating machines in accordance with the policies set by the Radiation Safety Committee; in compliance with governmental regulations; and in full support of the programs at participating institutions. Fulfillment of this mission relies strongly on fostering a spirit of cooperation and personnel working with radiation sources and instilling the necessary knowledge of regulations and safety procedures through formal training sessions and personal contact. The Office strives to maintain a high approval rating from participants by placing a strong emphasis on quality, productivity and cost effectiveness and by working cooperatively.

The mission is carried out through the following service model:

- Education, training and guidance for program participants.
- Evaluation and approval of valid proposals for the use of radioactive materials and radiation generating at Harvard University.
- Regular reviews of laboratory use of radioactive and radiation generating machines through surveys and permit reviews.
- Monitoring of individuals in accordance with potential radiation exposures or institutional policies.
- Environmental surveillance to control and ensure compliance with release limits.
- Management of radioactive waste, including removal, storage and disposal.
- Calibration of radiation monitoring equipment.
- Collection, management and reporting of data compiled in the performance of program operations.
- Emergency response.
- Regulatory liaison for the University.
- Maintaining a highly qualified and committed staff.

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I Policy

No one may use or bring into the University or remove from the University any radioactive materials or radiation generating devices without obtaining written authorization from the Radiation Protection Office (RPO) in the Department of Environmental Health and Safety (EH&S). This includes registration of radioactive materials in consumer products that are licensed for sale to the general public and do not require any registration with governmental agencies.

No one may enter or work in an area designated for use with radioactive materials except as authorized and under conditions specified by the RPO. Special arrangements may be made with the RPO for visitors accompanied by authorized personnel.

All work with radioactive materials must comply with the conditions of use specified in (a) the License issued to the University by the Commonwealth of Massachusetts Radiation Control Program; (b) federal, state, and University regulations; and (c) the authorization issued by the RPO.

No one may activate any radiation generating device unless it has been reviewed and approved by the RPO and the operator has been instructed in the safe use of the device.

All persons who work with radiation sources must ensure that work-related radiation exposures are kept as far below the limits established by regulatory limits as reasonably achievable (ALARA).

Radioactive waste must be handled in accordance with procedures established by the RPO and may not be disposed of as ordinary laboratory trash.

The amount of radioactive waste generated should be limited to as small a volume as is reasonably possible.

II General Policies and Procedures

1. General Policy Statement

Radioactive materials and radiation generating devices are potentially hazardous unless used safely. To ensure safety, institutions and governmental agencies have established extensive regulations, rules and safety practices to minimize the impacts on the user, members of the Harvard University Community and members of the general public. This Manual sets forth the roles and responsibilities associated with the use of radioactive materials and radiation generating devices at Harvard University as managed by the Radiation Protection Office.

2. Access to Program Documents

The Commonwealth of Massachusetts has issued Harvard University a License to use radioactive materials and registrations to use radiation generating devices. Under these regulatory requirements, the University is required to make available documents related to the License and registrations and any notice of violation issued by the Commonwealth's Radiation Control Program (RCP). These documents may be reviewed at the Radiation Protection Office.

Radiation users may request a copy of their radiation exposures annually or upon termination of employment. Request should be made in writing to the Radiation Protection Office.

3. Regulatory Basis and University License

The Commonwealth of Massachusetts has issued Harvard University a License to use radioactive materials under the regulatory provisions of 105 CMR 120.100. The University's Broad-Scope License permits the storage and use of radioactive materials. These materials are:

- Naturally occurring radioactive materials
- Source materials (uranium, thorium and related ores)
- Byproduct materials – radioactive materials that were made in a reactor
- Accelerator produced radioactive materials
- Special nuclear material
- Irradiators

The Commonwealth requires registration of radiation generating devices under the provisions of 105 CMR 120.020. These devices include x-ray machines, particle accelerators, electron microscopes and any other device that can generate an ionizing radiation beam.

As required by 105 CMR 121.012, Class 3B and 4 lasers must be registered with the Commonwealth and requires a laser safety program under 105 CMR 121.005.

As required by 105 CMR 122.001, devices generating electromagnetic fields in a frequency range of 10 kHz to 100 GHz must be managed by a safety program to ensure compliance with public and occupational exposure limits.

4. Program Administration and Responsibilities

4.1 Administration

The Vice President for Administration is responsible for the overall administration of the Radiation Protection Program. The Radiation Protection Program is administered by the Department of Environmental Health and Safety. To ensure safety, Harvard's Radiation Protection Program is overseen by the **Radiation Safety Committee** (RSC). The RSC is a University standing committee consisting of faculty and administration that sets policy and is responsible for the oversight of the Radiation Protection Program. The members of the RSC are appointed by their School or administrative unit. The RSC reports to the Vice President of Administration.

The Radiation Protection Office (RPO) in the Department of Environmental Health and Safety (EH&S) provides radiation protection services. EH&S is a department of University Operations Services (UOS), which is under the direction of the Associate Vice President for Facilities and Environmental Services. UOS is under the general administration of the Vice President for Administration. The Radiation Protection Officer is responsible for managing the day-to-day operations of the Radiation Protection Office.

To ensure local management and control of radiation (radioactive materials and radiation generating devices), the RSC issues Permits to those holding University appointments (faculty members and officers) whose training and experience are commensurate with the radiation sources in their laboratory's research. Each faculty member's Permit must specify the Authorized User, the person responsible for ensuring compliance with the Permit and the Radiation Safety Manual, as well as the Registered Users. The Registered Users are the scientists, students, research staff and others who use the radiation sources under the direct supervision of the Permit Holder and/or Authorized User.

4.2 The Radiation Safety Committee

The Radiation Safety Committee, a Standing Committee at Harvard University ("University") is the governing body for all aspects of radiation protection within the University, including all affiliated research, clinical, instructional and service units using radiation sources in facilities owned or controlled by the University. The Committee shall ensure that all possession, use and disposition of radiation sources by University personnel at Harvard University

complies with pertinent federal and state regulations and with the specific conditions of licenses issued to the University, and that all concomitant radiation exposures are maintained **As Low As Reasonably Achievable** (ALARA).

As noted in Committee's Charter, the Committee is a "University Standing Committee that is responsible for the oversight of the University Radiation Protection Program." In fulfillment of this role, the Committee promulgates policies, rules and procedures for the safe use of radiation sources. The Committee has the authority to grant, deny, or withdraw permission for the use of radioactive materials or any other radiation sources within the University. It is the intent of the University that no use of radiation proceeds without the knowledge and approval of the Committee.

The Committee reports to the University Vice President for Administration. In its oversight role of the Radiation Protection Office, the Committee is responsible for the following:

- Establishing University policies,
- Establishing training procedures and criteria,
- Review and approval of all proposals for radionuclide use and conditions of use as proposed by the Radiation Protection Office,
- Voting to approve, disapprove, or amend proposals,
- Ensuring that only qualified individuals are permitted to use radiation sources, or to supervise such use by others,
- Conducting an annual audit of the Radiation Protection Office that includes a review of documentation and performance required to comply with license conditions, Nuclear Regulatory Commission and Commonwealth of Massachusetts regulations, and Radiation Safety Committee Policies. This audit is reviewed and discussed at a Radiation Safety Committee meeting and is recorded in minutes,
- Enforcing compliance with the program, including imposition of sanctions for noncompliance,
- Voting to change service vendors as may be required by license, regulation, or commercial requirements,
- Maintaining a list of the members and their appropriate training and experience,
- Making recommendations to the University Vice President of Administration on risk management issues related to radiation safety.

4.3 Radiation Protection Office

Under the direction of the Radiation Safety Officer, the Radiation Protection Office is responsible for:

- Ensuring compliance with Commonwealth of Massachusetts Department of Public Health (DPH), U. S. Environmental Protection Agency (EPA) and U. S. Department of Transportation (DOT) regulations;
- Maintaining a registry of all persons and facilities subject to the Radiation Protection Program;
- Conducting educational programs in the safe use of radioactive materials and radiation generating devices, through both formal courses and orientation of personnel who begin work at Harvard between safety courses;
- Advising on implementation of all aspects of the Radiation Protection Program, including safety and cost-effectiveness;
- Assisting in storage, use, and waste disposal problems at the laboratory level;
- Calibrating instruments;
- Operating a radioactive waste management program. The program includes receipt of wastes, decay-in-storage, incineration, burial, and disposal through commercial vendors;
- Auditing approved permits and programs annually, through meetings with authorized users and inspection of operations;
- Monitoring users' procurement, transportation, storage, use, and disposal of radioactive materials, to ensure compliance with the DPH license and applicable regulations;
- Reviewing laboratory operations to determine compliance with the ALARA principle;

- Conducting an environmental monitoring and surveillance program, including air sampling, water sampling, and review of the release records of users, to ensure compliance with regulatory limits;
- Providing personnel monitoring and bioassay services;
- Responding to emergencies and supervising decontamination operations by the authorized user;
- Investigating incidents involving radioactive materials and violations of regulations;
- In cases of noncompliance, suspending authorizations in accordance with guidelines established by the Radiation Safety Committee;
- Conducting periodic leak testing of sealed radioactive sources as required by Commonwealth of Massachusetts regulations or the License;
- Conducting a semiannual inventory of all radioactive materials and radiation generating devices;
- Maintaining complete records of program operations that are in a form suitable for inspection by regulatory agencies and can be readily retrieved and distributed.

4.4 Radiation Safety Officer

The duties, responsibilities, and authority of the Radiation Protection Officer consist of:

- Day-to-day coordination and management of the Radiation Protection Program;
- Briefing senior management at least annually on the conduct of the licensed activities;
- Establishing action levels for personnel exposure, radiation and contamination limits;
- Executing the established policies of radiation protection and ensuring compliance with federal, state and local regulations;
- Supervising radiation control activities as required by the Radiation Protection Program and the Radiation Safety Committee;
- Investigating all proposals for radioactive material and radiation generating device use, use conditions, and the transmittal of proposals to the Radiation Safety Committee, with recommendations for approval or disapproval;
- Providing provisional approval to satisfactory proposals in accordance with guidelines of the Radiation Safety Committee;
- Halting operations involving radioactive materials and radiation generating devices if unsafe or unacceptable conditions exist (operations may resume only when authorized by the Radiation Safety Committee);
- Reviewing laboratory operations to determine compliance with the ALARA principle;
- In certain cases of noncompliance, suspending authorizations to use radioactive materials and radiation generating devices in accordance with guidelines established by the Radiation Safety Committee, and authorizing provisional reinstatement following achievement of compliance pending review and final action by the Radiation Safety Committee; and
- Maintaining records of program operations that are suitable for inspection by regulatory agencies and can be retrieved and distributed.

4.5 Authorized User Responsibilities

The Authorized User is an individual authorized by the Radiation Safety Committee to use and supervise the use of radioactive materials or radiation generating devices and is directly responsible for:

- Maintaining an up-to-date listing with the RPO of radiation generating devices, rooms where radioactive materials or radiation generating devices are used or stored, and names of personnel who may use these devices and materials;
- Ensuring that laboratory staff follow the Registered User Responsibilities;
- Allowing only personnel who are registered with and trained by the RPO to use radioactive materials or radiation generating devices;
- Contacting the Radiation Protection Office before:
- starting a new procedure that varies from the authorized protocols;

- renovating, altering, repairing or vacating any laboratory space;
- changing laboratory locations or leaving the University;
- repair, transfer or disposal of any radioactive-use equipment;
- students under 18 are involved in experiments using radioactive materials or radiation generating devices.
- Ensuring those working under his/her Authorization satisfactorily complete radiation safety training. This training includes satisfactory completion of the RPO Radiation Safety Seminar, laboratory specific safety practices and techniques and instructions on approved radiation safety protocols. It may also include direct supervision of experienced staff;
- Minimizing radiation exposures to the registered user, University Community, environment and general public;
- Ensuring that dosimetry is used and dosimeters are returned on time.
- Maintaining a written inventory and security over radiation generating devices and radioactive materials and methods that would identify potential diversions;
- Controlling the purchase, possession, use, transfer and/or disposal of radioactive materials or radiation generating devices in his or her possession;
- Maintaining records of purchase, receipt, use, surveys, and disposal;
- Minimizing and properly packaging radioactive wastes;
- Complying with the University's Policy governing the use of radioactive materials and radiation generating devices to ensure compliance with governmental regulation;
- Complying with any special conditions listed on his or her Permit;
- Implementing the policies of the Radiation Safety Manual.
- Notifying the RPO 30 days before terminating work with radioactive materials. Ensuring that the laboratory is properly surveyed for the presence of radioactive materials and all radioactive materials and radiation generating devices are disposed of as waste or transferred to other authorized users before leaving the premises.

4.6 Registered User Responsibilities

Persons who use radioactive material and radiation generating devices must follow all applicable regulations pertaining to the use of radioactive materials as presented in the Harvard University Radiation Safety Manual, in the permit issued to the Authorized User, and in notices issued by the Radiation Protection Office. Radioactive materials and radiation generating devices must be handled in a manner that also ensures the health and safety of others and protects the environment. In addition all users must:

- Registered with and receive training and authorization from the Radiation Protection Office prior to using any radioactive source or radiation generating source;
- Comply with the conditions on the laboratory's Permit;
- Receive appropriate instruction and dosimetry from the Radiation Protection Office before working with radioactive materials or radiation generating devices;
- Complete biannual radiation refresher training;
- Wear assigned radiation dosimetry, required protective clothing and participate in required and requested bioassays;
- Handle and use radioactive materials and radiation generating devices to minimize radiation exposures;
- Follow the requirements of [Section 6](#) when moving radioactive material between buildings, across campus to another facility or institution;
- [Maintain records](#) as required by the RPO or the Radiation Safety Manual;
- Complete a thorough personal and area radiation survey before leaving the laboratory after using radioactive materials.

5. Ensuring Compliance with Radiation Safety Policy

The University has promulgated a strong enforcement policy to maintain high standards for radiation protection. The State of Massachusetts Department of Public Health, which regularly inspects University laboratories for compliance, emphasizes the need for "meticulous attention to detail and a high standard of compliance with regulations." Adverse findings by the State DPH can result in fines, and in extreme cases, suspension of the University License to use radioactive materials or radiation generating devices, even if no significant harm results to individuals or the environment. A State DPH penalty could not only cripple the University's research program but do considerable harm in the area of public relations. Accordingly, the Radiation Safety Committee takes whatever measures it deems necessary to achieve compliance with governmental regulations.

The Radiation Safety Committee has promulgated a schedule of mandatory suspensions of authorizations, with the penalties dependent on the severity and frequency of observed violations. The suspension is effected by the Radiation Safety Officer as the agent for the Radiation Safety Committee. The Radiation Safety Officer will suspend the use of radioactive materials or radiation generating devices for any of the actions listed below, to ensure safety and to correct regulatory compliance issues or at the direction of the Radiation Safety Committee. Under the terms of this suspension, all radioactive materials or radiation generating device work covered by the Permit must stop and no new purchases will be authorized.

The Radiation Safety Officer has the authority to reinstate an authorization for an interim period until the next meeting of the Radiation Safety Committee with the satisfactory completion of an audit by a staff health physicist. This audit will review compliance with the conditions of the permit and implementation of measures to prevent recurrence of violations. The Permit may not be reinstated until the Permit Holder ensures effective resolution and documents the incident and corrective actions in writing to the Radiation Safety Committee.

A suspended authorization will not be fully reinstated until the incident is reviewed by the Radiation Safety Committee and the Committee is assured that reasonable measures have been instituted to prevent recurrence. This review may be a corrective action summary report presented by the Radiation Safety Officer or an appearance of the Permit Holder and, at the discretion of the Radiation Safety Committee, a dean of the school involved before the Radiation Safety Committee.

Enforcement Actions are ranked as follows:

- A. Those for which a single occurrence will result in a suspension of the authorization:
 - Radioactive waste in an unlabeled trash container;
 - Unsecured radioactive materials.
- B. Incidents that occur twice in a twelve-month period:
 - Use of radioactive materials or a radiation generating device in a space not approved on the Permit.
- C. Three occurrences of any particular incident in any twelve-month period:

Working with radioactive materials or radiation generating devices before successfully completing Radiation Protection training;

- Evidence of eating, drinking, or smoking in laboratories;
- Pipetting radioactive materials by mouth;
- Not wearing appropriate protective clothing in laboratories;
- Storing food or beverages in laboratory;
- Not recording a sink disposal;
- Not reporting a spill;
- Not wearing appropriate dosimetry;
- Not notifying the RPO of new personnel;

- Not performing personal surveys before leaving the laboratory;
- Not completing a bioassay. (The worker is also suspended from working with radioactive material until the bioassay is completed);
- Not ensuring annual calibration of survey instruments;
- Not defacing radioactive warning labels on empty containers and boxes.
- Not labeling radioactive materials

In addition to the conditions for mandatory suspensions noted above, the Radiation Safety Officer may halt operations involving radioactive materials whenever unsafe or unacceptable conditions exist.

6. Obtaining an Authorization

Any purchase, use or work undertaken with radioactive materials or radiation generating devices requires written authorization, referred to as a permit, from the Radiation Safety Committee. Such authorization requires registration with the Radiation Protection Office, an agreement in writing to become familiar with and comply with the requirements of the Radiation Protection Office (as described in the Radiation Safety Manual and supplementary publications of the Radiation Protection Office) and conformance with specified training and experience criteria. The Authorized User is responsible for controlling all radioactive materials and radiation generating devices covered by the permit from the time of receipt until transfer to the Radiation Protection Office as waste, shipment to another location or transfer to another Authorized User.

6.1 Applying for an Authorization

For an individual to become an Authorized User, the person must have acceptable training and experience before the Radiation Safety Committee will authorize his or her use of radioactive materials or radiation generating devices. The Authorized User or the designated Qualified User must file an [application](#) that meets the requirements of this section. The application process includes a technical review of qualifications by the Radiation Protection Office staff who will make a recommendations to the Radiation Protection Officer. This staff position will be reviewed by the Radiation Protection Officer and if deemed appropriate forwarded to the Radiation Safety Committee for consideration. Authorizations approved by Radiation Safety Committee are valid for 2 years, after which the Authorized User must file a renewal application with the Radiation Safety Committee.

The evaluation of an application to hold Authorized User status includes the following:

1. Identification and review of the types and proposed uses of all radiation sources in the application form. This review and subsequent permit approval is based on the radioactivity used at one time or the design parameters of the radiation generating device. Requests that include the possession of radioactive material will consider the amount used at one time, with purchase limits that are adequate to cover the laboratory operations. In addition, the applicant must agree to abide by all policies and procedures for acquisition, use, storage and disposal of radioisotopes.
2. The applicant must meet the requirements of a Qualified User (see below), by demonstrating the appropriate education, training, and practical experience commensurate with the radiation sources to be used. If the applicant does not meet these requirements, (s)he may, with the approval of the Radiation Safety Committee, delegate responsibility for all uses of radiation under the authorization to a Qualified User under his or her direct supervision.

A Qualified User is an individual who has:

- A college degree at the bachelor level, or equivalent training and experience, in the physical, biological, or engineering sciences;
- Satisfactorily completed the Radiation Protection Office Seminar in Radiation Safety and is qualified to work independently with radiation sources and to supervise such use by others;

- Who has provided evidence of adequate training commensurate with the proposed use of radiation. This training may be accomplished either within the institution or on the basis of documented prior training or by testing to document adequate knowledge.
3. The applicant is interviewed by a health physicist for the appropriate training, experience, and understanding of the University's Radiation Protection Policies. The laboratory facilities are reviewed against the design criteria; laboratory experimental technique is discussed; and access to appropriate instrumentation is verified.
 4. The health physics staff will audit to verify that the applicant satisfactorily complies with the requirements of this section. Following successful conclusion of this audit, the Radiation Safety Officer will make a recommendation to the Radiation Safety Committee requesting approval of the Permit. At the meeting, the Radiation Safety Committee reviews the application and votes by majority rule, to accept, modify, or deny the application. Alternatively, the Radiation Protection Office may seek Radiation Safety Committee approval by paper or electronic mail ballot. Approval by the Radiation Safety Committee is finalized by a signature of a designated representative of the Radiation Safety Committee (usually the Chair) but not by the Radiation Protection Officer. This authorization is valid for two years. If at the end of the two year period, a renewal application has been submitted before the expiration date, the permit will remain in effect until the completion of the renewal process.

6.2 Authorization Amendments

All requests for amendments must be submitted in [writing](#) to the Radiation Protection Office. Amendments include changes to experimental protocols, purchase limits, possession limits, registered laboratories and radiation users. The Radiation Protection Office will review the requested amendment with the Permit Holder or his/her designee. Health Physics staff can approve simple changes in experimental protocol, purchase limits, laboratories and users upon completion of the appropriate paperwork. The Radiation Protection Officer can approve increases in possession limits due to an increase in the laboratory size and addition of similar radioactive materials or devices. Any change of a Permit condition, not otherwise specified possession limit increase, addition of a new type of radioactive material or radiation generating device or complex experimental protocols must be approved by the Radiation Safety Committee. Any changes approved by the Radiation Protection Office to possession limits will be presented to the Radiation Safety Committee for confirmation.

6.3 Authorization Renewals

Each Permit will be subject to renewal every two years. At the discretion of the Radiation Protection Office, the Authorization may be renewed earlier. The Permit Holder will sign and return a Renewal Notice at least two weeks before the permit's expiration date. A Health Physicist will then meet with the Permit Holder to review the current and expected activities. This renewal will include a review of user initial training, retraining, laboratory compliance history, instrument calibrations, radiation exposure data and records. Based on this review, the Radiation Protection Office will make a recommendation on renewal to the Radiation Safety Committee. The Radiation Safety Committee will consider renewal at the next scheduled meeting.

6.4 Authorization Termination

Authorization to use radioactive materials or radiation generating devices terminates when the Permit Holder leaves the University or at the Permit expiration date. The Permit Holder must notify the Radiation Protection Officer at least 30 days before leaving the University or terminating an Authorization. The Permit Holder must ensure the proper transfer of materials, devices and records and the completion of appropriate bioassays and laboratory termination surveys before leaving the University or terminating the Authorization.

7. Special Considerations for Classroom Radioactive Material Use

Radioactive materials may be used for teaching and demonstration in academic classes only if that provision is included in a valid Permit that has been approved by the Radiation Safety Committee. The following information needs to be provided:

1. Name and radiation experience for the laboratory instructor(s);
2. Course duration and title;
3. A description of the proposed use, procedures, radiation safety instructions and description of the student's involvement with radiation;
4. Expected number of students (the Permit Holder will forward the name, birth date, Social Security number of all students at beginning of each semester);
5. Number of laboratory groups and number of students per group.

8. Minors and Radioactive Materials or Radiation Generating Devices

No person under 18 years of age is allowed to be in a laboratory that contains radioactive materials unless the person is first approved by the RPO and completes the notification in [Appendix E](#). Such persons must be Harvard employees or Harvard students.

No person under the age of 16 is allowed to be in a laboratory that contains radioactive materials or a radiation generating device.

9. Radiation User Registration

No one should begin working with radioactive materials or radiation generating devices without first receiving appropriate instruction and dosimetry from the Radiation Protection Office. Training can be taken either on the Web or a lecture format. For a schedule or a link to the online training go to:

<http://www.uos.harvard.edu/ehs/radsafety/training.shtml>

All users of radioactive materials and radiation generating devices must be registered on an Authorization issued by the Radiation Protection Office.

All workplaces where radioactive materials or radiation generating devices are used or stored must be registered with the Radiation Protection Office.

Anyone who must enter a laboratory registered for work with radioactivity or radiation sources, but who is not authorized to work with radioactive materials, must do so under the direct supervision of a registered user from that laboratory.

10. Pregnant or Potentially Pregnant Radiation Users

The Massachusetts Radiation Control Program has established a 500 mrem radiation dose limit to the embryo/fetus during the nine-month gestation period for those who declare their pregnancy in writing to the Radiation Protection Office. As described in the [Declared Pregnant Radiation User Policy](#) (Appendix A), this declaration may be made in confidence. When a person notifies the RPO of participation in this program, the RPO will provide a monitoring program that meets the requirements of the Policy. At the University, this Policy applies to males as well as females who are either pregnant or trying to become pregnant.

11. Radioactive Material Security

Secure all stock solutions, sealed sources, activated materials and other than trace quantities of waste from unauthorized removal or access by locking either the room or the container. Store radioactive materials only in areas registered with to the RPO. Record all removal or dispensing of controlled materials on the standard [Radioactive Material Inventory/Use form](#) (Appendix E). Post the form near the storage container or in a designated notebook. Retain the inventory use form for one year after the radioactive material is either decayed to background or disposed of as radioactive waste.

Control and maintain constant surveillance of radioactive materials when they are not in storage and prevent unauthorized access or removal by questioning any laboratory visitors.

Any of the following methods of security are acceptable:

- a) Store radioactive material inside a locked laboratory. When the room is locked, it is not necessary to physically secure the radioactivity inside the laboratory. Access to the room must be controlled by locking the doors. All avenues of access to the laboratory must be locked. When the door is unlocked, a trained radiation worker must maintain surveillance over the radioactive material and restrict access to the radioactive material to authorized radiation workers.
- b) Store radioactive materials in a locked container such as a freezer or other container that cannot be removed. Check the lock on the freezer or refrigerator to make sure it is secure.
- c) Store radioactive materials in a lock box or specialized container on a bench or inside a freezer or refrigerator. Physically secure these containers to an immovable object in the lab so they cannot be removed from the laboratory.
- d) Store the radioactive material in a locked room, such as an equipment room inside the laboratory.
- e) Liquid solutions may be secured by placing the material in a locked automated dispenser such as the Amersham Redivue Isotope Dispenser that cannot be removed from the laboratory.

III Radioactive Materials in Laboratories

1. Authorized Laboratories

1.1 General Requirements

Radioactive Materials may only be used in laboratories and rooms that are listed on an Authorization approved by the Radiation Safety Committee. A Permit Holder, the individual to whom the permit is issued, may add a new laboratory by filing an amendment to his/her Authorization. As part of the Authorization process, the RPO will review the laboratory space for the proposed purpose. This includes determining the survey frequency, posting requirements, security review and special considerations with the particular experimental protocols.

Typically, laboratories are assigned to and are under the direction of a single Permit Holder. However, there may be cases where one or more Permit Holders share a space. For shared laboratory spaces, any charges assessed by the RPO will be evenly distributed between the Permit Holders. In the event of enforcement actions taken against a shared laboratory space, the RPO will work with the Permit Holders to identify the individual responsible for the incident. If however the responsible party cannot be identified, the incident will be assigned to all Permit Holders using the laboratory.

1.2 Physical Requirements for Laboratories

Radioactive material work at the University typically involves small amounts of beta emitting sources and does not present a significant whole body exposure hazard. As a result, the radiation protection required is for internal exposure. Most work with radioactive materials throughout the University is done in research laboratories equipped for modern research and are well suited for work with radioactive materials. These laboratory facilities have nonporous surfaces and meet laboratory ventilation requirements. Iodinations are done in laboratory hoods vented to the atmosphere through the building ventilation system. All radioactive material use laboratories should have:

- Entries posted with a “Caution Radioactive Material” sign;
- Floors with a nonporous surface;
- Benches that are nonporous and easily decontaminated;
- Nonporous walls covered with easily washable paint;
- A high-quality chemical resistance fume hood suitable for work with radioactive vapors, dusts, fumes and gases with a minimum face velocity of 100 linear feet per minute;
- Facilities to adequately secure radioactive materials.

For a larger or unusual radiation related projects, the Radiation Protection Office may add guidance from The International Atomic Energy Agency (IAEA) Safety Guide, Safe Use of Ionizing Radiations in the Workplace for evaluating laboratories that use radioactive materials or the National Radiological Protection Board’s Categorization and Design of Working Areas in which Unsealed Radioactive Materials are Used.

1.3 Posting Requirements

Posting areas that use radioactive materials or radiation generating devices warns people about the potential for radiation exposure and meets regulatory requirements. The Massachusetts Radiation Control Program regulations define conditions under which signs and labels must be used to alert people to the presence of radiation and radiation sources.

To ensure that building occupants are properly notified of their rights and responsibilities associated with radioactive materials and radiation generating devices, the safety bulletin board or common area bulletin board on each floor that has labs with these materials will contain the Harvard University Rules and Regulations posting as well as the Massachusetts Radiation Control Program “[Notice to Employees](#)” (Appendix G).

The entrance to each laboratory that uses radioactive materials or radiation generating devices shall be posted by the Radiation Protection Office with the appropriate [signage](#) before radioactive materials or radiation generate devices are used. This laboratory posting will also include emergency contact information for the laboratory. It is the laboratory’s responsibility to ensure that this information is up-to-date. These signs may only be removed by or with authorization from the Radiation Protection Office.

Mark laboratory equipment such as beakers, flasks, centrifuges, test tube racks and pipetters used for radiation work with [a radiation symbol](#) to minimize the potential for inadvertent contamination. Containers that may be used for transitory use of radioactive materials and will not be left in a contaminated state do not need to be posted if they are under the direct control of a register user. Post all storage containers with a “Caution Radioactive Material” label that includes the radiation symbol, radionuclide, activity and reference date.

Prior to disposal of any laboratory equipment or supplies that have been used with radioactivity, survey the material with an appropriate instrument to ensure that it is not contaminated and remove all radiation, radioactive materials and radiation symbols.

2. Training

All radioactive materials users must take the Radiation Safety Training Seminar given by the Radiation Protection Office; refer to the RPO website for [schedule](#). The Radiation Protection Office may require additional training and suitable experience for specific proposed projects.

Radiation generating device users need to take device specific training as determined by the Radiation Protection Office.

All maintenance and other workers who need to enter a controlled area must receive suitable instruction from the Radiation Protection Office, or be directly supervised by a registered user while in the laboratory.

The Radiation Protection Office requires retraining every two years for all users of radioactive materials and staff supporting the laboratory operation who enter the registered space.

Table 1
Annual Occupational Exposure Limits

Type of Exposure	Annual State Limit	Harvard Goal
Whole body (head and trunk), active blood forming organs, gonads	5,000 mrem <small>(total effective dose equivalent)</small>	500 mrem
Lens of the eye	15,000 mrem	1,500 mrem
Skin, extremities	50,000 mrem	5,000 mrem
Embryo/Fetus	500 mrem (9 months)	50 mrem (9 months)

3. Dosimetry

3.1 Dosimetry Requirements

Radiation dosimetry is a device worn by a person or placed in an area to measure external radiation exposures. Dosimetry use ensures that radiation exposures follow the ALARA principle, keeping exposures as low as reasonably achievable. The RPO coordinates the dosimetry program, which uses dosimetry products from Landauer, Inc. (accredited by The National Voluntary Laboratory Accreditation Program, NVLAP). Radioactive material users are monitored and the results are sent to the Permit Holder. Dosimetry results are available from the Permit Holder and the RPO.

All radioactive material users and others who occupy radioactive material use areas must wear radiation dosimetry. In most cases, dosimetry is issued every other month (January, March, May, July, September, November), refer to the [radiation protection web site](#) for information on the dosimeter.

If you are working with more than **1 mCi** of any high-energy beta (e.g. ³²P), x- or gamma emitter (¹²⁵I and ⁵¹Cr), or x-ray diffraction unit you must wear a TLD finger ring.

3.2 Occupational Dose Limits

State and Federal regulators set low-risk annual exposure limits. Additionally, the Radiation Safety Committee set lower exposure goals based on the principle of "As Low As Reasonably Achievable" (ALARA). The RSC has established a conservative exposure limit of 10% of the regulatory limit. The University has a goal of keeping radiation exposures below this goal and to investigate and implement corrective action if exposures exceed the ALARA goals. Refer to [Appendix B](#). The annual occupational exposure limits and goals are shown in Table 1.



Figure 1
Wearing a whole body dosimeter

These occupational dose limits are set so that an exposed person will not exceed the insurance industry's definition

of safe-industry risk while working with radiation (at the annual exposure limit for a 50-year period). The lower exposure limits for [Declared pregnant workers](#) include additional considerations for the embryo/fetus.

Most users' radiation exposures are well below Harvard's exposure goals. In addition, the RSC has set Investigation Levels, which would initiate an investigation by the RPO. Based on a review of the exposure(s), the RPO will recommend appropriate safety measures to maintain exposures [ALARA](#).

3.3 Proper Dosimetry Use

A radiation user is assigned a temporary dosimeter at the successful completion of the required training program. Each dosimeter is assigned to an individual; do not wear the dosimeter assigned to another person. The dosimeter must be worn whenever you are in the laboratory, working with or around radiation sources.

Wear the whole body dosimeter on your torso as shown in Figure 1, positioned so that it is closest to the source of radiation. Wearing it on the chest or at bench level are two suitable locations. It should be worn outside the lab coat; use caution to prevent contamination.

Wear the TLD ring, as shown in Figure 2, on the hand used most often to handle radioactive materials, with the text side facing the inside of the palm. The TLD is worn inside of a glove.

3.4 Instructions for Laboratory Dosimetry Coordinator

Each laboratory group should assign one individual who is responsible for coordinating radiation dosimetry within the laboratory. This person is responsible for receiving and distributing dosimetry, maintaining dosimetry reports and making changes to the list of people receiving dosimeters through the Radiation Protection Office.

3.5 Dosimetry Exchange

Dosimeters are mailed to each laboratory group for arrival on the first of January, March, May, July, September, and November. The mail packet should include a Luxel dosimeter for each person in the laboratory and an extremity dosimeter for anyone who uses more than 1 mCi of a high-energy beta emitter or an x-ray diffraction unit. The new dosimeter should be exchanged for the old dosimeters, which are returned to the Radiation Protection Office within 14 days. Prompt return allows the RPO to properly monitor radiation exposures.

3.6 Dosimetry Records

Radiation dosimetry results are first reviewed by the vendor and then the Radiation Protection Office when the dosimeter is processed. A report is typically mailed to the laboratory with the next shipment of new dosimetry.

To ensure that doses follow the ALARA principal, the RPO will review radiation exposure results within about one week of return to the RPO. Any routine dosimeter with an exposure in excess of 100 millirem will be reviewed by the RPO. Other types of dosimeters have review criteria appropriate to the dosimeter use.

Dosimetry reports will be mailed to the laboratory in the next dosimetry shipment. The Dosimetry Coordinator should make this information available to the laboratory staff. If dosimetry reports are posted, personal information such as name, Social Security number or birth date should be removed prior to posting.

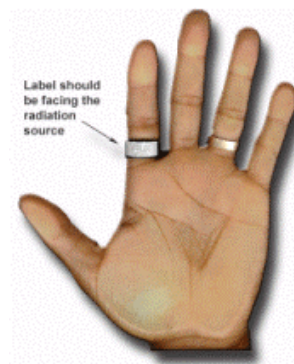


Figure 2
Wearing a finger dosimeter

4. Purchase or Procurement

4.1 Authorization to Receive Radioactive Materials

No one may order, receive, use, or bring into the University any radioactive material without prior authorization from the Radiation Protection Office. This includes purchases from commercial vendors, other universities or transfers from colleagues or gratis shipments from commercial vendors. Persons wishing to acquire radioactive materials need to contact the RPO for authorization.

4.2 Ordering Radioactive Materials

Before ordering a radioactive material, first ensure that the sum of the proposed order and the amount you already have on-hand does not exceed the Authorization's possession limit. If the total purchase plus inventory would be less than the possession limit, approval may be obtained by contacting the Radiation Protection Office at (617-49)5-2060 or on the Web at <http://www.uos.harvard.edu/ehs/radsafety/purchasing.shtml>. Authorization is given for specific radioactive materials and possession limits, and may also designate the compound and physical form. Refer to [Appendix D](#) for instructions on using the Web approval system.

Be prepared to provide the following information: Purchase Order, Name of Authorized User and Series Code, radionuclide, activity (in microCuries or milliCuries), lab number, laboratory contact and telephone number and the vendor. If authorization is requested on the Web, the user can choose to have the Radiation Protection Office order the product (with Perkin-Elmer/NEN, Amersham or ICN) or contact the vendor directly. The RPO will fax orders to the vendor at approximately 10:00 AM and 4:30 PM daily.

4.3 Ordering Radioactive Materials For Delivery to Other Institutions

Radioactive materials ordered for delivery to another institution are not ordered under the Harvard University License. These materials must first be approved for delivery by the destination institution. These materials may then be ordered under the destination institution's radioactive materials license. The individual laboratory ordering these materials is required to maintain records of this purchase.

4.4 Receiving Radioactive Materials

When a radioactive package is delivered to the Longwood Campus, HIM, or the Biological Laboratories, the RPO will receive the package. The RPO staff will conduct the Department of Transportation (DOT) required external package monitoring and maintain the compliance record; the RPO will not open the package. Packages that are properly authorized by the RPO will be delivered to the laboratory.

For packages delivered to other locations such as NERPRC, 812 Huntington Avenue, 1 Kendall Square, many Cambridge buildings or any other location where the RPO does not receive a package, the laboratory is responsible for completing the DOT required external package monitoring and completing the [receipt record](#). This is:

1. Visually inspect the package immediately upon receipt for integrity of the security seal and any evidence of crushing or breakage in transit. Look for stains or discoloration, which may indicate leakage from the package.
2. Wipe-test the package for removable contamination and count the wipe with the appropriate instrument such as a liquid scintillation counter.
3. Note activity and isotope stated on package, verify agreement with purchase requisition, and record information on the receipt form in [Appendix E](#).

4. Measure dose rate on the surface of the outer package and at one meter with a survey meter and enter result on receipt form.
5. Record results of dose rate measurements and wipe tests (including counting efficiency) on a [receipt form](#), and fax it to the RPO at (617-49)6-5509. If the contamination is over 1,000 disintegrations per minute on the exterior surface or over 10,000 disintegrations per minute on the inner container, immediately call the RPO at (617- 49)5-2060.

For all radioactive material, including those delivered by the RPO or received by the individual laboratory complete, the following steps:

1. Verify that the radioactive material in the package is what you ordered.
2. Sign for radioactive material packages when they are delivered to your laboratory.
3. Move the package to a designated radioactive work area. When receiving volatile radioactive materials, process the package in a vented hood.
4. Put on protective gloves and a lab coat before proceeding with package receipt. Open the inner package, remove the stock vial with appropriate remote handling devices and verify that the contents agree in name and quantity with the packing slip and it is what you ordered. Contact the RPO immediately at (617- 49)5-2060, if there is a discrepancy.
5. Wipe test the external surface of the stock material vial. Survey the wipe with a survey meter unless you are receiving 3H. Use a liquid scintillation counter when monitoring for 3H. Notify the RPO immediately at (617- 49)5-2060 if contamination is over 1,000 counts per minute.
6. Treat all packaging material as potentially contaminated until surveyed and confirmed to be uncontaminated. Use a survey meter to monitor the package liner, shielding, radionuclide container and Styrofoam packing inserts for contamination before disposal in the regular trash. Dispose of any material with a count rate more than 100 counts per minute above background as radioactive waste.
7. If material has been delivered in dry ice, refrigerate immediately.
8. Deface the label on the package before discarding the empty box into the trash can.
9. Ensure proper inventory, storage and security.

4.5 Inventory and Storage

After radioactive materials have been properly surveyed, properly store and secure the stock vial and create a radioactive material inventory form ([Appendix E](#)). Regulations require accurate up-to-date inventory of each radioactive material under the laboratory's possession. To ensure proper reconciliation for each vial, mark the bottle with unique identifier (such as the purchase order number) that is also recorded on the inventory form.

The radioactive material must be stored in a suitable container that meets the temperature requirement of the sample, has the required "Radioactive Materials" posting and meets the security requirements of Part 1 [Section 11](#).

Each user will record the date, how much radioactive material he/she took from the stock vial on the [Inventory Form](#). Once a radioactive material bottle has been completely used, deface the radioactive symbol on the side of the bottle and dispose of material as radioactive waste. Mark disposal date on the bottom of the inventory form. These inventory records are used to complete a semi-annual University-wide inventory conducted by the Radiation Protection Office. Radioactive Material Inventory Forms for empty vials may be disposed of after the next RPO inventory.

5. Transfer of Radioactive Materials

Since possession of radioactive materials is covered by the requirements of a radioactive materials license, all transfers of a radioactive material must have prior approval by the RPO. Radioactive materials can only be transferred to another Authorized User, either at the University or another institution. If the transfer is to another institution, allow enough time for the RPO to work with the other institution's Radiation Safety Office and complete the appropriate paperwork. The Authorized User is responsible for maintaining records of all transfers of radioactive material, both within the University and to other institutions.

6. Radioactive Material Transportation

Transportation of radioactive materials is regulated by the Massachusetts Radiation Control Program, U. S. Department of Transportation (DOT), U.S. Postal Service, License of the destination facility as well as other local regulations. To ensure the transportation of radioactive materials meets these regulatory requirements, all transportation for radioactive materials must first be approved by the Radiation Protection Office.

6.1 On-Campus Transportation

6.1.1 Transportation Without Crossing a Public Way

After approval by the RPO, radioactive materials can be transported to an approved Authorized User on the same campus without crossing a public way with the following provisions:

- The radioactive materials must be tightly sealed in a leak proof container;
- Verify that the external surface of this inner container is free of contamination;
- Place a radioactive material sticker on the vial that lists the radionuclide, activity and reference date;
- Place the radioactive internal container inside a second non-breakable container that has enough absorbent to contain all the radioactive material between the radioactive material vial and the internal surface of the secondary container;
- The radiation exposure rates may not exceed 20 mrad per hour at the package surface or 1 mrad per hour at 1 meter from the package surface;
- During transportation, the package must remain in the possession of and under the direct control of a person who is authorized by the Radiation Protection Office to use or transport the radioactive material.

6.1.2 Transportation Crossing a Public Way

Radionuclide	105 CMR Appendix C Value
Calcium-45	100 μ Ci
Carbon-14	100 μ Ci
Chlorine-36	10 μ Ci
Chromium-51	1000 μ Ci
Cobalt-60	1 μ Ci
Hydrogen-3	1000 μ Ci
Iodine-125	1 μ Ci
Iodine-131	1 μ Ci
Iron-59	10 μ Ci
Phosphorus-32	10 μ Ci
Phosphorus-33	100 μ Ci
Potassium-42	1000 μ Ci
Rubidium-86	100 μ Ci
Sodium-22	10 μ Ci
Sulfur-35	100 μ Ci
Technetium-99	100 μ Ci
Zinc-65	10 μ Ci

Radioactivity may be hand carried between University buildings with prior approval from the Radiation Protection Office when packaged in accordance with the requirements of Section 6.1.1, packaged in an RPO approved DOT shipping container and contains the total activity but does not exceed the limits listed in Table 2. Transfers must be recorded as described in [Section 5](#).

6.2 Off-campus Transportation

All transfers and transportation of radioactive material off-campus must first be approved by the Radiation Protection Office. All materials should be transported by either a University owned vehicle or a commercial carrier. Under limited conditions, radioactive materials may be transported locally in a private vehicle by a Radiation Protection Office trained and authorized individual.

Radioactive materials may be hand carried to adjacent Affiliated Institutions provided that all the provisions of Section 6.1.2 are met.

7. Guidelines for Using Sealed and Unsealed Sources

Radioactive materials, also known as radioactive sources, are produced in sealed and unsealed forms. Sealed sources are sources in which the radioactivity is securely sealed in containers in accordance with rigid specifications. The hazard from these sources is exposure to the radiation emitted from them. People can be protected against excessive external radiation exposure from sealed sources by: a) shielding - that is, placing absorbers in the path of the radiation to limit the amount reaching the body; b) working at a sufficient distance from the source, since the radiation level decreases inversely as the square of the distance; and c) minimizing the amount of time exposure to the source.

Unsealed sources are radioactive powders, liquids, and gases that are not sealed in a container designed to prevent leakage. Radioactive chemicals are sometimes used at levels at which they constitute external radiation sources; at the University, however, the use-levels are small and the exposure risk would arise primarily from ingestion, inhalation, or skin contact. The protective measures used to prevent uptake of radioactive materials into the body are similar to those used in handling of other hazardous chemicals and are consistent with prudent laboratory practices.

Beyond protecting workers and the environment, the procedures established for working with radioactive materials must comply with the regulations of the Nuclear Regulatory Commission and the Commonwealth of Massachusetts.

7.1 Guiding Principles

While governmental regulations must be observed in detail, a few basic rules are critical to protecting workers and the environment from the risk of exposure. These are:

1. Designate a radiation work area. This area should be space away from high traffic areas and should contain all of the materials and resources necessary for the labeling project. If it is not possible to place all the materials in this area, it should have convenient access to those remote materials. Cover this area with absorbent paper such as Benchcoat[®] and mark the area with 'Caution Radioactive Material' tape.
2. Post areas with warning signs and label all radiation sources as required to prevent exposure of individuals in the area.
3. Perform a "dry run", using stable or a small amount of radioactive material, to perfect your technique and identify potential problems.
4. Wear lab coats, gloves that are appropriate for the biological and chemical materials being used, safety glasses and close-toed shoes to minimize the chances of ingestion, skin contamination, or injury to the eyes. Be careful not to cross contaminate laboratory equipment. Remove gloves and lab coat when leaving the laboratory.
5. Minimize contamination. When working with unsealed radioactive materials, the most significant source of exposure is contamination. Promptly cleanup spilled radioactive materials.
6. Develop work habits that minimize exposure to ionizing radiation. Do not linger near sources of penetrating radiation; employ shielding appropriate to the sources used; and use tongs or other handling tools to increase distance from the source.

7. Use materials with the potential for vapors or gas release in a fume hood or glove box approved by EH&S for protection against airborne releases and the spread of contamination. Do not exceed release limits set by the RPO. Refer to Section 8 on volatile materials.
8. Use traps whenever necessary to minimize system contamination and accidental releases.
9. Use automatic pipetters, do not pipette by mouth.
10. Do not store or eat food, drink or smoke in rooms where unsealed radioactive materials are in use or in contaminated areas.
11. Do not dispose of any radioactive waste as normal laboratory trash. Monitor trash containers to detect accidental disposal of radioactive materials. Dispose only in accordance with the procedures promulgated by RPO, and maintain records of disposal.
12. When disposing of activity in sinks, use only registered sinks, and do not exceed limits set by RPO.
13. When you are finished working with radioactive materials or you are leaving the laboratory, secure your radioactive materials, complete personal and area radiation survey and wash hands. Record the results of the survey when working with more than 1 milliCurie.
14. Keep yourself informed of all safety measures pertaining to your work, as stated in this document, your permit, and RPO notices.
15. Immediately notify the Radiation Protection Office of known or suspected:
 - Accident or spill of radioactive materials;
 - Accidental release of radioactive materials to the atmosphere, drains, ventilation system or laboratory or building services;
 - Loss of radioactive material;
 - A person who has or may have had an inhalation, ingestion or injection of radioactive materials or personal contamination that cannot be immediately removed.

7.2 General Handling Precautions For Unsealed Sources

7.2.1 Preparation

- Clearly label containers, equipment, and areas for handling radioisotopes with radioactive labeling tape. The labeling tape can be obtained from your institution stockroom or through an [appropriate vendor](#). Minimize radioactive material work-space.
- Use absorbent material (e.g. Benchcoat[®]) and trays to confine spills and reduce the spread of potential contamination.
- Wear protective clothing. The minimum requirements include a laboratory coat, safety glasses, gloves and close-toed shoes. Wear either single or double disposable gloves, depending on the radionuclide you are working with. Choose gloves that are appropriate for the chemical and other hazards in your experiment. If you are unsure about the type of protective glove to use call the Radiation Protection Office (RPO) at (617-49)5-2060 or visit www.bestglove.com.
- Traps to collect radioactivity may be necessary (as required under some permits) e.g.: vacuum line traps. If a trap is not available, contact the RPO. Refer to Figure 3.
- Dedicate equipment such as pipettes and glassware to radioactivity work and avoid cross contamination.
- Plan your experiment to eliminate or minimize mixed waste (i.e. hazardous chemical or biologically active material combined with radioactivity). If they cannot be avoided contact the Radiation Protection Office (RPO) for further assistance.

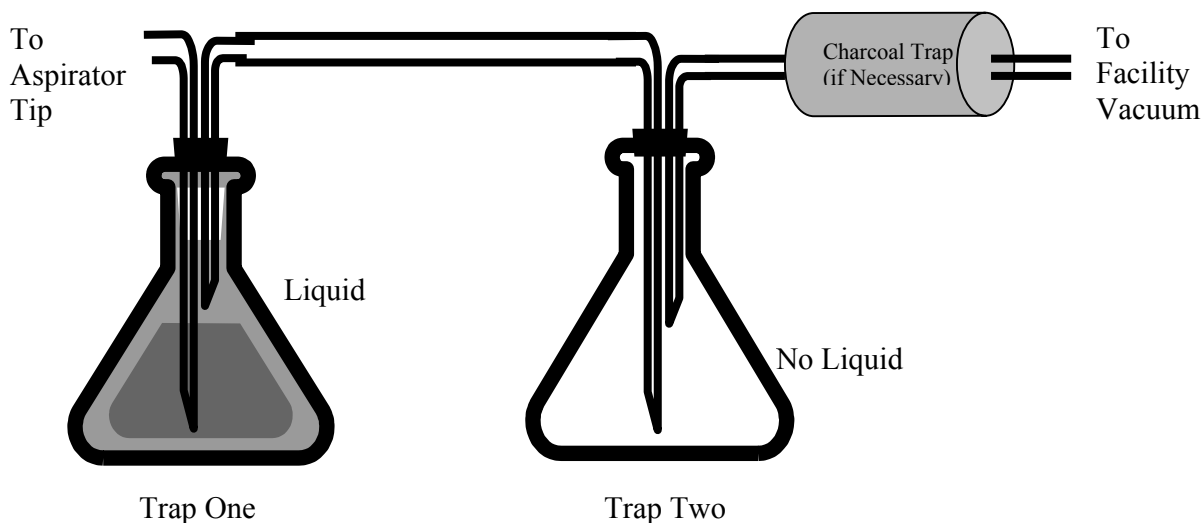


Figure 3
Typical Trap Configuration

7.2.2 Equipment/Supplies for General Use

- A Liquid Scintillation Counter for low energy beta radiation;
- Benchcoat;
- Contamination tape;
- Portable Survey Meter with appropriate probe(s);
- Disposable latex or plastic gloves;
- Luxel Dosimeter (and extremity monitor, if assigned);
- Lab coat, safety glasses, and close-toed shoes;
- Containers for radioactive waste;
- Pipettes dedicated to the use of your radionuclide;
- Safety glasses (to protect from splash and shield from beta radiation).



7.2.3 Work Practices

- Change your gloves often. Assume gloves are contaminated until proven otherwise. Do not leave the laboratory or touch things outside of the work space with potentially contaminated gloves. Remove gloves carefully from the inside out. Ensure that gloves are disposed of properly and wash hands immediately after using radioactive materials.
- Do not eat, drink, smoke, chew gum, or touch exposed areas of skin while working in a room where radioisotopes are handled. Be careful not to rub your eyes, scratch exposed areas of skin, or touch your hair when working with radioactive material.
- Use automatic or remote pipetting devices. Never pipette by mouth.
- Allow sufficient time for frozen stock solutions to thaw before attempting to withdraw an aliquot. If you are working with ^{35}S -methionine, Cysteine, and Translabel® refer to the related worksheet for ^{35}S volatility. Refer to [Section 8](#) for more information on working with volatile material.
- Handle volatile compounds, which have the potential for vapor or gas release (such as Na^{125}I or ^{35}S -Methionine or Cysteine) in a functioning fume hood.
- Handle and dispose of spin (centrifuge) columns with care. Place used columns in a sealed container (capped tube or Ziploc® bag) prior to discarding into the radioactive waste.
- After working in areas that contain radioactive material, wash your hands before eating, smoking, going about other work or leaving work.

7.2.4 Post-Work

- Lock-up and secure your radioactive stock solutions immediately after use.
- Promptly dispose of radioactive waste properly. Make a reasonable estimate of the amount of radioactivity in the waste and record on a radioactive waste tag.
- Sink disposal must be done according to the approved guidelines. Do not exceed the posted daily limit for the radionuclide, unless otherwise authorized by the Radiation Safety Committee (RSC) in the permit.
- Survey yourself and work area for contamination with an appropriate survey meter. Decontaminate if necessary. Remove protective clothing and wash hands thoroughly with warm water and soap before leaving the laboratory.
- Note the results of your survey on your personal survey record of the work area. This is required if you are working with more than 1 mCi.
- Participate in the bioassay program as requested by the Radiation Protection Office.

8. Special Consideration for Volatile Materials

Some radioactive material compounds may be naturally volatile or may volatilize during use. Examples of these radionuclides are sodium iodide, ^{35}S -methionine, sodium borohydride, succinic anhydride and acetic anhydride. Additionally, it is possible for other compounds to release radioactive materials, such as tritiated water, when they are heated. Volatility significantly increases the possibility of exposure without appropriate control measures. As a result of these concerns, bioassays are often required for those working with a volatile radioactive material.

To minimize radiation exposure for volatile radioactive materials, always work in a properly calibrated (within the last year) and functioning fume hood. Operate the fume hood with the sash at the proper height with an unobstructed air flow that does not impede the flow. Proper use of a fume hood will eliminate the need for respiratory protection. Additional measures to limit volatility include minimizing the number of freeze/thaw cycles, the use of charcoal adsorbents, evacuating volatilized material before use and removing aliquots through a septum top.

Purge a radioactive material stock vial of volatile materials by using a syringe or hypodermic needle and a charcoal trap, which may be purchased from radioactive material vendors such as Perkin Elmer and Amersham. The charcoal trap is a hypodermic needle that has a layer of glass wool, packed activated charcoal, and a final layer of glass wool that is sealed with plunger. Insert both the syringe and the charcoal trap into the air void above the solution being careful not to touch the liquid. Gently force the air from the syringe into the stock vial. This will push the volatilized material through the charcoal trap. Remove the syringe followed by the charcoal trap and do not attempt to recap the needle. Dispose of the charcoal trap in the radioactive waste.

8.1 Radioiodine

Radioiodine use will be reviewed by the Radiation Protection Office for volatility potential as part of the permitting process. Based on this review, the RPO may require that the experiment be done completely within a hood or glovebox that may contain a charcoal filter to remove the radioiodine and a charcoal stack monitoring system to measure environmental releases. All sodium-iodide users should also consider these additional precautions:

- Store Na^{125}I solutions at room temperature in a hood to eliminate a thaw/freeze cycle;
- Do not use bleach or chlorine with radioiodine;
- Maintain a pH of greater than 7 to reduce volatility;
- To prevent vacuum system contamination, use a trap whenever the experimental protocol requires use of a vacuum;
- Have a reducing agent such as sodium metabisulfite available;

- Whenever possible, complete the entire iodination within the original shipping vial by injecting the contents through a syringe or hypodermic needle;
- Purge any Na¹²⁵I vial with a charcoal trap before removing an aliquot;
- Remove all Na¹²⁵I aliquots with a Hamilton® or disposable hypodermic syringe inserted through the vial's septum top. Do not remove the rubber septum;
- Get a thyroid count before your first iodination and as required by your laboratory's Permit or the Radiation Protection Office thereafter.

8.2 ³⁵S Methionine, Cysteine and Translabel®

Radiolysis of ³⁵S labeled amino acids may lead to the release of ³⁵S labeled volatile impurities¹. Delivery vials and thawed materials should be opened in a fume hood. Vials of ³⁵S labeled cysteine and methionine should be opened and used in ventilated enclosures (exhaust hoods). The addition of stabilizers (buffers) will reduce (not prevent) the evolution of ³⁵S volatiles from tissue culture media. Vent ³⁵S amino acid stock vials with an open-ended charcoal-filled disposable syringe. The volatilized ³⁵S contamination often shows as contamination on freezers, incubators, centrifuges and rubberized products.

Radiolytic breakdown may occur during freezing processes, releasing as much as 1 µCi of ³⁵S per 8.0 mCi vial of ³⁵S amino acid during the thawing process. Place an activated carbon or charcoal canister, absorbent sheet, or tray (50-100 grams of granules evenly distributed in a tray or dish) into an incubator to passively absorb ³⁵S vapors. Discard absorbers in the solid radioactive waste.

³⁵S labeled amino acids (methionine, cysteine, and translabelled) appear to have a volatile radioactive component. There is some indication that the amount of volatilization is amino acid dependent, with ³⁵S-cysteine being less volatile than ³⁵S-methionine.

It is believed that the ³⁵S contamination is due to either SO₂ or CH₃SH and that the volatile component is water-soluble. This may lead to equipment contamination.

Recommendations for Researchers Using ³⁵S Amino Acids to Reduce Potential Contamination Due to Volatility:

- Thaw ³⁵S amino acids in a fume hood. Use a needle and rubber septum to aliquot the material. If multiple experiments are going to be conducted using the same stock solution, partition the entire stock solution at one time to eliminate multiple thaw/freeze cycles with the stock vial.
- Store aliquots in screw top tubes (example: NUNC tubes VWR Catalog).
- Consider incorporating charcoal paper into the procedure. Line incubators and storage boxes with activated charcoal paper.
- Change the incubator water after each labeling.
- Remember to survey yourself, and work area thoroughly after using ³⁵S amino acids or any radioactive material.

9. Laboratory Surveys

The Radiation Protection Office conducts random monthly surveys of all radiation laboratories. However, one of the most important components of any radiation protection program is the laboratory's own surveys. These surveys, conducted by the radiation user, are required after every use of radioactive material to eliminate residual radiocontamination that could inadvertently cause radiation exposure.

¹ When a fresh 8 mCi vial of ³⁵S-methionine is thawed without a lid in a large open container, approximately 0.01% was released. This may be due to product breakdown during freezing (a physiochemical breakdown). There also appears to be some volatilization when ³⁵S amino acids are initially introduced to cell culture medium at 37 C. This may indicate that the release is not metabolic in nature.

9.1 Requirements for Laboratory and Personal Surveys

The Radiation Protection Office requires two types of contamination surveys be performed after each use of radioactivity. A personal survey should be conducted after using radioactive material and before leaving the work area. A personal survey is a meter survey in which you check yourself for contamination. Check your labcoat, shoes, face, hair, and gloves to make sure you are not contaminated. If you detect any personal contamination, immediately contact the Radiation Protection Office at (617) 495-2060.

Once you have completed a personal contamination survey, survey your work area and equipment used during the experiment. Monitor nonradioactive (laboratory and biohazard) trash containers to ensure that radioactive waste is not improperly disposed of in these waste streams. Check the benchtop, floor, cabinets nearby, etc. for contamination. Unless you are using ^3H or other very low energy beta emitter, a meter survey is sufficient. If you are using ^3H , perform a wipe test survey and keep a copy of the liquid scintillation printout.

If you use 1 mCi or more of a beta-gamma emitter or 1 μCi of alpha emitters, record the survey results on a [Personal Survey Form](#) (Appendix E).

<i>Table 3</i>					
<i>Radionuclide Instrumentation Selection</i>					
<i>Radionuclide</i>	<i>Emission</i>	<i>Energy (MeV)</i>	<i>Detector</i>	<i>Probe</i>	<i>Pancake GM Efficiency* at 1 cm</i>
^3H	beta	0.0186	LSC	N/A	Not Detectable
^{14}C	beta	0.156	Survey meter	Pancake GM Probe	1% - 5%
			LSC	N/A	N/A
			LSC	N/A	N/A
^{32}P	beta	1.709	Survey meter	Pancake GM Probe	20% - 25%
^{33}P	beta	0.249	Survey meter	Pancake GM Probe	7% - 10%
			LSC	N/A	N/A
^{35}S	beta	0.167	Survey meter	Pancake GM Probe	3% - 8%
^{45}Ca	beta	0.257	Survey meter	Pancake GM Probe	6% - 8%
^{51}Cr	gamma	0.320	Survey meter	Pancake GM Probe	1% - 2%
^{60}Co	gamma	1.17, 1.33	Survey meter	Pancake GM Probe	< 1%
^{125}I	gamma	0.035	Survey meter	NaI	<0.01 %
^{131}I	gamma, beta	0.364	Survey meter	Pancake GM Probe, NaI	< 1%

* Low energy betas may not be detectable if the probe window is covered with paraffin film, plastic wrap, or other protective material. The efficiency for higher energy betas will be substantially reduced with any covering.

9.2 Meter Function Tests

Check the batteries and make sure the instrument is responding to radiation before using a radiation survey meter. At background conditions, a properly functioning Geiger Mueller probe should read about 30 cpm and a sodium iodide probe around 500 cpm. Periodically check the cable connecting the probe to the electronic package. With prolonged use, this cable may become defective, giving either no reading or false high readings even in the absence of a radiation field.

9.3 How to Perform a Meter Survey

With the appropriate probe, a meter survey is conducted by slowly passing the probe over the area or object to be surveyed. Be certain to survey at a constant speed - approximately 5 cm/sec. The distance from the surface or object should also be constant. A distance of 1 cm is suggested. Be careful not to contaminate the probe.

All readings should be recorded. Be certain to record readings as "net" (actually reading - background reading).

9.4 Selection and Use of a Survey Meter

Each portable radiation survey instrument has different detection capabilities. There are 3 common categories: Geiger-Muëller, scintillation, and ionization chambers. Typically, labs do not use an ionization chamber. Choose the hand-held survey meter or instrument as appropriate for the radionuclide from the Table 3.

In general, for betas, choose a pancake probe (preferable) or at least a Thin Window Geiger-Muëller detector.

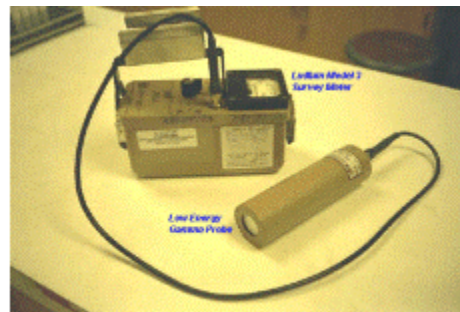


General Purpose Survey Meter with GM Probe

Geiger-Muëller Detector

The Geiger-Muëller (GM) probe is the most common radiation detection instrument on campus. In this meter, radiation detection causes both visual and audio responses. The meter detects radiation events and does not differentiate types of energies or radiation. The GM does is only used to detect radiation and does not measure radiation dose. The most common GM is a Pancake Probe, as shown below with a survey meter.

The GM probe has a thin 'window' at one end that is very fragile. This probe is used for detecting beta emitters (e.g. ^{32}P , ^{35}S , and ^{14}C). However, low energy beta emitters such as ^3H are not detectable since they do not have enough energy to penetrate the window. Instead use a liquid scintillation counter. ^{14}C and ^{35}S emit betas energetic enough to pass through the thin window. Examples of GM probe efficiencies (approx.) under ideal conditions are listed in the table.



Survey Meter with Scintillation Probe

Low energy betas may not be detectable if the probe window is covered with paraffin film, plastic wrap, or other protective material. The efficiency for higher energy betas will be substantially reduced with any covering. Because radioactive decay is random, the meter reading, at low count rates, often fluctuates widely. For this reason, the audio speaker is sometimes a better indicator of small amounts of radioactivity. At higher count rates, the speaker response is often faster than the meter reading. It is better, therefore, to have the speaker on and the response set to fast, "f", on the f/s switch, when using a survey meter to look for contamination. Once contamination is found, switch to slow ("s") response to measure the count rate.

Scintillation Detector/Probe

Scintillation detectors absorb radiation and emit light that is converted into a radiation measurement. There are two types of scintillation detectors a hand-held instrument and a liquid counting system.

The Liquid Scintillation Counter (LSC), is used to detect low energy emitters (^3H , ^{14}C , ^{35}S , and ^{125}I) and can be use to count contamination removed by wipe samples.

A scintillation probe is used on survey meters like the Ludlum 3 for low energy



photons (gamma-rays (^{125}I) and x-rays less than 40 keV). The efficiency of a low energy scintillation probe (shown right) for the detection of ^{125}I is about 30-35%.

Ionization Chamber

Ionization chambers are suitable for measuring radiation exposure rate or cumulative radiation exposure. This instrument is not recommended for use in labs to detect contamination.

9.5 Wipe Tests

A wipe test is simply a check for contamination that can be removed from a surface that is transferred on to a piece of filter paper or paper towel. With a gloved hand, rub the paper over the area to be tested. Typically, one would do an area about 100 cm². For a quick assessment, one can check this paper with a GM (for high energy beta). For a more complete analysis, use a liquid scintillation counter. Prepare the sample for the liquid scintillation counter by placing the filter paper in a liquid scintillation vial with a sufficient quantity of environmentally-safe scintillation cocktail, and count in a liquid scintillation counter. It is also necessary to establish a background level. To do this, follow the above procedure using an unused filter paper. Please be certain that the liquid scintillation counter is set up to count all the isotopes that are used in your laboratory. The amount of contamination is the difference between the wipe test actual and the background counts.

9.6 Radiocontamination Limits

To minimize the potential for accidental personal contamination or cross contamination of experiments, the RPO sets low radioactive contamination limits low. In practical terms, this means that detectable contamination should be promptly cleaned. With the typical laboratory survey instrument reading out in counts per minutes, a sample reading that is more than 100 CPM above background should be decontaminated. Be sure that no loose contamination, as measured by a wipe test, is left on surfaces. The contamination limits presented in Table 4 are guide values that the laboratory should use to ensure compliance with Commonwealth regulations. The contamination limits presented in Table 3 are guide values that the laboratory should use to ensure compliance with Commonwealth regulations.

	Alpha Contamination		Beta/Gamma Contamination	
	Total (dpm/100 cm ²)	Removable (dpm/100 cm ²)	Total	Removable (dpm/100 cm ²)
Lab Use Areas such as benches	1,000	50	5,000 (dpm/100 cm ²) 0.25 (mR/h)*	1,000
Skin and personal clothing	100	Non-detectable	1,000 (dpm/100 cm ²) 0.1 (mR/h)*	Non-detectable
Release of areas or materials after recorded survey	100	20	5, 000 (dpm/100 cm ²) 0.1 (mR/h)*	1,000
[#] Radiation Protection Office may use different criteria depending on the application.				
* is measured at 1 cm above the contamination.				

10. Radioactive Materials Incidents

10.1 Responsibilities in a Radioactive Materials Incident

A radioactive materials incident is any event that involves a loss of control over radioactive material and must be promptly reported to the Radiation Protection Office. Examples of these incidents are:

- Missing radioactive material;
- Unmonitored release of radioactive materials to the environment;
- Unexpected or unmonitored airborne release of radioactive materials;
- Malfunction of a radiation device or radiation generating device;
- Exposure to a radiation field in excess of 25 mR/h;
- A spill of radioactive materials that contamination exceeds the limits in [Section 9.6](#);
- Receipt of a contaminated package;
- Personal contamination;
- A fire or flood involving radioactive materials.

In general, response to radiation incidents should minimize any additional radiation exposures or contamination, notify others of the radiation hazard, secure the area, contact the Radiation Protection Office at (617-49)5-2060, and await further instructions from the Radiation Protection Office.

All radiation users are responsible for reporting radiation incidents to the Radiation Protection Office. The individual user and laboratory, through the Permit Holder, are responsible for remediating a radiation incident. To ensure effective remediation and compliance with policy and regulation, the Radiation Protection Office may direct the response and provide additional staff.

10.2 Response to a Spill

A spill of radioactive materials is when radioactive material contaminates an area or equipment not directly associated with the experiment. Proper preparation and training before work with radioactive materials should minimize both the risks and impacts of spills. Laboratories should be equipped with spill response supplies such as paper towels, cleaning agents, extra radioactive waste bags and gloves. The laboratory's initial response should follow guidance for the acronym SPILL:

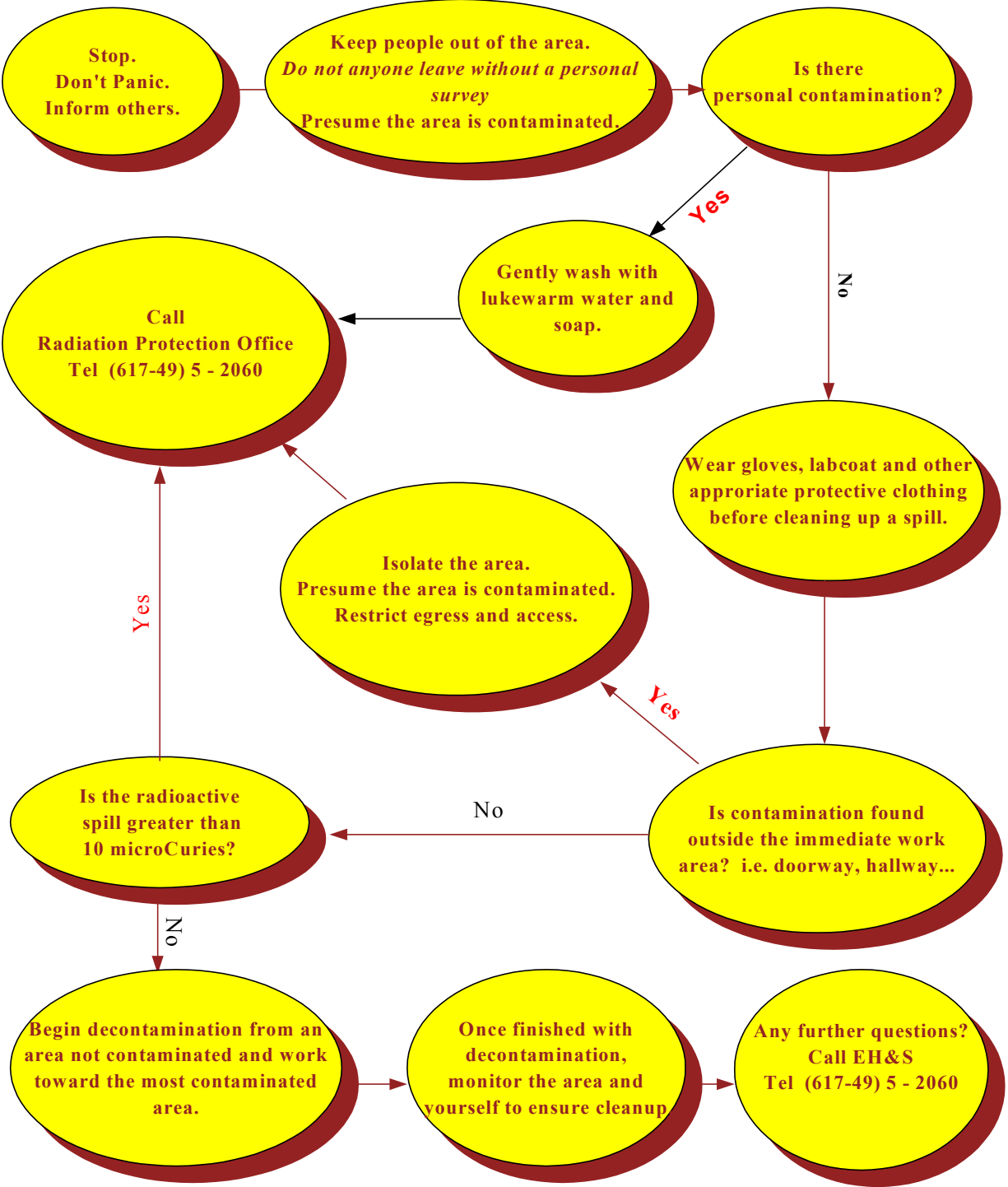
Stop ... **working - get your thoughts together and don't panic**
Presume ... **everything is contaminated until proven otherwise**
Inform ... **others about the spill**
Localize ... **the spilled material to contain the spill**
Label ... **or cordon off the area to limit access**

Cleanup of a radioactive materials spill shall begin immediately after the initial response listed above. To clean up a spill follow these instructions and the Spill Response [Flowchart \(Figure 4\)](#):

1. Prevent the spread of contamination. Do not panic, but stop what you are doing. Presume the area is contaminated. Inform others of the situation and restrict access to the area.
2. Survey for personal contamination. Remove any contaminated clothing. Call the RPO if there is:
 - a) Contamination on skin.
 - b) Activity of the spill is greater than 10 μ Ci.
 - c) The spill is outside of the immediate work area.

- d) The spill covers a large area or volume.
3. Wear your dosimeter and the proper protective equipment: gloves, laboratory coat, eye protection, booties, before attempting spill clean up.
 4. Survey the contaminated area. Mark the perimeter of the spill and any isolated spots.
 5. Thoroughly clean by wiping the contamination with dampened paper towels working from the perimeter towards the center of the spill. Cleaning solutions such as: Dow™ "Scrubbing Bubbles", Windex™, Fantastic™, or 409™ are generally as effective as Count-off™ or RadiacWash™.
 6. Dispose of contaminated paper towels in the corresponding radionuclide's radioactive waste container (e.g. for cleaning up ^{32}P contamination...throw contaminated paper towel in the ^{32}P waste container).
 7. Once finished with the decontamination, survey the area to make sure that have returned to background levels. Perform an extensive personal survey. Take your time in surveying your hands, shoes, laboratory coat, pants and your face.

Spill Response Flow Chart
What to do in case of a radioactive material spill



10.3 Personnel Contamination

Through the proper use of protective clothing and contamination control, the risks of skin contamination, ingestion, or inhalation are low. Due to the nature of the radioactive materials used, the radiation energy is usually deposited in a very localized area and may result in high localized doses, especially to the skin. Any case of personal contamination requires prompt attention.

To remove skin contamination, gently wash with mild soap and luke warm water. When washing, be careful not to redden or abrade the skin. If the material is not completely removed within two or three washings, contact the Radiation Protection Office.

If you have reason to believe that someone may have inadvertently ingested or inhaled radioactive materials, immediately contact the Radiation Protection Office for bioassay instructions.

10.4 Volatile Material and Airborne Releases

Work with volatile or potentially volatile radioactive materials should be done in a properly functioning fume hood to minimize inhalation potential and must be reviewed with the Radiation Protection Office before beginning work (refer to [Section 8](#) for additional guidance).

If you are working with radioactive materials that accidentally volatilize:

- Hold your breath;
- Cover spill, if possible, to minimize airborne release;
- Turn on the hood if it is not already on;
- Shut off all general ventilation, heating and air-conditioning equipment that could transport contaminated air from the laboratory to other parts of the building
- Evacuate the laboratory, closing the doors behind you;
- Secure the laboratory area and do not let anyone enter;
- Seal doors with tape, if there could be significant leakage of airborne material into the corridor (for example, if there is no net flow of air into the room because hoods are inoperative).
- Immediately contact the Radiation Protection Office.

11. Contaminated Clothing

Monitor all potentially contaminated clothing and determine that it is free of contamination before releasing it to a commercial general laundry. Clean any isolated contaminated areas on protective clothing by topical methods to below allowable release limits in [Section 9.6](#).

If clothing is contaminated with levels higher than those listed in [Section 9.6](#), the article of clothing can be disposed of as radioactive waste stored for decay in the laboratory. If you choose not to dispose of the clothing as radioactive waste, contact the Radiation Protection Office for guidance and assistance.

12. Minimizing Exposures (ALARA)

ALARA is a basic principle of working with radioactive materials and the University has established an ALARA Plan ([Appendix B](#)). This principle refers to keeping doses and releases as low as reasonably achievable. Therefore, the goal is to keep any exposures as far below the limits as possible. Follow these principles to minimize your radiation exposures:

Pre-Work:

- Order and use only the amount of radioactive material necessary to perform experiments.
- Dry-run: Try the experiment without radioactive material first to familiarize yourself with the experiment and equipment.
- Wear protective clothing:
 - **Laboratory Coat**
 - **Gloves**
 - **Protective Glasses/Goggles**
- Do not wear open-toed sandals or shoes in the laboratory.
- Contamination Prevention: Work in designated radioactive materials areas on benches covered with an absorbent liner.

While Working:

- When working with liquids be aware of the potential for splashes, splatters or spills;
- Store stock solutions in secondary packing when not in use, such as the plastic container used for shipping;
- Clean loose and removable contamination;
- Minimize time spent near radioactive materials;
- Keep as much distance between yourself and the radiation source(s) as possible;
- Use shielding to maintain radiation exposures as low as possible. Consider shielding needs of others who may be behind or next to your experiment;
- Use shielding appropriate for the radionuclide that you are using, notice the penetration abilities in Figure 5. An effective shield should provide protection in all directions. Place the radioactive material close to the shield to maximize the "shadow area" (area where radiation is blocked out by the shield in Figure 6) cast by the shield are protected;
- Do not use lead with high energy beta radiation (e.g. ^{32}P) because it will cause secondary radiation that is more penetrating x-ray type radiation;
- For beta radiations, use low atomic number materials such as plastics, Lucite, Plexiglas, and glass. For gammas, use lead foil (roof flashing) or thin lead sheets (for ^{125}I);
- Survey shielding to ensure proper placement;
- Survey materials and equipment before removing it from the work area.

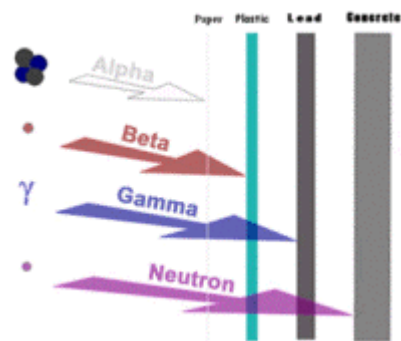


Figure 5
Radiation Penetration Abilities

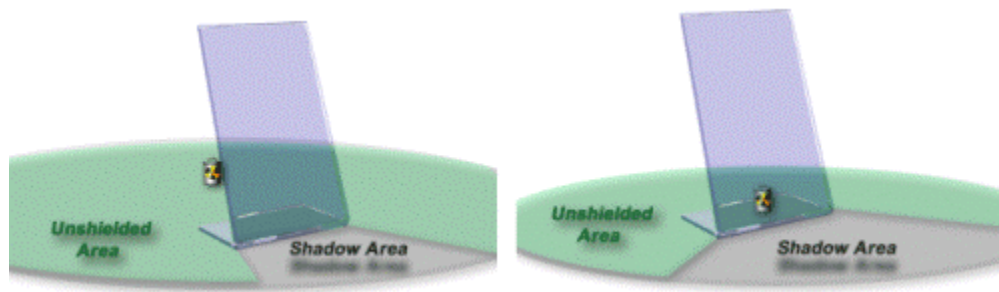


Figure 6
Proper Shield Setup

Post-Work:

- Minimize and properly dispose of radioactive waste in the appropriate labeled radioactive waste container;
- Store radioactive material (stock material, waste) as far as practical from the working area and behind sufficient shielding;
- Secure all radioactive materials;
- Perform a comprehensive post-experimental and personal survey;
- Wash hands before leaving the area.

13. Bioassay Requirements

Bioassays are measurements of radioactivity in the body and are used to assess radiation dose from ingestion, inhalation or absorption. Bioassays also can be a valuable means of testing the effectiveness of control procedures for unsealed sources. The Radiation Safety Committee has adopted a [Bioassay Plan](#) (see Appendix C) that establishes monitoring criteria that is in concert with the ALARA Plan.

Bioassays are required when a person uses above a certain level of radioactive material in a period of time or if a person was involved in a contamination event. If a

Table 5 Recommended Bioassay Levels when using liquids on the open bench		
Isotope	Physical Form	Recommended Bioassay Level (mCi / month)
¹⁴ C	Liquid	1,700
³ H	Liquid	670
¹²⁵ I	Volatile	0.33
¹³¹ I	Volatile	0.25
³² P	Liquid	500
³³ P	Liquid	2,500
³⁵ S	Liquid	1,700
³⁵ S	Volatile Forms such as Methionine, cysteine or trans-labeled ³⁵ S	170

person uses more than the amount of radioactivity listed in Table 5, a bioassay is required within one week. The Radiation Protection Office will determine the appropriate bioassay method for the radionuclide, using the guidance of the International Commission on Radiation Protection.

14. Radioactive Materials in Experimental Animals

14.1 General Responsibilities

Work with radioactivity in an animal is jointly managed by the Animal Resource Center (ARC) and the Radiation Protection Office. All users need to obtain authorization from both the Animal Resource Center and the Radiation Safety Committee for the particular protocol before research begins. The Permit Holder is responsible for ensuring radiation safety, conducting radiation surveys and radioactive waste disposal. Through the authorization process, the Permit Holder will address and resolve animal care and posting requirements and the training, monitoring and protective clothing for Animal Resource Center staff. Contact the ARC staff at (617-43)2-2185 for information on use of animals in research.

14.2 Animals Housed in Central Facilities

Animal Resource Center requires that all animals be housed in central facilities. Special arrangements may be made, under limited conditions to house animals in a laboratory, contact the Animal Resource Center for requirements.

14.3 Animals Housed in the Laboratory

The Animal Resource Center requires that animals be housed in central facilities. As a result, the Animal Resource Center requires prior approval for any animal that would be housed outside of the Animal Resource Center. This prior approval will include detailed procedures for animal care and will address waste disposal and cage decontamination or replacement. When an animal is housed in the laboratory, the Permit Holder is responsible for comprehensive care of the animal as well as all radiation safety aspects.

14.4 Special Radiation Considerations

Use trays lined with absorbent material when injecting animals with radioactive materials.

Label all cages housing animals injected with radioactive materials, showing the radionuclide involved, the amount injected per animal, the date of injection and authorized user's name and telephone number. Put a "Caution -- Radioactive Materials" label on the cage. Segregate these cages from those of other animals.

Provide adequate ventilation in areas where animals are kept if they have been injected with radioactive material that may be volatilized and dispersed following excretion or exhalation.

Treat all cages, equipment used and rooms housing the animals as contaminated until a recorded survey has demonstrated otherwise.

Provide animal handlers with written instructions on radiation control measures and safety precautions, and animal, bedding and excreta handling requirements.

Do not discard needles in radioactive waste. Handle needles as biohazard, sharp/needle hazard and post the waste container as radioactive.

Use the sewer to dispose of animal excreta, unmixed with sawdust or wood shavings, if the calculated activity does not exceed the quantity listed in [Table 6](#). Otherwise, the excreta must be absorbed with absorbent material, placed in plastic bags and disposed of through the RPO.

Place animal carcasses in heavy black plastic bags, at least 4 mil thick, labeled to indicate the radionuclide, quantity, user, date and department, and store in a secured freezer in a room that is listed on the Permit before disposal through the RPO.

15. Radioactive Waste

Waste disposal is very expensive and a strictly regulated process. Regulation involves not only the Commonwealth of Massachusetts Department of Public Health, which issues the University's License, but the U. S. Department of Transportation, which regulates the transport of radioactive materials on public highways, and the U. S. Environmental Protection Agency. On the state level, the Department of Environmental Protection and the Department of Public Health regulate how the University disposes of radioactive materials. The storage and handling of radioactive wastes are also of concern to the Governing Boards of the University, the local Fire Department and members of the public who live near University waste handling and storage facilities. To ensure compliance with regulations and to minimize releases of radioactivity to the environment, the University requires that users of radioactive materials follow very carefully the procedures prescribed in this chapter for packaging, labeling and processing of waste materials.

By careful experimental design, following appropriate working procedures and cleaning up slightly contaminated materials, it is often possible to dramatically reduce the volume of waste requiring disposal as radioactive. Monitor waste material and dispose of only the contaminated parts as radioactive. Use short-lived radioactive materials whenever possible. Doing so will systematically reduce waste disposal costs and make it easier to manage the laboratory radiation safety program.

The costs of disposal methods vary widely. Disposal at a commercial low-level radioactive waste disposal facility is by far the most expensive option. Where possible, segregate and package waste so that alternative methods can be used. Collect separately solid radioactive wastes with half-lives of less than 180 days for placement in the University decay storage facility where the waste will be stored until the radioactivity is insignificant. Also package separately liquid scintillation vials for shipment by an authorized broker to incinerators authorized by the EPA and the NRC to burn the waste.

15.1 General Responsibilities

Do not discard non-radioactive materials as ordinary laboratory trash or as other non-radioactive hazardous waste such as biohazard or hazardous chemical wastes.

Minimize the disposal of nonradioactive materials in radioactive waste.

Minimize the production of radioactive waste and the cost of disposal -- for example, by using materials with short half-lives.

Restrict sink disposal to sinks registered with the Radiation Protection Office. Ensure that the disposal is within [authorized limits](#) listed in Table 6, the wastes are water soluble and records of disposals are kept.

Follow instructions for packaging and labeling radioactive wastes.

Control volatility of liquid radioiodine wastes by adding a solution of 0.1 M sodium hydroxide, 0.1 M sodium iodide and 0.1 M sodium thiosulfate. Do not freeze sodium iodide because the freeze/thaw cycle will increase the release of volatile components. Do not store volatile wastes under flow cabinets or biological safety cabinets or any other place where air may be recirculated.

15.2 Managing Non-Radiological Hazards

To meet requirements of various state and federal laws, the Radiation Protection Office will not accept radioactive waste that contains hazardous wastes, untreated biological pathogenic or infectious wastes or improperly packaged sharps.

The Radiation Protection Office does not normally approve of procedures that generated mixed chemical and radioactive waste. If it is possible that an experiment will generate an EPA classified hazardous waste, carcinogen, reproductive toxin or other toxic material, contact the Radiation Protection Office before carrying a experiment to determine proper waste disposal options.

Treat wastes containing hazardous biological, pathogenic or infectious materials with a chemical disinfectant such as bleach or Wescodyne[®] or autoclave to inactivate the hazard. For more information contact the Biological Safety Office. Before autoclaving radioactive waste and consider [volatility issues](#) for radioiodine and ³⁵S products because of the potential for contaminating equipment and releasing radioactive vapors.

Sharps and broken glass need to be packaged in a RPO-approved container to protect those who may be handling the waste.

Needles contaminated with radioactive materials must be properly treated for any biological hazard and packaged in an approved needle container using a method approved by the Biological Safety Office. Place the needle container in a clear plastic bag provided by the RPO with a properly completed radioactive waste tag.

15.3 Preparing Radioactive Waste, General Guidelines

The RPO has established procedures to ensure that wastes are disposed of in the least expensive way that will meet regulatory requirements. To assist users in preparing radioactive wastes, the RPO provides the typical supplies (such as bags, plastic bottles, labels and tags) that are required for disposal. The laboratory may need to provide specialty containers and supplies; the specification for these materials will be determined by the RPO to meet disposal and safety requirements. It is important to separate short and longer-lived materials so that the shorter-lived wastes can be stored only as long as necessary for radiation to decay to background levels.

Maintain a running estimate of the total radioactivity placed in a waste bag. The activity should be a reasonable estimate of the amount placed into waste.

Minimize mixed radiological and hazardous wastes. If the radioactive waste contains a hazardous material, follow hazardous as well as radiological waste preparation standards. Contact the Radiation Protection Office for disposal instructions for mixed wastes.

Treat all waste for non-radiological hazards before packaging as radioactive waste. Non-radiological hazards include broken glass, needles, unabsorbed liquids and hazardous chemicals.

Control volatility as appropriate for the radionuclide.

Deface radioactive material symbols, labels and markings before disposal in radioactive waste. Labels may be torn off, scratched or painted with a spray can or marker so that they cannot be identified.

Package lead separately for pick-up by the Radiation Protection Office.

Segregate waste by radionuclide (³²P, ¹²⁵I, ¹⁴C, ³⁵S, ³H) and physical characteristics (e.g., solid waste, absorbed liquids, scintillation vials, sharps, etc).

Complete a radioactive waste tag for every radioactive waste package as shown in Figure 7.

If the material is to be brought to the RPO wasteroom or truck, place the bag in a secure container, such as a 10-gallon steel pail that is labeled with a radioactive material warning sign.

15.3.1 Dry Radioactive Wastes

Package solid waste sorted by radionuclide, excluding iodine and animal carcasses, in clear, 4 mil plastic bags provided by the RPO. Double bag iodine or other volatile waste in individually sealed 4 mil clear plastic bags. Place animal carcasses into 4 mil black plastic bags. Seal the waste in the plastic bags using tape around the twisted bag.

Place sharps such as broken glass and pipettes in an RPO approved sharps-container that is individually packaged in a clear plastic bag.

Place needles in an approved needle container and individually package in a clear plastic bag.

Residual liquids from test tubes and eppendorf tubes may be included in dry radioactive waste if there is sufficient absorbent (such as paper towel) to fully absorb twice the liquid waste volume.



Figure 7
Completing a Radioactive Waste Tag

15.3.2 Liquid Radioactive Wastes

Absorb nonflammable, pH neutral (5.5 to 9.5) aqueous radioactive wastes, other than liquid scintillation media in RPO approved containers.

Place organic liquid in non-breakable containers appropriate for the material without absorbent. Disposal instructions for these wastes are determined on a case-by-case basis by the RPO and are usually identified in the RPO's experimental review process. If beginning a new of different experiment that will generate organic or hazardous materials in radioactive wastes consult the RPO before starting the experiment.



Minimize volatility of liquid radioiodine wastes by adding a sodium metabisulfite solution (0.1M sodium hydroxide, 0.1 M sodium thiosulfate, and 0.1 M sodium iodide).

Store any flammable liquid radioactive waste in a flammable materials storage cabinet; contact the RPO for disposal instructions.

15.3.3 Uranium and Thorium Wastes

While uranium and thorium may be purchased as a nonradioactive material, they must be disposed of as radioactive waste.

Place unused chemical stock materials, in the original container, in a clear 4 mil plastic bag.

Place unabsorbed liquid uranium and thorium wastes in a tightly-capped plastic bottle that is placed into a clear 4 mil plastic bag.

Place gloves, absorbent materials and other dry solid materials in a clear plastic bag.

Secure the plastic bag with a properly completed radioactive waste tag as shown in Figure 7.

15.3.4 Liquid Scintillation Media

Use only high flashpoint (above 141 F), nontoxic, nonhazardous liquids scintillation media. Refer to [Appendix F](#) for a list of RPO approved cocktails.

Segregate scintillation vials by radionuclide (^3H and ^{14}C may be placed in one bag). For vials that contain only ^3H and ^{14}C segregate those with an activity of less than 0.05 μCi per milliliter (less than about 100,000 disintegrations per minute per vial).

Tightly cap scintillation vials and pack in vial-boxes that are sealed in a 4 mil plastic bag or double bag in 4 mil plastic bags with no more than 200 full sized or 400 mini-vials per container.

Bulk scintillation fluids, such as that from flow-through counters, may be collected in one gallon or smaller plastic or plastic safety coated glass containers.

List the manufacturer and product name of the liquid scintillation media on the radioactive waste tag.

15.3.5 Radioactive Biological Waste

Biological waste includes animal and animal-related wastes from experiments involving radioactive materials. This waste may contain carcasses, animal bedding, specimens contained in vials or other containers that have been properly treated for nonradiological hazards. This waste may not contain active biological hazards or sharps, see [Section 15.2](#) for treatment.

Place carcasses, absorbent and tissues in 4 mil opaque black plastic bags provided by the RPO. Remove all tissue samples from containers such as a plastic bottle or test-tube before disposing as radioactive waste. Very small amounts of paper, plastic and other non-animal wastes may be placed into this bag.

Place animal bedding in clear 4 mil plastic bags.

Refrigerate biological wastes in a room that is on the Permit while awaiting pickup by the RPO.

15.4 Radioactive Waste Storage

Store radioactive waste prior to pick-up in tight containers away from work areas and conventional trash. Post the container with radioactive materials and multi-language "Do Not Empty" signs. Where necessary, use additional shielding around or as part of the container design to minimize personnel exposure (e.g. Lucite for beta emitters, lead for gamma emitters).

15.5 Sink Disposal

Radioactive material may be disposed of only in approved sinks, and in quantities below the daily sink disposal limits in [Table 6](#). Dispose of any unused radioactive chemicals and/or original source material through the Radiation Protection Office if the material is still radioactive. For disposal of trace amounts and washings, observe the following conditions:

Use a sink approved and registered by the Radiation Protection Office for radioactive waste disposal that is posted with a "Caution-Radioactive Material" sign.

Record each such disposal on a [Radioactive Material Sink Disposal Log](#) (refer to Appendix E) that is posted near the sink. Record the date of each disposal, a reasonable estimate of the maximum activity discharged, and the initials of the individual making the disposal.

Use sink disposal only for material that is readily soluble or dispersible in water and not hazardous. There are many approaches that may be used to determine a chemical compound's solubility in water. If the chemical form of all materials contained in the liquid waste is known, it is possible to use either a solubility class or formal solubility to determine if the material is soluble in water.

15.5.1 Solubility Class Determination

The solubility can be determined directly from most any chemistry or physics handbook. If:

- The classification of the chemical compound is "vs" (very soluble) or "s" (soluble),
- the chemical compound is "**readily soluble**".
- The classification of the chemical compound is "i" (insoluble), "sls" (slightly soluble), or "vsls" (very slightly soluble), the chemical compound is "**not readily soluble**".
- The decomposed (classified as "d" (decomposed)) species of these compounds are either "vs" or "s" the parent compound is "**readily soluble**". If these decomposed species are simple ions then they (class d) should be considered "**readily soluble**".

The compound may be sink disposed if the class is vs, s or readily soluble.

Table 6
Daily Sink Disposal Limits
(in μCi^*)

^3H	1,000
^{14}C	100
^{22}Na	10
^{24}Na	10
^{32}P	10
^{35}S	100
^{36}Cl	10
^{42}K	10
^{45}Ca	10
^{51}Cr	1,000
^{55}Fe	100
^{59}Fe	10
^{60}Co	1
^{64}Cu	100
^{65}Zn	10
^{75}Se	10
^{82}Br	10
^{86}Rb	10
^{90}Sr	0.1
^{109}Cd	10
^{111}In	10
^{125}I	1
^{131}I	1
^{198}Au	100
^{201}Tl	100
$^{46}\text{Sc}^*$	10
$^{85}\text{Sr}^*$	10
$^{95}\text{Nb}^*$	10
$^{103}\text{Ru}^*$	10
$^{113}\text{Sn}^*$	10
$^{114}\text{In}^*$	10
$^{141}\text{Ce}^*$	100
$^{153}\text{Gd}^*$	10
Not Specified	0.1

* If the nuclide is on a microsphere, the values is 0.

15.5.2 Formal Solubility Determination:

If the **formal solubility** of a compound is greater than **0.003 mole/liter**, then the compound is "**readily soluble**". Anything else is classified as "**not readily soluble**".

Formal solubility, S_f is given by:

$$S_f = \sqrt{(K_{sp} / m^m a^a)}$$

$$K_{sp} = [M]^m [A]^a$$

Where: K_{sp} is the solubility product (the equilibrium constant that describes the reaction by which a precipitate dissolves in pure water to form its constituent ions),
 $[M]$ is the molar concentration of the metal ion (cation),
 $[A]$ is the molar concentration of the anion,
 m is the number of moles of dissolved cation per mole of dissolved substance, and a is the number of moles of the dissolved anion per mole of dissolved substance.

Do not discharge more material into the sink each day than the amounts given in [Table 6](#), unless otherwise authorized by the Radiation Protection Office. Flush the sink thoroughly with water, continuing until the material is washed from the sink.

The RPO will collect the sink disposal logs and compile records on releases to the environment, as required by Federal, Local and State regulations.

15.6 Waste Transfer to Radiation Protection Office for Disposal

The Radiation Safety technician will monitor waste packages received from the user to determine if the waste meets disposal criteria or if there are any inconsistencies between the declared contents of containers and the radiation measurement. If discrepancies cannot be resolved, the waste cannot be accepted for disposal; it is the laboratory's responsibility to ensure proper record keeping, treatment, labeling and packaging.

16. Laboratory Record Requirements

The Permit Holder is required to maintain laboratory specific records and to make those readily available to laboratory staff, RPO and regulatory inspectors. These records include:

- **Receipt, use and transfer of radioactive materials.** Complete a Radioactive Material Inventory Form (referred to [Appendix E](#)) for each sealed source or stock bottle. Record the amount of radioactivity, that date, and the user for each removal of material from a stock bottle. If radioactive material is transferred to another Authorized User within the University, record his/her name, the radionuclide and activity transferred and date of transfer on the inventory form for a stock material or bought and other suitable record for samples. If radioactive material is transferred out of the University, maintain records of the RPO approval, name and institution of the recipient, the radionuclide and activity transferred and date of transfer. Keep these records for at least three years.
- **Inventory** The Authorized User is responsible for maintaining a current inventory at all times and for providing a written inventory to the RSC every six months at the request of the RPO. This inventory will include the radionuclide, physical form, amount of radioactivity, and location. Keep these records while the source/bottle is in the laboratory. Inventory sheets may be disposed of six months after the source is disposed of.

- **Personal and area surveys** are required whenever 1 mCi or more of an unsealed radioactive material is used. This record may be included in a laboratory notebook and must be immediately available on request. A sample Personal Survey Form is included [Appendix E](#). Keep these records for at least three years.
- **Dosimetry and Bioassay Records** will be provided to the Permit Holder who will make them available to laboratory staff. The laboratory should keep these records for one year. Original copies are retained by the RPO.
- **Sink disposal** records must be maintained of each disposal. Post these records at or near the sink so they may be reviewed and collected by the RPO. The RPO will maintain the required record after collection from laboratory.
- **Waste disposal** records will be maintained for each disposal. These records will be recorded on a radioactive waste tag and transferred to the RPO for recordkeeping.
- **Authorization to work with radioactive materials** - the Authorized User is responsible for maintaining a copy of his/her Permit to use radioactive materials and informing users of its requirements.
- **Radiation surveys by the RPO** should be retained by the Permit Holder for one year.
- **Iodination Logs**. A record of all iodinations and required surveys will be maintained on an Iodination Log (refer to [Appendix E](#)). These records are kept by the Authorized User for at least three years.

17. Sealed Sources and Irradiators

Sealed sources are radioactive materials encapsulated or enclosed to prevent leakage and may be in the form of disks, foils, seeds, wires or welded capsules. Sealed sources must meet the regulatory requirements of the Nuclear Regulatory Commission or the Commonwealth of Massachusetts Radiation Control Program. Small sealed sources may be used for bench level experiments or calibration standards and may be included in laboratory instruments such as liquid scintillation counters and gas chromatographs. Large sealed sources are often used to irradiate materials and are called irradiators.

17.1 General Responsibilities

Unlike unsealed sources, sealed sources do not present contamination problems unless integrity of the source has been damaged. However, the sources are usually larger and may present a significant exposure hazard. To control these hazards, purchase sealed sources that have been approved by the Nuclear Regulatory Commission. Maintain documentation of that approval.

Before ordering or receiving a sealed source, obtain approval from the RPO for the specific source and use-location.

Irradiators have substantial facility requirements that must be reviewed by a structural engineer and the RPO before purchase and installation.

Ensure that the sealed source is leak tested and inventoried by RPO within five days of receipt.

Be aware of environmental issues that may lead to degradation of the source encapsulation such as corrosive atmospheres, liquids, solvents or pressures.

Minimize rubbing and abrading the surface of alpha emitting sources which may damage the source. sources designed to emit alpha radiation have the radioactive material electroplated onto a surface. As a result, the alpha radiation source can be removed by abrasion.

All users must successfully complete the RPO's sealed source or irradiator training, as appropriate and laboratory-based training specific to the source and experimental techniques.

Store sealed sources in a secure location where only people authorized to use the source have access. If the sources removed from this area, it must be at direct supervision of a properly trained sealed source user.

Post storage locations for sealed sources and irradiators with a "Caution Radioactive Materials" sign.

Notify the RPO if a sealed source is lost or damaged, may have or could have caused an exposure in excess of 100 mrem, or is leaking.

17.2 Leak Testing

The RPO will conduct a leak test of all sealed sources and irradiators every six months, except sources designed for emitting alpha radiation which will be tested every three months.

17.3 Source Use Guidelines

The primary safety consideration for working with sealed sources is external radiation exposure. Safety measures should minimize your radiation exposure:

- Wear a whole body radiation monitor when working with any sealed source.
- Wear a finger ring when handling any sealed source greater than 1 mCi.
- Minimize both extremity and whole body radiation exposures. Review the radiation exposure rate near the source from laboratory, manufacturer or RPO references.
- Use remote handling tools when handling sealed sources that are in excess of 10 mrem per hour at 1 inch.
- Verify that radiation levels in areas accessible to members of the general public are less than 1 mrem per hour.
- For alpha emitting sources, verify which side of the source is active before handling. Be aware that handling the active side of the source or placing tape on it may irreparably damage the source or lead to area or personal contamination.

Additional considerations for irradiators:

- Record each use in the instrument's use log.
- Verify that all interlocks, control mechanisms, and safety warning devices are operational before each use. Discontinue use and notify the RPO of failure of any of the safety systems.
- Ensure that emergency procedures, determined through the permitting process, are posted at or near the irradiator's control panel.

IV X-ray Producing Equipment

1. General X-ray Considerations

Research and medicine uses many types of x-ray equipment including analytical, medical, dental, fluoroscopic, veterinary, cabinet systems and electron microscopes. All radiation generating devices such as x-ray machines must be registered with the Radiation Protection Office (RPO). The device is registered by [obtaining a Permit](#) issued by the RPO. This Permit specifies the Authorized User, usually a Faculty Member, use restrictions and approved machine operators. All operators, except for electron microscope users, must register with the RPO and receive training before using any x-ray equipment. Training and permitting is required to ensure that the user is aware of the hazards posed by the high radiation intensities of these beams.

While these devices produce a large amount of radiation in a small diameter beam, it is readily shielded and protected from causing human exposure. The common x-rays used in diffraction and fluorescent x-ray spectroscopy are in the range of 0.5 to 10×10^{-1} m. With this low energy or wavelength, the intensity of these x-rays can be easily reduced by a factor of ten with a thickness of only a few mm of Al, Fe, or Pb. This is the principle that is used to create the common Cu Ka x-ray used in x-ray crystal radiography. It is the ability of these radiations to be readily absorbed in tissue that poses the for radiation safety problems, especially because of the intense beam; see Biological Effects of Acute Radiation Exposures below.

Regulations² vary according to the type of x-ray equipment. As a result, guidance is given by machine type. The RPO will classify the equipment at the time of permitting to determine the regulatory and safety requirements.

2. Biological Effects of Acute Radiation Exposures as Related to X-ray Systems

With a properly functioning machine, there is little risk of radiation exposure. However, one should know the signs of an acute exposure to a localized area of the human body. These symptoms are shown in [Table 7](#). Be aware that these effects can be

caused by contact with the beam for only a fraction of a second. Typical primary beam exposures are 100,000 to 400,000 rad per minute.

The most common effect from a large radiation exposure from an x-ray device is reddening of the skin (erythema). With a

dose of a few hundred rem the superficial layers of the skin are damaged and the skin will redden in a fashion similar to but more complex than a sunburn. The erythema effect will most often reverse itself within a few weeks. It is also possible that doses on this level could damage cell division and temporarily stop hair growth and possibly cause the hair to fall out. With a low enough dose, hair growth should return. There could also be damage to the sebaceous glands that produce the skin oil, which could cause a temporary decrease in the amount of oil produced.

Received Dose	Symptoms
200 - 300 rad to the skin	Erythema (redness of the skin). The area may turn red within two to three weeks after the exposure depending upon dose. Epilation (hair loss) is possible within two to three weeks.
1,000 to 5,000 rad to the skin	Wet or dry blisters within one to two weeks of exposure that usually break open and are subject to infection. Epilation may be permanent.
Over 5,000 rad to the skin	Severe transepidermal injury that resembles intense scalding or chemical burn with the immediate onset of pain. Epilation is permanent.
Above 200 rad to the eye	There may be conjunctivitis (inflammation of the eye). It is possible that chronic exposures may lead to cataract formation.

² MA Department of Public Health, Radiation Control Program, 105 CMR 120.000.

There are other less common and less transitory responses. If a large area is exposure to a large amount of radiation, there could be changes in the skin pigmentation. This effect may not be reversible and could result in permanent skin changes. If the exposure is large the transitory damage to the skin, skin hair, or sebaceous glands could cause skin scarring or lead to Radiation Dermatitis, Chronic Radiation Dermatitis, or radiation induced skin cancer. To protect yourself from the radiation consider the following potential sources of radiation exposure:

1. The primary beam.
2. Primary beam leakage from poor shielding or guide tube replacement.
3. Beam penetration through stops and shutters.
4. Secondary radiations from beam interaction of the primary beam with the sample or shielding.
5. Radiation released from the diffraction of the beam.
6. Radiation produced from support equipment such as power supplies.

3. Analytical x-ray

The predominant x-ray-producing equipment used in research is analytical x-ray. It produces intense beams of low-energy x-rays. Exposure to the direct beam can cause severe injury. To prevent exposures, newer instruments are designed with hood enclosures, interlocks and beam shielding to minimize the risk of inadvertent exposures. It is possible that the radiation exposure rate from the primary beam can be up to 40,000 Roentgen per minute. With this high exposure rate, the hazard is not limited to the primary beam, but can also be related to leakage or scatter radiation. As result, these x-ray machines should not be modified without the authorization of the RPO. A radiation survey should be done whenever a new sample is placed in the beam, the beam is diffracted, experimental setup changed or equipment is replaced.

The analytical x-ray machines usually have a low energy that can be readily shielded with about 1 mm of lead. Due to the intensity of the primary beam, leakage and scatter may create a significant source of unwanted radiation. Use shutters and collimators, secure unused ports, reduce the beam cross-section by collimation, and whenever appropriate enclose the entire beam path or use a sufficient beam stop. Consider additional sources of x-rays from miscellaneous support equipment such as high-voltage supplies.

3.1 Dosimetry

All equipment operators are required to wear ring and whole body dosimeters. While equipment is designed to keep exposures to a minimum it is possible that unusual events such as the alignment for sample manipulation could lead to inadvertent exposures. These operations should never be attempted without appropriate safety precautions.

3.2 Training

All users must attend the RPO Radiation Users Training Session and must also be provided specific written instructions by the Permit Holder before using the equipment. These instructions include notice of radiation hazards; machine specific safe work practices; and symptoms of acute, localized exposure to radiation.

3.3 Postings

The following document should be placed near the controls of each analytical x-ray unit and readily accessible to the operator:

- Specific written instructions
- Analytical x-ray Emergency Procedure

- Symptoms of Injury from Acute Local Exposure to Radiation
- Radiation Hazards from Analytical x-ray Units
- Safe Working Practices for Analytical x-ray

3.4 Labels

Analytical x-ray equipment will be posted and labeled with:

A label bearing the words "Caution Radiation This Equipment Produces Radiation When Energized" near the tube activation switch.

A sign "Caution High-Intensity x-ray Beam," next to each tube-head. The sign must be clearly visible to any person operating, aligning, or adjusting the unit or handling or changing a sample.

A posting on the exterior side of the room's doors indicating the presence of x-ray producing equipment such that visitors to the lab will see the sign.

3.5 Indicators

All x-ray machines will contain an operational and clearly visible indicator of an active x-ray beam near the x-ray tube. In addition, there must be a shutter status indicator that unambiguously reports if the shutter is open or closed.

3.6 Interlocks and Safety Devices

Operational interlocks and safety devices will be provided to ensure that the primary x-ray beam can not be interrupted by any portion of an individual's body or extremities or by machine equipment under any operating condition. If the beam is interrupted, this interlock will shut off the primary beam.

Interlocks and safety devices may not be altered without the written authorization of the RPO. Approved temporary modifications must be terminated as soon as possible, specified in writing and posted near the x-ray machine tube and operators console.

Securely close any unused tube ports to prevent accidental opening.

3.7 Analytical X-ray Emergency Procedure

If there is a suspected or actual case of accidental radiation exposure, turnoff the system power and notify the RPO immediately. If required, exposed individuals should go to the University Health Services Urgent Care Clinic to seek medical attention.

3.8 Safe Working Practices for Analytical x-ray Equipment

3.8.1 Beam Alignment

1. Wear a finger dosimeter.
2. Whenever available, use electronic alignment.
3. Use long handles on the fluorescent alignment screens.
4. Only a trained and qualified user should do an alignment.

5. If safety locks must be bypassed, first gain RPO approval and then post a sign indicating the safety switch status. Reinstate the safety switch as soon as possible.
6. Use the lowest power settings possible for beam alignment procedures.

3.8.2 Sample Changing

Ensure the x-ray beam is inactive by using a radiation detector.

Use the shutter to stop x-rays. Verify shutter activation and that the shutter indicator is properly reporting shutter status.

3.9 General Operation

To ensure the safety of users and visitors of x-ray equipment, follow the safe-use requirements in the x-ray [Diffraction/Fluorescence General Safety Protocol](#).

4. Cabinet X-ray Systems

A cabinet x-ray system is a x-ray system where the x-ray tube is enclosed in a structure that contains the irradiated material, provides radiation shielding, and excludes people.

4.1 Operating and Emergency Procedures

Since cabinet x-ray systems are designed to exclude people, they are exempt from many of the regulations that apply to other x-ray devices. However, these devices must be [registered with the RPO through a Permit](#) and have written operation and emergency procedures that are approved by the RPO. These devices must follow the guidance listed in [X-ray Cabinet General Safety Protocol](#).

These documents must specify:

- a. User training.
- b. Use records and records maintenance.
- c. Security of the x-ray system when not in use.
- d. Biological effects of ionizing radiation (refer [Table 7](#) and Radiation Protection³).
- e. Radiation hazards associated with the x-ray system.
- f. Safety practices.
- g. Procedure for notifying proper supervisory personnel in the event of an emergency and instructions to obtain medical assistance.
- h. Maintenance and repair procedures.
- i. Dosimetry requirements.

³ Radiation Protection, Jacob Shapiro, Harvard University Press, 1990.

5. Electron Microscope Systems

An electron microscope system is an x-ray system where the x-ray tube is enclosed in a structure that contains the irradiated material, provides radiation shielding, and excludes people.

Each microscope shall bear the following labels:

- Place a label bearing the words "Caution--Radiation--This Equipment Produces Radiation When Energized" near any switch that energizes a tube.
- Place a sign with the words "Caution--High-Intensity x-ray Beam," adjacent to each tube head so it is clearly visible to anyone operating, aligning, or adjusting the unit or handling or changing a sample.

5.1 Operating and Emergency Procedures

Since electron microscopes are designed to exclude people, they are exempt from many of the regulations that apply to other x-ray devices. However, these devices must be [registered with the RPO through a Permit](#) and have written operation and emergency procedures that are approved by the RPO. These devices must follow the guidance listed in the [Electron Microscope General Safety Protocol](#).

These documents must specify:

- a. User training.
- b. Use records and records maintenance.
- c. Security of the x-ray system when not in use.
- d. Biological effects of ionizing radiation (refer to [Table 7](#) and Radiation Protection⁴).
- e. Radiation hazards associated with the x-ray system.
- f. Safety practices.
- g. Procedure for notifying proper supervisory personnel in the event of an emergency and instructions to obtain medical assistance.
- h. Maintenance and repair procedures.
- i. Dosimetry requirements.

⁴ Radiation Protection, Jacob Shapiro, Harvard University Press, 1990.

V Laser Safety

1. Introduction

A laser emits a highly collimated monochromatic beam of extremely intense electromagnetic radiation when energized. This radiation is emitted over a wide range of the electromagnetic spectrum from the ultraviolet region through the visible to the infrared region. The range of commonly available lasers is from 200 nanometers to 10.6 micrometers. Laser radiation may be emitted as a continuous wave or in pulses.

Lasers produce radiation that may damage the eyes and the skin through heat absorption. In the ultraviolet region laser damage may be induced by photochemical effects. The potential hazards depend upon the type of laser, the wavelength and the uses of the laser system.

The laser safety program aims to prevent injury by helping the user identify, evaluate and control potential hazards. This manual discusses potential hazards and injuries lasers can cause, precautions to avoid these injuries and the administrative and regulatory resources available to assist Permit Holders and laser users. Laser safety terms are defined in [Appendix M](#).

1.1 Recognizing Potential Laser Radiation Hazards

Laser users encounter many hazards in the use of a laser. Unless the user takes active precautions to minimize these hazards, there can be significant effects, see [Appendix N](#) for a personal account of a laser accident.

1.2 Beam Hazards

The direct beam (Figure 1), diffuse reflection (Figure 2) or specular reflection (Figure 3) from a laser can damage the eye and skin. Direct intrabeam exposures and specular reflections from class 3b and 4 lasers may blind people, burn their skin, and set fires. Diffuse reflections from class 4 lasers may also cause these hazards.

Eye: Corneal or retinal burns are possible from acute exposure. The location and extent of injury depends on the wavelength and laser classification. Corneal opacities (cataracts) or retinal injury may be possible from chronic, as well as acute, exposures to excessive levels of either visible or invisible laser radiation. Eye hazards are easily controlled by using laser safety eyewear that is appropriate for the specific laser system, or by other engineering safety controls.

DIRECT INTRABEAM EXPOSURE

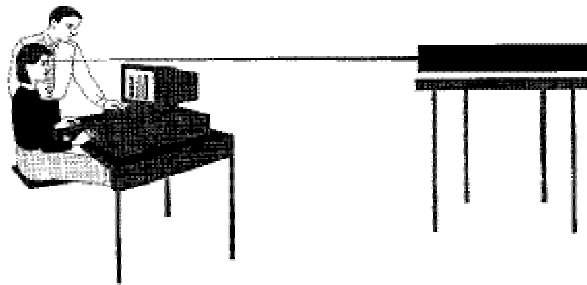


Figure 1 Direct Intrabeam Exposure to a Laser Beam

DIFFUSE REFLECTION

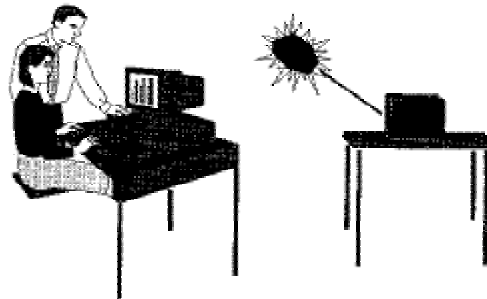


Figure 2 Diffuse Reflection of a Laser Beam

Skin: Skin burns are possible from acute exposure to high levels of laser radiation, especially in the infrared region. Erythema (skin reddening), skin cancer, and accelerated skin aging are possible effects in the ultraviolet wavelength range. Shielding the beam and reflections or covering the skin with opaque materials will help prevent skin effects.

Fire: Combustible material such as research logs and cardboard boxes can be ignited by the beam. Other potential fire hazards include electrical components and the flammability of Class 4 laser beam enclosures. The risks of fire can be reduced by using only fire resistant materials near radiation beams and scatter of class 4 lasers.

1.3 Electrical Hazards

Potentially lethal electrical hazards may be accessible in a laser system, especially in high-powered lasers. High voltage components such as power supplies and discharge capacitors may present an electrical hazard. Work with energized electrical equipment requires implementation of the Harvard University [Lock-out Tag-out Program](#).

1.4 Hazardous Chemicals

Some material used in laser systems, especially gases and chemical solutions, may be hazardous or toxic substances. In addition, laser induced reactions may produce hazardous particles or gases around the laser system.

Solvents used in dye lasers may be extremely flammable and ignited by high voltage components or flash lamps. Direct beams and unforeseen visible or invisible specular reflections, as shown in Figure 3, of high-powered infrared lasers are capable of igniting combustible materials during laser operation.

1.5 Other Hazards

Cryogenic laser coolants, excessive noise from high powered systems, and x-radiation from high-voltage power supplies may also be hazardous.

1.6 Hazard Controls

The hazard controls necessary for the safe use of laser radiation depend upon the:

- [Laser classification](#);
- Environment where the laser is used;
- Laser operating characteristics;
- Laser operator; and
- General population within the vicinity of the laser.

Laser safety procedures can best be described by the laser class. [Appendix O](#) provides a list of appropriate control measures for each laser classification.

Review of incidents demonstrates that accidental eye and/or skin exposures to laser radiation, and accidents related to the ancillary hazards of a laser or laser system happen with:

- Unanticipated eye exposure during alignment;

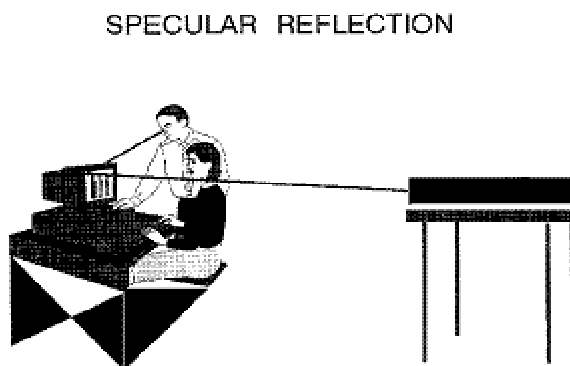


Figure 3 Specular Reflection of a Laser Beam

- Misaligned optics;
- Not wearing eye protection;
- Equipment malfunction;
- Improper handling of high voltage;
- Intentional exposure of unprotected personnel;
- Operator unfamiliar with laser equipment;
- Lack of protection for ancillary hazards;
- Improper restoration of equipment following service;
- Inadvertent beam discharge; and
- Insertion of flammable materials into beam path.

2. Laser Program Responsibilities

2.1 Radiation Protection Office

The [RPO](#) provides services to assist the Permit Holder in maintaining a comprehensive laser safety program. These services include:

- Registration of all Class 3b and 4 lasers and laser users;
- Re-registration of lasers and laser users every two years;
- Initial and annual laser safety [inspections](#);
- Coordination of baseline eye examinations (see [Appendix P](#) for the Harvard University policy for laser eye exams);
- Recommendations for appropriate laser safety eyewear required prior to laser system use, (see [Appendix Q](#) for recommended vendors);
- Initial laser safety training seminars for laser users; and
- Retraining of laser users every two years.

2.2 Permit Holders

Each Laser Permit Holder is responsible for:

- [Registration](#) of all Class 3b and Class 4 laser systems with RPO;
- Biennial re-registration of all Class 3b and Class 4 lasers;
- Participating in periodic RPO laser safety [inspections](#);
- Sending laser users to RPO-provided laser safety seminars before initial use and every two years;
- Providing permit specific training and procedures including experiment-specific and equipment-specific safety precautions for individual laser users before the individual uses any laser;
- Posting required laser warning signs as shown in [Appendix R](#);
- Ensuring the operability and use of safety systems such as interlocks and warning indicators;
- Developing and posting standard operating procedures which include safety practices for all Class 3b and Class 4 lasers;
- Providing the necessary equipment and work environment for the safe use of the permit's lasers;
- Informing the RPO of: any new lasers, significant changes in the current laser use, and new users, and
- Implementing all laser safety requirements described in this program and prescribed by the RPO, with particular emphasis on wearing laser protective eyewear and on following standard operating procedures, especially for [beam alignment](#).

2.3 Laser Users

Each registered laser user is responsible for:

- Complying with all requirements of the Harvard University Laser Safety Program including obtaining a [laser eye examination](#) before working with a laser;
- Wearing [appropriate laser eyewear](#) as necessary;
- Conducting all laser activities in accordance with the posted standard operating procedures and accepted good safety practices, and
- Attending initial laser safety training and biennial retraining.

2.4 Laser Registrations

All Class 3b and Class 4 lasers must be [registered with the RPO](#). The Permit Holder must complete and submit the registration form to the RPO. The registration will include Standard Operating Procedures including necessary safety requirements, for all Class 3b and Class 4 lasers. Upon receipt of the completed registration form, the RPO will conduct a laser safety inspection. See [Appendix O](#) for a list of items covered during a laser safety inspection.

2.5 Laser Safety Training and User Registration

Anyone working with Class 3b and Class 4 lasers is required to register with the RPO, complete a baseline laser eye exam, and receive RPO and lab-specific laser safety training before using a laser. The RPO will maintain a record of laser user registrations.

Class	Hazard Capabilities
1	Cannot produce hazardous radiation.
2	Continuous intrabeam exposure damages the eye. Momentary intrabeam exposure (<0.25 seconds) is not damaging to the eye. Applies to visible radiation only.
2a	Continuous intrabeam exposure damages the eye. The accessible radiation shall not exceed Class 1 accessible emission levels for an exposure duration <10 ³ seconds.
3a	Eye damage may occur if the beam is viewed directly or with optical instruments.
3b	Eye and skin damage will occur for direct, momentary intrabeam exposure.
4	Can damage the skin as well as the eye during direct, momentary intrabeam exposure or exposure to diffuse reflections. May be a potential fire hazard.

2.6 Laser Classifications

Lasers are classified based on the American National Standards Institute (ANSI) laser hazard classification system in publication ANSI Z136.1, Safe Use of Lasers. Laser manufacturers have been required to label the Class of their products since September 19, 1985 (21 CFR Part 1040). Specifications on the appropriate eyewear for a specific laser may be obtained from the manufacturer at time of purchase or from the RPO. Table 8 summarizes the laser classification scheme and the hazard capabilities associated with each class of laser.

3. Eye Protection and Maximum Permissible Exposures

Laser irradiation of the eye may cause damage to the cornea, the lens or the retina, depending on the wavelength of the light and the energy absorption characteristics of the ocular media. Lasers cause biological damage by depositing heat energy in a small area, or by photochemical processes. Infrared, ultraviolet, and visible laser radiation are capable of causing damage to the eye. [Table 9](#) summarizes the various tissues at risk for different spectral regions.

3.1 Retinal Damage

Visible and Infrared A (Spectral Regions 400-760 nm and 760-1400 nm)

Visible and infrared A wavelengths penetrate through the cornea and are focused on a small area of the retina, the fovea centralis (see Figure 4). The focusing process as the laser light passes into the eye greatly amplifies the energy density and increases the potential for damage. Lesions may form on the retina as a result of local heating of the retina subsequent to absorption of the light.

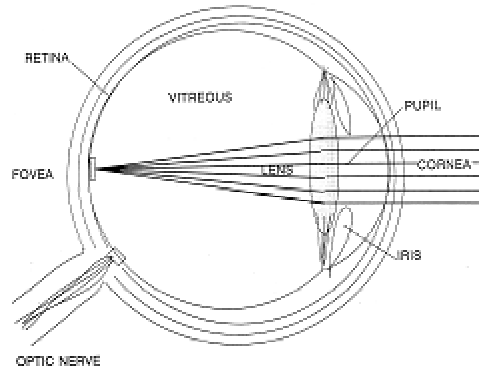


Figure 4 Ocular Absorption of Visible Light and infrared

3.2 Lens Damage

Ultraviolet A (Spectral Region 315-400 nm)

Wavelengths in this spectral region are primarily absorbed in the lens (see Figure 5). Damage to this structure, either photochemical or thermal, disrupts the precise relationship between the tissue layers of the lens. This results in areas of increased light scatter - a cataract. Under normal conditions, the lens will begin to harden with age. Exposure to UV-A accelerates this process and may lead to presbyopia (the loss of the ability of the lens to accommodate or focus).

3.3 Corneal Damage

Infrared B and Infrared C (Spectral Region 1.4 to 100 μm)

The cornea is opaque to infrared radiation (see Figure 6). The energy in the beam is absorbed on the surface of the eye and can overheat the cornea. Excessive infrared exposure causes a loss of transparency or produces a surface irregularity on the cornea.

Ultraviolet B and Ultraviolet C (Spectral Region 100-315 nm)

The cornea is opaque to ultraviolet radiation. As with infrared radiation, the energy of the beam is absorbed on the surface of the eye (see Figure 6). Excessive ultraviolet exposure results in photokeratitis (welder's flash), photophobia, redness, tearing, conjunctival discharge, and stromal haze. There is a 6-12 hour latency period before symptoms to photochemical damage appear.

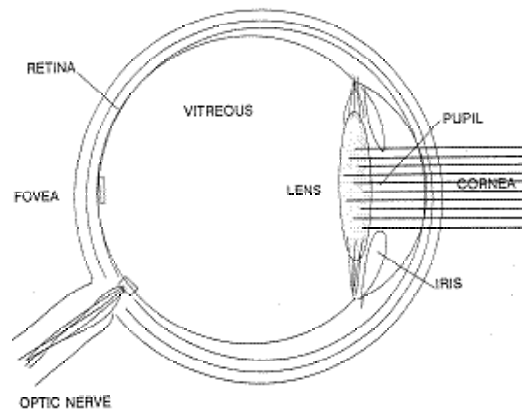


Figure 5 Ocular Absorption of Infrared B, Infrared C, Ultraviolet B and Ultraviolet C

3.4 Other Ocular Damage

There are two transition zones which can damage both the cornea and the retina. These are located at the bands separating UV-A and visible light, and the IR-A and IR-B regions. An example of this hazard would be the Nd:YAG laser in the IR-A region. This wavelength can be focused but not perceived by the eye. As a result, the retina can be damaged in the same manner as visible light even though the beam itself is invisible.

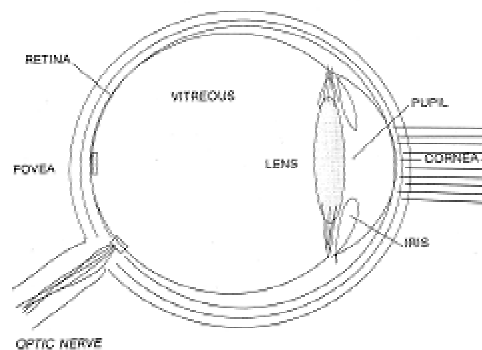


Figure 6 Ocular Absorption of Ultraviolet A

4. Maximum Permissible Exposure (MPE)

Maximum permissible exposure limits have been recommended by the American National Standards Institute (ANSI Z136.1-1999) on the basis of retinal damage thresholds and light concentration by the lens. The MPE values for visible light are based on a pupil diameter of 7 mm, which is considered the maximum opening of the eye's iris. For other wavelengths, the incident laser energy is averaged over a 1 mm diameter. The MPE values are less than known hazard levels. However, exposures at MPE values may be uncomfortable to view. It is good practice to maintain exposure levels as far below the MPE values as practical.

	Wavelength	Principal Tissue at Risk
Ultraviolet C	100 - 280 nm	Cornea
Ultraviolet B	280 - 315 nm	Cornea
Ultraviolet A	315 - 400 nm	Lens
Visible Light	400 - 760 nm	Retina
Infrared A	760 -1400 nm	Retina
Infrared B	1.4 - 3.0 μ m	Cornea
Infrared C	3.0 - 1000 μ m	Cornea

5. Protective Eyewear

ANSI Z136.1 requires that protective eyewear be worn whenever hazardous conditions may result from laser radiation or laser related operations. These glasses attenuate the intensity of laser light while transmitting enough ambient light for safe visibility (luminous transmission). The ideal eyewear provides maximum attenuation of the laser light while transmitting the maximum amount of ambient light. No single lens material is useful for all wavelengths or for all radiation exposures. In choosing protective eyewear, careful consideration must be given to the operating parameters, MPEs, and wavelength. To minimize confusion, protective eyewear shall be marked with its protective rating such as effective wavelength and optical density. The RPO will specify the appropriate laser safety eyewear during the laser registration process. A list of laser safety eyewear manufacturers can be found in [Appendix Q](#).

For lasers operating in the visible region, laser alignment glasses are available which provide acceptable protection during reduced power alignment procedures while allowing a fraction of the beam to be seen. Appropriate eyewear information for a particular laser is available from the manufacturer or the RPO. The RPO will evaluate protective eyewear requirements during safety inspections.

It is extremely important that laser users wear the appropriate laser safety eyewear correctly. For example, only eyewear such as goggles specifically designed to fit over prescription glasses may be worn with prescription glasses. Other protective eyewear worn over prescription glasses may not provide complete eye protection. When wearing eyewear be aware that it is possible to be caught from behind by a reflected laser beam.

6. Skin Exposure

Acute exposure of the skin to large amounts of laser energy may cause skin burning that is similar to thermal or radiant burns. The incident radiation is converted to heat that is not dissipated rapidly enough due to poor thermal conductivity of the tissue. The resulting local temperature rise causes tissue protein denaturation. Skin injury depends on the wavelength of laser light, exposure time, and degree of skin pigmentation. Skin carcinogenesis may occur at some specific ultraviolet wavelengths (290-320 nm).

7. Safety Precautions

7.1 Electrical Hazard

Laser systems include a substantial amount of electrical equipment and related high voltage supplies. Precautions should be taken to minimize the risk of electrocution and other laser-related electrical accidents. Contact Environmental Health and Safety (EH&S) at (617-49)5-2060 if you have any electrical safety questions. To minimize the electrical shock risks:

- Avoid wearing rings, metallic watchbands and other metallic objects;
- When possible, only use one hand when working on a circuit;
- Assume that all floors are conductive when working with high voltage;
- Check that each capacitor is discharged, shorted and grounded before allowing access to the capacitor area;
- Inspect capacitor containers for deformities or leaks;
- Provide safety devices such as grounding sticks, insulating mats and appropriate rubber gloves;
- Do not work alone;
- Do not work on live electrical equipment without specific approval that is included in the laser permit; and
- Implement the requirements of the [EH&S lockout/tagout program](#), as required.

7.2 General Safety Procedures

Apply these safety precautions with any Class 3b or Class 4 laser:

- Work with or near only those lasers that you are trained, registered and authorized to use;
- Do not enter a room or area where a laser is energized unless authorized to do so;
- Position the beam path well above or below eye level. Be aware this varies with a person's height. Enclose as much of the beam path as possible;
- Verify that you are correctly using the proper safety devices for the unit before energizing any laser. These precautions may include opaque shielding, non-reflecting and/or fire-resistant surfaces, goggles and/or face shields, door interlocks, and ventilation for toxic material;
- Make sure that a pulsed laser unit cannot be energized inadvertently. Discharge capacitors and turn off power before leaving the laser unit unattended;
- Never look directly into the laser beam. Use appropriate eyewear during beam alignment and laser operation;
- Perform laser alignment procedures at lowest practical power levels;
- Control access to the laser facility. Clearly designate those who have access to the laser room. Lock the

- door and install warning lights and signs on the outside door;
- Never leave the laser unattended when it is in operation;
- Remove any jewelry (anything with a reflective surface including watches and belts with metallic buckles) to avoid inadvertent reflections;
- Securely fasten all mountings in the beam path (mirrors, prisms, beam stops, etc.). Securely fasten the laser itself;
- Use beam shutters and laser output filters to reduce the beam power when the full output power is not required;
- Keep extraneous items out of the beam path, particularly reflective objects which may cause specular reflections. Jewelry should not be worn while working with laser systems (see not above);
- Block optical cells and chambers before looking inside;
- Block the laser beam before placing new components into the beam;
- Clearly mark where a laser beam travels out of the horizontal plane and mount a solid stray beam shield above the area to prevent accidental exposure;
- Verify that the laser warning light is properly functioning when the laser is in operation.

8. Class-based Laser Safety Controls

8.1 Class 3b Controls

- Never aim the laser at an individual's eye;
- Permit only experienced personnel to operate the laser unsupervised;
- Enclose as much of the beam path as possible. Even a transparent enclosure will prevent individuals from placing their head or reflecting objects within the beam path.
- Use terminations at the end of the direct and any secondary beam paths;
- Place shutters, polarizers and optical filters at the laser exit port to reduce the beam power to the minimal useful level;
- Control spectators, the laser operator is responsible for their safety;
- Ensure that a warning light or buzzer indicates laser operation whenever the laser is active;
- Operate the laser only in a controlled area - for example, in a closed room without windows;
- Place a [laser warning sign](#) on the door to a laser area;
- Place the laser beam path well above or well below the eye level of any sitting or standing observers whenever possible;
- Always use [proper laser eye](#) protection if a potential eye hazard exists for the direct beam or a specular reflection;
- Install a key switch to minimize tampering by unauthorized individuals;
- Never view the beam or its specular reflection with optical instruments such as binoculars or telescopes without sufficient protective filters;
- Remove all unnecessary mirror-like surfaces from the vicinity of the laser beam path; and
- Do not use reflective or partially reflective objects such as credit cards and glossy objects to check beam alignment.

8.2 Class 4 Controls

In addition to the controls listed for Class 3b laser systems apply these additional controls to Class 4 lasers:

- Operate Class 4 lasers within a localized enclosure, in a controlled workplace, or where the beam is directed into outer space;
- Operate indoor laser in a light-tight room with interlocked entrances to assure that the laser cannot emit energy while a door is open if a complete local enclosure is not possible;
- Wear [appropriate eye protection](#) when working within the controlled area;
- Use a suitable shielding between the laser beam and any personnel or flammable surfaces if the laser

- beam irradiance is sufficient to be a serious skin or fire hazard;
- Use remote firing with video monitoring or other remote (safe) viewing techniques when feasible;
 - Use positive stops on the azimuth and elevation traverse on outdoor high-power laser devices such as satellite laser transmission systems and laser radar to ensure that the beam cannot intercept occupied areas or non-target aircraft;
 - Use beam shutters, beam polarizers, and beam filters and limit use to authorized personnel;
 - Shield flashlamps in optical pump systems to eliminate any direct viewing;
 - Use backstops that are diffusely reflecting, fire resistant target materials;
 - Use safety enclosures to contain hazardous reflections from the work area when microwelding and microdrilling work pieces; and
 - Minimize the risk of hazardous levels of laser radiation being reflected back through the optics by using microscopic viewing systems to study the work pieces.

9. Special Laser Safety Precautions

9.1 Beam Alignment

Literature clearly shows that most laser injuries occur during beam alignment procedures. These procedures require exact positioning of the beam, and too often those performing the alignment do not wear their laser protective eye wear. It is often the case, as well, that beam alignment accidents happen most often with visible beams. This is because beam alignment with infrared and ultraviolet lasers requires the use of indirect beam viewing, for example using IR or UV sensitive cards in the beam path, not the unprotected eye. People using visible beams are tempted to align objects with their unprotected eye.

Based on past [experiences related in literature](#), research laser users have a higher potential for injury, especially those working with visible beams and performing alignment procedures. Wearing laser protective eye wear can minimize the level of risk particularly during alignment procedures. To assist users who want to remove protective glasses while doing precision alignments, because the lenses filter out most of the beam, special alignment glasses are available for beam alignment. These glasses transmit a small percentage of the beam so it can be seen when it strikes targets, while filtering out the greater percentage of the beam which could cause injury. Laser users should use alignment glasses to prevent injury.

In some cases, alignment glasses will not work or may not be available and regular laser protective eye wear must be worn. With regular glasses, indirect beam viewing methods must be used since the beam will not be visible. To further complicate alignment in these cases, many lasers may have their beam intensity reduced during alignment procedures making it more difficult to view the laser with protective glasses. In some cases, this power reduction may allow alignment without laser protective eye wear, but **only** when the RPO verifies through calculations, or measurements or other methods to prove that the beam intensity is within an acceptable level. It is unacceptable to perform any laser work that may involve exposure in excess of the maximum permissible exposure limits without laser eye protection.

Refer to [Appendix S](#) for a comprehensive description of beam alignment safety practices.

9.2 High-Powered Pulsed Lasers

- Use safety interlocks at the entrance of the laser facility so unauthorized or transient personnel are denied access to the facility while the laser power supply is charged and capable of firing;
- Design laser electronic-firing systems so that accidental pulsing of a stored charge is avoided. The design should incorporate a fail-safe system;
- Use an alarm system including muted sound, flashing lights (visible through laser safety eyewear) and a countdown procedure once the capacitor banks begin to charge;
- Paint walls and ceilings with nonreflective paint to produce a diffuse surface. Diffuse black is preferred

- in the target area, and a light color in the surrounding area to maximize the lighting distribution from general lighting fixtures;
- Operate solid-state lasers by remote control firing with television monitoring, if feasible. This eliminates the need for personnel to be physically present in the same room. An alternative is to enclose the laser, the associated beam, and the target in an appropriate light-tight enclosure; and
 - Maintain good housekeeping.

9.3 Low Powered CW Gas and Semi-Conductor Laser Systems

- Aim lasers with great care to avoid specular reflection;
- Terminate a laser beam at the end of its useful beam path by a material that is a diffuse matte of such color or reflectivity to facilitate positioning but minimize reflection;
- Eliminate reflective material from the beam area; and
- Maintain good housekeeping.

9.4 Carbon Dioxide-Nitrogen Gas Lasers

CO₂-N₂ lasers require specific precautions to prevent accidental thermal burns and ignition of flammable materials because the output is invisible infrared radiation. These precautions should include:

- Exclusion of personnel from the path of the beam;
- Terminate the beam with materials such as firebrick;
- Construct the laser assembly of a material opaque to the ultraviolet light generated by the gas discharge;
- Control infrared laser beam reflections by enclosing beam and target area or, when necessary, require personnel to wear full-face shields. (Plexiglass face shields effectively attenuate CO₂ laser radiation); and
- Maintain good housekeeping.

9.5 Gas Lasers Using Chlorine or Fluorine

Users should be aware of the extreme toxicity of chlorine and fluorine gases. Concentrations as low as 0.1 ppm of fluorine are considered toxic. Gases should be stored in such a way as to ensure proper ventilation to minimize any hazardous effects.

10. Laser Incidents

In the event that a laser user suspects they have been exposed to excessive levels of laser radiation:

- Notify the Laser Permit Holder immediately;
- Notify the RPO immediately;
- Report to the Harvard University Health Services for an eye exam;
- File a laser incident report with RPO.

The RPO will investigate any suspected exposure to excessive levels of laser radiation and file a report to the Radiation Safety Committee. A copy of the report will be maintained in the laser Permit Holder's file.

References

Code of Federal Regulations. 10 CFR Part 20.

Massachusetts Regulations for the Control of Radiation, 105 CMR 120.

Shapiro, J., Radiation Protection. A Guide for Scientists and Physicians, Harvard University Press, Cambridge, Massachusetts, 1990.

Radiological Health Handbook. 1970. Washington, D.C.:GPO

Commonwealth of Massachusetts Radioactive Materials License issued to Harvard University.

U.S. Nuclear Regulatory Commission Regulatory Guide Series:

NUREG 0247. Principles and Practices for Keeping Occupational Radiation Exposure at Medical Institutions as Low as Reasonably Achievable.

Regulatory Guide 8.10, Operating Philosophy for Maintaining Occupational Radiation Exposures as Low as Is Reasonably Achievable.

Regulatory Guide 8.18, Information Relevant to Ensuring that Occupational Radiation Exposures at Medical Institutions Will Be as Low as Reasonably Achievable.

Regulatory Guide 8.23, Radiation Safety Surveys at Medical Institutions.

Regulatory Guide 10.8, Guide for the Preparation of Applications for Medical Programs.

Glossary

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

Agreement State - Any state with which the U.S. Nuclear Regulatory Commission has entered into an effective agreement under subsection 274b. of the Atomic Energy Act of 1954, as amended. Under the agreement, the state regulates the use of by-product, source, and small quantities of special nuclear material within said state.

Airborne Radioactive Material - Radioactive material dispersed in the air in the form of dusts, fumes, particulates, mists, vapors, or gases in any room, enclosure, or operating area in which concentrations of airborne radioactive materials either:

exceed the amounts specified in the Code of Massachusetts Regulation, 105 CMR 120.296 Appendix B, Table I, Column 3; or

averaged over the number of hours in any week during which individuals are in the area, exceed 25 percent of the amounts specified in Appendix B, Table I, Column 1.

ALARA - Acronym for "As Low As Reasonably Achievable". Making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken. It takes 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, societal and socioeconomic considerations, and in relation to utilization of radioactive materials and licensed materials in the public interest. See [ALARA Plan](#) for specific University details.

Alpha Particle - A positively charged particle ejected spontaneously from the nuclei of some radioactive elements. It is identical to a helium nucleus, with a mass number of 4 and a charge of +2.

Annual Limit on Intake (ALI) Annual intake of a given radionuclide by "Reference Man" which would result in either a committed effective dose equivalent of 5 rems or a committed dose equivalent of 50 rems to an organ or tissue.

Attenuation - The process by which radiation is reduced in intensity when passing through some material. It is the combination of absorption and scattering processes.

Ancillary Worker - Any individual who works in support of the laboratory operations and does not work with radioactive materials directly.

Authorization - The approval issued to an individual by the Radiation Safety Committee to use and supervise the use of radioactive materials.

Authorized User - The individual authorized by the Radiation Safety Committee to use and supervise the use of radioactive materials. Typically, the Authorized User is a senior investigator or faculty member who has the primary scientific, financial, and legal responsibility for a research program. The Authorized User may use the authorized radiation sources directly or, with the approval of the Radiation Safety Committee, may delegate the operational responsibilities to a Qualified User. The Authorized User has primary responsibility for radiation safety in facilities under his or her control.

Background Radiation - Radiation from cosmic sources; naturally occurring radioactive materials, including radon and fallout from nuclear weapons tests.

Beta (particle) - High speed electrons, which are emitted from the nuclei of radioactive atoms during radioactive decay, as a result of the transformation of a neutron into a proton. They can be stopped by a thin (thickness varies for different radionuclides) sheet of plastic or glass.

Becquerel - A unit, in the International System of Units (SI), of measurement of activity equal to one decay per second.

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

Biological Half Life The time that is required by an organism to eliminate half the amount of a substance that has entered it

Bremstrahlung - X-rays produced when a charged particle loses energy in interactions with heavy nuclei when moving through matter.

Calibration - The check or correction of the accuracy of a measuring instrument to assure proper operational characteristics.

Charged Particle - An elementary particle or ion which carries a positive or negative electric charge.

Committed Effective Dose Equivalent - The dose equivalent to organs or tissues of reference that will be received from an intake of radioactive material by an individual during the 50 year period following intake.

Contamination - The deposition of unwanted radioactive material on the surfaces of structures, areas, objects, or personnel. Can either be fixed or removable.

Counter - A general term used for a radiation detection instrument, survey meter, or a liquid scintillation counter (LSC) that detects and measures radiation. The signals (needle blip and audio beep) show ionization events called counts.

CPM (Counts Per Minute) - A commonly used measure of radioactivity from particle emitters; since a detection instrument cannot operate at 100% efficiency, the CPM found will be less than the actual DPM

Critical Organ - The organ receiving the highest dose or highest amount of a particular nuclide that results in the greatest damage to the body as a result of an intake.

Cumulative Dose - The total dose resulting from repeated exposures of radiation to the same region, or to the whole body, over a period of time.

Curie (Ci) - The basic unit used to describe the intensity of radioactivity in a sample of material. The curie is equal to 37 billion disintegrations per second, which is approximately the rate of decay of 1 gram of radium. Named for Marie and Pierre Curie, who discovered radium in 1898.

Decay, Radioactive - The decrease in the amount of any radioactive material with the passage of time, due to the spontaneous emission from the atomic nuclei of either alpha, beta particles, or gamma rays.

Declared Pregnant Worker - A woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

Decontamination - The reduction or removal of contaminating radioactive material from a structure, area, object, or person.

Deep Dose Equivalent - A term that applies to external whole-body exposure, and is the dose equivalent at a tissue

depth of 1 cm.

Deregulated Wastes - Wastes that have been designated by the Radiation Protection Office as eligible for handling and disposal as nonradioactive, according to the regulations of the Nuclear Regulatory Commission and the Commonwealth of Massachusetts.

Detector - A material or device that is sensitive to radiation and can produce a signal suitable for measurement or analysis. A radiation detection instrument.

Disintegration - See decay, radioactive.

Dose - A generic term referring to the amount of radiation received by a biological organism.

Dose Equivalent - The product of the absorbed dose in tissue, quality factor, and other modifying factors at the location of interest. The units are mrem.

Dose Rate - The ionizing radiation dose delivered per unit time, such as mrem/hour.

Dosimeter - A portable instrument for measuring the total accumulated exposure to ionizing radiation.

DPM (Disintegrations per Minute) - The number of radioactive disintegrations per unit time; there are $2.2E6$ disintegrations per minute in a microCurie (μCi)

Effective Dose Equivalent - The sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to each of the body organs or tissues that are irradiated.

Effective Half-Life - The time required for the amount of a radioactive element deposited in a living organism to be reduced by 50% from the combined removal mechanisms of radioactive decay and biological elimination.

Embryo/Fetus - The developing human organism from conception until the time of birth. More specifically; embryo: 2 weeks (implantation) - 8 weeks; fetus : 8 weeks - term.

Exposure - 1) A measure of the ionization produced in air by x or gamma radiation. The unit of exposure is the Roentgen (R). 2) Being exposed to ionizing radiation or to radioactive material.

Exposure Rate - The amount of ionization in air caused by x-ray or gamma ray radiation per unit time; unit of measurement is the Roentgen per unit time (R/hr)

External Dose - The portion of the dose equivalent received from radiation sources outside the body.

Extremity - Arm below the elbow and the leg below the knee.

Eye Dose Equivalent - Applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 cm.

Gamma Ray - Relatively short wavelength electromagnetic radiation released from the nucleus of an atom.

Geiger-Mueller Counter (GM) - A radiation detection instrument that can detect alpha, beta and gamma radiation; response is not energy dependent.

Half-life - The time in which half the atoms of a particular radioactive substance disintegrate to another nuclear form. Measured half lives vary from millionths of a second to billions of years. Also referred to as the physical half-life.

Half Value Layer - The thickness of any given absorber (shield) that will reduce the intensity of incident radiation to one half of its initial value.

Health Physics - The science concerned with recognition, evaluation, and control of health hazards from non-ionizing and ionizing radiation.

High Radiation Area - An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.1 mrem in 1 hour at 30 cm from the radiation source or from any surface that the radiation penetrates.

Intake - Quantity of material introduced into the body by inhalation, ingestion, or through the skin.

Internal Dose - That portion of the dose equivalent received from radioactive material taken into the body.

Ionization - The process of adding or removing one or more electrons from atoms or molecules. High temperatures, electrical discharges, or radiation can cause ionization.

Ionization Chamber - An instrument that detects and measures ionizing radiation by measuring the electrical current that flows when radiation ionizes gas in a chamber, making the gas a conductor of electricity.

Ionizing Radiation - Any radiation capable of displacing electrons from atoms or molecules, producing ions. Examples: alpha, beta, gamma, x-rays, neutrons, and ultraviolet light. High doses may produce severe skin or tissue damage.

Irradiation - Exposure to radiation.

Isotope - One of two or more atoms with the same number of protons, but different number of neutrons, in their nuclei. Example: ^{12}C , ^{13}C , and ^{14}C are isotopes of the same element. Isotopes have very nearly the same chemical properties, but often different physical properties (^{12}C and ^{13}C are stable, while ^{14}C is radioactive).

Limits - The permissible upper bounds of radiation doses.

Liquid Scintillation Counting - A method of determining activity of a radioactive sample using a liquid Fluor and a means of detecting the scintillation resulting from the interaction of radiation with the Fluor.

NaI (Sodium Iodide) Detector - A detector which combines a scintillation crystal (produces light when struck by ionizing radiation), a photomultiplier tube, and associated electronic circuits for counting light emissions produced in the crystal (NaI) by ionizing radiation. A NaI scintillation probe with a ratemeter can be used for detection of gamma and x-rays.

Nuclide - A general term referring to all known isotopes, both stable (~279) and unstable (~5000), of the chemical elements.

Occupational Dose - The dose received by an individual in a restricted area or in the course of employment in which the individual's assigned duties involve exposure to radiation and to radioactive material. This does not include dose received from background radiation, as a patient from medical procedures, from voluntary participation in medical research programs, or as a member of the general public.

Permit - Official document issued by the Radiation Safety Committee to the authorized user stating scope of the authorization to use radioactive materials and conditions of use.

Permit Holder - The individual to whom the Permit is issued by the Radiation Safety Committee.

Personnel Monitoring - The determination of the degree of radioactive contamination on individuals using survey meters, or the determination of radiation dosage received by means of dosimetry devices.

Physical Half Life - The time required for a radioisotope to reduce activity by half.

Pig - A container (usually lead) used to ship or store radioactive materials. The thick walls protect the person handling the container from radiation. Large containers are usually called casks.

Potentially Radioactive Materials - Any materials that could become radioactively contaminated as a result of laboratory work.

Proportional Counter - A radiation detection instrument in which an electronic system receives pulses that are proportional to the number of ions formed in a gas-filled tube/probe by ionizing radiation.

Quality Factor - The modifying factor that is used to derive dose equivalent from the absorbed dose. They vary for different radiation types and reflect the degree of biological effect.

Qualified User - An individual who through appropriate training and experience is qualified and authorized to work independently with radiation sources and to supervise such use by others. A Qualified User works under the direction and authority of an Authorized User, but does not necessarily have his or her own Authorization.

Quarter - A period of time equal to one-fourth of the year observed by the licensee (approx. 13 consecutive weeks). Providing that the beginning of the first quarter in a year coincides with the starting date of the year and that no day is omitted or duplicated in consecutive quarters.

Rad - The special unit of absorbed dose. One rad is equivalent to 100 ergs/gram or 0.01 J/kg.

Radioactive Contamination - The presence of radioactive material in any place where it is not supposed to be.

Radiation - Alpha particles, beta particles, gamma rays, x-rays, neutrons, high speed electrons, high speed protons, and other charged particles capable of producing ions. Radiation, as used in this context, does not include non-ionizing radiation, such as radio waves, microwaves, or visible, infrared, or ultraviolet light.

Radiation Area - An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 5 mrem in 1 hour at 30 cm from the radiation source or from any surface that the radiation penetrates.

Radiation Detection Instrument - A device that detects and records the characteristics of ionizing radiation.

Radiation Generating Device or Machine (RGD) - Any device capable of producing radiation except those which produce radiation only from radioactive material.

Radiation Safety Committee - The University Committee that is responsible for the oversight of and for setting the policies of the radiation protection program.

Radiation Safety Officer - The individual responsible for implementing the policies and procedures of the Radiation Safety Committee and for the day-to-day operation of the radiation protection program.

Radiation Shielding - Reduction of radiation by placing a shield of absorbing material between any radioactive source and a person, work area, or radiation sensitive device.

Radiation Source - Usually a manmade sealed source of radiation used in teletherapy, radiography, as a power source for batteries, calibration, or in various industrial gauges. Machines such as accelerators, radioisotope generators, and natural radionuclides may be considered sources.

Radiation Standards - Exposure standards, permissible concentrations, rules for safe handling, regulations for

transportation, regulations for industrial control of radiation and control of radioactive material by legislative means.

Radiation Warning Symbol - An officially prescribed symbol (a magenta trefoil) on a yellow background that must be displayed where certain quantities of radioactive materials are present or where certain doses of radiation could be received.

Radioactive Materials - Any material that spontaneously emits ionizing radiation at levels significantly above natural background levels; the level of significance and the method of determination are established by Environmental Health and Safety in compliance with governmental regulations.

Radioactive waste - A solid, liquid, or gaseous material from experiment/research operations that is radioactive and for which there is no further use.

Radioactivity - The spontaneous emission of radiation, generally alpha particles, beta particles, or gamma rays from the nucleus of an unstable isotope.

Radioisotope - An unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation.

Registered Worker - An individual whose official duties and responsibilities involve the use of radioactive materials or radiation generating devices under the supervision of an Authorized User. Registered workers include authorized user, personnel listed in the permit issued to the authorized users, and other individuals, such as maintenance personnel, who may come in contact with radioactive material.

Rem - The special unit for dose equivalent. The dose equivalent in rem is equal to the absorbed dose in rads, multiplied by the quality factor.

Removable Surface Radioactivity (Contamination) - Radioactive deposits on a surface that are removable by wiping the surface with a standard absorbent material and procedure.

Reportable Spill - Any unexpected contamination of a person, laboratory area, or noncontrolled with radioactive materials. If a spill involves less than 1 microcurie and is confined to a controlled working area, monitored, and cleaned up to nondetectable levels, it need not be reported.

Roentgen (R) - A unit of exposure to ionizing radiation. It is that amount of gamma or x-rays required to produce ions carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter of dry air under standard conditions. Named after Wilhelm Roentgen, German scientist who discovered x-rays in 1895.

Restricted Area - An area, access to which is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation or radioactive materials. Restricted area does not include areas used as residential quarters, offices, etc.

Scintillation Detector - A radiation detection instrument comprised of a phosphor, photomultiplier tube(s), and associated electronic circuits for counting light emissions produced in the phosphor by ionizing radiation.

Sealed Source - Radioactive material that is permanently bonded or fixed in a capsule or matrix designed to prevent release and dispersal under the most severe conditions which are likely to be encountered in normal use and handling.

Secondary Radiation - Radiation originating as the result of absorption of other radiation in matter. It may be either electromagnetic (e.g. Bremsstrahlung from ^{32}P betas passing through lead) or particulate in nature.

Shallow Dose Equivalent - Applies to the external exposure of the skin or an extremity. This is the dose equivalent at a tissue depth 0.007 cm averaged over an area of 1 square centimeter.

Shielding - Any material or obstruction that absorbs radiation and thus tends to protect personnel or materials from the effects of ionizing radiation.

Survey Meter - Any portable radiation detection instrument especially adapted for inspecting an area to establish the existence and amount of radioactive material or contamination present.

TLD (ThermoLuminescent Dosimeter) - A crystalline material which emits light when heated after radiation exposure; used in dosimetry.

Whole Body - Refers to the head, trunk (including gonads), arms above the elbow, and legs above the knee.

Wipe Sample - Wiping of 100 square centimeters of a surface with a filter paper or a cotton swab for the purpose of determining if removable contamination is present. The wipe is then analyzed with a radiation detection instrument, such as a survey meter or a LSC).

X-rays - Penetrating electromagnetic radiation (photon) having a wavelength that is much shorter than that of visible light. They can be produced by excitation of the electrons around certain nuclei (characteristic x-rays) or by the interaction of high speed electrons with the electric fields around nuclei.

Appendix A

Declared Pregnant Radiation User Policy

**Harvard University - Environmental Health and Safety
Radiation Protection Office**

**Plan pertaining to
Work with Radioactive Material by Pregnant Women**

As part of a revision of regulations in January, 1994, the Nuclear Regulatory Commission (NRC) issued a rule limiting fetal radiation dose received as a result of a pregnant worker's occupational exposure to 500 mrem in the gestation period⁵. For this limit to apply, the regulation requires the woman to declare pregnancy in writing and give the estimated date of conception. If a woman chooses not to declare her pregnancy, the normal occupational dose limit of 5,000 mrem per year would be in effect with the provision to maintain occupational radiation exposure "as low as reasonably achievable" (ALARA)⁶.

A radiation worker who decides to declare a pregnancy would do so by submitting the attached form to the Radiation Protection Office and, at the woman's discretion, to her supervisor. As required by law⁷, the University maintains this declaration and any dose records to the embryo/fetus with those of the declared pregnant worker which are protected from public disclosure. This notification will initiate a process by which the RPO will assess potential doses, evaluate potential exposures from ionizing radiation, and review the individual's radiation exposure history. If this process identifies exposure potential to the embryo/fetus that is not in concert with the ALARA Plan, the individual will be contacted, (even if the Declaration Form did not request consultation with a Health Physicist). Recommendations on minimizing radiation exposure may be made on an individual basis after this review.

It has always been Harvard University's Policy to keep radiation doses to potentially exposed individuals ALARA. While the radiation dose limit for occupationally exposed individuals is 5,000 mrem per year, greater than ninety percent of all users of all radioactive material at Harvard have had an annual dose less than 100 mrem.

Anyone with questions relating to radiation protection measures for the embryo/fetus, the Radiation Protection Program or procedures on the declaration of a pregnancy is encouraged to contact the Radiation Protection Office (495-2060) or the local safety office for information.

(Declaration Form is on the reverse side)

⁵ The Code of Federal Regulations, Standard for Protection Against Radiation 10 CFR 20.1208

⁶ *ibid* 10CFR 20.1003.

⁷ *ibid* 10CFR 20.2106.

Harvard University
Radiation Protection Office
46 Oxford Street
Cambridge, MA 02138
Tel. (617) 495-2060

Date:

To: Joseph P. Ring, Ph.D., Radiation Protection Officer

From: _____, Signature

University Telephone: _____ Social Sec No.

Working Under Permit Holder:

University Address:

With this notice I inform you that I am pregnant or trying to become pregnant with an estimated conception date of _____ and an expected delivery date of _____. I understand the radiation exposure limit set by the Nuclear Regulatory Commission for embryo/fetus of the declared pregnant worker* is 500 mrem for the entire gestation period. In line with Harvard's policy of minimizing radiation exposure, I will continue to minimize my exposure and participate in a monitoring program for pregnant workers.

Please check the following as appropriate:

- I have questions related to the radiation protection of the embryo/fetus and would like to have a health physicist from the Radiation Protection Office contact me at _____.
- I do not wish to inform the principle investigator at this time.
- I have informed or will inform the principle investigator.
- I have questions related to the radiation protection of the embryo/fetus and will contact the Radiation Protection Office at 495-2060.
- I do not have questions related to the radiation protection at this time. I understand that I may contact the Radiation Protection Office if I have any questions in the future concerning this pregnancy.

* The NRC defines a declared pregnant woman as "a woman who has voluntarily informed her employer in writing of her pregnancy and estimated date of conception."

Harvard University
Radiation Protection Office
46 Oxford Street
Cambridge, MA 02138
Tel. (617) 495-2060

Pregnancy Consultation Record

_____ reviewed the risks of working with radiation while pregnant and received a complete copy of the US Nuclear Regulatory Commission (NRC) Regulatory Guide 8.13, a reminder notice of the University's safety practices on safe radioactive material use and a copy of her radiation exposure history.

Date:

Declared Pregnant Woman:

Radiation Protection Office:

Appendix B
ALARA Plan

Harvard University - Environmental Health and Safety

Radiation Protection Office

ALARA Plan

Harvard University follows the policy of minimizing radiation exposures to individuals or releases of radioactivity to the environment resulting from work with radioactive materials. This policy is known as ALARA, an acronym for As Low As Reasonably Achievable. This document sets forth the University's operational plan for implementing ALARA. The plan is based on the Nuclear Regulatory Commission's definition of ALARA, which is maintaining exposures as far below the regulatory limits as practical with consideration of economics, state of technology, and other societal and socioeconomic considerations. To be effective, the plan seeks to establish goals which are accepted by all levels of management and those involved in the use of radioactive material.

Responsibilities

The Radiation Safety Committee (RSC) is responsible for maintaining oversight of activities under the plan. It reviews measures to achieve ALARA. It examines individual and collective doses and releases to the environment for conformance with ALARA. It conducts a comprehensive annual audit of the radiation protection program including the effectiveness of adherence to ALARA concepts. This audit includes review of operational procedures, authorization approvals, radiation incidents, radiation dose records and environmental release data. Table 1 sets the ALARA goals and the standards for achieving these goals.

The Radiation Protection Office (RPO) is responsible for executing the plan through the following measures:

- (a) Follow ALARA guidelines in reviewing and approving proposed uses of radioactive materials and recommend modifications to experiments where indicated.
- (b) Identify measures to achieve ALARA, such as use of protective devices, operational controls, and consideration of ALARA in designing experiments.
- (c) Formulate written procedures where applicable in specific instances.
- (d) Monitor and track all activities affecting potential exposures of workers and the public.
- (e) Provide the training and guidance necessary to University management, the RSC, Authorized Users and University staff to meet the goals of the ALARA plan.
- (f) Review records of radiation surveys, occupational exposures, and environmental releases at least quarterly to determine compliance with ALARA and good practice principles.
- (g) On an annual basis, the RPO will conduct a comprehensive review of the radiation protection program for adherence to ALARA concepts and for general program functionality.

Standards

Standards for achievement of ALARA goals are given in Table 1. The table gives measurement levels at which prescribed actions are to be taken by the Radiation Protection Office. If a measurement point is below Level I for a calendar quarter, no additional action will be required. Should the value be between Level I and Level II, the RPO will review the circumstances and, at its discretion, take additional steps to investigate and/or take action to reduce the value. Any value which exceeds Investigation Level II requires investigation and efforts to reduce the exposure with consideration of total cost and scientific impact. Reports of all investigations shall be presented, along with an exposure/release history, to the RSC.

Table 1 ALARA Plan Goals and Investigation Levels				
	Regulatory Limit	Goal	Investigation Level I (mrem per calendar quarter)	Investigation Level II (mrem per calendar quarter)
Whole Body Exposures	5,000 mrem/y	500 mrem/y	125	375
Lens of the Eye	15,000 mrem/y	1,500 mrem/y	375	1125
Skin and/or Extremity	50,000 mrem/y	5,000 mrem/y	1250	3750
Minors (whole body)	100 mrem/y	50 mrem/y	10	30
Embryo/Fetus	500 mrem in the 9 month gestation period	50 mrem in the 9 month gestation period	20	60
Member of Public on site (NRC)	100 mrem/y whole body exposure	20 mrem/year	5 ^a	15 ^a
Member of Public offsite (EPA) ^b	10 mrem/y with less than 3 mrem due to radioiodine from airborne releases	3 mrem/year	1 ^a	3 ^a
Environmental Releases ^c	10 CFR 20 Appendix B averaged over one year at the unrestricted area boundary.	10 % of 10 CFR 20 Appendix B averaged over one year at the boundary; or listed value at the stack.	10 % of 10 CFR 20 Appendix B averaged over the calendar quarter at the boundary; or listed value at the stack.	30 % of 10 CFR 20 Appendix B averaged over the calendar quarter at the boundary; or listed value at the stack.

^a Mathematical models are used to calculate dose based on releases to the environment.

^b EPA regulations apply to airborne exposure to a member of the public while NRC regulations apply to all sources of radiation from the institution to the highest exposed member of the public.

^c Values based on a total effective dose equivalent of 50 mrem per year.

Appendix C
Bioassay Plan

Harvard University Radiation Protection Office Bioassay Plan

The Harvard University Radiation Safety Committee (RSC) believes that biomedical research with radioactive materials should result in minimal radiation exposures to individuals. To ensure that internal radiation exposures are kept to a minimum, this Bioassay Plan is based on the RSC's ALARA Plan. The ALARA Plan is based on the Nuclear Regulatory Commission's definition of ALARA, which is maintaining exposures as far below the regulatory limits as practical with consideration of economics, state of technology, and other societal and socioeconomic factors. This Bioassay Plan includes a predictive as well as post incident component. The predictive model specifies radionuclide use levels under a variety of working conditions that warrant monitoring to show radiation exposures are not in excess of the ALARA Level 1 action level. This use level is called an Investigation Level. The post-incident component sets a requirement for a bioassay for individuals directly involved in an incident such as a spill or contamination event. With these two components, this Plan recommends monitoring levels that are well below the requirements of the University's Radioactive Materials License or applicable State (CMR 120) and Federal (10CFR20) regulations. Positive bioassays will be reviewed and documented as required by the ALARA Plan.

A bioassay is a procedure that allows for the monitoring of radiation workers for internal radiation contamination. The two most common bioassay methods for biomedical radionuclides are thyroid counting and urinalysis. Thyroid counting allows for the detection of iodine contamination in the thyroid gland, using a sodium iodide (NaI) detector. Urinalysis involves the counting of a urine sample on an appropriate laboratory radiation detector, usually a liquid scintillation counter (LSC).

Technical Basis

The Bioassay Plan sets exposure levels at which an investigation should begin, called an Investigation Level. According to regulation (MA RCP 120.226), radiation exposures in excess of 10 percent of the legal limit (500 mrem) must be recorded. Typically, radiation exposures at 1 percent of the limit are investigated to ensure compliance. The Investigation Levels in this plan meet both compliance levels and the ALARA Level 1 action. Since internal radiation exposure regulations are based on intake, these Investigation Levels must consider the specific radioisotope's Annual Limit on Intake (ALI), the quantities handled by individuals, the potential operations and procedures involved, and handling frequency.

These Investigation Levels are based on the Hazard Index (HI), from draft NUREG 1400 Air Sampling in the Workplace. The Hazard Index predicts investigation levels by considering the radioisotope's ALI, the levels of radioactivity that could potentially be handled by a worker in any given time, the potential for intake and possible confinement factors such as fume hoods. The Hazard Index is a fraction comparing the potential for intake to the maximum allowed intake as selected by the user. This means that a Hazard Index of 1.0, or above, requires monitoring while a value less than 1.0 does not require monitoring.

The Hazard Index is defined as:

$$HI \equiv \frac{Q R F}{10^5 ALI C} , \quad \text{Equation 1}$$

Where, as defined in NUREG 1400:

- Q = Quantity of radioactive material handled per time interval,
- R = Release Fraction,
- F = Time modifying factor (1 year, 12 per year for monthly, etc),
- C = Confinement factor,
- ALI = Annual Limit of Intake,
- 10^5 = a numerical adjustment to convert the Hazard Index to a percentage of the ALI.

Equation 1 can be solved for the quantity of radioactive material handled in a time interval while setting Hazard Index to 1. Thus the Investigation Level, the periodic use requiring a bioassay, is:

$$Q = \frac{(10^5)(ALI)(C)}{(R)(F)}, \quad \text{Equation 2}$$

The ALARA Plan Goal, 500 mrem, corresponds to 10 percent of the applicable ALI. The Time modifying factor, F, will adjust the Investigation Level to the ALARA level 1 for the appropriate time. For example, quarterly monitoring would yield a dose of 125 mrem that is the ALARA Level 1 value listed in the ALARA plan.

$$Q = \frac{(10^4)(ALI)(C)}{(R)(F)}, \quad \text{Equation 3}$$

Since action is required at ALARA Level 1, is prudent to require bioassays at 10 percent of this value. When substituting the Time Modification Factor for monthly monitoring (F=12), Equation 3 is rewritten as:

$$Q = \frac{(10^3)(ALI)(C)}{(R)(12)}, \quad \text{Equation 4}$$

Equation 4 is the amount of radioactivity used by one radioactive materials user in a month that requires a bioassay. Bioassay values for the most common radionuclides are listed in Table 1 for the most common physical form. A complete list of bioassay values is provided in the Excel file 'Bioassay Tables.xls'.

In addition to the bioassay recommendations for routine exposures, it is appropriate to collect bioassays after incidents simply to verify exposures. Bioassay requirements for those involved in a spill or with personal contamination are provided in Table 2.

Table 1 Recommended Bioassay Levels when using liquids on the open bench		
Isotope	Physical Form	Recommended Bioassay Level (mCi / month)
¹⁴ C	Liquid	1,700
³ H	Liquid	6,700
¹²⁵ I	Volatile	0.33
¹³¹ I	Volatile	0.25
³² P	Liquid	500
³³ P	Liquid	2,500
³⁵ S	Liquid	1,700,000

Table 2 Additional Bioassay Guidelines	
Indicator	Bioassay Requirement
An individual with hair or skin contamination	Over 1 RCL ⁺
An individual involved in a spill	Over 10 ALI*

* The ALI is the Annual Limit on Intake as defined by ICRP 30

+ The RCL is a removable contamination limit defined in the Table 3

Table 3 Acceptable Surface Contamination Levels for Unrestricted Release (in dpm/100 cm²)			
Nuclides ^a	Average ^{b,c,f}	Maximum ^{b,d,f}	Removable (RCL) ^{b,c,f}
U-nat, U-235, U-238, and progeny	5,000 α	15,000 α	1,000 α
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.	5,000 $\beta\gamma$	15,000 $\beta\gamma$	1,000 $\beta\gamma$

- a 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.
- b As used in this table, dpm (disintegrations 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.
- c 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.
- d The maximum contamination level applies to an area of not more than 100 cm².
- e 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 proportionally and the entire surface should be wiped.
- f The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/hr at 1 cm and 1.0 mrad/hr at 1 cm, respectively, measured through not more than 7 mgrams per square centimeter of total absorber.

Table of Parameter Values

Table A1. Contains the Release Fraction R values used to determine Q:

Table A1 Values for the Release Fraction R	
Physical Form	Release Fraction (R)
Gases or volatile material	1.0
Nonvolatile powders	0.01
Liquids	0.001
Surface contamination	0.001
Encapsulated material	0.0

Table A2. Contains the Confinement Factor C values used to determine Q.

Table A2 Values for the Confinement Factor C	
Type of Confinement	Confinement Factor (C)
Glove-box	10.0
Well ventilated Hood	1.0
Open Bench with normal ventilation	0.1
Non-routine or special jobs with unknown ventilation	0.01

Appendix D

Entering Orders in the Radiation Web-Purchase Authorization System

1. Use either Internet Explorer or Netscape. Internet Explorer is recommended.

As an operational note the computer will print a description of the information for a data input box if you are using IE and place the mouse over the box.

2. Click on the bookmark for RAM Ordering or go to the radiation home page and follow the links to online ordering system
3. Pick Permit Holder off the list. Note you can enter the first letter of the PI's last name and then scroll down the list to find the PI. Tab to the Series Code box and enter the series code in CAPITAL LETTERS and then click "CONTINUE"
4. Enter the lab's Purchase Order Number. This PO should be obtained from the local resource for

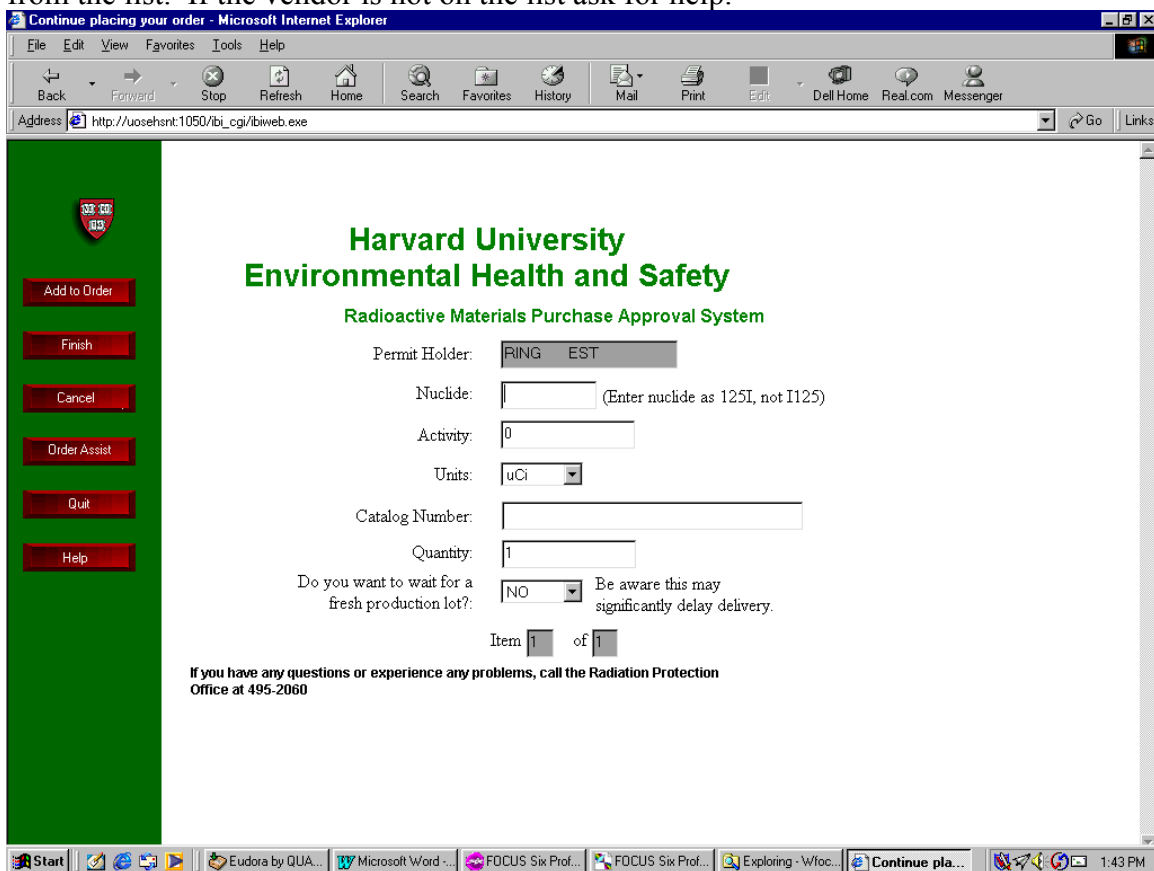
The screenshot shows a Microsoft Internet Explorer browser window displaying a web form titled "Harvard University Environmental Health and Safety Radioactive Materials Purchase Approval System". The form includes the following fields and options:

- Permit Holder:
- Purchase Order:
- Contact's Name:
- Contact Phone:
- Person to ship to:
- Inst. where P.O. is drawn:
- Lab to Deliver Package to:
- Delivery Priority: (Options: 1 - Same Day (NEN) only, 2 - Next Day, 3 - Ship when available)
- Self-Order?:
- Vendor: (For other vendors, contact the Radiation Protection Office)

At the bottom of the form, it says: "Call the Radiation Protection Office at 495-2060 with questions or problems." On the left side of the page, there are three red buttons: "Continue", "Quit", and "Help". The browser's address bar shows "http://uosehant:1050/ibi_cgi/ibiweb.exe".

purchasing. Do not use a request number, it must be the final PO. Enter the name of the person who the vendor should contact if there are questions with the ordering and that person's telephone number. Enter the person to whom the RPO should deliver the package and ask them the lab the person is in. Note the computer will only list the labs the PI is authorized for. If they ask for a lab not on the list tell an HP because this is not OK. Select the institution where the PO is drawn on from the list. Enter the delivery priority using the info on the screen. If you do not know

choose 1. If the person is calling the vendor directly enter NO into the direct order data box. Typically, the PIs want to order the material directly so this would be YES. For people at HIM/BID where the BID Radiation Safety staff orders the material it is YES. Enter the vendor from the list. If the vendor is not on the list ask for help.



5. For the actual material order enter radionuclide (for example: 32P), the activity and the right units from the selection box. The activity to enter into the box is the activity of the product; if they are ordering more than one of the products that is taken care of in the quantity part. If the lab people give you a Catalog number it is better for them but you could enter a '1'. If the lab wants to let the vendor hold the material for a fresh manufacturing lot, which can delay the delivery select YES otherwise use the default NO. As the person how many of the product catalog items they are buying and enter that in the quantity. Click 'Add to Order' to add more packages to the order and "FINISH" if that is all they want to order.
6. When you press 'Finish' the requested materials will be displayed so you can enter or delete items. If the information is correct press 'Submit'. The application will give you another chance to verify that you want to make the request and by asking DO YOU WANT TO SUBMIT THIS ORDER? "OK or CANCEL". If it is right press OK.
7. The request to purchase radioactive material has been submitted when the 'OK' but has been pressed.

Appendix E

Radioactive Material Forms

1. [Radioactive Material Receipt Form](#)
2. [Radioactive Materials Inventory Form](#)
3. [Sink Disposal Form](#)
4. [Personal Survey Form](#)
5. [Iodination Log](#)
6. [Minors and Radioactive Materials or Radiation Generating Devices Notification](#)

Harvard University
Radiation Protection Office

STATEMENT OF RECEIPT OF RADIOACTIVE MATERIALS

This statement must be completed by an individual authorized to accept shipment of radioactive materials by the Radiation Protection Office.

Fax the completed form and the shipping paper to the RPO at 617-496-5509

Record the following information, one form per package. ALL INFORMATION IS REQUIRED.

Purchase order number: _____
Vendor: _____
Nuclide: _____
Activity received in μCi : _____
Principle Investigator: _____
Exposure, contact in mR/hr: _____
Wipe test in DPM: _____
Exposure, 3 feet in mR/hr: _____
Package Type: _____ (LQ, W1, YII, YIII)
Receipt date: _____
Receipt time: _____
Person receiving: _____

Signature: _____

Exposure is measured with a Geiger-Mueller (GM) pancake probe-equipped survey meter in a low background area. Exposure on contact is highest on surface of package exterior. Exposure at 3 feet is highest measured at any point 3 feet from package.

A wipe test is conducted wiping a filter paper over 300 cm^2 (about a 7" by 7" area) of the package exterior. Count the wipe test with a liquid scintillation counter.

LQ is a package with no label; respectively, W1 is a white 1; YII is a yellow II, and YIII is a yellow III labeled package.

Notify the RPO at 617-495-2060 immediately if a package appears damaged, leaking, or the wipe test is greater than 3,000 DPM.

RPO Email: Radiation_Protection@Harvard.edu

Form RP 251.1

Revision 1

Harvard University
Radiation Protection Office

Notification of Minor Using Radiation

Date: _____
To: Joseph P. Ring, Ph.D., Radiation Protection Officer

Name:	Signature:
Social Security Number:	Birth Date:
University Telephone:	
University Affiliation: <input type="checkbox"/> Student <input type="checkbox"/> Staff	Laboratory Address:
Permit Holder/Faculty Member:	Signature:

With this notice I inform you that I am between the ages 16 and 18 and a member of the Harvard University Community who intends to work with radioactive material or a radiation generating device. I will be working with the following radiation sources:

Radioactive Material	Typical Activity Use	Form
Laser Media	Laser Class	Mode (CW/Pulsed/Q-Switch)
X-ray Devices	Energy	Output
Other Device		

Please check the following as appropriate:

- I have questions related to the radiation protection and would like a health physicist from the Radiation Protection Office contact me at _____.
- I have questions related to the radiation protection of the embryo/fetus and will contact the Radiation Protection Office at (617-49)5-2060.
- I do not have questions related to the radiation protection at this time. I understand that I may contact the Radiation Protection Office if I have any questions in the future.

Appendix F Approved Liquid Scintillation Cocktails

Scintillation Cocktail	Manufacturer
BCS	Amersham
BetaMax ES	ICN Radiochemicals
Betaplate Scint	Wallac
Bio-Safe II	Research Products International
Bio-Safe NA	Research Products International
CytoScint ES	ICN Radiochemicals
DPA	Packard Instruments
Ecolite +	ICN Radiochemicals
Ecolume	ICN Radiochemicals
Econo-Safe	Research Products International
Ecoscint	National Diagnostics
Ecoscint A	National Diagnostics
Ecoscint O	National Diagnostics
Emulsifer Safe	Packard Instruments
Envirosafe	Anorak Scientific
Flo Scint V	Packard Instruments
High Efficiency Mineral Oil Scintillator	Packard Instruments
Instamix 40	Packard Instruments
Irgasafe	Packard Instruments
Irgasafe Plus	Packard Instruments
Microscint 20	Packard Instruments
Microscint 40	Packard Instruments
Microscint AF	Packard Instruments
Microscint O	Packard Instruments
Mono-Flow 5	National Diagnostics
Omni-Flour	Packard Instruments
Opti-Flour	Packard Instruments
Opti-Flour O	Packard Instruments
Opti-Phase HiSafe	Wallac
Opti-Phase HiSafe 2	Wallac
Opti-Phase HiSafe 3	Wallac

Scintillation Cocktail	Manufacturer
Opti-Phase HiSafe Polysafe	Wallac
Opti-Phase HiSafe Supermix	Wallac
Optiscint HiSafe	Wallac
Optisolv Solubilizer	Wallac
Organic Solv 3	Anorak Scientific
Pico-Safe	Packard Instruments
Poly-Flour	Packard Instruments
Ready Safe	Beckman
ScintiSafe 30%	Fisher Scientific
ScintiSafe Econo 1	Fisher Scientific
ScintiSafe Econo 2	Fisher Scientific
ScintiSafe Econo F	Fisher Scientific
ScintiSafe Gel	Fisher Scientific
ScintiSafe Plus 50%	Fisher Scientific
Scintiverse BD	Fisher Scientific
Solvable	Packard Instruments
Solvent-Free	Isolab, Inc.
Starscint	Packard Instruments
Ultima Gold	Packard Instruments
Ultima Gold AB	Packard Instruments
Ultima Gold F	Packard Instruments
Ultima Gold LLT	Packard Instruments
Ultima Gold M	Packard Instruments
Ultima Gold XR	Packard Instruments
Ultima-Flo AF	Packard Instruments
Ultima-Flo AP	Packard Instruments
Ultima-Flo M	Packard Instruments
UniverSol ES	ICN Radiochemicals

If you would like more information about the liquid scintillation cocktails, please visit the manufactures web page.

Amersham : www.amersham.co.uk
 ICN Radiochemicals www.icnpharm.com

Wallac www.wallac.com/
 National Diagnostic www.nationaldiagnostics.com/index.htm
 Packard Instruments www.packardinst.com/index2.htm
 Beckman www.beckman.com/
 Fisher Scientific www2.fishersci.com/main.jsp

Appendix G
Massachusetts Radiation Control Program “Notice to Employees”

This posting can also be found at <http://www.state.ma.us/dph/rcp/notice.pdf>

MASSACHUSETTS DEPARTMENT OF PUBLIC HEALTH RADIATION CONTROL PROGRAM
NOTICE TO EMPLOYEES
STANDARDS FOR PROTECTION AGAINST RADIATION; NOTICES,
INSTRUCTIONS AND REPORTS TO WORKERS; INSPECTIONS

The Radiation Control Program (Agency) of Massachusetts Department of Public Health has adopted regulations in 105 CMR 120.200 which establish standards for your protection against radiation hazards. In 105 CMR 120.750, the Agency has also established certain provisions for the options of workers engaged in work under the Department license or registration.

YOUR EMPLOYER'S RESPONSIBILITY

Your employer is required to-

Apply these regulations to work involving sources of radiation.

Post or otherwise make available to you a copy of the Massachusetts Department of Public Health regulations for control of radiation, and the operating procedures which apply to work you are engaged in, and explain their provisions to you.

Post Notice of Violation involving radiological working conditions, proposed imposition of civil penalties and orders.

YOUR RESPONSIBILITY AS A WORKER

You should familiarize yourself with those provisions of the department regulations, and the operating procedures which apply to the work you are engaged in. You should observe their provisions for your own protection and protection on your co-workers.

WHAT IS COVERED BY THESE REGULATIONS

Limits on occupational exposure to radiation and radioactive materials;

measures to be taken after accidental exposure;

personal monitoring, surveys, and equipment;

caution signs, labels, and safety interlock equipment;

exposure records and reports;

options for workers regarding Agency inspections; and

related matters.

REPORTS ON YOUR RADIATION EXPOSURE HISTORY

The Department of Public Health regulations require that your employer give you a written report if you receive an exposure in excess of any applicable limit as set forth in the regulations or the license. The basic limits for exposure to employees are set forth in 105 CMR 120.211 through 120.218 of the regulations. These sections specify limits on exposure to radiation and exposure to concentrations of radioactive material in air.

If you work where personal monitoring is required:

Your employer must advise you of your occupational radiation dose each year, and

Upon termination of your employment, your employer must give you a written report of your dose if you request it.

INSPECTIONS

All licensed or registered activities are subject to inspection by representatives of the Department of Public Health, Radiation Control Program. In addition, any worker or representative of workers who believes there is a violation of the M.G. L.c.111, the regulations issued thereunder, or the terms of the employer's license or registration with regard to radiological working conditions in which the worker is engaged, may request an

inspection by sending a notice of the alleged violation to the Department of

Public Health, Radiation Control Program. The request must set forth the specific grounds for the notice, and must be signed by the worker as the representative of the workers. During inspections, Department inspectors may confer privately with workers, and any worker may bring to the attention of the inspector any past or present conditions which he believes contributed to or caused any violation as described above.

INQUIRIES

Direct all inquiries on the matters outlined herein to:
Massachusetts Department of Public Health
Radiation Control Program
90 Washington Street
Dorchester, MA 02121
Phone: (617) 427-2944
Emergency Phone: (617) 427-2913

POSTING REQUIREMENT

COPIES OF THIS NOTICE MUST BE POSTED IN A SUFFICIENT NUMBER OF PLACES IN EVERY ESTABLISHMENT WHERE EMPLOYEES ARE EMPLOYED IN ACTIVITIES LICENSED OR REGISTERED, PURSUANT TO 105 CMR 120.750, BY THE DEPARTMENT OF PUBLIC HEALTH, RADIATION CONTROL PROGRAM, TO PERMIT EMPLOYEES WORKING IN OR FREQUENTING ANY PORTION OF A RESTRICTED AREA TO OBSERVE A COPY ON THE WAY TO OR FROM THEIR PLACE OF EMPLOYMENT.

Appendix H
Sample X-ray Machine Operating Log

Appendix I

Electron Microscope General Safety Protocol

**Harvard University
Radiation Protection Office**

Electron Microscope General Safety Protocol

Machine Identification:

Manufacturer: _____ Model: _____

Principal Investigator: _____ Telephone: _____

General Safety Regulations:

1. Only personnel trained and approved by the responsible Principal Investigator may operate an electron microscope.
2. An operational fail-safe light is visible to the operator indicating when x-rays are being produced.
3. Use interlocks, barriers or administrative controls to ensure no one can gain access to the primary beam or high scatter radiation areas.
4. Use a calibrated thin-window GM survey meter to verify shielding effectiveness and monitor radiation levels.
5. Secure electron microscopes against unauthorized use by using a unit key control or the room lock. Stop the primary beam by secured shielding that cannot be readily displaced.
6. Secure unused ports to prevent accidental exposures.
7. Maintain an operating log that includes the date, operator, beam voltage, and current time on and off (or total exposure time).
8. Do not modify the built-in shielding and viewing ports. If modifications must be made, contact the Radiation Protection Office of Environmental Health and Safety for a safety survey of the unit.
9. Notify the Radiation Protection Office immediately in the event of any abnormal personnel radiation exposure.
10. Changes in the location or disposition of electron microscopes must have the approval of the Radiation Protection Office. Notify the RPO prior to the acquisition, disposal, or transfer of any electron microscope.
11. Contact the RPO for information regarding radiation safety or radiation survey instrumentation. A copy of the Massachusetts Radiation Control Regulations is available at the RPO.

Appendix J
X-ray Diffraction/Fluorescence General Safety Protocol

**Harvard University
Radiation Protection Office**

X-ray Diffraction/Fluorescence General Safety Protocol

Machine Identification:

Manufacturer: _____ Model: _____

Principal Investigator: _____ Telephone: _____

General Safety Requirement:

1. Diffraction/fluorescence units may only be operated by Radiation Protection Office authorized personnel. All authorized personnel must receive instruction in and demonstrate an understanding of the operation of the machine before starting unsupervised work.
2. An operational fail-safe light is visible to the operator indicating when x-rays are being produced.
3. Use interlocks, barriers or administrative controls to ensure no one can gain access to the primary beam or high scatter radiation areas.
4. Use a calibrated thin-window GM survey meter to verify shielding effectiveness and monitor radiation levels.
5. If the machine is modified, obtain RPO authorization before using the equipment.
6. Whole body and finger ring dosimetry is required for all personnel working with diffraction/fluorescence units.
7. Do not use the safety interlock to turn the machine off; use the main switch.
8. Do not override the safety interlock unless there is a Radiation Protection Office approved written procedure.
9. Make sure the machine is OFF before changing samples or the primary tube safety shutter is closed and verify there is not active beam present; always check the current and voltage meters and/or use a survey meter to detect x-rays.
10. Do not operate with removed covers, shielding materials, or tube housings; or with modified shutters, collimators or beam-stops. Verify that the tube is off and remains off until the machine is completely reassembled and any modifications have been approved. Use the main switch to shut the machine off; do not rely on the safety interlock.
11. Check radiation scatter with a survey meter after each realignment. Notify the Radiation Protection Office immediately if there are unusually high readings.
12. Secure unused ports to prevent accidental exposures.
13. Secure diffraction/fluorescence against unauthorized use by using a unit key control or the room lock. Stop the primary beam by secured shielding that cannot be readily displaced.

14. Maintain an operating log that includes date, operator, beam voltage and current, and time on and off (or total exposure time) for each unit use.
15. Notify the Radiation Protection Office immediately if there is a real or perceived abnormal personnel radiation exposure.
16. Obtain approval for any location changes, purchase or removal of diffraction/fluorescence units from the Radiation Protection Office. Notify the RPO prior to the acquisition, disposal, or transfer of any diffraction/fluorescence unit.
17. Contact the RPO for information regarding radiation safety or radiation survey instrumentation. A copy of the Massachusetts Radiation Control Regulations is available at the RPO.

Appendix K
X-ray Cabinet General Safety Protocol

Harvard University
Radiation Protection Office

X-ray Cabinet General Safety Protocol

Machine Identification:

Manufacturer: _____ Model: _____

Principal Investigator: _____ Telephone: _____

General Safety Requirements:

1. Only individuals authorized on the permit may operate the machine. All authorized users must receive instruction in and demonstrate an understanding of the operation of the machine before starting unsupervised work.
2. An operational fail-safe light is visible to the operator indicating when x-rays are being produced.
3. Use interlocks, barriers or administrative controls to ensure no one can gain access to the primary beam or high scatter radiation areas.
4. Use a calibrated thin-window GM survey meter to verify shielding effectiveness and monitor radiation levels.
5. Whole body and finger ring dosimetry is required for all personnel working with cabinet units.
6. Do not use the safety interlock to turn the machine off; use the main switch.
7. Do not override the safety interlock unless there is a Radiation Protection Office approved written procedure.
8. Make sure the machine is OFF before changing samples or the primary tube safety shutter is closed and verify there is not active beam present; always check the current and voltage meters and/or use a survey meter to detect x-rays.
9. Do not modify the built-in shielding. If modifications must be made, contact the Radiation Protection Office approval to restart instrument.
10. Secure unused ports, if any, to prevent accidental exposures.
11. Secure cabinet units through a unit key control or room lock.
12. Maintain an operating log that includes date, operator, beam voltage and current, and time on and off (or total exposure time) for each unit use.
13. Notify the Radiation Protection Office immediately if there is a concern for or any abnormal personnel radiation exposure.
14. Obtain approval for any location changes, purchase or removal of diffraction/fluorescence units by the Radiation Protection Office. Notify the RPO prior to the acquisition, disposal, or transfer of any diffraction/fluorescence unit.
15. Contact the RPO for information regarding radiation safety or radiation survey instrumentation. A copy of the Massachusetts Radiation Control Regulations is available at the RPO.

Appendix L

Radioactive Materials Permit Holder's Checklist

Radioactive Permit Holder's Checklist

Refer to and follow this checklist regularly to ensure that your protection program is in compliance with the major University requirements for the use of radioactive materials.

1. Review the Permit to ensure:
 - a) All laboratory personnel listed; notify the RPO if the list is not accurate.
 - b) All laboratory personnel trained.
 - c) All radioactive materials that are used are listed; do not use radioactive materials not listed and request for an amendment.
 - d) Verify that quantities of all radioactive materials on hand are within possession limits; report excess quantities immediately to the RPO and do not use.
 - e) Verify that radioactive materials are used and stored in areas listed on the permit.
 - f) Radiation Generating Devices such as lasers and x-ray machines are properly listed.
2. Verify that all radioactive materials or radiation generating device purchases are pre-approved by the RPO including sources for which payment is not required.
3. Ensure that all persons who receive radioactive materials:
 - a) inspect packages within 3 hours of receipt;
 - b) Secure packages immediately;
 - c) Send completed [receipt form](#) to the RPO.
4. Radiation monitoring instrumentation is:
 - a) Available and working;
 - b) Not damaged or malfunctioning;
 - c) Respond as expected to background radiation and to check source;
 - d) Calibrated by the RPO and is within one year of the last calibration.
5. Laboratory Operations:
 - a) Doors to laboratories are posted with [appropriate signs](#), (Caution Radioactive Materials, Caution Radiation Area, etc.)
 - b) Radioactive materials containers are labeled;
 - c) Wearing assigned dosimetry;
 - d) Wearing lab coats or other appropriate protective clothing, including safety glasses;
 - e) Complete personal and laboratory surveys before leaving the laboratory. This survey must be recorded when using more than 1 mCi;
 - f) Make sure work with radioactive materials is [ALARA](#);
 - g) [Secure](#) radioactive materials are when not in use;
 - h) Do not eat, drink, smoke or apply cosmetics in the laboratory, and do not mouth pipette.

- i) Report for thyroid scans, submit urine samples for analysis, or complying with other bioassay procedures [as required](#);
- j) Report [spills](#) to the RPO;
- k) Obtain prior approval of all [transfers](#) of radioactive materials;
- l) Label radioactive waste containers;
- m) Do not place radioactive wastes in unlabelled containers or regular trash;
- n) Deface "RADIOACTIVE" labels on all empty packages;
- o) [Sink disposals](#) are within limits and recorded.
- p) [Maintain records](#)

Appendix M

Laser Definitions

Absorption. Transformation of radiant energy to a different form of energy by interaction with matter.

Accessible emission limit (AEL). The maximum accessible emission level permitted within a particular laser class.

Attenuation. The decrease in the radiant flux as it passes through an absorbing or scattering medium.

Average power. The total energy imparted during exposure divided by the exposure duration.

Aversion response. Movement of the eyelid or the head to avoid an exposure to a noxious stimulant or bright light. It can occur within 0.25 seconds including the blink reflex time.

Beam. A collection of rays which may be parallel, divergent, or convergent.

Beam diameter. The distance between diametrically opposed points in that cross-section of a beam where the power per unit area is $1/e$ (0.368) times that of the peak power per unit area.

Coherent. A light beam is said to be coherent when the electric vector at any point in it is related to that at any other point by a definite, continuous function.

Continuous wave (CW). The output of a laser which is operated in a continuous rather than a pulsed mode. In this program, a laser operating with a continuous output for a period of 0.25 seconds is regarded as a cw laser.

Controlled area. An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from radiation hazards.

Cornea. The transparent outer coat of the human eye which covers the iris and the crystalline lens. The cornea is the main refracting element of the eye.

Diffuse reflection. Change of the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.

Divergence. The increase in the diameter of the laser beam with distance from the exit aperture. The value gives the full angle at the point where the laser energy or irradiance is $1/e$ (36.8%) of the maximum value. For the purposes of this program, divergence is taken as the full angle, expressed in radians of the beam diameter measured between those points which include laser energy or irradiance equal to $1/e$ of the maximum value of the angular extend of a beam which contains all the radius vectors of the polar curve of radiant intensity that have length rated at 36.8% of the maximum. Sometimes this is also referred to as beam spread.

Diffraction. Deviation of part of a beam determined by the wave nature of radiation and occurring when the radiation passes the edge of an opaque obstacle.

Duty factor. The product of the pulse duration and the pulse repetition rate.

Electromagnetic radiation. The flow of energy consisting of orthogonally vibrating electric and magnetic fields lying transverse to the direction of propagation. X-ray, ultraviolet, visible infrared, and radio waves occupy various portions of the electromagnetic spectrum and differ only in frequency and wavelength.

Embedded laser. An enclosed laser with an assigned class number higher than the inherent capability of the laser system in which it is incorporated, where the system's lower classification is appropriate due to the engineering features limiting accessible emission.

Enclosed laser. A laser that is contained within a protective housing of itself or of the laser system in which it is incorporated. Opening or removal of the protective housing provides additional access to laser radiation above the applicable MPE than possible with the protective housing in place.

Hertz (Hz). The unit which expresses the frequency of a periodic oscillation in cycles per second.

Irradiance (E) at a point of a surface. Quotient of the radiant flux incident on an element of surface containing the point at which irradiance is measured, by the area of that element. Units are watt per square centimeter ($W\text{-cm}^{-2}$).

Joule (J). A unit of energy. 1 joule = 1 watt-second.

Laser. A device which produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions to lower energy levels. An acronym for Light Amplification Stimulated by Emission of Radiation.

Limiting aperture. The maximum diameter of a circle over which irradiance and radiant exposure can be averaged.

Maximum permissible exposure (MPE). The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin.

Nominal hazard zone (NHZ). The nominal hazard zone describes the space within which the level of direct reflected or scattered radiation during normal operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.

Nominal ocular hazard distance (NOHD). The distance along the axis of the unobstructed beam from the laser to the human eye beyond which the irradiance or radiant exposure during normal operation is not expected to exceed the appropriate MPE.

Protective housing. An enclosure that surrounds the laser or laser system that prevents access to laser radiation above the applicable MPE level. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing may enclose associated optics and a work station and shall limit access to other associated radiant energy emissions and to electrical hazards associated with components and terminals.

Pulse duration. The duration of a laser pulse, usually measured as the time interval between the half-power points on the leading and trailing edges of the pulse.

Pupil. The variable aperture in the iris through which light travels to the interior of the eye.

Q-switch. A device for producing very short (<30 ns) high-power pulses by means of a Q-switch.

Radian (rad). A unit of angular measure equal to the angle subtended at the center of a circle by an arc whose length is equal to the radius of the circle. 1 radian = 57.3 degrees; 2π radians = 360 degrees.

Radiance (L). Radiant flux or power output per unit solid angle per unit area. Unit: Watts per centimeter squared per Steradian ($W\text{-cm}^{-2}\text{-sr}^{-1}$).

Radiant energy (Q). Energy emitted, transferred or received in the form of radiation. Unit: joule (J).

Radiant exposure (H). Surface density of the radiant energy received. Unit: joules per centimeter squared ($J\text{-cm}^{-2}$).

Radiant flux (W). Power emitted, transferred or received in the form of radiation. Unit: watt (W). Also called *radiant power*.

Specular reflection. A mirror-like reflection.

Appendix N

An Accident Victim's View

(From *Laser Focus*, August 1977)

Accident Victim's View

Because laser injuries to eyes are rare, users tend to discount the importance of safety precautions. The following dramatic account by Dr. C. David Becker, a victim of such an accident earlier this year, was prepared in the hope that his experience may increase vigilance among his colleagues.

The necessity for safety precautions with high power lasers was forcibly brought home to me last January when I was partially blinded by a reflection from a relatively weak neodymium-YAG laser beam. Retinal damage resulted from a 6 millijoule, 10 nanosecond pulse of invisible 1064 nanometer radiation. I was not wearing protective goggles at the time, although they were available in the laboratory. As any experienced laser researcher knows, goggles not only cause tunnel vision and become fogged, they become very uncomfortable after several hours in the laboratory.

When the beam struck my eye I heard a distinct popping sound, caused by a laser-induced explosion at the back of my eyeball. My vision was obscured almost immediately by streams of blood floating in the vitreous humor, and by what appeared to be particulate matter suspended in the vitreous humor. It was like viewing the world through a round fishbowl full of glycerol into which a quart of blood and a handful of black pepper have been partially mixed. There was local pain within a few minutes of the accident, but it did not become excruciating. The most immediate response after such an accident is horror. As a Vietnam War Veteran, I have seen several terrible scenes of human carnage, but none affected me more than viewing the world through my bloodfilled eyeball. In the aftermath of the accident I went into shock, as is typical in personal injury accidents.

As it turns out, my injury was severe but not nearly as bad as it might have been. I was not looking directly at the prism from which the beam had been reflected, so the retinal damage is not in the fovea. The beam struck my retina between the fovea and optic nerve, missing the optic nerve by about three millimeters. Had the focused beam struck the fovea, I would have sustained a blind spot in the center of my

field of vision. Had it struck the optic nerve, I probably would have lost the sight of that eye.

The beam did strike so close to the optic nerve, however, that it severed nerve-fiber bundles radiating from the optic nerve. This has resulted in a crescent-shaped blind spot many times the size of the lesion. The effect of the large blind area is much like having a finger placed over one's field of vision. Also I still have numerous floating objects in the field of view of my damaged eye, although the blood streamers have disappeared. These "floaters" are more a daily hinderance than the blind areas, because the brain tries to integrate out the blind area when the when the undamaged eye is open. There is also recurrent pain in the eye, especially when I have been reading too long or when I get tired.

The moral of all this is to be careful and to wear protective goggles when using high power lasers. The temporary discomfort is far less than the permanent discomfort of eye damage. The type of reflected beam which injured me also is produced by the polarizers in q switches, by intracavity diffraction gratings, and by all beamsplitters or polarizers in optical chains.

Appendix O

Control Measures for Different Laser Classes

Control Measure (ANSI Paragraph No.)	Class 1	Class 2a	Class 2	Class 3a	Class 3b	Class 4
Protective Housing(4.3.1)	X	X	X	X	X	X
Without Protective Housing(4.3.1)	+	+	+	+	+	+
Interlocks on Protective Housing(4.3.2)	▼	▼	▼	▼	X	X
Service Access Panel(4.3.3)	▼	▼	▼	▼		X
Key Control(4.3.5)	—	—	—	—	●	X
Viewing Portals(4.3.5)	—	—	MPE	MPE	MPE	MPE
Collecting Optics(4.3.5)	MPE	MPE	MPE	MPE	MPE	MPE
Totally Open Beam Path(4.3.6)	—	—	—	—	X/NHZ	X/NHZ
Limited Open Beam Path(4.3.6)	—	—	—	—	X/NHZ	X/NHZ
Enclosed Beam Path(4.3.6)	N/A	With protective housing and interlocks				
Remote Interlock Connector(4.3.7)	—	—	—	—	●	X
Beam Stop or Attenuator(4.3.8)	—	—	—	—	●	X
Activation Warning Systems(4.3.9)	—	—	—	—	●	X
Emission Delay(4.3.9)	—	—	—	—	—	X
Indoor Laser Controlled Area(4.3.10)	—	—	—	—	X/NHZ	X/NHZ
Class 3b Laser Controlled Area(4.3.10)	—	—	—	—	X	—
Class 4 Laser Controlled Area(4.3.10)	—	—	—	—	—	X
Laser Outdoor Controls(4.3.11)	—	—	—	—	X/NHZ	X/NHZ
Laser in Navigable Airspace(4.3.11)	—	—	—	●	●	●
Temporary Laser Controlled Area(4.3.12)	▼/MPE	▼/MPE	▼/MPE	▼/MPE	—	—
Remote Firing and Monitoring(4.3.13)	—	—	—	—	—	●
Labels(4.3.14 & 4.7)	X	X	X	X	X	X
Area Posting(4.3.15)	—	—	—	●	X/NHZ	X/NHZ
Standard Operating Procedures(4.4.1)	—	—	—	—	●	X
Output Emission Limitations(4.4.2)	—	—	—	+	+	+
Education and Training(4.4.3)	—	—	●	●	X	X
Authorized Personnel(4.4.4)	—	—	—	—	X	X
Alignment Procedures(4.4.5)	—	—	X	X	X	X
Protective Equipment(4.4.6)	—	—	—	—	●	X
Spectator(4.4.7)	—	—	—	—	●	X
Service Personnel(4.4.8)	▼/MPE	▼/MPE	▼/MPE	▼/MPE	X	X
Demonstration with General Public(4.5.1)	*/MPE	—	X	X	X	X
Laser Optical Fiber Systems(4.5.2)	MPE	MPE	MPE	MPE	X	X
Laser Robotic Installations(4.5.3)	—	—	—	—	X/NHZ	X/NHZ
Eye Protection(4.6.2)	—	—	—	—	●/MPE	X/MPE
Protective Windows(4.6.3)	—	—	—	—	X/NHZ	X/NHZ
Protective Barriers and Curtains(4.6.4)	—	—	—	—	●	●
Skin Protection(4.6.5)	—	—	—	—	X/MPE	X/MPE
Other Protective Equipment(4.6.5)	Use may be required					
Warning Signs and Labels(4.7)	—	—	●	●	X/NHZ	X/NHZ
Service and Repairs(4.8)	+	+	+	+	+	+
Modification of Laser Systems(4.9)	+	+	+	+	+	+

Key for Control Measures

X	Required use;
●	Required if working with an enclosed Class 3B or 4 laser;
▼	Should be used;
MPE	Shall used if the MPE is exceeded;
NHZ	Nominal Hazard Zone Analysis Required;
—	No Requirement;
*	Applicable to UV and IR Lasers Only;
+	Laser Safety Officer will make the determination during a laser hazard evaluation.

Appendix P

Eye Exam Policy for Laser Users

I. Scope

This policy applies to all individuals directly involved with the use of Class 3b and 4 lasers at Harvard University. Incidental laser users (e.g. custodial, clerical) are excluded from the eye exam requirements.

II. Purpose

To establish the Harvard University Policy for pre-laser-use eye exams, periodic eye exams, termination eye exams, and incident-related eye exams. These requirements reflect those stated in ANSI Z136.1. Supervisors of laser installations are requested to publicize this policy and are responsible for ensuring that these requirements are met.

III. Requirements

Pre-laser-use Medical Exams - This medical exam is to establish a baseline against which ocular damage may be measured. For laser users, ocular histories, visual acuity measurement and selected examination protocols are required dependent on the specific laser radiation wavelength. These examinations shall be performed by, or under the supervision of, an ophthalmologist or other specified in the paragraph for examination protocol. Records of these results shall be maintained in the individual's medical file.

Periodic Eye Examination - Periodic eye examinations are not required. No chronic health problems have been associated with laser work.

Termination Eye Examination - Termination eye examinations for all class 3b and 4 laser users can document their visual status at the time of termination from a laser Permit. Termination eye examinations are required for laser users. This exam shall include those procedures specified in Section IV. Records of these results shall be maintained in the individual's medical file at the University Health Services.

Incident-Related Eye Exams - In the event of any accidental or suspected eye exposure to laser radiation, a thorough eye examination shall be conducted as specified in Attachment I. Records of these results shall be maintained in the individual's medical file. One copy of these results shall be sent to the Harvard University Radiation Protection Office.

Billing Procedures - The Permit Holder is responsible for all the cost associated with the laser eye exam.

IV. Examination Protocol

The laser user is provided a Laser Eye Examination approval form at the time of training. This form informs the individual to make a laser eye examination appointment by contacting the University Health Services Eye Clinic. The Laser Eye Examination form will be signed by the physician performing the examination. The laser user then returns the completed form to the RPO. The RPO maintains a roster of personnel who have received laser eye examinations. Examinations may include the following examination elements:

Ocular History. The past eye history and family histories are reviewed. Any current complaints concerned with the eyes are noted. Inquiry should be made into the general health status with a special emphasis upon systemic diseases which might produce ocular problems. The current refractions may cause the laser user to be at an increased risk for chronic exposure. Use of photosensitizing medications, such as phenothiazines and psolarens, lower the threshold for biological effects in the skin, cornea, lens and retina of experimental animals exposed to ultraviolet and near ultraviolet radiation. Aphakic individuals would be subject to additional retinal exposure from near ultraviolet and ultraviolet radiation. Unless chronic viewing of these wavelengths is required, there should be no reason to deny employment to these individuals.

Visual Acuity. Visual acuity for far and near vision should be measured with some standardized and reproducible method. Refraction corrections should be made if required for both distant and near test targets. If refractive corrections are not sufficient to change acuity to 20/20 for distance, and Jaeger 1+ for near, a more extensive examination is indicated.

Macular Function and Contrast Sensitivity. An Amsler grid or similar pattern is used to test macular function for distortions and scotomas. The test should be administered in a fashion to minimize malingering and false negatives. If any distortions or missing portions of the grid pattern are present, the test is not normal. Contrast (or glare) sensitivity should be documented by the Arden sine-wave patterns or similar acuity tests which include low contrast images.

Examination of the Ocular Fundus with an Ophthalmoscope. This portion of the examination is to be administered to individuals whose ocular functions are not normal. Points to be covered are: the presence or absence of opacities in the media; the sharpness of outline of the optic disc; the color of the optic disc; the depth of the physiological cup, if present; the ratio of the size of the retinal veins to that of the retinal arteries; the presence or absence of a well-defined macular and the presence or absence of a foveal reflex; and any retinal pathology that can be seen with an ophthalmoscope (hyper-pigmentation, depigmentation, retinal degeneration, exudate, as well as any induced pathology associated with changes in macular function). Even small deviations from normal should be described and carefully localized.

Appendix Q

List of Laser Protective Eyewear Manufacturers or Vendors

American Allsafe Co.
99 Wales Ave.
Tonawanda, NY 14150
(800) 231-1332

American Optical Company
Safety Products Group
14 Mechanic St.
Southbridge, MA 01550
(617) 765-9711

Ealing Electro-Optics, Inc.
New Englander Industrial Park
Holliston, MA 01746
(508) 429-8370

Edmund Scientific Co.
101 E. Glouster Pike
Barrington, NJ 08007-1380
(609) 547-3488

Energy Technology, Inc.
PO Box 1038
San Luis Obispo, CA 93406
(805) 544-7770

Engineering Technology Institute
601 Lake Air Drive, Suite 1
Waco, TX 76710
(800) 367-4238

General Scientific Equipment Co.
525 Spring Garden
Philadelphia, PA 19123
(215) 922-5710

Glendale Protective Technologies
130 Crossways Park Dr.
Woodbury, NY 11797
(800) 645-7530

MWK Industries
198 Lewis Court
Corona, CA 91720
(800) 356-7714

Omicron Eye Safety Corp.
73 Main Street
Brattleboro, VT 05301
(802) 257-7363

Optical Coating Laboratory, Inc.
2789 Northpoint Parkway
Santa Rosa, CA 95407-7397
(707) 525-7709

Fred Reed Optical
PO Box 27010
Albuquerque, NM 87125-7010
(800) 545-0912

Rockwell Laser Industries
7754 Camargo Road
Cincinnati, OH 45243
(513) 271-1568

U.S. Laser Corp.
PO Box 609
825 Windham Ct. N.
Wychoff, NJ 07481
(201) 848-9200

UVEX Safety, Inc.
10 Thurber Blvd.
Smithfield, RI 02917
(800) 343-3411

Appendix R Laser Postings



Figure 1 Posting for a Class 3b Laser



Figure 2 Posting for a Class 4 Laser



Figure 3 Posting for Laser Alignment or Repair

Appendix S

Specific Precautions for Beam Alignment from a Laser Spectroscopist

Laser users are in most danger while aligning a laser beam. When doing an alignment, you change the positions of the optics and the laser beam. This in turn changes the locations of back reflections and focal points. To align a laser, it is usually necessary to remove beam stops and the laser's protective housing. A new optic may be mis-aligned and could send the beam in an unanticipated direction or the optic may not be securely mounted. If bumped, the beam could be directed toward you or someone else. A new optic may burn, break or otherwise fail, causing the beam to be redirected. Most accidents have occurred during alignment.

Wearing laser protective eye wear during beam alignment is the single most effective action you can take to ensure your safety. Most people who have laser accidents are not wearing adequate protective eye wear. This might seem surprising, but there is a reason for this. Alignment procedures require exact positioning of the beam, and users, trying to see the beam clearly, endanger themselves by not wearing their laser protective eye wear. To align a beam, you should use a combination of good alignment practices and indirect viewing tools.

Good Alignment Practices:

- Personally notify everyone in the lab that you are doing a beam alignment. Warning signs on the entrances to your lab are good, but speaking with everyone is more effective;
- Do not allow anyone into the lab without eye protection;
- Remove your watch and any jewelry (such as belts with metal buckles) to avoid placing a reflective surface in the path of a laser beam;
- Be ready to contain the laser beam quickly if someone comes in your lab without proper eye protection;
- Use the lowest possible amount of laser light for alignment. For pulsed lasers, you can often turn off the Q-switch or un-optimize the Q-switch timing to reduce the beam power. Filters and polarizers may be useful. This is not always possible, especially in the case of femtosecond lasers;
- Always contain the beam;
- Be systematic: Focus on one optic at a time. Before allowing light to hit a new optic, use a card to ensure that the light is going to hit the optic in the right place. Make sure the optic is securely mounted so that it will not move if bumped. Make sure you know where the beam will go after it hits the optic and have a beam stop ready to intercept the beam. Do not look directly at the optic when you first allow the beam to hit it. Instead look at the beam stop where the light is supposed to end up. If it doesn't get there, it could be coming at you. By looking away from the optic, you are protecting the foveal region of your eye from a beam coming from the optic. Check that any back reflections from the optic are intercepted by a beam stop as early as possible. Allow the beam to hit only one additional optic at a time;
- Minimize the need for realignment. Although this is mainly a matter of convenience, the less often you have to realign, the safer you are. Buy good, solid mounts. Cover optics so they don't get dusty. Cleaning them may require realignment. Do small alignments frequently, so that a full realignment of all optics is not needed;
- Keep the lab cool to prevent your goggles from fogging up;
- Minimize the number of reflective objects on the laser table or area where you are aligning the laser beam,

including optics, tools, or plastic boxes;

- Brightly light the lab. Protective eye wear reduces the amount of light getting to your eyes. If the room is well lit, you will be less tempted to remove your eye wear just to get a good look at something. As an additional benefit, the brighter the room is, the smaller your pupils will be. If your pupils are smaller, they make a smaller target for a stray beam. However, bright lighting does make it more difficult to see the beam on a card or to detect stray beams.

Alignment Tools

Cards: Make full use of light sensitive, fluorescent cards and TV cameras for alignment. Fluorescent paint on a 3 x 5 card is excellent for viewing visible and UV light. Business cards are also good for UV. Business cards and fluorescent painted cards are often good for the near-IR as well. For the infrared, use IR viewing cards for the near-IR and black ceramic blocks for the mid-IR. Commonly, IR cards are laminated, producing specular back reflections. Try to avoid these cards. Always angle the card down, into the table, to avoid sending strong diffuse or specular reflections. Remember that cards are flammable and be careful with high power beams.

TV cameras and viewers may be helpful. Often a TV camera can see farther into the IR than can the human eye, so they are helpful for the near-IR.

Handheld electronic IR and near-IR viewers are also available. For example, for laser systems with wavelengths from the visible to ~850 nm, ITT manufactures night vision goggles (available from Edmund Scientific or West Marine) that are fairly resistant to saturating from the intense laser light. However, these goggles are not suitable for ~1064 nm YAG/YLF/Vanadate light; the Find-R-Scope viewers are suitable for those wavelengths, but they tend to saturate easily and have less depth of field. Some prefer the focusing characteristics of the Find-R-Scope, though.

Alignment eye wear: These glasses and goggles do not stop all the light at the laser's wavelength. They allow a small percentage of the beam to be seen when it diffusely reflects off a target, allowing you to see enough of the beam to align it. This eye wear will protect you from dangerously intense diffuse reflections, and reduce the intensity of a direct hit from the laser beam. You will not be completely safe, but this eye wear may be useful in certain circumstances.

Alignment laser: It may be appropriate to rough align the optics with a low power HeNe laser or laser pointer. You can place one of these lasers in the beam path and check the alignment before using a more powerful beam.

All laser users are encouraged to contact the Radiation Protection Office to discuss their laser procedures to jointly find ways to minimize the risks of injury.