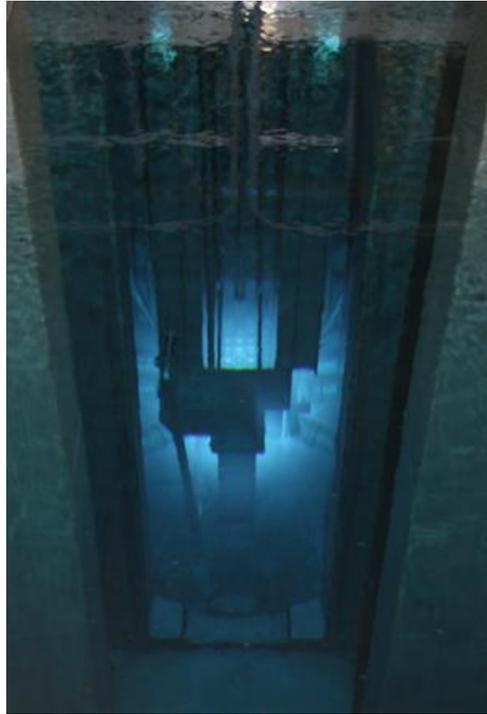
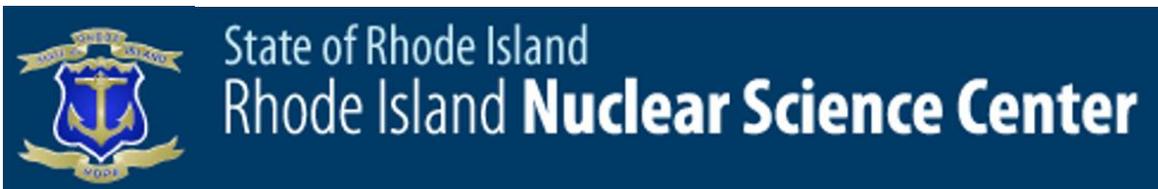


Radiation Safety Manual



Rhode Island Nuclear Science Center
Radiation Safety Office
16 Reactor Road
Narragansett, RI 02882
Phone: 401-874-2600
Fax: 401-874-9452
www.rinsc.ri.gov



4/2015
Updated 7/2019

Table of Contents

1. Introduction	1
2. Radiation Protection Policy and ALARA	3
3. Responsibilities for the Radiation Workers	5
Authorized Users	5
Radiation Workers	6
Worker Training	7
4. Application for Use of Radioactivity and/or Radiation Sources	8
5. Irradiation and Beam Line Studies	9
5.1 Irradiation Studies	9
5.2 Beam Line Studies	12
6. Radioactive Material Purchase, Receipt and Check-In, Inventory Record, Record of Use, Transfer, and Storage Procedures	15
Purchase	15
Package Receipt and check in	15
Inventory Number	17
Record of Use	17
Transfer of Radioactive Material	17
Storage of Radioactive Material	17
7. Training	18
8. Personnel Monitoring	19
Obtaining Dosimeters	19
Proper Use of Dosimeters	19
Proper Storage of Dosimeters	19
Lost or Damaged Dosimeters	20
Pregnant Workers	20
Electronic Direct Reading Dosimeters	20

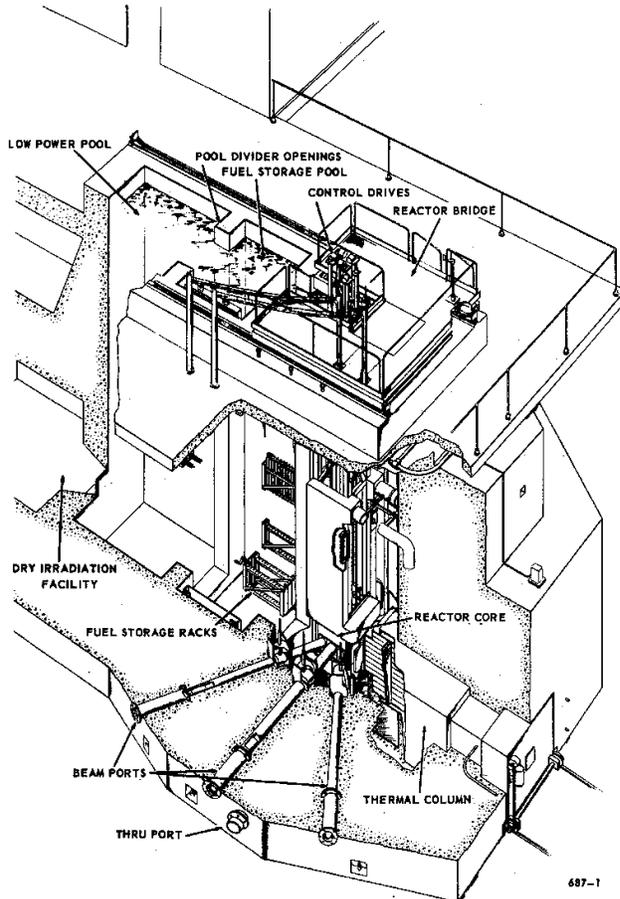
9. Bioassay	22
Radioiodine	22
Tritium (H-3)	22
10. Radiation Safety Procedures for the Use of Reactor or Radioactive Materials in Animals	24
11. Radioactive Material Laboratory Safety Guidelines	26
12. RINSC Facility Radiation Survey, Radioactive Material Laboratory Survey and Wipe Test Procedures	28
RINSC Facility Survey Procedures	28
General Survey procedures	28
Wipe Tests	29
Documentation	29
13. Sealed Sources	30
Use	30
Storage	30
Stuck Sources	30
Leak Tests	30
Transport	31
14. Radioactive Waste Disposal Procedures	32
Waste Segregation and Minimization	32
Solids	33
Sharps	33
Liquid	33
Liquid Scintillation Vials	34
Biological	34
Animal Remains	34
Source Vials	34
Lead Pigs	35
Other Waste Including Sealed Sources	35
Activated Materials	35

15. Posting and Labeling	36
Work Area	36
Exemptions to Posting and Labeling Requirements	37
16. Emergency Response, Radioactive Material Spill, and Accident	38
Radiation Incident & Emergency Phone Numbers	38
General Facility Emergencies	39
Medical Emergencies	39
Radioactive Material Spill	40
Decontamination	41
Accident Involving Radioactive Dusts, Mists, Fumes, Organic Vapors and Gases	43
Minor Fires	43
Major Fires, Explosions, or Major Emergencies	44
Accident/Incident	44

1. Introduction

The Rhode Island Nuclear Science Center (RINSC) features an extremely versatile and adaptable open pool research reactor operating under a U.S. Nuclear Regulatory Commission (NRC) license. The reactor is a two-megawatt, research reactor immersed in an approximately 36,000-gallon pool of demineralized water. The pool is contained in an open shielded tank, divided into three sections, that is approximately 22.5 feet long, 8.5 feet wide, and 32 feet deep. The high power section is circular with a diameter of 8.5 feet, and a depth of 32 feet. Neutron beam ports, six and eight inches in diameter, penetrate the shield and terminate at the core face. Two pneumatic systems (2" diameter tube) terminate at the core face. A thermal column (5'x5'x10') extends through the shield to the high power end of the pool.

The reactor core is configured from individual fuel elements placed in a core grid box 26 feet



beneath the pool surface. The grid box is attached to the base of a suspension frame that in turn is attached above the pool surface to a movable bridge that spans the width of the pool. Control of the reactor is achieved through the use of four shim-safety blades and one regulating blade. The safety blades are an alloy of aluminum and boron (known as boral); the regulating blade is a hollow, stainless steel, rectangular tube. The shim-safety blades are held up by electromagnets at the ends of aluminum extensions that attach to drive motors above the pool surface. The normal method for shutting down the reactor is insertion of the blades with their drive motors. In an emergency, electric current can be turned off to the electromagnets and blades will drop freely into the core.

The present reactor core consists of Low Enriched Uranium (LEU) type fuel. A typical reactor core configuration consists of 14 fuel elements. Each element is 3 inches by 3 inches by 24 inches long. Standard elements contain 275 grams of uranium-235 (U-235) in 22 aluminum-clad fuel plates. The U-235 enrichment in the fuel is slightly less than 20 percent.

The RINSC also has a variety of specially equipped laboratories operating under the University of Rhode Island (URI) Broad Scope Materials license which is issued by the Rhode Island Department of Health, Office of Facilities Regulations, Radiation Control Program (RIDOH). Those laboratories support research and development activities involving radioactive materials made in the reactor and radioactive materials obtained elsewhere. The facility houses the reactor, labs, lab equipment, machine, and electronic shops.

Radiation Safety is the responsibility of all individuals at the RINSC including staff, students, researchers, and visitors. The use of radioactive materials at RINSC makes strict compliance to federal and state regulations and RINSC policies important for the safety and protection of all individuals at the RINSC.

The Nuclear and Radiation Safety Committee (NRSC) is responsible for safety at the RINSC including the Reactor Operation and Radiation Safety Program. University of Rhode Island (URI) Authorized Users (AUs) not utilizing the reactor must be approved by the URI Radiation Safety Committee (RSC) and follow the URI Radioactive Material Safety Manual as well as the applicable portion of the RINSC Radiation Safety Manual. The purpose of the Safety Manuals are to assist all individuals in complying with the NRC and RIDOH radiation regulations.

This Manual is not intended to be a fully comprehensive reference. Further advice concerning hazards associated with specific radioactive material and/or the development of new and unfamiliar procedures should be obtained through consultation with the Assistant Director for Operations and the Radiation Safety Officer (RSO).

The Radiation Safety Manual is enforceable under both NRC and RIDOH licenses by which the RINSC is authorized, and violations of its policies and procedures are citable as areas of non-compliance by the NRC and RIDOH.

Where existing or future federal, state, or local regulations and the RINSC policies are found to be different from the requirements contained in this manual, those legally accepted regulations shall supersede this document.

This manual has been submitted and approved by the NRSC and represents official RINSC policy on radiation and radioactive materials. The format and administrative content of the forms associated with this manual can be revised with pending approval of the NRSC. New forms may also be added as necessary. However, changes which would result in any condition of non-compliance with applicable regulations or license conditions shall not be approved.

2. Radiation Protection Policy and ALARA

Radiation Protection Policy

Radiation dose received by any individual from external and internal exposure at the RINSC are required to be kept As Low As Reasonably Achievable (ALARA) consistent with effective use of radioactive materials and operation of the reactor. Exposure of personnel and the general public must never exceed regulatory limits.

Every effort should be made to avoid contamination of work areas and release of airborne or waterborne radioactivity exceeding regulatory limits. Every effort should be made to avoid accidental releases. Disposal of all radioactive waste shall follow procedures contained in this manual.

The radiation dose received by any individual from external and/or internal exposure to ionizing radiation in a non-controlled area should be kept as close to natural background levels as possible. Exposure to the general public from any operation at the RINSC must not exceed the annual regulatory dose limits of 100 mrem (1 mSv) above the natural background level. Individual and collective dose to workers are maintained ALARA.

ALARA

ALARA is a principal for radiation workers, such as RINSC staff, researchers including professors and students, contractors, etc. Management at all levels, and in all areas, as well as each individual worker, must take an active role in minimizing this radiation exposure.

In accordance with our commitment to keep occupational exposure ALARA, our ALARA program operates within the following objectives:

1. The annual total effective dose equivalent to individual workers shall be maintained ALARA with maximum annual whole body radiation exposure to any individual not to exceed 500 mrem (5 mSv). 500 mrem is 10% of the regulatory limits.
2. Any unexpected deep dose, which generally results from high beta, photon, and neutron exposure, during one monitoring period in excess of 100 mrem (1 mSv) shall be brought to the attention of the RSO. The RSO investigates the exposure to determine why the exposure occurred, and takes steps to prevent its recurrence. The issue can be brought to the attention of the NRSC and becomes an agenda item at its next scheduled meeting if necessary.

Failure to comply with the rules and regulations set forth throughout this manual may lead to disciplinary actions and/or the cessation of further work with radioactive materials and/or radiation sources at the RINSC. The RSO has authority to cease the activity temporarily and report to the RINSC Director and the NRSC. The NRSC may suspend and/or terminate any radioisotope or radiation use authorization if it may result in situations jeopardizing health and safety, the environment, or RINSC and URI licenses.

3. Responsibilities for the Radiation Workers

Radiation workers are directly responsible for compliance with all regulations governing radiation safety while working in the RINSC. The radiation workers are RINSC staff, researchers (URI faculty, staff, and students, and other non-URI individuals), and contractors who received radiation safety training for radiation workers. Workers will be required to receive annual refresher training. Non-radiation workers who may have access to restricted areas (for example, URI campus security personnel) are also trained annually.

All radioactive material use except URI RSC approved use at the RINSC must be approved and authorized by the NRSC.

New radiation workers must submit the Reactor Experiment Request Form to the Assistant Director for Operations or the RINSC director if the individual plans to utilize the reactor. URI AUs planning to use radioactive materials at the RINSC must submit the Radioactive Material Use Application to the Radiation Safety Office, Rhode Island Nuclear Science Center, 16 Reactor Road, Narragansett Bay Campus, or by E-mail for the RSO's review. The application must be filled out completely and the radiation safety staff is available for assistance if necessary. All radiation workers must be listed on the application and anyone not listed on the form will not be allowed to work with radioactive materials for any reason.

The information provided on the application is very critical and it will help the Assistant Director for Operations or the RINSC director, and the RSO to prepare necessary safety measures and assist the workers in implementing these measures.

If the NRSC/URI RSC determines that the training, facilities and safety precautions are adequate for the authorization requested, a formal written authorization to use the reactor and/or radioactive materials will be issued. The AU must keep a copy of this authorization on file.

Authorized Users (Supervisors):

All authorized users (URI and non-URI individuals) must:

1. Ensure that individuals working under their control are properly supervised and trained to enable safe working habits and prevent exposures to themselves and others and/or contamination of the work areas or environment. Inadequate supervision and lack of training lead to unnecessary exposure and/or contamination.
2. Be aware of the potential radiation hazards inherent in a proposed activity; be responsible for instructing personnel in safe practices or directing personnel to sources of information concerning safe practices.

3. Maintain inventory and knowledge of the various forms (physical and chemical) and quantities of radiation that are present in their work areas.
4. Avoid any unnecessary exposure, either to themselves or to other workers.
5. Understand the risks associated with the possession and use of all radioactive materials. Federal and state regulations control the use of radioactive materials and certain other hazardous materials.
6. Maintain constant surveillance and immediate control of radioactive materials to prevent unauthorized removal or tampering, and/or assure that all of the workers occupying the area maintain security.
7. Label radioactive use equipment and work areas.
8. Notify the Radiation Safety Office of any personnel changes, including addition or termination of employees, and/or changes of areas where radioactive materials may be used or stored.
9. Assure instruction of female radiation workers of the risks associated with working with radioactive materials during pregnancy.
10. Ensure that radiation safety surveys are performed in work areas after each experiment and/or at the end of each day and maintain records for review.
11. Be aware of regulations and requirements pertaining to the use of radioactive materials and maintain compliance and a safe working area.
12. Use radioactive materials and/or radiation according to statements, representations and conditions set forth in the authorized use approval given by the NRSC¹ and/or URI RSC.
13. Maintain use logs for radioactive materials and radiation sources.

Radiation workers will:

1. Comply with all laws, rules, regulations, license conditions and guidelines pertaining to the use of radioactive materials and radiation sources.
2. Wear their assigned radiation dosimeter during work within controlled areas of the RINSC.
3. Practice ALARA in their work, and minimize the potential for exposures, contamination or release of radioactive materials.
4. Monitor radiation work areas after each use of radioactive material. If contamination is found, it must be cleaned up and the RSO must be notified.
5. Make no changes in experimental procedures for using radioactive materials and/or radiation sources without the approval of the AU. Do not take short cuts. The NRSC must approve changes in experimental procedures impacting safety (higher quantities, higher risk, materially different procedures or processes, etc.).
6. Report any abnormal occurrence immediately to the AU and the RSO such as spills, significant contamination, equipment failure, loss of radiation dosimeters and unplanned release.

¹ Note: The Nuclear and Radiation Safety Committee must approve changes from the approved procedures in an amendment or new application prior to the implementation of the change.

7. Clean any contamination or spills that occur in their work area. DO NOT LEAVE IT FOR ANOTHER PERSON TO CLEAN UP except with the RSO's approval.
8. Return the radiation dosimeter to its storage area and report any loss or contamination of the dosimeter to the Radiation Safety Office.
9. Users must inform the Radiation Safety Office of any exposures that have occurred at a previous employer when beginning employment at RINSC. Users are also responsible for notifying the Radiation Safety Office of termination of employment and returning the radiation dosimeter at the end of their employment.
10. Maintain security of radioactive materials.

Worker Training

The Radiation Safety Office provides radiation safety training for individuals who work with or around radioactive materials or other generators of ionizing radiation. Radiation Workers using radioactive materials must have initial training before using radioactive materials. Annual retraining is required for the continued use of radioactive materials and/or radiation-producing equipment. Training will be tailored to specific job functions for non-radiation workers who have access to restricted areas.

All new radiation workers are instructed to review the RINSC Radiation Safety Manual and/or URI Radioactive Material Safety Manual after the initial training and before the initial use. Copies of the Manual are available at the Radiation Safety Office and on the web pages of www.rinsc.ri.gov for the RISNC manual and www.uri.edu/radiation for the URI manual.

For URI workers, AUs are responsible for their workers' training under their supervision. Special classes for large groups may be given as needed if prior arrangements are made with the Radiation Safety Office.

URI non-radiation workers are retrained annually and are scheduled through their individual departments. Additional training classes for administrative and secretarial staff are also offered if requested.

4. Application for Use of Radioactivity and/or Radiation Sources

The NRSC authorizes specific individuals to acquire and use radioactivity and/or radiation sources. URI users can use the RINSC facility for their research, however, the user must submit an application and receive authorization from the NRSC for using the reactor during their research in RINSC. Normally, those individuals are university faculty or staff members, RINSC staff, contracted employees, or commercial representatives. Persons not specifically authorized may use sources of radiation only under the supervision of the authorized individuals. Those seeking authorization must be familiar with the requirements of this manual.

Applicants must submit an application form to the Radiation Safety Office for authorization to use radioactive material and/or radiation producing equipment in RINSC and must submit the form to the Director or Assistant Director for Operations to use the reactor. Each applicant must provide a description of the radioactive material and/or radiation source, its proposed use, the applicant's qualifications, available radiation detection instruments, proposed work area, a basic radiation protection program for those work areas, and waste retention and disposal plan. URI authorized users planning to use radioactive material must be approved by the URI RSC before using the material in the RINSC.

If the NRSC determines that the training, planned work areas and safety precautions are adequate for the radioactivity and/or radiation sources requested, a formal written authorization to use the source of radiation will be issued. The authorized user must keep a copy of authorization on file.

Authorization must be received before an individual may receive or make radioactive materials.

5. Irradiation and Beam Line Studies

5.1 Irradiation Studies

Irradiation studies are those experiments where materials are placed near or into the reactor core for activation analysis, radiation effects studies or radioisotope production. RINSC provides several ways to conduct irradiation studies such as in-core, pneumatic tube, beam port and the thermal column studies.

Irradiation studies shall be planned and conducted to maintain radiation exposures ALARA. All users shall be adequately trained on the safety features, hazards and operation of their irradiation method before they will be permitted to attempt any experimental irradiation. Irradiation studies shall be conducted in accordance with approved procedures.

Samples measuring over 100 mrem/hr on contact cannot leave the confinement building or lab with the rabbit system without special permission from the RSO or designee.

1. Irradiating In-Core

Irradiation targets of various sizes and shapes can be irradiated by placing them in or near the reactor core. In-core irradiations are usually done manually and the samples are left in the core for longer periods of time (e.g., a day or more). The facility has standard irradiation containers and facilities that can accommodate a variety of sample requirements. The maximum neutron flux level is approximately 1.8×10^{13} n/cm²/sec.

The primary radiation safety concerns associated with in-core irradiations are sample containment integrity, radiation effects on the sample, induced sample activity, high radiation levels immediately following withdrawal from the core and removable contamination.

At the higher-fluence exposures available in the core, sample containment integrity must be considered due to the effects of radiation and heat on the sample holder. Sample initiated effects relating to internal pressure generation, corrosive materials, radiation-induced chemical effects and sample instability must also be considered. For exposures of a day or more ($\geq 10^{18}$ neutrons per cm²), samples should be irradiated in a quartz vial inside a metal container, (usually aluminum).

Experimenters will calculate the expected sample activity using the standard activation equation: $A = \phi \sigma n (1 - e^{-\lambda t})$ where ϕ is the flux, neutrons per cm² per second; σ is the activation cross-section, cm²; λ is the decay constant; n is the number of target atoms; t is the activation time. Sample activation at these flux levels can be substantially higher than those encountered with pneumatic system. In-core irradiation positions have a relatively high epithermal neutron

component. As a result, the induced activity in nuclides with a significant epithermal cross-section can be substantially higher than would be expected based only on thermal neutron fluence and cross-section.

Impurities can be significant contributors to the sample activity. Since the levels of impurities are generally unknown, plan a short test exposure with a small quantity of the sample. Changes in the source of supply of the irradiation material or changes in the preparatory procedures for the sample may also result in a sample with different contaminant characteristics. If such changes are made, plan an additional short test exposure with a small quantity of the new sample to determine its contaminant characteristics. The short irradiation test identifies radionuclides likely to be encountered following the longer in-core irradiation from both the sample and its impurities. The AU will estimate expected dose rates from the sample based on short irradiation tests. The Radiation Safety Office can assist in the calculation of expected activity and the resulting radiation levels. High initial dose rates are frequently the result of the presence of short-lived radionuclides. Samples can usually be raised to an out-of-core position to allow those short-lived radionuclides to decay.

2. Using the RINSC Pneumatic Tubes ("Rabbit System")

Pneumatic systems that propel a sample holder to an irradiation position are generally called "rabbit systems." The RINSC rabbit system has two pneumatic tubes that transport a sample holder to its irradiation position within the reactor. That position provides a sample fluence rate of approximately 2×10^{12} n/cm²/sec with a thermal to fast neutron ratio of 10.

Sample holders are called rabbits and may be made of aluminum or plastic. RINSC rabbits hold samples up to one-inch in diameter and six inches long, and are usually made of polyethylene. Significant activation products in polyethylene include Na-24, Mn-56, Mn-54 and Zn-65. The rabbit receiver is mounted in a shielded box providing control of external exposure and contamination and monitored by a wall-mounted gamma instrument.

Users shall be properly monitored, attired for work within a potentially contaminated area and working under an approved protocol. The wall monitor near the receiver station will detect abnormally high radiation levels in the area. If the wall monitor alarms while the sample is still in the shielded receiver, you should leave the area and notify the Control Room and the Radiation Safety Office. If the wall monitor alarms as the sample is being removed from the receiver, you should return the sample to the receiver, and consult with Assistant Director for Operations and the Radiation Safety Office. In either case, the Radiation Safety Office will survey the sample to determine the cause of the unexpected activity.

General Precautions

1. Without prior approval, only polyethylene may be used for spacers and packaging.
2. At contact, exposure rates of a freshly irradiated rabbit can be quite high. Remote handling procedures are essential.

3. Samples inserted into the system must be packaged according to the procedures in the experimenter's proposal and approved under the NRSC authorization.
4. After decay, handle irradiated rabbits with gloves to control skin contamination.

Contamination Control Procedures

The following rules should be observed to avoid the spread of contamination:

1. Perform all work with previously irradiated rabbits at designated areas such as lab bench, hood, etc.
2. Use gloves when handling radioactive contaminated rabbits.
3. Do not touch handling tools and electronic controls with gloves used to handle rabbits.
4. Use tools (not hands) to handle irradiated rabbits.
5. Treat the designated areas as contaminated until verified to be clean.
6. Store handling tools at designated location to keep their handle away from contamination.
7. Clean up work areas after finishing work each day.
8. Place radioactive wastes (e.g., contaminated paper, old rabbits), in the radioactive waste container.
9. Any samples, vials, papers or other items left from a previous day's irradiation by an experimenter may be considered waste and thrown away.

3. Using Beam Ports

Six horizontal beam ports, four 6 inch and two 8 inch ports, and a tangential thru-tube are available for long-term irradiation. The horizontal beam ports penetrate the reactor pool wall and terminate at the face of the core. The maximum neutron flux at the core end of a beam port is normally 3.0×10^{12} n/cm²/sec and minimum flux at the flange end is normally 5.0×10^7 n/cm²/sec. AUs wishing to use the beams ports or thru-tube should contact the Director or Assistant Director for Operations.

4. Using the Thermal Column

A thermal column made of a stack of 5' x 5' x 10' graphite with a central radial beam hole is available for irradiations. The thermal column's shielding removes fast neutron and gamma components of the reactor's radiation flux to provide a mostly thermal neutron field. The thermal column can be used for neutron radiography and the activation of large objects. AUs wishing to use the thermal column should contact the Assistant Director for Operations. The maximum thermal neutron flux level is approximately 1.2×10^9 n/cm²/sec.

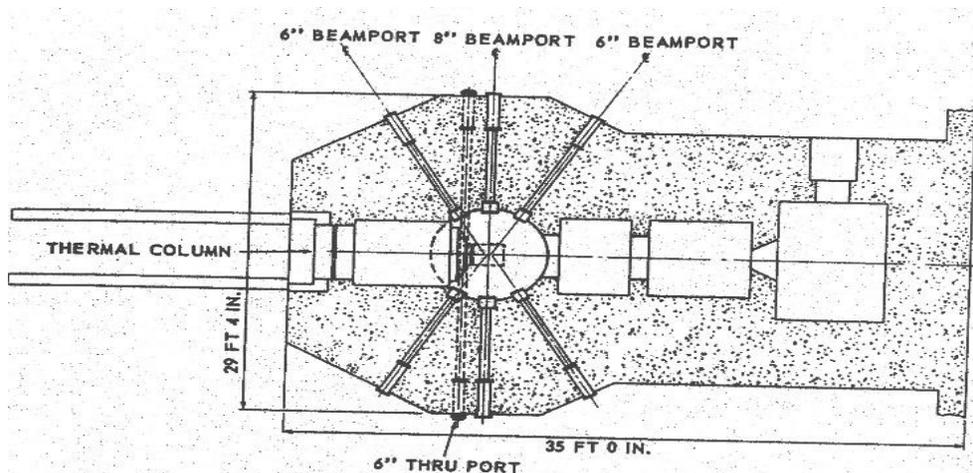
5. Using the Capstone Beam Port

A device located at the opening of a 6 inch un-shielded beam port that allows sample changes while the reactor is in operation. The sample cart allows a maximum sample size of 6 inch long x 6 inch wide x 6 inch high. A neutron detector is located behind the cart to allow for counting

of neutron levels when the lead shutter is in place. AUs wishing to use the capstone beam port should contact the Director or Assistant Director for Operations. The maximum neutron flux level inside of the cart is approximately 4×10^7 n/cm²/sec. The counts recorded on the neutron detector behind the cart are approximately 8.3×10^4 n/sec with the lead shutter in place.

5.2 Beam Line Studies

Beam line studies are those experiments that utilize external beams of neutrons guided out of the reactor at controlled locations. Normally, beam line experiments may be viewed as consisting of three components attached externally to the beam line: 1) the neutron beam conditioning equipment, 2) the experimental sample, and 3) the data collection apparatus.

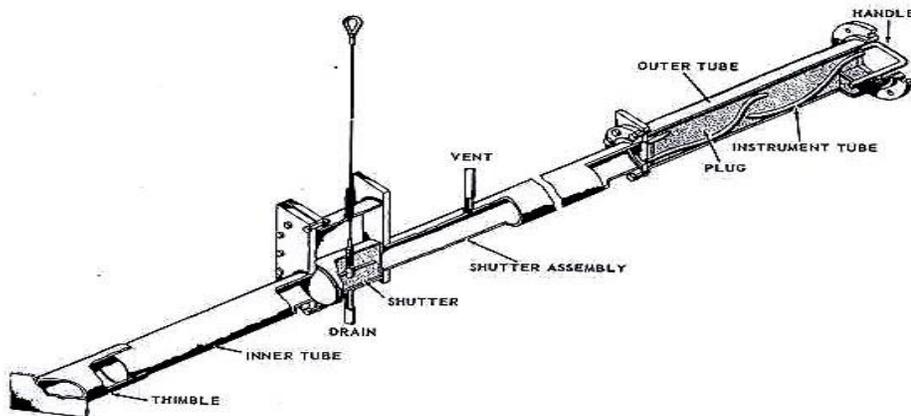


Beam line studies shall be planned and conducted to maintain radiation exposures ALARA. A shielding and access control perimeter shall be established to support ALARA objectives. Access controls and area postings shall comply with RINSC standards.

All users shall be adequately trained on the safety features, hazards and operation of their beam line before they will be permitted to use any experimental equipment.

As shown in the cross section drawing above, six horizontal beam ports and a tangential thru-tube are available for neutron beam extraction experiments such as neutron radiography and neutron spectroscopy. There are four six-inch diameter and two eight-inch diameter beam tubes. The horizontal beam ports penetrate the reactor pool wall and terminate at the face of the core.

As shown in the drawing on next page, each beam port consists of a thimble, inner and outer tubes, drain, shutter, vent, instrument tube, plug and handle. The shutter effectively isolates the experiment from the reactor even when the reactor is operating.



The primary radiation safety issues associated with beam line studies are the adequacy of the shielding, preventing access to the neutron beam path and the general radiation fields produced by items such as collimators and samples introduced into the beam path by the experiment. The in-beam dose equivalent rate is substantial and when designing your beam line experiment, you should consider the likely radiation safety impacts of your neutron beam conditioning equipment, experimental sample and data collection apparatus.

The design of shields for beam line experiments is controlled by the specific requirements of the individual experiment. In designing and using a shield, AUs should consider the following general principles:

1. Thermal neutrons should be captured in boron or lithium to minimize the high-energy gamma fields produced in other materials.
2. If lead is used for gamma shielding, it should be installed in a manner that allows its separate and easy removal. When the shield is discarded, the lead must be surveyed to reduce mixed wastes.
3. If paraffin-filled, steel-shell shields are used, the sides facing the neutron source should be lined with a thermal neutron absorber. The lining reduces activation of the steel and decreases the thermal neutron dose rate from the shield.
4. Joints and gaps between shielding materials should be minimized. Any joints should be surveyed for radiation-streaming problems.
5. Large shields seldom fit exactly and they never get back to the same fit when disassembled for experimental modifications or adjustments. Thus, surveys are needed when the shield is installed and whenever it is reassembled.

1. Neutron Beam Conditioning Equipment

Beam conditioning equipment alters the path of the neutrons and can cause significant local increases in neutron and gamma dose equivalent rates. Selectable collimators can dramatically change the neutron fluence. If a selectable collimator is located near the extraction point of the beam, the dose equivalent rate from prompt gammas may be a significant problem. Movable internal shielding can create local high dose equivalent rates at certain rotational orientations. Selectable monochromators can significantly change both the neutron fluence and the in-beam gamma intensity. In general, pyrolytic-graphite monochromators provide much lower radiation fields than copper monochromators. Misaligned slits may create local high dose equivalent rates where none existed.

In the design, consider barriers, beam enclosures and other safety systems to ensure no beam access. Provide beam status indicators, (e.g. beam on/off signs, shutter indicator lights, etc.). Provide local shielding in areas where conditioning equipment intersects the neutron beam. Contact Radiation Safety for assistance with the design and shielding of beam conditioning equipment.

2. Experimental Sample

Sample activation, though minimal at these flux levels should be considered if the samples will be removed from the Center. You should calculate the sample activation using the standard activation equation: $A = \phi \sigma n (1 - e^{-\lambda t})$ where ϕ is the flux, neutrons per cm^2 per second; σ is the activation cross-section, cm^2 ; λ is the decay constant; and t is the activation time; and n is the number of target atoms.

Beam line activation samples generally meet requirements for limited quantities under DOT regulations. If you wish to remove activated samples from the Center, contact the Radiation Safety Office for assistance with packaging and shipment. If you wish to store your samples in the RINSC, contact the Radiation Safety Office and be prepared to provide the isotope(s), estimated activity for each radionuclide present and date that activity was estimated.

3. Data Collection Apparatus

Beam experiments employ many different kinds of instruments and measurement methods including, but not limited to, single, double and triple diffractometers, reflectometers, time-of-flight detectors, small-angle neutron scatters, spin-echo experiments, depth profiling, prompt-gamma analysis, and interferometers. The primary radiation safety concern with data collection apparatus is the use of adequate shielding to prevent serious radiation exposures during experimental runs.

6. Radioactive Material Purchase, Receipt and Check-In, Inventory Record, Record of Use, Transfer, and Storage Procedures

Purchase

Radioactive material may be acquired only by the URI AU or individuals specifically listed in the AU's permit. All Purchase Requisitions for radioactive material must be approved by the RSO or designee before the order is processed through the Purchasing Department.

Note: Chemical compounds containing uranium or thorium must be purchased as radioactive material, because these compounds may be subject to radioactive waste disposal requirements.

The AU must be approved to possess the isotope and activity ordered. The activity, when added to the current isotope inventory, must not exceed the AU's approved possession limit for that isotope. The Radiation Safety Office will review each request to ensure that orders are consistent with the user's authorization. If these conditions are met, the Radiation Safety Office will approve the acquisition the same day it is received.

Any acquisitions of radioactive materials from a vendor, collaborator or another institution require prior approval of the Radiation Safety Office. This includes but is not limited to replacement shipments, trial kits, and free samples.

When filling out a purchase requisition, the following information is required for processing by the Radiation Safety Office and must be clearly printed on the requisition:

1. Radioisotope, e.g. P-32, C-14, etc.
2. Maximum activity per vial, e.g. 500 microcuries (μCi), 0.5 mCi, etc.
3. Compound(s), e.g. DCTP, Thymidine, etc.
4. Total number of vials
5. Vendor and catalog number for the isotope ordered
6. Name and signature of the AU authorized for the order
7. Individual who place the order if different from AU
8. Location and phone number of the receiving laboratory approved for radioactive material use

Package Receipt and check in

Radioactive material packages are delivered directly to the Radiation Safety Office. The Radiation Safety Office must be notified of expected time of delivery. Radioactive material

packages will not be accepted outside of normal business hours or on weekends or holidays unless previously arranged with the RSO.

All radioactive material shipments are checked in and must be inspected within 3 hours of delivery by the Radiation Safety personnel. Packages of radioactive materials should be opened using the following procedures or other procedures approved by the Radiation Safety Office:

1. Wear proper protective equipment (PPE) including lab coat; latex, vinyl, butyl, or nitrile gloves; safety glasses; dosimeters if assigned; etc.
2. Check for evidence of mishandling and potential contamination such as packages that are crushed, wet, or damaged. If the package has evidence of damage, contact the RSO immediately.
3. Open all packages containing volatile radioactive materials (ex. I-125, I-131) in an approved fume hood.
4. Monitor all packaging material for contamination with a survey meter and record results.
5. Conduct wipe tests on the outside of the container, the vial container, and the vial for removable contamination. The outside container must be wiped at least 300 cm² according to DOT regulations (49 CFR 173.443)
6. Analyze the wipes using an appropriate counting device such as Planchette Counter. Record the results on a signed and dated form and included the actual analysis print out if available. Make a copy for the Radiation Safety Office.
7. If there is any evidence of leakage or external contamination, contact the RSO immediately.
8. If there is no contamination above the action level (240 dpm/100 cm²) on the outside package, remove and/or completely deface the radiation warning labels before disposing of the items as non-radioactive trash. If counts are detected the above the action level, please contact the RSO for any further action required.
9. Retain all survey results for the shipment for a minimum of three years for the URI records.

Packages with unacceptable levels of contamination or with external radiation levels exceeding applicable regulatory limits will be investigated and the final delivery carrier immediately notified. The RSO or his/her designee shall notify the RIDOH by telephone or facsimile when required.

Inventory Number

Each radioisotope is assigned a specific inventory number by the Radiation Safety Office. This is recorded on the vial and a vial container to prevent isotope mix up if multiple materials exist, and also on the radioactive material tracking Form. A radioactive material tracking form must be maintained while using the material and a copy of the form must be returned to the Radiation Safety Office when the material is no longer in use or is used completely. The form must be maintained by AUs for their records and also by the Radiation Safety Office. Inventory of all radioisotopes is electronically maintained by the Radiation Safety Office. A physical review of all inventoried radioactive material stock vials will be performed during the Radiation Safety lab audits.

Record of Use

The radioactive material tracking form must be kept up to date and filled out completely at each time of use. The form must indicate when the radioisotope is no longer in use or is completely used. If any activity remains, this must be indicated on the form as well. Upon receipt of the completed forms, the radioisotope will be deleted from the AU's radioactive material inventory. Failure to return the forms in a timely manner may cause the AU to exceed maximum possession limits and could prevent or delay approval of new radioisotope orders.

Transfer of Radioactive Material

All transfers of radioactive material between AUs within the University must be documented and approved by the RSO. The radioactive material tracking form will be used when the material is transferred. A new radioactive material tracking form and inventory number will be issued for the transferred radioisotope.

AUs leaving the university and transferring their radioactive material to another institution must arrange to properly ship their material in consultation with the RSO. A minimum of 2 weeks prior notification should be provided.

Storage of Radioactive Material

Radioactive material packages shall only be delivered to the approved locations. All radioactive materials shall be stored in a locked cabinet, refrigerator, freezer, or room, and when not in a locked device or room (such as during working hours), it shall be accompanied by a trained radiation worker at all times. All radioactive materials must be stored in secure areas to prevent unauthorized removal. Radioisotopes must also be stored behind sufficient shielding as necessary to reduce radiation exposures. Radiation Safety personnel will inspect all radioactive material labs to ensure that appropriate safety measures are in place and proper safety procedures and controls are being followed prior to working with radioisotopes.

7. Training

The Radiation Safety Office provides radiation safety training for individuals who work with or around radioactive materials, radiation producing devices, and the reactor. All users at RINSC are required to receive appropriate radiation safety training, as determined by the RSO, before working at RINSC. Annual refresher training is required for all active users. Inactive users must have completed radiation safety training within a year to re-attain active status.

The user training will include basic radiation physics, radiation hazard, regulations, RINSC/URI policies, safety procedures, package receiving, contamination survey, and waste disposal. Non-user training will include radiation hazard, safety procedures, RINSC/URI policies, and regulations.

All new RINSC radiation workers are instructed to review the RINSC Radiation Safety manual. Copies of the Radiation Safety manual can be obtained by direct request to the Radiation Safety Office or on the RINSC web page, www.rinsc.ri.gov.

Each AU is responsible for training workers under his/her supervision on radiation safety procedures and practices specific to each particular research.

Non-radiation workers who may access to the restricted areas (i.e., Maintenance, Security and Custodial) are retrained annually and as scheduled through the individual departments. Additional training classes for administrative and secretarial staff are also available by request.

Special classes for groups may be given as needed if prior arrangements are made.

8. Personnel Monitoring

Each individual likely to receive 1/10 of the maximum permissible exposure limits annually, 500 millirem (mrem), per NRC and RIDOH Regulations shall wear a radiation dosimeter (radiation badge). This includes all radioactive material users except low beta (ex. H-3, C-14, S-35) users. Other personnel may request dosimetry that will be provided at the discretion of the Radiation Safety Office.

Obtaining Dosimeters

The Radiation Safety Office issues personal radiation dosimeters to new radiation workers and personnel who are likely to receive 1/10 of the maximum permissible exposure limits annually. Radiation workers must complete the training class and fill out the radiation badge request form. If there is any doubt concerning the need for radiation dosimetry, contact the Radiation Safety Office.

Proper use of Dosimeters

The whole body dosimeter shall be worn between the neck and waist. If, however, one area of the body is more likely to be exposed than the rest, the dosimeter should be worn in that area. The front of the dosimeter must be exposed toward the source of radiation with no obstruction such that it correctly reads the exposure of the radiation worker. It is recommended that the dosimeter be worn inside of any personal protective equipment (PPE) such as gloves, apron or lab coat unless the user is wearing a shielded PPE. Please consult with the Radiation Safety Office as to where and how dosimeters should be worn when you use shielded PPE.

Extremity dosimeters (ring dosimeters) should be worn under any protective gloves on the hand most likely to receive the greatest exposure. The front of the ring dosimeter should face toward the radiation source.

Dosimeters are issued to a single user and shall not be shared. Dosimeters must to be returned promptly at the end of each cycle to assure the Radiation Safety Office can take timely action, consistent with implementation of ALARA, in the event any significant dose is measured.

Proper storage of dosimeters

Store dosimeters in a radiation-free area, such as a desk drawer, when not in use. Do not take the dosimeters out of the facility.

Lost or Damaged dosimeters

Report lost or damaged dosimeters such as those crushed, broken, and melted to the Radiation Safety Office as soon as you are aware of the situation. This will be recorded at least with name and date, and the record shall be kept at least 5 years from the reported date.

Pregnant Radiation Workers

A special situation arises when a radiation worker becomes pregnant or intends to get pregnant. Under these conditions, radiation exposure could also involve exposure to the embryo or fetus. The State of Rhode Island also requires that the maximum permissible exposure for a declared pregnant worker during the gestation period is 500 mrem. Any radiation worker who is pregnant, thinks she may be pregnant, or intends to get pregnant may declare the pregnancy verbally or by electronic mail to the RSO. This notification will be followed up with a written and signed notification in order for the prenatal exposure limits to take effect. The radiation worker will then meet with the RSO, and a complete assessment of her radiation exposure potential will be made. Additional counseling will be provided if necessary and a fetal badge will be assigned. The assigned fetal badge is normally worn on the abdomen and the badge will be exchanged on a monthly basis. Exposures should be maintained under 50 mrem per month generally. An individual may undeclare her pregnancy at any time, but this also should be documented.

Electronic Direct Reading Dosimeters



Electronic Direct reading dosimeters, such as Canberra Dosicard, are rugged, precision instruments about the size of a credit card, which are used to measure accumulative doses from gamma (X-ray) radiation. A metal clip is used to attach the dosimeter to an individual's pocket or to any available object in an area to be monitored for total radiation exposure. Dosicard features a silicon detector, complete analog and digital circuitry, including a microcontroller with large non-volatile memory, a LCD display and audio and visual alarms. Three touch buttons

allow programming and display setup of the current dose, dose rate and cumulative doses. These dosimeters are used by visitors and short time irregular users for monitoring their exposure during their visit. They are also sometimes assigned to radiation workers who work in a high radiation area for a long period time. The dosimeter shall be turned off after the use and

turned on before the use. The read out always starts with “0” mrem when turn it on. See picture on the left.

9. Bioassay

Bioassay is the determination of the kinds, quantities or concentrations, and, in some cases, the locations of radioactive material in the human body. Bioassays may be conducted by direct measurement (*in vivo* counting) or by analysis and evaluations of materials excreted or removed from the human body. Bioassays may be required for anyone handling or using unsealed radioactive sources at the RINSC.

Bioassays are required for radiation workers who are likely to receive a measurable internal radiation dose. Bioassay procedures include, but are not limited to, thyroid screening and urinalysis. Bioassays are required for adults likely to receive an annual intake in excess of 10 percent of the applicable annual intake limits.² Bioassays will also be required for minors and declared pregnant women likely to receive an annual intake in excess of 1 percent of the annual intake limits for adults.

Radioactive iodine

A bioassay is required any time more than 1 mCi of radioactive iodine in volatile form is used at once. The Radiation Safety Office must be notified before handling more than 1.0 mCi of volatile radioactive iodine to make a plan to perform a bioassay for anyone involved in the procedure. The bioassay thyroid scan must be performed within 72 hours but no earlier than 8 hours. Generally the bioassay will be performed in approximately 24 hour periods.

Tritium (H-3)

The Radiation Safety Office must be notified before handling more than 10 mCi of H-3. Bioassays are required and background urinalysis will be performed before any procedure involving 100 mCi of H-3 or more. Tritium sources in metallic foils are exempt from bioassay requirements.

Urine bioassays must be done for H-3 users in accordance with the following schedule:

1. Less than 100 mCi - bioassays are performed at the discretion of the RSO or when requested by the AU or the RSC.
2. Greater than 100 mCi but less than 1.0 Ci - bioassays are performed weekly until results are in the normal range if necessary.
3. Greater than 1.0 Ci - bioassays are performed daily until results are in the normal range if necessary.

² Found in Rhode Island Department of Health's Rules and Regulations For The Control of Radiation, R23-1.3-RAD Part A, Appendix B, and 10 CFR 20, Appendix B.

Following approval by the RSO, tritium users may perform their own bioassays and submit the results to the Radiation Safety Office. The bioassay procedure can be obtained from the Radiation Safety Office.

10. Radiation Safety Procedures for the Use of Reactor or Radioactive Materials in Animals

The URI AUs planning to work with radioactive material or the reactor with animals must be approved by or submitted to the URI Institutional Animal Care and Use Committee (IACUC) before submitting the Application for Use of Radioactive Materials. The AU must attach IACUC approval or submitted application with the application for use of radioactive materials. The use of radioactive material in animals requires additional safeguards in the handling of affected animals. The information provided on the application will enable Radiation Safety to formulate necessary safety measures and assist the AU in implementing these measures. The AUs utilizing the reactor for irradiating animals must submit the application to the NRSC for approval before use.

Details concerning the actual use of animals must be discussed with the Animal Care and the research protocol approved by the IACUC. No research activities using animals can be started without prior approval.

The application will be submitted to the NRSC or RSC for review and approval. Approved AUs will receive an authorization permit to work with radioactive material in animals at URI or an authorization permit to work with the reactor for animal research at RINSC and this may be submitted with Grant Proposals. The IACUC will be notified and provided with a copy of the approved application.

The AU is responsible for the overall radiation safety of the project, including radiation exposure monitoring of the animals, cages, and procedures; analytical determination of radioactivity in urine, feces, and bedding; and labeling of all cages containing radioactive animals. Consultation and assistance will be provided upon request. Tags for this purpose must indicate at least the radioisotope, the activity (in μCi or mCi), and date for radioactive material use, and irradiation time, projected dose, and the date for reactor use. Animal Care must be notified per terms of the IACUC protocol prior to housing these animals in their facility. Such notification may not be necessary for animal use within the AU's authorized laboratories.

All animal remains containing radioactive material [except H-3 and C-14 as described below] are to be disposed of as follows:

- Place the remains in a (preferably yellow) radioactive materials waste bag. Secure the bags closed with tape and indicate the radioisotope, the activity (in μCi or mCi) and the date on the tags. Submit a waste request to the Radiation Safety Office. The bag will be collected by the radiation safety personnel and stored in the radioactive material labeled freezer at the Radioactive Waste Facility for future disposal.

- All animal wastes with short half-life isotopes (< 90 days) will be placed in a clear bag or red biohazard bag, securely shut with tape, and marked on a radioactive material sticker with the radioisotope, the activity (in μCi or mCi) and the date. Submit a waste request and the bag will be collected and stored in the radioactive material labeled freezer at the Radioactive Waste Facility for at least 10 half-lives. After 10 half-lives, the waste will be surveyed and transferred for disposal as animal wastes.
- Animal remains containing H-3 and/or C-14 in quantities less than 0.05 μCi per gram, may be disposed of as non-radioactive waste. The RSO must be consulted before disposal of animal wastes. The AU must maintain inventory records with the date, activity, and radioisotope used in the animal and provide a copy to the RSO.

From RIDOH regulation 216 RICR 40 Subchapter 20;

1.15.5 Disposal of Specific Wastes.

For the purpose of this Part, disposal of specific wastes is defined by 10 CFR 20.2005.

1.16.8 Records of Waste Disposal

For the purpose of this Part, requirements for maintenance of records of waste disposal are defined by 10CFR 20.2108.

11. Radioactive Material Laboratory Safety Guidelines

Basic laboratory safety guidelines are necessary to ensure personnel safety and prevent radioactive contamination or spills and ensure compliance. Consistent and active participation by all laboratory personnel including radiation workers is necessary.

The following set of guidelines is not comprehensive.

- Personnel without radiation safety training should not be near while radioactive procedures are in progress in laboratories.
- Radioactive material work area (hot work area) must be away from heavy traffic and doorways. AU must not change pre-approved work space without consultation with the RSO.
- Every container of radioactive material should be labeled for identification with the radiation warning symbol or “radioactive material” and pertinent information such as the radionuclide content, date and activity. The container does not need to be labeled if it holds radioactive material that is used that same day and solely by a user.
- Must use caution in handling radioactive materials and use double containers and shielded containers when transporting the material to protect against external radiation exposure and spills if necessary.
- Must wear laboratory coats if handling unsealed materials and other recommended protective clothing including gloves at all times when working with radioactive materials.
- Must not handle food, drink, or personal items including a cell phone while working with radioactive materials. Do not eat, drink, apply lip balm, or apply cosmetics in any area where radioactive materials are stored or used.
- Do not store food, drinks, or personal items within radioactive material labs.
- Dispose of radioactive wastes only in specially labeled receptacles.
- Never pipette by mouth.
- Absorbent paper shall be used to cover workbenches and other surfaces where radioactive materials are handled. In addition, absorbent materials should be used in trays if applicable.

- Survey hands and clothing for contamination after each procedure or before leaving the area. This is done using a survey meter with the exception of H-3 users.
- Survey all areas where radioactive materials are used in unsealed form after each procedure and/or at the end of the day. Decontaminate immediately if necessary.
- Work should be planned ahead and a practice run should be performed to test the procedure.
- The laboratory should be kept clean and orderly at all times.
- Radiation survey instruments should be checked prior to use to ensure proper operating conditions if possible. This includes a battery check to be performed before each use.
- Radiation badges, when assigned, shall be worn at all times while in areas where radioactive materials are stored or used. Assigned ring badges shall also be worn at all times when handling radioactive materials.
- All radioactive materials must be secured at all times to prevent unauthorized access and the laboratory must be locked when no one is present.

12. RINSC Facility Radiation Survey, Radioactive Material Laboratory Survey and Wipe Test Procedures

AUs shall perform contamination surveys and document the results in appropriate units for all areas where radioactive materials are used or stored under their supervision. The Radiation Safety Office will conduct periodic surveys and audits to assure proper use of all radioactive materials, verify compliance, and to keep records for agencies inspections.

Surveys must be conducted after each experiment using radioactive materials or at least at the end of the day when radioactive materials are used. Survey documentation shall include meter information such as model and serial number, etc. Wipe tests are strongly recommended accompany the survey when unsealed form was used. All records require both count rate measurements with an appropriate, calibrated survey meter and wipe tests performed to identify removable contamination. These checks are necessary to keep radiation exposures ALARA.

RINSC Facility Survey Procedures

The Radiation Safety Office will conduct periodic surveys, and audits to assure proper use of the reactor, all radioactive materials including activated materials, verify compliance, and to keep records for agencies inspections.

All records require count rate or exposure rate measurements with an appropriate calibrated survey meter, and wipe tests, if necessary, performed to identify removable contamination. These checks are necessary to keep radiation exposures ALARA.

General Survey procedures

A survey must be performed using a survey meter on all labs using activated materials and radioisotopes except for H-3 use labs. Before using any survey meter, check for current calibration and proper functioning. If the batteries are weak, contact the Radiation Safety Office to replace the battery and to perform a functional check before its use. Check that the meter is properly responding by holding the probe close to the radiation source, without touching it. Obtain background readings before surveys. Additional training on this procedure should be requested as needed.

Monitoring for contamination is performed by slowly moving the detector over all surfaces at a distance of approximately 1 to 2 centimeters. The survey meter should be turned on before entering any radiation area starting with the lowest setting for known radiation fields. The

audio should always be “on” since small increases of radiation exposure are easily detected by listening to the audio and it is easier to pay attention to the surface being monitored. Make sure not to contaminate the probe by touching the surface being checked. Request assistance from the RSO if needed.

Any area with meter readings consistently above twice background or greater with the survey meter must be thoroughly investigated and immediately decontaminated if necessary. A resurvey should then be performed to confirm that the area is less than two times background.

Calibrations of survey meters must be performed annually as coordinated by the RSO or the RSO’s designee. Calibration is also required after a repair or the replacement of parts (e.g. probe). Calibrated meters will have a calibration label affixed to the side or bottom with the date of calibration, performed by, and serial number of the instrument. The calibration certificate will also be kept for records by the Radiation Safety Office.

Wipe Tests

Wipe tests are necessary for the use of H-3. Cotton swabs or small filter paper discs are used for performing wipe tests. Either dry or wet wipe tests are acceptable. To perform a wipe test, sample at least 100 cm² of the surface. Appropriate personal protective equipment must be worn when performing wipe tests.

Wipes are to be taken at locations around the laboratory based on knowledge of material use. Any area found with a wipe test resulting above action level of 220 disintegrations per minutes (dpm) per 100 cm² or greater from a liquid scintillation counter, Planchette counter, or other applicable analytical equipment is considered contaminated. This area must be immediately decontaminated until the wipe test count is below the 220 dpm.

Documentation

Lab surveys and wipe tests must be recorded with the locations of each survey and wipe test properly identified. Completed survey documentation must be kept for your records. The radiation safety surveys will be kept in the Radiation Safety Office for records and for agency inspections.

13. Sealed Sources

Sealed sources are designed and licensed for specific tasks, (e.g., calibration, measure moisture and density of soils). Sealed source containing devices typically contain one or two radioactive sources, (e.g., an Americium-241: Beryllium (Am-Be) source and a Cesium-137 source). Each sealed source will be used and maintained in accordance with its manufacturer's manual or regulatory requirements.

Use

Sealed source containing devices may be operated only by (or under the direct supervision of) a properly trained user. The device operator will maintain constant surveillance of the device during use and restrict access to the immediate area of the device.

Storage

Sealed sources shall be shielded to meet regulatory requirements when in storage or transit. They shall also be secured against unauthorized removal from their storage areas when not in use.

Stuck Sources

If the device has malfunctioned such as a source being stuck in a position that prohibits normal operation, the operator shall immediately notify the RSO to receive further assistance. Areas around the sealed source must be secured to prevent unauthorized personnel from entering the area to prevent access to where the source is pointing. The operator should remain on the site and maintain surveillance of the source unless the area can be securely locked to prevent from unauthorized access. The device manufacturer should be consulted if necessary.

Leak Tests

Only qualified personnel, such as radiation safety personnel, should test the sealed source(s) in any device for leakage. In general, beta and gamma emitting sealed sources with activity of more than 100 uCi are leak tested and physically inventoried at least every six months (alpha emitting sources more than 10 uCi are typically tested every 3 months). If devices are not in use and in storage they are exempt from leak tests, however physical inventory will be performed as scheduled (at least every six months).

Transport

Sealed sources will only be shipped or transported by the US Department of Transportation (DOT) trained Radiation Safety Personnel or the Radiation Safety Office designated DOT trained personnel.

The DOT³ has determined that transport radioactive materials in a state vehicle for non-commercial purposes such as research, training, etc. is not subject to the Hazardous Materials Transport Act (HMTA) regulations.

³ Hazardous materials transported by a state employee in a state-owned vehicle for non-commercial purposes are not subject to the HMTA regulations. The US DOT's Office of Hazardous Materials, chief of Regulatory Review and Reinvention provided the interpretation in a letter to Mr. David Wiik; USDOT dated November 19, 2004., Reference No.: 04-0256

14. Radioactive Waste Disposal Procedures

Radioactive waste requires the same safety and security measures similar to radioactive materials. The AU is responsible for the safe, secure, and proper storage of radioactive wastes generated until removed by the radiation safety personnel. The URI Radioactive Material Safety Manual establishes guidelines to ensure compliance with the required procedures for collection, packaging, labeling, transport and disposal of radioactive wastes generated under licensed activities conducted under the URI AU without reactor use. Any activity involving reactor use in the RINSC facility will follow the RINSC and URI waste disposal procedures.

Do not place radioactive waste in the ordinary waste. Accidental and improper radioactive waste pick-up and/or disposal must be reported immediately to the RSO. All non-radioactive waste generated in RINSC will be surveyed before being disposed.

The Radiation Safety Office is responsible for the pickup and disposal of all radioactive wastes generated at RINSC. Radioactive waste management, including segregation, direct handling, repackaging, and physical disposal will be conducted by trained and authorized personnel only under the direction of the RSO. Poor radioactive waste disposal practices including sharps in the dry waste container can lead to a higher threat of radioactive material contamination and personnel health hazards. Non-compliance items are expected to be addressed immediately by means of waste handling retraining and discussion to prevent recurrence.

Specific information such as AU, waste type, activity, etc. must be provided before pickup. The waste will be picked up by the radiation safety personnel and stored in the radioactive waste storage at the RINSC. Contact the Radiation Safety Office for questions and assistance with waste pickup and documentation.

Waste Segregation and Minimization

Waste segregation by form and isotope is an effort to minimize the volume of radioactive waste disposed of in licensed land disposal facilities. For this initiative to succeed, it is necessary that all AUs and laboratory personnel follow proper radioactive waste procedures.

Radioactive waste must be segregated by radioisotope and physical form. The only general exceptions are the radioisotopes H-3 and C-14 which can be stored together. Any other exception must be pre-approved by the RSO. The basic physical forms are: solids, glass, sharps, liquid, liquid scintillation vials (LSV), biological, animal remains, source vials, lead pigs, sealed sources, and activated materials.

Solid

Solid radioactive waste is comprised mostly of solid disposable items that have been contaminated with radioactive material including absorbent work surface coverings, gloves, tubing, etc. The plastic waste bag, preferably yellow, must be placed in waste receptacles that remain closed at all times. Deface or remove all radioactive labels before placing waste into the bags if possible. Do not place anything in the bags in such a way that they may tear. Inspect the plastic waste bag for tears prior to removal from the container if possible. Use a secondary bag to contain the waste if needed. Do not mix liquid scintillation vials, lead pigs, and stock vials with the solid waste, **especially sharps**. Plastic source vial containers, but not the lead impregnated type, may be disposed of in the solid waste after being defaced of all radioactive labels. Every waste container must have complete waste information attached prior to pickup.

Sharps

Sharps are defined as anything that could tear the yellow radioactive material bag including needles, razor blades, capillary tubes, broken glass, etc. This waste type must be disposed of in puncture resistant plastic containers. Make sure that all sharps are dry before placing them into a container. When full, securely close the container and attach complete waste information prior to pickup.

Liquid

Radioactive liquid waste can be further divided into aqueous, acids and bases, and pump oils. Aqueous liquids are water-based liquids with a pH between 5.5 and 9, such as saline and buffer solutions and weak acids and bases. No radioactive liquid is to be poured down the sink. Sinks will be checked during routine lab surveys and wipe tests performed by the Radiation Safety Office. Pipettes and other such items must not be placed in the container. All biological material in the containers must be properly deactivated or neutralized such as by using a bleach solution. Do not mix liquid waste types in the container.

Double containment in a tray or pan that will adequately contain the liquid is recommended as a precaution against leakage or spills. This will also control accidental overflow and drips due to pouring. At a minimum, plastic backed absorbent paper shall be placed under all liquid waste containers. Containers should be kept as free of contamination as possible.

Liquid waste should be placed in recyclable containers that can be returned to the laboratory by the Radiation Safety Office. These containers should be made of heavy gauge plastic. Judgment should be used in the selection of plastics since many organic chemicals will dissolve them.

The Radiation Safety Office will not accept liquid waste that has been placed in glass containers unless pre-approved by the RSO. Contact the Radiation Safety Office if you have any questions about the type of container to use for your liquid waste or if the liquid waste contains any regulated chemicals. Every container must have completed waste information attached prior to pickup.

Liquid Scintillation Vials

Liquid Scintillation Vials are glass or plastic vials containing organic or aqueous based liquid scintillation fluid. This waste can be disposed of as non-radioactive material wastes if below the regulatory limits. For more information, contact the Radiation Safety Office. The AU must know what is in the liquid scintillation vials and the activity. The Radiation Safety Office strongly recommends the use of biodegradable scintillation cocktail unless other chemical based cocktail is necessary. Liquid scintillation waste with short half-life (less than 90 days) isotopes will be picked up by the Radiation Safety Office and held for at least 10 half-lives, surveyed, and disposed of as exempted chemical waste if biodegradable or disposed of as chemical waste if non-biodegradable. The disposal records must be maintained at the Radiation Safety Office.

Biological

The Radiation Safety Office will not pick up any radioactive waste containing biological waste unless it is properly deactivated or neutralized. Liquids must be absorbed into some absorbent material such as paper towels, sponges, gauze, etc. prior to being placed into bags. Pathogenic and infectious waste must be sterilized by chemical treatment. Do not autoclave radioactive contaminated biological waste unless the autoclave is dedicated for such waste only.

Animal Remains

This category covers radioactive animal carcasses and animal research by-product waste. Animal remains containing radioactive material are subject to handling according to the guidelines stated in the Radiation Safety Procedures for the Use of Radioactive Material in Animals section. Every waste bag must be securely sealed with a tag attached indicating the AU, the date, radioisotope, and total activity. Liquids must be absorbed into some absorbent material such as paper towels, sponges, gauze, etc., prior to being placed into bags.

Source Vials

These are the original vials that the radioactive material was shipped in to a lab and which are waiting for disposal. All returned source vials are considered wastes. A copy of the Radioactive Material Tracking Form must be returned along with the source vial.

Lead Pigs

The inner lead lining of a lead pig must first be removed from the plastic container. The plastic container should then be surveyed to make sure it is uncontaminated. Any radiation labeling must be completely defaced before the plastic container is disposed of as regular trash. Lead is a regulated material and cannot be disposed of as trash. It must also be surveyed and free of contamination before the Radiation Safety Office will pick it up. Lead pigs and lead impregnated shielding containers must be kept separate from the solid waste.

Other Wastes including Sealed Sources

These wastes include calibration sources, check sources, quenched standard sets, electron capture gas chromatograph detectors, etc. Final survey and/or leak tests are required to be performed on all sealed sources prior to disposal. All sealed sources must be turned in to the Radiation Safety Office for proper disposal even if they are decayed. AUs and radiation workers must check for broken or crushed sources and handle these damaged sources with extreme care. Notify the RSO immediately if a source breach or contamination is found or suspected. Sealed sources must be kept separate from the other wastes for disposal. A Radioactive Waste Disposal Form is not required. Segregation by radioisotope does not apply to sealed sources.

Activated Materials

Activated materials are generated from the reactor operations. Expected materials must be indicated on the use application which is submitted to the NRSC for approval. These wastes can be handled similarly to solid waste but must be segregated from other wastes. User must notify the radiation safety personnel and provide complete waste information with the waste.

15. Posting and Labeling

All rooms and areas where regulated quantities of radioactive materials are used or stored must be posted with appropriate signs and labels to inform personnel and visitors to use caution upon entering the area. The NRC and the RIDOH "Notice to Employees" information documents must be posted so that all employees can observe and have the opportunity to read the notice on their way to or from their work area. All postings and signage may be obtained from the Radiation Safety Office.

The signage and postings include a Radiation symbol, a "Caution Radioactive Materials" sign, emergency contact information, and the "Notice to Employees" information documents.

Work Areas

A "Caution Radioactive Materials" sign must be visibly posted for each area where licensed quantities of radioactive materials are stored or used. Use of warning signs for labeling personal items is not permitted. For example, labeling a non-radioactive notebook as "radioactive" to keep others away is not permitted.

The NRC and the RIDOH "Notice to Employees" information documents must be posted in an area where the radiation workers can observe them on their way to or from their work area.

Mark areas where radioactive materials and/or radiation levels could exist with warning signs. Use "Radiation Area" and "High Radiation Area" signs as defined below.

"Radiation Area" refers to any area accessible to personnel in which the radiation levels are such that a major portion of the body could receive a dose of 5 mrem or more in one hour or 100 mrem in any five consecutive days.

"High Radiation Area" refers to any area accessible to personnel in which the radiation levels are such that a major portion of the body could receive a dose of 100 mrem or more in one hour. Ropes or fences should be used in addition to the warning signs to clearly mark restricted areas. In addition, a visual or sound warning system must be used when the area becomes a high radiation area during the reactor operation and/or high radiation area is accessible.

Entrances to a radioactive material laboratory work area must be posted with the "Caution Radioactive Materials" sign clearly visible. Equipment used to store radioactive materials should be prominently labeled with a "Caution Radioactive Material" sign. All radioactive waste containers must be labeled with a "Caution Radioactive Material" sign. The trefoil labels must be large enough and clearly visible from all sides of the waste container.

All "Radioactive Material" labels must be removed or defaced prior to disposal or removal of containers or other laboratory equipment that is no longer radioactive.

All radioactive-labeled refrigerators, freezers or other storage units for radioactive materials in unsecured areas must have a security lock to limit access to the materials or must contain a secured, labeled lock-box within. Either the storage unit or an internal lock-box should be kept locked, even if they do not contain any radioactive materials.

Exemptions to Posting and Labeling Requirements

Areas or rooms containing radioactive materials for periods of less than 8 hours are exempt from posting requirements if either of the following conditions is met:

1. Containers are attended by an individual who takes the precautions necessary to prevent the exposure of other people (less than 2 mrem in any one hour at a distance of one foot) and does not involve the manipulation of open radioactive materials;
2. Containers are in transport and are packaged and labeled in accordance with the U.S. Department of Transportation regulations.

16. Emergency Response, Radioactive Material Spill, and Accident

Emergencies may result from reactor operations and/or experimental work within our laboratories. Emergencies involving the reactor may require evacuation of the RINSC. In the event of an emergency with the reactor, RINSC personnel will initiate response in accordance with the Emergency Plan Implementing Procedures.

Other emergencies may occur in the individual laboratories. Radioactive material incidents may involve three levels of response due to severity: spills, accidents, and emergencies. All these events may raise exposure and contamination concerns with potentially increased dose both internally and externally to the lab personnel, the environment and members of the public. Each incident must be carefully evaluated before proceeding and approached properly to prevent additional hazards and personnel exposure. Each AU is responsible for ensuring that the Radiation Safety Office is notified immediately when these events occur.

Radiation Incident & Emergency Phone Numbers

Working Hours:

Radiation Safety Office	(401) 874-2600
Radiation Safety Officer	(401) 874-9439
Health Physicist	(401) 874-9451

After Hours:

URI Public Safety (Emergency)	(401) 874-2121
URI Public Safety (Non-Emergency)	(401) 874-4553
Medical Emergencies (Must go to Rhode Island Hospital for any radiation injuries)	911

General Facility Emergencies

General facility emergencies include reactor accidents, major fires, explosions, multiple personnel injuries or illnesses, etc. and may require evacuation of parts or the entire Center. Any of the following communication methods may alert you to an emergency condition requiring evacuation of personnel:

- (1) Telephone intercom system (PA system); and
- (2) Evacuation-horn alarm system.

The RINSC telephone system is equipped with an intercom system which permits general announcements to be communicated from any one phone set to make general announcements in the RINSC by using the intercom system. This system will promptly alert the RINSC staff to the emergency situation.

The evacuation horn alarm system may be activated from any one of five (5) stations located as follows:

1. Control Room near door.
2. Reactor Room main floor, just inside the confinement door, on the confinement side.
3. Reactor Room main floor, just outside the confinement door, on the office side.
4. Confinement garage door, next to the door in the confinement room.
5. Emergency Generator Room, inside next door.

Activation of this system generally means an emergency has been identified which requires evacuation of the facility. Activation of this alarm system is limited to RINSC operating staff members only.

Medical Emergencies

For serious injuries involving radioactive material, such as a life-threatening situation, immediately call 911 (must go to the Rhode Island Hospital). Minor cuts should be allowed to bleed, thereby reducing absorption. First aid of major cuts or abrasions, lacerations, etc., should be considered before decontamination. Proceed with personnel decontamination if possible. Contact the RSO for assistance. Please note the following:

- Treatment of a serious injury should take precedence over almost all concern for contamination control and radiation exposure.
- No transport restrictions should be imposed that would seriously compromise the patient's medical care.
- When transporting a contaminated patient to a hospital emergency room or the designated emergency receiving point, the following procedures should be followed:

- Contaminated clothing should be removed if possible.
 - If skin decontamination is necessary, wash the patient thoroughly with soap or detergent and water.
 - Wrap the patient in a clean sheet or blanket.
 - A representative from Radiation Safety should accompany the patient, but do not delay transport if Radiation Safety personnel are not present.
- External contamination is not immediately harmful to the patient unless the skin is badly punctured or wet.
 - Minor injuries can usually be treated at the scene and can usually wait until after an initial radiation survey has been completed.

All radiation accidents (wound, overexposure, ingestion, and inhalation) must be reported to the RSO as soon as possible since this may require regulatory notification. No one involved in a radiation injury will be permitted to return to work without the approval of the RSO.

Radioactive Material Spill

A radioactive material spill may be in the form of liquid, powder, mist, fume, organic vapor, or gas. The spill may pose cross-contamination concerns to the lab and adjacent areas, as well as personnel.

Two types of spills are possible in a lab situation depending on the volume and activity:

Minor Spill

A minor spill is a spill that remains contained, can easily and effectively be cleaned up without assistance from the Radiation Safety Office, does not involve personnel contamination, and is typically less than 100 uCi of activity and/or a small volume of liquid within a small area. The Radiation Safety personnel will provide assistance with small spills whenever requested.

1. Notify others in the area of the minor spill.
2. Survey hands and surrounding areas; remove gloves if required and replace gloves.
3. Remove contaminated bench paper and dispose of as radioactive waste.
4. Decontaminate and verify that all contamination is removed.
5. Re-survey immediate and surrounding areas.
6. Dispose of all spill clean-up material as radioactive waste. This includes any contaminated brooms, mops, dust pans, etc.
7. Report to the Radiation Safety Office and do not resume work in the area until the Radiation Safety Office has cleared the area.

Major Spill

A major spill involves large amounts of radioactivity greater than 100 uCi, high radiation exposures at the surface (> 2 mR/hr), a large volume of fluid, and/or a large surface area of contamination, involves personnel contamination, and/or results in contamination outside of the intended work area. The RSO or other Radiation Safety personnel must be contacted immediately for major spills to take charge of cleanup operations and follow up to verify decontamination to acceptable levels. Personnel are expected to use sound judgment in initiating cleanup efforts.

1. Notify others in the area of the major spill.
2. Have somebody not involved in incident (if practical) call the Radiation Safety Office for assistance and guidance.
3. Check shoes for potential contamination.
4. Have unaffected personnel (if available) survey the area for contamination boundary.
5. Barricade area at the boundary of contamination to prevent spreading of contamination.
6. With assistance and replacement items, remove contaminated clothing or footwear.
7. Do not leave the area until the initial investigation by the Radiation Safety Office has been completed.

Decontamination

Decontamination is the removal of unwanted radioactive materials. Contamination can be to an area, on personnel, and in some cases, involves injury to personnel. Major personal injuries take priority over decontamination which can be performed at a later time.

Personnel Decontamination

Clothing Decontamination:

1. Remove the contaminated clothing carefully to avoid or minimize contaminating the skin.
2. Check the skin for possible contamination; decontaminate the skin as indicated below before continuing with clothing decontamination.
3. Determine approximate activity on the clothing.
4. The clothing material will be labeled and held in storage by the Radiation Safety Office until the activity is decayed, it is decontaminated, or it is disposed of as radioactive.

Skin Decontamination

1. Contact the Radiation Safety Office for assistance.
2. Wash with mild soap and running water (or wetted towels).
3. Do not abrade skin or scrub raw.
4. Survey after each washing and drying for cleaning efficiency.

Area Decontamination

All persons not involved and not contaminated should leave the area.

1. Put on appropriate personal protective equipment (double gloves, booties, etc.) before entering areas where there may be contamination.
2. Define an outer boundary of contamination.
3. As soon as possible clean from the outer edge of the contamination and work inward.
4. Use a spray solution and wipe up with paper towels or other absorbent material to remove as much removable contamination as possible.
5. Low activity spills not containing hazardous materials can be cleaned up by using mild soap with running water.
6. While cleaning towards the center area, check newly cleaned areas for loose contamination before walking or kneeling in these areas. Absorbent paper may be placed over these areas to prevent recontamination.
7. Mark any areas where the contamination cannot be easily removed for further decontamination efforts or shielding.
8. Re-survey the area.
9. Using a filter paper or cotton swab, wipe the area. Count the wipe using a scintillation counter, a Planchette counter or a gamma counter as appropriate. If the count is greater than action level of 220 dpm, repeat area decontamination until the count is below this level.
10. Dispose of all radioactive waste properly according to the radioactive waste procedures.

Equipment Decontamination

1. Use spray cleaning solution and wipe up with paper towels or other wetted absorbent material to remove as much of the contamination as possible. Be careful not to flood the area with cleaner since that will wash contamination into cracks, which will make it harder to clean up later.
2. Low activity spills not containing hazardous materials can be cleaned using soap and water, and then disposed down the sanitary sewer, provided the activity does not exceed sewer disposal limits.
3. Wash until removable contamination is below the limits. When wipe tests indicate only fixed contamination remains, label the instrument with isotope, activity and date.
4. For hood decontamination, ensure that fume hood is running. Volatile isotopes should be put into bags and sealed before removing from hood.
5. Re-survey area.

Accidents Involving Radioactive Dusts, Mists, Fumes, Organic Vapors and Gases

1. Notify all personnel to vacate the room immediately.
2. Vacate the room and seal it, if possible.
3. Notify the Radiation Safety Office.
4. Ensure that all access doors to the areas are closed and posted with radiation warning signs, or post trained guards at all access doors to prevent accidental opening of the doors or entry to the area.
5. Survey all persons who could possibly have been contaminated. Decontaminate as directed by the Radiation Safety Office.
6. Promptly report suspected inhalations and ingestions of radioactive materials to the Radiation Safety Office.
7. Reenter the area to decontaminate it only when advised or supervised by the Radiation Safety Office.
8. Allow no one to return to work in the area without approval of the Radiation Safety Office.
9. Assist the Radiation Safety Office in determining cause and corrective actions.
10. Bioassay samples may be requested by the Radiation Safety Office if ingestion, inhalation, absorption, and/or wound intakes are suspected.

Minor Fires

1. Immediately attempt to put out the fire by approved methods (e.g., fire extinguisher) if other fire hazards or radiation hazards are not present.
2. Notify all persons present to vacate the area and have one individual immediately call the Radiation Safety Office and Narragansett Fire Department (911, 789-1000).
3. Once the fire is out, isolate the area to prevent the spread of contamination.
4. Survey all persons involved in fighting the fire for possible contamination.
5. Decontaminate personnel by removing contaminated clothing and flushing contaminated skin with lukewarm water, then washing with mild soap.
6. In consultation with the Radiation Safety Office, determine a plan for decontamination, the personal protective clothing and equipment, and survey instruments necessary to decontaminate the area.
7. Allow no one to work in the area unless approved by the Radiation Safety Office.
8. Assist the Radiation Safety Office in determining cause and corrective actions.
9. Bioassay samples may be requested by the Radiation Safety Office if ingestion, inhalation, absorption, and/or wound intakes are suspected.

Major Fires, Explosions, or Major Emergencies

In the event of a fire, explosion or other major emergency, the Radiation Worker will:

1. Notify all persons in the area to leave immediately.
2. Notify the Narragansett Fire Department (911, 789-1000).
3. Notify the Radiation Safety Office.
4. Upon arrival of firefighters, inform them where radioactive materials are stored or where radioisotopes were being used; inform them of the present locations of other radioactive materials and the best possible entrance route to the affected area(s), as well as any precautions to avoid exposure or risk of creating radioactive contamination by use of high pressure water.
5. Allow no one to return to work in the area unless approved by the Radiation Safety Office.
6. Assist the Radiation Safety Office in determining cause and corrective actions.
7. Bioassay samples may be requested by the Radiation Safety Office if ingestion, inhalation, absorption, and/or wound intakes are suspected.

Accident/Incident

Accidents may involve a release of radioactive material into the air, water system, or outside the lab. In case of an accident involving radioactive material, notify all personnel to leave the area and also notify the RSO immediately. An accident/incident report should be filled out by the radiation worker and sent to the Radiation Safety Office as soon as possible.

The report must include basic information such as the name of the person involved, the date and time of the incident, the date and time it was reported to the Radiation Safety Office, the location of the incident, any personnel involved if more than one, the isotopes and activities involved. The second part of the form consists of a written description that includes: how the incident occurred; what caused the incident; the areas, personnel, and/or equipment that were contaminated, if any; the current status; and any procedural changes required to prevent a recurrence of the incident. If the incident involved contamination of an area, equipment, or personnel, a copy of the contamination survey should be attached. This survey should include a diagram of the affected area or equipment and the results of meter and wipe tests indicating contamination levels in dpm or μCi . The original surveys should be placed in the AU's file with the laboratory survey records. Do not re-enter the room until approval of the RSO is obtained.