RADIATION SAFETY MANUAL

ENVIRONMENTAL HEALTH AND SAFETY CENTER
RADIATION SAFETY DIVISION
VERSION IV, 2005

PREFACE

The objective of North Carolina State University's Radiation Safety program is to assist all levels of the NC State Research and academic community in fulfilling the NC State commitment to furnish a place of employment and learning that is as free as possible from recognized radiation hazards that cause or are likely to cause harm to institutional personnel and the surrounding community. It is vital that faculty, staff and students have enough information available to aid them in the safe conduct of their daily work activities relating to radioactive materials and devices.

To that end, the North Carolina Radiation Protection Section issues a broad license to the NC State University authorizing the receipt, possession, storage, transfer and use of radionuclides and radiation-producing devices. An essential component of the licensing is this Radiation Safety Manual. A significant factor in being allowed the flexibility of a broad license by the North Carolina Radiation Protection Section is that NC State implicitly accepts the responsibility to regulate and control the broad use of radioactive materials and radiation-producing machines within its jurisdiction.

The purpose of the NC State Radiation Safety Manual is to assist both personnel and management in complying with the objectives of the North Carolina Department of Environmental, Health and Natural Resources, Radiation Protection Section regulations and the NC State Health and Safety Policies. The items in this manual are reiterated in the Radiation Safety training sessions provided by the Radiation Safety Division.

This manual is not intended to be an exhaustive or fully comprehensive reference, rather a guide for principal investigators and other technically qualified individuals. Further advice concerning hazards associated with specific radioactive substances, devices and the development of new or unfamiliar activities should be obtained through consultation with the Radiation Safety Committee, the Radiation Safety Officer or the Radiation Safety Division. All users of radioactive material and radiation producing devices must be familiar with the requirements set forth in this manual and applicable regulations of the North Carolina Radiation Protection Section, and must conduct their operations in accordance with them.

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1. PURPOSE AND SCOPE

This manual is designed to support the safe and effective use of radioactive materials and radiation-producing machines in research, education, and veterinary medicine. This manual addresses specific actions and procedures required of its users as they function within the administrative, technical, and physical environments encountered at NC State.

This manual is *not* intended to replace the official regulations as enforced by the North Carolina Radiation Protection Section (NC RPS) and the North Carolina Regulations for Protection Against Radiation, 15A NCAC 11. It will, however, provide valuable guidance and information related to NC State practices, policies and procedures for Principal Investigators. All Principal Investigators and their staff should become familiar with the 15A *NCAC 11* sections that may apply to their particular applications. As a North Carolina Licensee, NC State shall comply with all applicable provisions of .0100, .0200, .0300, .044, .0500, .0600, .0700, .0800, .1000, .1100, .1200, .1500, .1600 of NCAC.

Although the bulk of this document shall be considered literal commitments for policy and procedure to NC RPS, the formats and administrative content of the forms as collectively grouped in Appendix I shall be revised pending the approval of both the Radiation Safety Officer and the Radiation Safety Committee. New forms can also be added. No changes shall be approved that would result in any condition of noncompliance with applicable regulations or license conditions. The Radiation Safety Division will submit to the NC RPS within 30 days of final approval, copies of revised radiation authorization and control forms.

In keeping with the definition used by the National Council on Radiation Protection and Measurements, the verb “shall” denotes that the ensuing recommendation is necessary or essential to meet the currently accepted standards-of-protection. The verb “should,” indicates advisory recommendations that are to be applied when feasible.

2. ORGANIZATION AND RESPONSIBILITIES

2.1 NORTH CAROLINA STATE UNIVERSITY

North Carolina State University is a dynamic institution of higher learning located in the capital city of North Carolina. Radiation sources are employed at the institution predominantly as tools for research, with onsite activities facilitated by the issuance of a broad radioactive materials license by the North Carolina Department of Environmental and Natural Resources, Radiation Protection Section. Radiation is also used for diagnostic purposes in several locations throughout the campus and approved satellite locations in the form of registered x-ray machines, including Student Health facilities and the College of Veterinary Medicine.

2.2 RADIATION SAFETY ORGANIZATION AND POLICY

The fundamental objective of a radiation safety program is to ensure the safety of NC State faculty, staff, and other employees while experiencing the scientific benefits available through the use of radioactive materials and radiation-producing machines. No less imperative is the need for protecting the general public and the environment from avoidable additional radiation exposure and contamination as the result of licensed activities at NC State.

In matters related to radiation protection of NC State workers and the general public, the principle of As Low As Reasonably Achievable (ALARA) shall be exercised. To avoid unnecessary radiation dose (and resulting additional health risks), following the ALARA principle means making efforts to maintain exposures to radiation at a minimum, taking into consideration the state of technology, economic factors, benefits to the public and other societal and socioeconomic considerations.

An effective broad-license radiation safety program is governed using a two-tier approach. The Radiation Safety Committee directs policy relying on the diverse expertise of institutional resources. Additionally, the Radiation Safety Officer guides administrative support necessary to maintain compliance. An integral component of the “administrative chain” for a radiation safety program is the ability to enforce safe practices and regulatory compliance should sensitivity to these issues be lacking in individual situations.

The following section of this manual documents the specific responsibilities of the individual organizations, administrators and individuals at NC State that support portions of the institutional radiation safety responsibilities.

2.3 RADIATION SAFETY COMMITTEE

2.3.1 Committee Function

The Radiation Safety Committee is responsible for formulating policy about the use of radiation sources and for regulating their use in compliance with State of North Carolina regulations and NC State policy. In this regard, the committee serves as the primary regulatory body for the institution in all matters related to the use of radioactive material and radiation-producing devices.

2.3.2 Committee Appointments

Members are appointed by the Vice Chancellor for Finance and Business and the Provost, based on recommendations from the current Radiation Safety Committee Chair and the Radiation Safety Officer. In usual practices, committee appointments are for a three-year term. As indicated in the NC State Faculty Handbook, members of the Committee will represent the various colleges and components of the University, who have a working knowledge of Radiation Safety practices and/or Health Physics.

Other members may be appointed at the discretion of the Vice Chancellor for Finance and Business and the Provost, based on recommendations from the current Radiation Safety Committee Chair and the Radiation Safety Officer.

- Non-faculty representative from areas including the Faculty Senate, University Management, Veterinary College Management, Department of Radiology, and Facility Operations.

Permanent, ex officio, Radiation Safety Committee members will include:

- Radiation Safety Officer
- Member of Radiation Safety Division
- Director of Environmental Health and Safety
- Chair of the Reactor Safety and Audit Committee (RSAC)
- Reactor Health Physicist
- Member of Nuclear Reactor Program

2.3.3 Committee Meetings

The committee shall meet at least two times per year, upon due notice by the chair or the Radiation Safety Officer, who shall advise committee members of the time and place of the meetings. A Radiation Safety Committee quorum shall exist when at least fifty percent of the membership is present, with the faculty comprising the majority of the quorum. Included in the quorum shall be the Radiation Safety Committee Chair, or designee, and the Radiation Safety Officer, or designee. In the absence of a meeting call from the chair, and if pending business before the committee requires timely resolution, a meeting may be called solely by the Radiation Safety Officer, or by regularly appointed

members of the committee. A quorum must be present to constitute an official meeting. The proceedings of each meeting shall be transcribed, published and circulated to committee members as well as other indicated parties, and may be made available to interested persons upon request.

2.3.4 Committee Functions and Responsibility

The Radiation Safety Committee is responsible for the following:

A. Review and approval of policies and procedures governing the use of radioactive materials, radiation-producing devices and the Pulstar Nuclear Reactor. A majority vote of a quorum will be required to approve an agenda item

B. Review and issue final approval of applications for possession and use of radioactive materials and radiation-producing devices within NC State

C. Review and approval of amendments to the radioactive materials licenses and registrations, as submitted to the North Carolina Radiation Protection Section

D. Review the Radiation Safety Program Activities and Status reports (at a minimum) at each Radiation Safety Committee Meeting

E. Assist with preparation and compilation of an annual audit of Radiation Safety program operations and performance

F. Provision of professional advice to the Chancellor or a designee regarding the Radiation Safety Officer's qualification and performance

G. Provision of professional advice to the Radiation Safety Officer on matters regarding radiation safety

H. Review and approval (or denial) items required by the Pulstar Technical Specifications, as applicable

I. Review and approve the Reactor Safety and Audit Committee (RSAC) actions

2.3.5 Radiation Safety Committee Subcommittee – Reactor Safety and Audit Committee

The Reactor Safety and Audit Committee, mandated by the Nuclear Regulatory Commission license, provides specialized, regulatory oversight of the research nuclear reactor at North Carolina State University. The primary responsibilities of the RSAC are

specified in the Pulstar Reactor Technical Specifications and assure that the reactor is operating in compliance with the facility license conditions and all applicable regulations.

2.3.6 Committee Disciplinary Mechanisms

Investigation of safety violations may be initiated by the Committee or the Radiation Safety Officer of any facilities where radiation sources are used. A prompt report of the investigation shall be submitted to the committee for review and appropriate action upon completion.

After consideration of the violation report, the committee may:

A. Make a recommendation for mandatory remedial action, including, but not limited to suspension of ordering privileges, heightened inspection schedules, recertification of training. Failure to comply with committee remedial action may result in withdrawal of the Committee's approval of the investigator's radioactive material use authorization, or

B. Revoke the authorization forthwith, if the violation significantly endangers the health or safety of persons or property. In the event the committee withdraws its approval, the activity shall no longer be carried out within NC State until a new authorization application has been submitted, reviewed and approved.

The investigator involved has the right to be present at the committee hearing and to present his or her position.

2.4 RADIATION SAFETY OFFICER

2.4.1 Role of the Radiation Safety Officer

The Radiation Safety Officer (RSO) is responsible for investigating incidents; monitoring and implementing established policies on matters relating to radiation safety and is the Radiation Safety Committee's authorized representative regarding radiation protection within NC State. The Radiation Safety Officer may designate an Associate Radiation Safety Officer, or equivalent, pending appropriate qualifications pertaining to these assigned duties.

2.4.2 Emergency Authority

The Radiation Safety Officer shall have the responsibility and authority during a suspected or confirmed emergency to take prompt remedial action without prior approval of the Radiation Safety Committee. Should such independent action be required, the Radiation Safety Officer shall promptly report details of the situation to the Radiation Safety Committee, Environmental Health and Public Safety representatives, and the

department head and/or dean of the respective use area.

2.4.3 Radiation Safety Officer Function and Responsibility

The responsibilities of the Radiation Safety Officer are as follows:

A. to establish and oversee operating safety, emergency, and ALARA procedures, and to review them at least annually to ensure that the procedures are current and conform with *15A NCAC 11* rules;

B. to oversee and approve all phases of the training program for operations and/or personnel so that appropriate and effective radiation protection practices are taught;

C. to ensure that required radiation surveys and leak tests are performed and documented in accordance with these rules, including corrective measures when levels of radiation exceed established limits;

D. to ensure that personnel monitoring is used properly by occupationally exposed personnel, that records are kept of the monitoring results, and that timely notifications are made as required by regulatory entities;

E. to investigate and submit appropriate documentation to NC RPS for each known or suspected case of radiation exposure to an individual or radiation level detected in excess of limits established by these rules and each theft or loss of source(s) of radiation, to determine the cause(s), and to take steps to minimize a recurrence;

F. to investigate and cause a report to be submitted to the appropriate Agency for each known or suspected case of release of radioactive material(s) to the environment in excess of limits established by these rules;

G. to have knowledge of management policies and administrative procedures of the license;

H. to review and provide provisional approval as needed of Principal Investigator applications, amendments, protocols and possession limits. Provisional approvals will be reported at the next Radiation Safety Committee meeting for final approval.

I. to assume control and have the authority to institute corrective actions, including shutdown of operations when necessary in emergency situations or unsafe conditions;

J. to ensure that records are maintained as required by 15A NCAC 11

regulations;

K. to ensure the proper storing, labeling, transport, and use of sources of radiation, storage, and/or transport containers;

L. to ensure that inventories are performed in accordance with the activities for which the license application is submitted;

M. to ensure that personnel are complying with these rules, the conditions of the license, and the operating, safety, and emergency procedures of the license.

N. to provide oversight or assistance to the Hazardous waste disposal program for radioactive materials.

2.5 RADIATION SAFETY DIVISION

The Radiation Safety Division (RSD) is responsible for all aspects of the operational radiation safety program at NC State. The Radiation Safety Officer provides direction to the Radiation Safety Manager/Assistant Radiation Safety Officer, if applicable, and the Radiation Safety Division. The operational radiation safety program stewards the implementation of the policies and procedures as prescribed by the Radiation Safety Committee and promulgated in applicable state and federal regulations and relevant NC State procedures.

2.5.1 Radiation Safety Division Function and Responsibility

The responsibilities of the Radiation Safety Division includes, but is not limited to:

A. Maintain timely radiation and contamination surveys for control of worker and student radiation exposure and protection against unnecessary exposure to the public

B. Recommend, provide, and manage personnel radiation dosimetry for NC State

C. Ensure that Principal Investigators operate in compliance with applicable regulations and within the scope approved by the Radiation Safety Committee

D. Perform investigations of abnormal events, *e.g.*, spills, suspected radiation overexposure situations, and lost or stolen radioactive materials

E. Formulate, maintain, and conduct radiation safety training for new faculty,

staff and student employees at NC State according to regulatory expectations

F. Establish and maintain programs for the authorized procurement and use of radioactive material, and provide oversight for the disposal of radioactive material at NC State. This program will continually strive to control inventory and shipping of all radioactive material and radiation producing machines. As a parallel procedure, the RSD shall maintain an inventory of all licensed radioactive materials and registered radiation-producing machines for the institution

G. Perform and document regular radiation safety inspections of laboratories and other areas in which radioactive materials and radiation-producing machines are used. Determine compliance with state and federal regulations and additional constraints imposed by the Radiation Safety Committee

H. Provide management oversight of the radioactive waste disposal program for materials generated by NC State licensed activities as needed. These activities are performed in conjunction with the Environmental Affairs Waste Manager and an approved waste contractor

I. Serve as advisor and source of unbiased information for NC State radiation workers concerned about effects of radiation on their health and safety

J. Perform and document regular leak tests for sealed radioactive sources as required in *15 NCAC 11.1600*

K. Oversee the posting and maintenance of signs, notices, emergency response contacts and other information as required by *15A NCAC 11*

L. Maintain and make available to NC State radiation workers copies of all applicable state and federal regulations pertaining to safe use of licensed materials and registered equipment

M. Generate and retain radiation safety records required for compliance with *15A NCAC 11* requirements

N. Prepare reports on the function of the Radiation Safety Division for presentation to the Radiation Safety Committee at their regular meetings. The RSO will document and present an annual audit of Radiation Safety Division activities to the Radiation Safety Committee. Copies of this audit will be maintained for inspection

2.6 PRINCIPAL INVESTIGATOR

A principal investigator is an individual who by virtue of position, training and experience is designated by the Radiation Safety Committee as a user of radioactive material under the NC State radioactive material license. This authorization permits the procurement and use of radioactive material within a defined protocol or work activity under the supervision of the authorized user provided that the materials are used within the guidelines of safe practice, and within the rules, regulations and recommendations of the Radiation Safety Committee and NC State policy.

2.6.1 Principal Investigator Function and Responsibility

All Principal Investigators associated with the use of radioactive materials must comply with the conditions of their authorization and of the radioactive material licenses of NC State. A partial list of specific responsibilities of the Principal Investigator is provided below to assist the user in maintaining good safety practice. (Additional information is included throughout this manual.)

The Principal Investigator shall:

A. Establish and maintain an awareness for radiation safety in the workplace. This shall include control of radiation exposure to the lowest reasonable level (ALARA)

B. Ensure the following services for laboratory areas and radiation workers under their supervision are provided:

   1. Appropriate personnel dosimetry;

   2. Bioassay services;

   3. Personal protective equipment;

   4. Availability of appropriate and calibrated survey instrumentation;

   5. Facility maintenance.

C. Follow procedures for procurement of radioactive materials and radiation-producing devices

D. Provide correct and current posting of laboratory areas, radioactive material containers and radiation-producing equipment

E. Ensure maintenance of accurate and current inventory records for all radioactive materials under his or her responsibility

F. Follow established procedures for packaging, inventory listing, disposal and notification of Environmental Health and Safety for collection of radioactive wastes

G. Immediately report to the Radiation Safety Division any potentially hazardous spills, suspected radiation overexposures, loss or theft of radioactive materials, or other incidents having possible radiation safety implications

H. Perform radiation and contamination monitoring as required by applicable regulations, procedures in this manual, and commitments to the Radiation Safety Committee. Maintain accurate records of such monitoring results

I. Provide adequate use-specific safety training for all radiation workers under their supervision. This supplements the general, required employee radiation safety training provided by the Radiation Safety Division

J. Notify the Radiation Safety Division of any need for changes in the authorized use of licensed materials or registered equipment, including changes in use as well as a possession limit increase. Such changes may require the review and approval of the full Radiation Safety Committee following the Radiation Safety Officer

K. Obtain the prior approval of the Radiation Safety Division for procurement of radioactive materials

L. Follow established procedures for transfer of licensed radioactive materials to other authorized NC State users

M. Arrange with the Radiation Safety Division for appropriate actions in the event of anticipated extended absence from NC State

N. Arrange for disposal or transfer of all radioactive materials promptly upon termination of the authorized use or application

2.7 INDIVIDUAL

One of the basic tenets of safety programs is that individuals, from the Principal Investigator to research staff, must take responsibility for their own safety in daily activities, and must ensure that any personal actions do not contribute to increased hazard to coworkers or to the environment.

2.7.1 Individual's Function and Responsibility

The responsibilities of individuals using radioactive materials includes:

A. Maintain awareness of and compliance with applicable regulations, license commitments, Radiation Safety Committee restrictions, and standards of good safety practice (such as those presented in this manual or other NC State safety manuals)

B. Maintain required records, *e.g.*, laboratory contamination surveys, radioactive material inventory, waste disposal records, *etc.*, in collaboration with the Principal Investigator

C. Notify the Principal Investigator or the Radiation Safety Division promptly of incidents, spills, personnel contamination, or significant contamination of NC State facilities

D. Strive to minimize personal radiation dose in accord with the principles of As Low As Reasonably Achievable (ALARA)

E. Ensure proper use of personnel dosimetry. This includes proper wear location (at the belt, on the collar, etc.), timely exchange for new dosimeters and storage in proper location when not in use to guard against accidental exposure of the dosimeter

F. Assist the Principal Investigator in maintaining proper posting of work areas and labeling of radioactive material containers

G. Be familiar with the radiation safety precautions in their specific work areas. This should include procedures for safe use of radioactive materials and correct operating procedures for radiation-producing equipment

2.8 RIGHTS OF THE RADIATION WORKER

As required by the *North Carolina Regulations for the Protection Against Radiation (15A NCAC 11.1000 and .1600)*, copies of the "Notice to Employees" shall appear in a sufficient number of places to permit individuals engaged in activities under the license or registration to observe them in a work locale. This document lists the rights of radiation workers and the address of the North Carolina Department of Environment and Natural Resources to which the worker has access.

Some specific rights are:

A. Access to a complete copy of the *15A NCAC 11*. If a copy is not available from the supervising Principal Investigator, contact the Radiation Safety Division or access the information online via North Carolina Department of Environment and Natural Resources

B. Access to licenses, certificates of registration, notices of violation and operating procedures that apply to work in which the worker is engaged

C. Explanation of relevant regulations, licenses, certificates of registration, notices of violations and operating procedures as given above

D. Instruction in basic principles of radiation safety

E. A written report of a radiation exposure in excess of any applicable limit as set forth in the regulations or in the license

F. Upon the worker's written request to the Radiation Safety Division, an annual report of radiation exposure

G. Upon the worker's written request to the Radiation Safety Division, a report of radiation exposure

I. The right to request an inspection by the North Carolina Department of Environment and Natural Resources, Radiation Protection Section (RPS). NC State may not terminate employment or discriminate against the employee because of such action

3. LICENSING REQUIREMENTS AND CONDITIONS

3.1 GENERAL REQUIREMENTS

NC State operates under a broad license for the use of radioactive materials in research and development as issued by the North Carolina Department of Environment and Natural Resources, Radiation Protection Section. Under the conditions of the broad license, the Radiation Safety Committee (RSC) may issue authorizations for specific radioactive material usage. The RSC may also withdraw authorizations. Although possession and use of radiation-producing machines is not covered under the RPS broad license, but under separate registrations or specific licenses, the RSC possesses the authority and responsibility for control of such uses at NC State. Therefore, before any investigator may acquire, possess, or use any quantity of radioactive material or any radiation-producing device, the RSC shall review and approve the application.

3.2 APPLICATION FOR NON-HUMAN USE OF RADIOACTIVE MATERIAL

In general, application for authorization to use radioactive materials (excluding human or animal use) requires the submission of four forms:

A. RS 01 - Application for Non-Human Use of Radioactive Material

B. RS 02 - Training, Experience, Laboratory Staff, and Equipment Addenda

C. RS 03 - Radiation Safety Training and Experience

D. RS 04 - Dosimetry Service Request and Exposure History Form

These forms are available from the Radiation Safety Division and via the Internet.

Forms RS 03 and RS 04 may be required from technical staff and other personnel who may potentially be exposed to radiation while working on a project.

3.2.1 Filing the Application

After completing the applicable forms, the investigator should send them to the Radiation Safety Division for review. If required, the investigator will be contacted to arrange an appointment to further discuss the application with the Radiation Safety Officer or designee. The investigator is also asked to provide any additional supporting documentation to demonstrate prior training and experience with sources of radiation. Such documentation might include a copy of a specific radioactive materials license that identifies the individual or, a letter from a previous Radiation Safety Officer attesting to the formal training, experience and compliance history. Additionally, the applicant should submit a current CV with the application.

3.2.2 Processing the Application

In general, new applications for the acquisition and use of radioactive material may require the completion of Forms RS 01, RS 02, RS 03, and RS 04.

The application review procedure will generally include the following parameters:

A. Whether the procedure can be carried out safely, including:
- Need for appropriate personnel monitoring and/or bioassay
- Frequency for surface contamination surveys to be performed in lab
- Primary users availability to perform adequate and frequent supervision

B. Whether the individual user and all others involved are qualified, including:
- Appropriate training and experience of users
- Identify users/staff and/or assistants to work under sublicense
- Enough in-service training for any handler of radioactive material

C. Whether the laboratory design and location are suitable including:
- Engineering controls
- Hoods,
- Ventilation,
- Shielding,
- Sinks
- Waste storage facilities

D. Whether adjacent low-level counting work will be affected.

The RSO will initially review the application and if deemed complete, will refer it to subcommittee members for further review. Following this review, the application is referred to the Radiation Safety Committee for further consideration and final approval at the next feasible RSC meeting.

3.2.3 Approval of Application

Approval by the RSC results in the granting of a sublicense to the Principal Investigator. An approval memo will be sent to the PI and will contain notification of the committee's decision, and any stipulations, restrictions or special conditions placed upon the sublicense. An authorization number is issued to the investigator, who may then acquire and use the radioactive material according to the specifics of the sublicense. In the event that the committee does not approve the application, it will be returned to the investigator with recommended corrective measures for deficient aspects. When the unsatisfactory conditions that led to deferral or disapproval have been remedied, the application may be resubmitted and will be reviewed in light of the new information. An authorization to possess and use radioactive material may be suspended or withdrawn by the Radiation Safety Committee for failure to observe and comply with any condition of

NC State's Radioactive material license or of the Radiation Safety Manual, or as warranted by unsafe or improper conditions.

3.3 Amendment of the Authorization

An authorization is valid only for the protocols stated in the original application. Minor changes to the authorization may be warranted and made without affecting its validity by requesting in writing a review, and specifically stating the changes desired. However, if in the judgment of the Radiation Safety Officer, alterations in the conditions materially compromise radiation safety, the authorization may be withdrawn for further review by the Radiation Safety Committee. Another application may then be submitted and will be reviewed on its own merit. The RSO has the right to issue provisional approval of any protocol amendments and will present the amendment to the RSC for final approval.

3.3.1 Changes in Users and Staff

For changes in staff working under a Principal Investigator, Form RS-5 or a written request for update should be submitted by the PI to the Radiation Safety Division. New staff members shall submit forms RS-3 and RS-4. Personnel dosimetry will be issued as required and training will be scheduled.

3.3.2 Changes in Radionuclides or Quantities

For changes in the amounts of radionuclides already authorized, the principal investigator shall file Form RS-5 with the Radiation Safety Division for subsequent review and provisional approval by the Radiation Safety Officer and the final approval by the Radiation Safety Committee.

For the addition of radionuclides not presently authorized, a new authorization request should be filed on Form RS-1 by the Principal Investigator for subsequent review and approval by the Radiation Safety Officer or Radiation Safety Committee.

3.3.3 Changes in Research Protocols

For changes in research protocols under an existing authorization, the Principal Investigator shall file an RS-5 form together with the new proposed protocol/supporting documentation with the Radiation Safety Division for subsequent review and provisional approval by the Radiation Safety Officer and final approval by the Radiation Safety Committee.

3.3.4 Addition of Laboratory

To add a new laboratory to an authorization, the Principal Investigator should file Form RS-5 with the Radiation Safety Division. Radiation Safety Division will complete

necessary documentation, postings and related radiation safety items to properly complete the addition request.

3.3.5 Decommissioning a Laboratory

To decommission and remove a radioactive material laboratory from a protocol, the Principal Investigator or department head should complete a Form RS-5 and inform the Radiation Safety Division. The Radiation Safety Division will then conduct a review and decommissioning effort.

3.4 Absence of Principal Investigator

3.4.1 Temporary Absences

For temporary absences from NC State, a Principal Investigator may designate another investigator on the project staff to supervise the project. Alternatively, the Principal Investigator may request in writing assistance from the Radiation Safety Officer and the Radiation Safety Committee in designating an alternate Principal Investigator, or the project may be tendered temporarily inactive.

For temporary absences from NC State exceeding one month, a Principal Investigator or the department head should report the absence in writing to the Radiation Safety Officer so that the need for a replacement may be explored with the Radiation Safety Committee and the Principal Investigator, or so that the project may be discontinued.

3.4.2 Permanent Absence

In the situation where the Principal Investigator becomes permanently unavailable to the project, either through prolonged absence or departure from NC State, written notification should be submitted to the Radiation Safety Division so that the Radiation Safety Committee can take appropriate action.

3.5 Discontinuation of the Authorization or Relocation of a Project

The Radiation Safety Division should be notified before termination of an authorization or of vacating a laboratory. Rooms and equipment are to be decontaminated, radionuclides properly disposed or transferred, and all records closed. After conducting surveys to ensure that the area is free from contamination and verification of necessary records, Radiation Safety personnel will conduct a decommissioning survey and remove signs and labels from rooms and apparatus (See Section 9.4).

3.6 Review of Authorization

The Radiation Safety Division will review authorizations issued by the Radiation Safety Committee for the use of radiation sources. The purpose for such reviews is to provide for renewal of the authorization if the investigation is continuing, to determine if any of the conditions of the authorization have significantly changed, and to verify the authorization information on file with the Radiation Safety Division. This authorization review is performed in conjunction with the audit schedule outlined in Section 9 "Laboratory Safety Audits by the RSD".

3.7 USE OF RADIOACTIVE MATERIAL IN ANIMALS

3.7.1 General Requirements

Before beginning any experiment involving the use of radioactive materials in animals, the principal investigator must:

A. Be an authorized user of radioactive materials

B. Complete Form RS-6, "Application for Radioactive Material Use in Animals," and submit it to the Radiation Safety Division. Upon approval, a signed copy will be returned to the principal investigator with a letter of authorization from the Radiation Safety Division. The Authorization number assigned to the PI will be necessary to complete the University Animal Use Committee (IACUC, 515-7507) applications

Investigative procedures involving animal systems vary widely as do applicable safety techniques. The information provided in Form RS-6 will enable the Radiation Safety Division to formulate necessary measures and to assist the Principal Investigator in effecting these measures.

3.7.2 Rules for Using Radionuclides in Animals

A. The areas that animals are kept should be posted in accordance with Section 8.4

B. Cages and pens should bear labels specifying: the radionuclide, quantity and date administered, ambient radiation levels, and the names of the responsible individual and/or principal investigator. These cages and pens should be separated from those housing non-radioactive animals

C. Ventilation should be adequate to handle possible evolution of airborne radioactivity. This may, in some instances, require the use of a fume hood or self-contained controlled environmental systems

D. Animal excreta should be treated, handled, and disposed as radioactive waste, as appropriate. Biologically active agents must be considered

during waste disposal. Further waste disposal considerations should be addressed the Environmental Affairs Division of EHSC

E. Disposal methods for carcasses or other animal remains should be approved by the Radiation Safety Division, and executed by the Environmental Affairs Waste Manager

F. Animal caretakers should be instructed and adequately trained by the principal investigator with respect to general and specific handling procedures, dose levels, occupancy time limits and other special conditions

3.7.3 Radiation Monitoring in Animals

The principal investigator is responsible for overall radiation safety of the project, including but not limited to:

A. Radiation monitoring of the animal(s), cages, and/or the actual procedure when it is performed, pursuant to conditions of the protocol outline in Form RS-6

B. Determination of radioactivity in urine, feces and bedding (if required)

C. Labeling all cages containing radioactive animals. Tags for this purpose showing the radionuclide, the activity (in μCi or mCi) and the date are available from the Radiation Safety Division

3.7.4 Radioactive Animal Waste Disposal

All animal remains, *i.e.*, viscera, tissue, serum, or other fluids, and the carcass, containing radioactive material should be disposed as follows:

A. The carcass and associated waste should be double bagged in a thick mil plastic carcass bag and sealed shut

B. The bag should then be secured and labeled with a radioactive and/or biological waste disposal tag identifying the radionuclide(s), activity, date, authorized user, and laboratory number

C. The carcass bag should be placed in the appropriate freezer for storage until pick up and disposal or decay

D. Collection of radioactive biological waste is not routine. Place a request, in advance, for hazardous waste pickup to the Environmental Health and Safety Office via the Hazardous Waste Manager. The bag and contents will be picked up for final disposal

3.8 Authorization to Use Radioactive Material in Humans

NC State's Radioactive Material license prohibits the use of radionuclides in human subjects. Special projects may warrant additional consideration of the Radiation Safety Committee and the North Carolina Radiation Protection Section. The Radiation Safety Committee must review all use of radioactive materials in humans. The study must first be submitted to the Institutional Review Board for the Protection of Human Subjects in Research for their review and approval as well as any other required University committee. All users must be authorized by the Radiation Safety Committee after filing an application as given in Section 3.2 above.

To qualify for use of radioactive materials in humans, a researcher shall meet the requirements of *15A NCAC 11*. Contact the Radiation Safety Division for further details.

3.9 Radionuclide Generator Use

Radionuclide generator use may be required at the College of Veterinary Medicine, in the Nuclear Medicine Division, as well as other locations on campus with prior approval by the Radiation Safety Office. The use of radionuclide generators involves special precautions. These include:

A. Generator users should wear an extremity monitor due to the high potential for personnel dose

B. Manufacturer's instructions should be strictly adhered to in the installation and operation of the generator

C. A portable survey meter capable of measuring the appropriate radiation types and energies used in the laboratories should be available

D. Each generator should be tested for breakthrough in accordance with the manufacturer's prescribed method

E. Shielded containers, shielded syringes, tongs, forceps or other suitable remote handling devices should be used whenever feasible during generator eluant (product) collection, storage, processing and transport

3.10 Application to obtain a Radiation-Producing Device

Any person planning to obtain or construct a radiation-emitting device, including X-ray machines (analytical, diagnostic, therapeutic), electron microscopes and other X-ray equipment, should submit the following information to the Radiation Safety Division before obtaining the device via the Form RS-10, "Radiation Producing Device Authorization Form".

Radiation Safety will review the proposed plans and facilities for safety and compliance with regulations and will evaluate the need for and type of radiation badges required. Radiation Safety should complete the required shielding calculations prior to installation of the equipment; if shielding recommendations are provided by an outside agency, Radiation Safety must review these recommendations prior to facility construction or installation of the machine. A post-installation survey should be performed after initial installation, relocation, or any renovations or alterations to the machine to assure radiation safety.

All radiation-producing machines shall be registered with the NC Radiation Protection Section. Radiation Safety registers such machines on behalf of NC State. Each possessor of such a device is required to notify the Radiation Safety Division regarding the machine location, as it must be registered with the state agency within 30 days of initial operation.

All radiation-producing devices to be surplused, donated or transferred to another NC State facility or other business, should be inspected by Radiation Safety before leaving the institution. Contact the Radiation Safety Division for further guidance.

Under some circumstances, a device may be tagged by Radiation Safety to prevent its use. No attempt to energize or otherwise use the device should be made without prior notification of and approval from the Radiation Safety Division.

4. PROCUREMENT, INVENTORY, AND TRANSFER OF RADIOACTIVE MATERIAL

4.1 ORDERING RADIOACTIVE MATERIAL

After authorization for the use of radioactive materials is issued by the Radiation Safety Committee, the Principal Investigator may purchase radionuclides within the scope of that specific authorization.

All acquisitions of radioactive materials require approval from the Radiation Safety Division. The Principal Investigator must notify the Radiation Safety Division of the intended order. Completing an order request on the web-accessed Health Physics Assistant system or preparing a facsimile copy and submitting it to the Radiation Safety Division accomplish this.

The following *Ship To* address should be used for radioactive material orders:

North Carolina State University
Radiation Safety Division/EHS Center
Box 8007, 2620 Wolf Village Way
Raleigh, North Carolina 27695-8007
Attn: (insert Principal Investigator's name)

To maintain inventory control, the requisition should contain this pertinent information:

A. Name of Principal Investigator;

B. Authorization number;

C. Radionuclide;

D. Quantities in millicuries (mCi);

E. Chemical form and compound;

F. Activity per vial, total number of vials and total activity of the order;

G. Name and telephone number of the person to notify when the material is received;

H. Purchase order number;

I. Vendor name; and

J. Additional information.

The Radiation Safety Division approves requisitions submitted via facsimile or telephone if the Principal Investigator identified on the order has an active authorization number and meets the conditions of the sublicense agreement. Orders submitted electronically via the HP Assistant system, which is monitored by the Radiation Safety Division, will be automatically approved if the Principal Investigator is within his/her approved limits. The Radiation Safety Division will ensure that the total on-hand radioactive material inventory for the Principal Investigator remains within the activity limits authorized by the Radiation Safety Committee.

4.1.1 Order Approval

Each supplier of radioactive material is required by state and federal regulations to validate NC State's license to possess and to use such material. The Radiation Safety Officer will arrange for copies of the institution's license to be made available to suppliers. If a copy is needed by a new or prospective supplier, the Principal Investigator must advise the Radiation Safety Division which will in turn forward a copy to the supplier.

Once the radioactive material requested by the Principal Investigator is approved, the Principal Investigator may place the order with the radioactive material vendor. Radiation Safety will assist with vendors as needed, but does not routinely order isotopes for campus laboratories.

4.2 Receipt of Radioactive Material

Radioactive material shipments are reviewed and processed through the Radiation Safety Division. Packages are inspected for contamination in accordance with 15A NCAC 11.1627. Inspection information is recorded on the Radioactive Material Package Receipt Information Sheet (Form RS 07). Radiation Safety shall assure that the external surfaces of secondary containers are not contaminated. Once check-in procedures are complete, it will be delivered at the earliest opportunity that day or within 3 hours of the next business day if the delivery is late. Laboratory personnel will sign, date, and take possession of the radioactive inventory and associated forms upon receipt of the package. Inventory forms will be maintained by the laboratory personnel and returned to Radiation Safety once the radioactive material is completely used.

In special circumstances, radioactive material shipments may be received directly at laboratories. If this is the case, arrangements must be made with the Radiation Safety Division for the appropriate receipt processing prior to purchasing the materials.

4.3 Radioactive Material Inventory Requirements

4.3.1 Package Inspection Report and Radionuclide Inventory Form

Each Principal Investigator should have a record of all radioactive material available for review. Such records cannot be maintained solely by the Radiation Safety Division because, by their nature, these records represent a dynamic condition of new

supply, use, disposal and radioactive decay. The individual Principal Investigator should keep a current inventory of all radioactive materials. These records should be kept in a form that permits convenient, periodic review. The Radioactive Material Package Log of Use (Form RS 08) associated with approved radioactive material orders will be provided to the PI by the Radiation Safety Division with the radioactive material package.

The following information is required for each isotope and must be recorded on the disposal form:

A. Date of use or disposal.

B. Activity used or amount disposed. Realistic and practical estimates are acceptable. The person performing the protocol/disposal must also be noted on the form.

C. Disposal tags from the Radiation Safety Division should be completed when disposing of waste in order to track disposal of material.

When the radioactive material is fully disposed, the laboratory should retain a copy of the completed Log of Use record (RS 08). The original should be forwarded to the Radiation Safety Division via fax or campus mail (not with the waste containers).

4.4 TRANSFER OF RADIOACTIVE MATERIAL

A Principal Investigator may transfer radioactive materials to another Principal Investigator provided the recipient is authorized for the radioactive material and quantities involved. The Radiation Safety Division should be notified before the transfer so a new Radioactive Material Log of Use (RS 08) can be generated for the recipient. The transferring user records the transfer on their Log of Use (RS 08) and this original form is submitted to the Radiation Safety Division if the vial is empty

4.5 SHIPMENT OF RADIOACTIVE MATERIAL

The Radiation Safety Division must approve shipments of radioactive material. Shipment of any radioactive materials to an outside institution requires verification by the Radiation Safety Division that the receiving institution is licensed to receive the materials. Verification may follow any of the methods listed in 15A NCAC 11. Generally, this means that a copy of the license authorizing the recipient to possess the source must be on file in the Radiation Safety Division before shipping the source.

All regulated radioactive materials and devices will be shipped from this institution in accordance with the U.S. Department of Transportation regulations and with assistance from the Radiation Safety Division.

Licensed radioactive materials must not be removed from NC State

without the specific approval of the Radiation Safety Division.

Each package to be transported or shipped from NC State will be inspected for safety and compliance with transport regulations by a designated representative of the Radiation Safety Division. No radioactive materials may be sent through campus mail.

All costs for inspection and transport or shipping will be assessed to the originating department or operating unit.

Inspection and transport/shipping records will be maintained by the Radiation Safety Division and for an interval dictated by the U.S. Department of Transportation and other pertinent regulatory agencies.

5. DISPOSAL OF RADIOACTIVE WASTE

All radioactive wastes stemming from NC State research laboratories shall be disposed of in such a way as to minimize the hazard to the health of personnel, to the value of property or to the community. Adherence to the recommendations and requirements established in this section will achieve these goals, as well as ensure compliance with the North Carolina Regulations for the Protection Against Radiation. The Hazardous Waste Manager, within Environmental Health & Safety is charged with the responsibility of collection, treatment, and disposal of radioactive wastes, under the ultimate direction of the Radiation Safety Officer and the Environmental Affairs Manager. Reports, procedures, and records pertaining to sources of radiation are generated under the supervision of the RSO, and are submitted to the Radiation Safety Committee.

For assistance in matters relating to waste disposal during normal working hours, submit an online waste request through HazTrack. For emergency waste disposal issues, call the Environmental Affairs Division at 515-6863 or the Radiation Safety Division at 515-2894.

5.1 TYPES OF RADIOACTIVE WASTE

A. **Solid:** Solid materials that have become contaminated during research protocols. These may include gloves, absorbent paper, pipette tips, etc.

B. **Liquid:** Liquid materials that have become contaminated during research protocols. These include solutions, buffers, rinses, etc.

C. **Biological/Animal Carcass:** Biologically active or remains of animals which have been subjected to radioactive material protocols. These include animal carcasses, pathological waste, microbiological waste, etc.

D. **Sharp/Broken Glass:** Sharp objects or broken glass that have become contaminated during research protocols. These may include needles, razor blades, Pasteur pipettes, broken glass, etc.

5.2 GENERAL REQUIREMENTS AND RESPONSIBILITIES

Each Principal Investigator must ensure, *prior to the procurement of any radioactive materials*, that a satisfactory waste disposal method exists and that proper receptacles are in place.

A. Each Principal Investigator should accurately identify, quantify and label the types, quantities, and forms of radioisotopes that are placed in the radioactive waste generated in under their authorization

B. Radioactive waste containers should be posted with a “Caution Radioactive

Material" label

C. Radioactive waste containers in the lab should be stored as close to the work area as possible to minimize the probability of spillage during the transfer to the containers

D. Radioactive waste containers should be properly shielded while storing radioactive waste as to minimize the exposure to personnel below 2 mR/hour

E. Unattended waste containers should not be stored in unrestricted areas

F. Radioactive waste containers should be covered when not in use.

G. When handling or transferring radioactive waste the individual should wear proper personal protective equipment

H. Radioactive wastes containing carcinogens, biological hazards, sharps, or acutely hazardous chemicals must be inactivated, if possible, and packaged to present minimal hazards to hazardous waste management personnel

5.3 DRY SOLID WASTE DISPOSAL

Dry solid waste consists of items that have come into contact with radioactive materials and have approximately 3% or less free liquids. Such items include, but are not restricted to, absorbent padding and other protective coverings, plastic/rubber gloves, tubing, glassware, and plastic, paper and metal. This waste is disposed by the generator into segregated containers at various facilities throughout NC State properties.

A. Solid radioactive waste is segregated at the generation point (e.g. laboratory or clinic) by isotope categories.

B. Waste segregation is facilitated with appropriate waste containers, lined with plastic bags, supplied by the Hazardous Waste Manager and Environmental Health and Safety.

To properly identify and dispose:

C. A completed radioactive waste disposal tag is attached to the waste container identifying the laboratory or Principal Investigator, radionuclide, date, activity of the waste and other pertinent information.

D. Once the container is ready for retrieval, submit a waste pickup request online via Haztrack. Waste is picked up at least once a week. If a special situation exists, call the Hazardous Waste Manager or the Radiation Safety

office to make arrangements for immediate pickup.

5.4 LIQUID RADIOACTIVE WASTE DISPOSAL

Liquid radioactive waste consists of aqueous or organic waste effluents generated in the course of research activities. This waste is collected from each laboratory location and disposed of properly. Guidelines for the proper handling, storage, and disposal of liquid radioactive waste follow:

A. As general practice, no radioactive waste is to be disposed via the sanitary sewer or sink. Disposal of any radioactive materials via the sink and sewer system is reviewed on a case-by-case basis for special circumstances only.

B. Radioactive liquid waste should be segregated *by radionuclide* into the following groupings:

1. Phosphorus 32

2. Isotopes with a Half Life less than 100 days: ^{35}S, ^{131}I, ^{86}Rb, ^{33}P, ^{51}Cr, ^{125}I

3. Isotopes with a half-life greater than 100 days: ^{14}C, ^{3}H, ^{45}Ca, ^{60}Co

(*Disposal of any other isotopes not listed above, please contact the Radiation Safety Division for details).

And the following categories:

1. Radioactive Liquid Waste – **Aqueous,** listing the components of the solution

2. Radioactive Liquid Waste - **Organic** (>10% hydrocarbons)

C. The waste should be readily soluble or readily biologically dispersible material. Corrosive or reactive wastes should be chemically neutralized as part of the experimental procedure.

D. The waste should be placed in capped plastic containers provided by Environmental Health. Glass containers are not recommended for storage of liquid waste, unless the liquid waste will react with the plastic container.

E. The waste should be stored in a remote but accessible location in the laboratory. The container and storage area should be marked with a radioactive material warning label, and appropriate shielding should be used to limit dose rates to personnel working in the laboratory.

F. Containers should be closed and placed in secondary containment to prevent spills.

To dispose:

G. When the container is full, complete the radioactive material disposal tag/label, already attached to the receptacle, identifying the laboratory, the isotope, radionuclide, activity, date and other pertinent information.

H. Submit an online waste pick up request via HazTrack for collection by waste management personnel. Waste management personnel will provide replacement containers at this time.

5.5 Liquid Scintillation Vial Waste Disposal

Liquid scintillation vial waste is waste generated from the use of liquid scintillation counting methods. This waste is disposed by the generator into segregated containers located at various locations throughout NC State. Guidelines for the storage, collection, and disposal of liquid scintillation vial waste follow:

A. Scintillation vials should be segregated at the point of generation into the following categories.

1. Scintillation vials containing ^{3}H and ^{14}C, with an activity of less than 0.05µCi/g.

2. Segregate all other scintillation vials by the following information:

- Phosphorus 32
- Isotopes with a Half Life less than 100 days: ^{35}S, ^{131}I, ^{86}Rb, ^{33}P, ^{51}Cr, ^{125}I
- Isotopes with a half-life greater than 100 days: ^{14}C, ^{3}H, ^{45}Ca, ^{60}Co (*Note ^{14}C and ^{3}H exemption above)

(*Disposal of any other isotopes not listed above, please contact the Radiation Safety Division for details).

To facilitate the segregation process, labeled containers are available through the Radiation Safety Division.

To dispose:

A. Liquid scintillation vials should be placed in a plastic bag and proper container and securely sealed.

B. A completed disposal tag, previously attached to the container, should identify the laboratory, radionuclide, date, and activity of the waste.

C. The container should be stored in the laboratory until the waste is retrieved. Submit a waste pickup request via HazTrack or call the Hazardous Waste Manager.

5.6 Biological and Sharp Waste

5.6.1 Biological Waste

Radioactive biological waste is defined as animal carcasses and associated wastes, pathological waste, microbiological waste, and sharps that have come into contact with radioactive materials. Guidelines for the storage, collection, and disposal of radioactive biological waste follow:

A. All radioactive biological waste should be first segregated into categories by isotope.

B. All biological waste should be double-bagged in thick mil opaque bags and sealed with tape or tie wrap. Absorbent should be placed in bags containing animal carcasses or free liquids if possible.

C. A biological or radioactive waste disposal tag should then be attached to the bag identifying the type of waste, radionuclide, activity, date and other pertinent information. **Waste that contains an infectious agent should have the name of the infectious agent clearly identified on the label! Infectious waste should be placed into a biohazard bag!**

D. Animal Carcasses should be stored in appropriate freezers until disposal arrangements are available. Call the Radiation Safety Division (515-2894) or the Hazardous Waste Manager (515-6864) for collection of carcass waste or further information.

E. When possible, infectious wastes should be treated prior to disposal.

5.6.2 Radioactive Sharps Waste

Sharps (needles, razor blades, Pasteur pipettes, and broken glass, etc.) contaminated with radioactive materials shall be placed in an approved sharps container prior to disposal. The sharps container should be labeled with a "Caution Radioactive Material" label. Environmental Health will pick up these containers and provide replacements.

5.7 Equipment Releases

Equipment containing a radioactive source (e.g. liquid scintillation counters, gas chromatographs, spectrometers) or equipment contaminated by radioactive material (e.g. refrigerators, centrifuges, water baths) must be properly decontaminated or arrangements have been made for the source to be removed prior to transferring to surplus, off-site, or to an unrestricted area. Guidelines for the transfer of equipment follow:

A. For equipment that has come into contact with radioactive materials, investigators shall decontaminate equipment and conduct the appropriate surveys to ensure that any contamination is below the release for unrestricted use limits stated in 15A NCAC 11

B. For equipment that contains a radioactive source, the Radiation Safety will help make arrangements to extricate the source and arrange for the proper disposal

C. Prior to transfer of the equipment, the Radiation Safety Division should be contacted. A confirmatory survey will then be conducted and approval for the transfer will be granted

5.8 Airborne Releases of Radioactive Material

Prior to utilizing gaseous radionuclides (i.e. radioactive noble gases, etc.), special approval must be obtained from the Radiation Safety Division. Prior to approval, the Principal Investigator should supply procedures to the Radiation Safety that identifies:

A. Measures to ensure compliance with 15A NCAC 11.1606

B. A method for reporting all pertinent disposal information (e.g. radionuclide, activity concentration, chemical form, date) to the Radiation Safety Division

5.9 Radioactive Waste Minimization and Source Reduction

Waste minimization and source reduction is the principal of reducing radioactive waste disposal by controlling and reducing the amount and volume of source material.

A. When possible, non-radioactive materials should be substituted for radioactive materials

B. When possible, radionuclides with short half-lives should be substituted for those with long half-lives

C. Radioactive waste should be segregated from non-radioactive waste at the

point of generation

D. Secondary containment should be used when handling, storing, or transporting liquid waste

E. Non-bulky materials should be used when cleaning spills

F. Compatible materials should be used in experiments

G. Microscale techniques should be used when possible

H. New lab personnel should be indoctrinated and trained in proper methods for waste minimization in the lab

6. LIMITATION AND MINIMIZATION OF RADIATION EXPOSURES

6.1 THE ALARA PRINCIPLE

In recent years, a philosophy of control of radiation dose called As Low As Reasonably Achievable (ALARA) has become an integral, functioning part of radiation protection programs. Radiation safety programs have traditionally been most conservative in minimizing radiation exposure to workers, and ALARA is simply a more formal commitment to this basic principle of radiation protection. All uses of radioactive materials and radiation-producing machines at NC State shall be conducted with ALARA as a guiding principle.

The ALARA action level at NC State is defined as 2.5% quarterly or 10% annually of any applicable occupational limit. NC State Radiation Safety Division shall investigate a personnel dosimeter reading exceeding the predetermined ALARA level. This investigation will examine workload and protocol changes, dosimeter placement variations, personnel dose trends, or possible methods of dose minimization for future protocols.

6.2 RADIATION DOSE LIMITS

6.2.1 Occupationally Exposed Adults

Table 1: Annual occupational dose limits and NC State ALARA action level for adult radiation workers.

Applicable Dose Limit	Annual Limit (mrem)	ALARA Action Level Quarterly/Annually (mrem)
Total Effective Dose Equivalent (TEDE)	5000	125/500
Total Organ Dose Equivalent (TODE)	50,000	1250/5000
Skin Dose Equivalent (SDE)	50,000	1250/5000
Extremity Dose Equivalent	50,000	1250/5000
Eye (Lens) Dose Equivalent (LDE)	15,000	375/1500

6.2.2 Limits for Individual Members of the Public

The dose limits for individual members of the public are described in 15A NCAC 11.1611. These regulations state that each licensee will limit operations such that:

A. The total effective dose equivalent to members of the public does not exceed 0.1 rem in a year;

B. The dose in any unrestricted area from licensed/registered external sources does not exceed 0.002 rem in any one hour.

6.2.3 Occupational Dose Limits for Minors (Radiation Workers under Age 18)

The annual occupational dose limit for minors is 10% of the annual occupational dose limits specified for adult workers in 15A NCAC 11.1604 & 0.1609. (Section 6.2.1 of this document).

6.2.4 Occupational Dose Limits for a Declared Pregnant Worker

A "declared pregnant woman" means a woman who has voluntarily informed her employer (the licensee), in writing, of her pregnancy and the estimated date of conception. This information should be conveyed to the Radiation Safety Officer for proper documentation and monitoring according the NC RPS Regulations. 15A NCAC 11.1610 provides specific guidance for dose limits to the fetus/embryo.

For additional information regarding prenatal radiation dose risks to the fetus, foundation for established dose limits, and responsibilities of the female radiation worker, the U.S. Nuclear Regulatory Commission published Regulatory Guide 8.13, which is available from the Radiation Safety Division.

6.2.5 Dose Limits for the Embryo/Fetus

If a woman declares her pregnancy, the licensee shall ensure that the dose to the embryo/fetus during the entire pregnancy, resulting from occupational exposure of a declared pregnant worker, does not exceed 0.5 rem (5 millisieverts). If the worker chooses not to declare pregnancy in writing, the occupational dose limits specified in 15A NCAC 11.1604 are applicable. In addition, efforts shall be made to avoid substantial variation above a uniform monthly exposure rate to a declared pregnant worker.

If, by the time the worker declares pregnancy, the dose to the embryo/fetus has exceeded 0.45 rem (4.5 millisievert), the embryo/fetus is limited to 0.05 rem (0.5 millisievert) for the remainder of the pregnancy.

6.3 DOSE MINIMIZATION

In accordance with the ALARA principle, all procedures, protocols, examinations, and tutorials shall be conducted in a manner that minimizes the radiation dose to workers and the general public.

6.3.1 Engineered Control of Dose Minimization

Radioactive material or radiation-producing machines are to be used or stored only in those rooms or areas that have been approved by the Radiation Safety Division. Research laboratories for such use must meet the following requirements:

6.3.2 Facility Requirements

A. A means of controlling access and securing the room when no authorized individual is in the area is required. This condition intends to prevent accidental exposure of a member of the general public.

B. Radionuclide experiments that potentially generate aerosolized radioactive material should be performed under conditions of controlled ventilation. In general, ventilation control may be accomplished through the use of negatively pressured work cabinets (e.g. chemical fume hoods). The operating parameters of the ventilating cabinets will follow manufacturer specifications. Hoods found not meeting these specifications will not be certified for radioactive material use, and lab personnel will be informed of the need for alternative ventilation.

C. Exhausted air with the potential for airborne contamination should be adequately filtered to minimize radioactive material released to the environment.

D. All radioactive material laboratories shall be designed or shielded in accordance with *15A NCAC 11* dose limits for individual members of the general public.

E. It is the responsibility of the principal investigator to provide adequate shielding to ensure that all personnel radiation exposures are kept as low as reasonably achievable.

F. The Radiation Safety Officer should be apprised of any new facilities or renovations and remodeling of existing facilities that utilize radioactive materials or radiation–producing devices.

6.3.3 Administrative Control of Dose Minimization

The engineered controls specified in the design of the radioactive material laboratory may be augmented through additional administrative controls. These may take the form of training, procedures, or supplemental Principal Investigator conditions or restrictions.

6.3.4 Control of Dose from External Sources

Sources of radiation external to the body account for the overwhelming majority of radiation dose at NC State. Therefore, procedures and policies should be in place to administratively control external radiation exposure.

A. **Time** - Decreasing "exposure time" reduces personnel dose linearly. To this end, "dry-runs" of critical steps involving radioactive material in a new protocol may help identify problems, avoid errors, and speed the completion of the task.

B. **Distance** - Increasing the distance between personnel and the radiation source is an effective means of reducing dose. The radiation dose rate follows the "inverse square law". Simply put, the dose rate drops by the inverse square of the distance. For this reason, remote-handling devices (e.g. tongs, tweezers, or other long-handled tools) can significantly reduce personnel dose, especially to the hands.

C. **Shielding** - Shielding a source of radiation generally reduces the radiation levels around the radioactive source. In particular, shielding should be utilized for stored sources (e.g. the primary vial or high-activity radioactive waste). For the majority of biomedical research uses, the blue or gray plastic shield supplied by the manufacturer fulfills this reduction schema. . Use additional shielding around radioactive waste receptacles, when needed. Shielding is required when radiation levels exceed 2 mrem hr^{-1} in an unrestricted area.

1. *Beta-emitting sources* - most effectively shielded using low atomic number shielding material (e.g. hydrogen, oxygen, and carbon). Three-eighths inches (or one centimeter) of Plexiglas™ is recommended for high-energy beta-particle emitters (e.g. ^{36}Cl and ^{32}P).

2. *Gamma-emitting sources* - most effectively shielded using high-atomic number and high-density materials (e.g. lead, concrete, or iron). Shielding thickness will depend upon the radionuclide, activity, and storage location. Contact the Radiation Safety Division for further information.

3. *Alpha-emitting sources* - short-range particles in air. Therefore, alpha particles are not considered an external hazard. No shielding is generally required.

D. **Source Reduction** - reducing the activity used in each laboratory protocol will linearly reduce the dose rate. By possessing only the required activity for each protocol, personnel dose will be minimized.

E. **Source Substitution** - substitution of non-radioactive reagents is recommended to help minimize personnel dose.

6.3.5 Control of Dose from Internal Sources

The control methods outlined above do not readily apply when considering minimization efforts for internally deposited radionuclides. The primary control method for internal deposition is *prevention*. Preventing the inhalation and ingestion of radionuclides is the recommended method for internal dose control.

The four major pathways of internal deposition of radionuclides are:

A. **Inhalation** - inhaling airborne radioactive species.

B. **Ingestion** - consuming a contaminated liquid or food.

C. **Absorption** - skin contamination may result in absorption of radioactive material into the blood though the capillary system.

D. **Injection** - direct puncture or piercing of the protective layer of the skin.

Volatile radioactive compounds are defined as those compounds that readily become airborne. Examples of volatile radioactive compounds include ^{125}I and ^{131}I in a NaI solution, tritiated water (HTO), compounds with high-vapor pressure, and powdered radioactive solids. Furthermore, nonvolatile reagents may become airborne when heated agitated, powdered, or treated. Prevention of deposition pathways includes both facility requirements and administrative control procedures. The following guidelines should be used to minimize internal dose to personnel:

A. **Fume Hoods** - A chemical fume hood suitable for radioactive materials shall be used when using high activities of volatile radioactive compounds. Enclosures other than suitable fume hoods must receive *a prior* review and approval from the Radiation Safety Division.

B. **No Smoking, Eating, or Drinking in Laboratories** - To minimize the risk of intake of radioactive materials through the ingestion pathway, consumption in a laboratory area where radioactive materials (excluding sealed sources) are used is prohibited. This includes smoking, chewing tobacco, eating, and drinking. In addition, eating utensils, etc should not be stored where radioactive cross-contamination is likely. Microwave

ovens in laboratories where radioactive materials are used or stored should not be used for food preparation.

C. **Use of Protective Clothing** - Personal protective equipment furnishes an initial barrier in protecting against the absorption and injection pathways. This equipment may take the form of disposable gloves, laboratory jackets, long pants, closed-toe footwear, safety glasses and face shield. The majority of skin contaminations observed in research environments may have been prevented through the proper use and application of protective clothing. Therefore, the following limitations are promulgated:

1. Gloves shall be worn when working with unsealed radionuclides.

2. Laboratory jackets or coats shall be worn when the protocol requires the use of unsealed radionuclides.

3. When performing radionuclide protocol research, protective clothing covering the legs is strongly recommended.

4. Closed-toe footwear shall be worn when performing radionuclide protocols.

5. Eye protection shall be worn when performing radionuclide protocols.

D. **Proper Handling of Contaminated Sharps** - Sharp objects that are contaminated with radioactive material present an injection hazard. Therefore, personnel should minimize the handling of sharps. Do not recap syringes after completion of the injection. Sharp materials should be handled with thick gloves (e.g. leather or chain mesh) in order to reduce the injection potential.

6.4 General Precautions for Contamination Control

The prevention of an internal exposure caused by the entry of radioactive materials into the body, and the prevention of external exposure requires the development and use of sound laboratory techniques. Good housekeeping, good personal habits, and the proper use of equipment are essential ingredients. Typical guidelines for investigators or laboratory personnel using radioactive materials are as follows:

A. Non-essential persons should not be allowed into the laboratory while radioactive procedures are in progress.

B. A portion of the laboratory should be set aside only for procedures involving the use of radioactive materials. Radioactive materials should be

handled and used only in this designated work area, and nonessential materials should not be brought into this area. Locate work areas away from heavy traffic or doorways.

C. Work with radioactive materials should be performed rapidly but carefully.

D. Bottles, flasks, tubes, and/or other appliances containing radioactive material should be identified by the proper international radiation warning symbol (Section 8.4 of this document).

E. Exercise deliberate care in handling radioactive materials. Do not splash, splatter, or spill radioactive liquids.

F. Smoking, eating, drinking, and applying cosmetics is prohibited in the laboratory at all times.

G. Refrigerators shall not be used for the common storage of food and radioactive materials.

H. The laboratory should be kept clean and orderly.

I. Pipetting radioactive materials by mouth is prohibited at all times. Rubber bulbs, syringes, or mechanical devices shall be used.

J. All transfers and dilutions with a significant potential for inhalation should be performed in functioning exhaust hoods or glove boxes.

K. Work should be planned ahead, and whenever possible, a dummy run should be accomplished to test the procedure.

L. Absorbent paper should cover workbenches, trays and other work surfaces where radioactive materials protocols are performed.

M. Rubber or plastic gloves should be worn while working with radioactive materials.

N. When a procedure is completed, and before leaving the laboratory, wash and monitor the hands. (Monitoring means to check for radioactivity using an appropriate survey meter.) Decontamination of the hands may not be easy and may require vigorous and repeated washing. Wash hands with soap in a full stream of water. Use a scrub brush, if necessary, but be careful not to damage the protective skin layers.

O. Radioactive material in liquid form should be stored and transported in double containers.

P. Primary radioactive material vials should be stored in secondary container, such as the blue, yellow, or gray plastic container used for shipping.

Q. All items of equipment intended to provide features of safety should be checked periodically to insure that they are providing the safety feature intended.

R. Radioactive material must be stored in an appropriately secure and shielded area.

7. PERSONNEL DOSIMETRY

The purpose of the radiation dosimetry program is to measure the radiation dose equivalent from occupationally exposed radiation workers at North Carolina State University. The dosimetry results verify and document adherence with the occupational dose limits in 15A NCAC 11.1604. An ancillary purpose is the identification of problems and to monitor the efficacy of existing radiation safety measures.

Radiation dose equivalent is received in two general ways:

1. Radiation sources which are external to the worker's body.

2. Radiation sources which are internal to the worker's body.

Consequently, the dose equivalent from these two categories is measured in different manners. The Radiation Safety Division administers the external dosimetry program. Insofar, a National Voluntary Laboratory Accreditation Program (NVLAP) dosimetry contractor will process the personnel dosimeters issued by the Radiation Safety Division. The Radiation Safety Division also administers the internal dosimetry program. To this end, the internal dose assessment procedures or protocols will be consistent with NCRP and NC RPS recommendations.

7.1 EXTERNAL RADIATION DOSIMETRY

A. The Radiation Safety Division should monitor occupational exposure to radiation and supply and require the use of individual monitoring devices by:

   1. Adult radiation workers likely to receive, in one year from radiation sources external to the body, a dose in excess of 10% of the limits in 15A NCAC 11. 1604.

   2. Minors and declared pregnant workers likely to receive, in one year from sources external to the body, a dose in excess of 10% of any of the applicable limits in 15A NCAC 11.1609 and .1610.

   3. Individuals entering a high or very high radiation area; and

   4. Individuals using and maintaining x-ray equipment if the maintenance procedures require the presence of a primary x-ray beam when any safety component in the x-ray system is disassembled or removed.

B. The Radiation Safety Division will determine what groups are likely to exceed 10% of any applicable dose limit using all available data. This data may include facilities, equipment, radionuclides, and activities in use.

C. The Principal Investigator should notify the Radiation Safety Division of protocol changes significantly affecting radiation dose equivalent in the laboratories under their authorization.

D. The ALARA investigation level at NC State is defined as 2.5% of any applicable occupational limit. To this end, the Radiation Safety Division should investigate a dosimeter measurement in a monitoring period exceeding this ALARA level. This investigation will examine workload and protocol changes, dosimeter placement variations, or possible methods of dose minimization for future protocols.

E. Radiation dosimeters shall not be deceptively exposed. These devices are an integral safety component and must accurately reflect the worker's true exposure scenario. If a situation arises, please contact the Radiation Safety Division for resolution.

1. Under no circumstances should a dosimeter assigned to one person be worn by another person.

2. Dosimeters in storage and not being worn should not be stored near sources of radiation.

3. Dosimeters should not be exposed to high heat, chemical, or physical insults, including the washing machine.

4. Dosimeters shall not be worn during medical or dental examinations.

5. The Principal Investigator should inform the Radiation Safety Division upon discovery of any misrepresentative dosimeter information.

F. For information regarding the management of personal dosimeters at NC State, please contact the Radiation Safety Division.

G. Location and use of individual monitoring devices:

1. An individual monitoring device used for monitoring the dose to the whole body shall be worn at the unshielded location of the whole body likely to receive the highest exposure. When a protective

apron is worn, the location of the individual monitoring device is typically at the collar, outside the apron.

2. If an additional individual monitoring device is used for monitoring the dose to an embryo/fetus of a declared pregnant worker, it should be located at the waist under any protective apron being worn.

3. An individual monitoring device used for monitoring the eye dose equivalent should be located at the neck or a location closer to the eye, outside any protective apron being worn by the monitored individual.

4. An individual monitoring device used for monitoring the dose to the extremities should be worn on the extremity likely to receive the highest dose. Each individual monitoring device, to the extent practicable, should be oriented to measure the highest dose to the extremity being monitored.

H. Any employee likely to receive 10% of any applicable dose limit working with radiation at NC State may receive a copy of their dose records upon written request.

I. Upon employment termination, a dose termination report shall be provided to NC State from the dosimetry company for reference.

J. The deep dose equivalent, eye dose equivalent, and shallow dose equivalent may be assessed from surveys, use factors, exposure time calculations or other measurements for the purpose of demonstrating compliance with the occupational dose limits, if the monitoring device was mishandled, destroyed, or lost.

K. The Radiation Safety Division may issue personnel monitors for occupationally exposed individuals who are not likely to exceed 10% of the dose limits in 15A NCAC 11.1604. Personnel monitoring records for these individuals are not subject to the recordkeeping and notification requirements specified in 15A NCAC 11.1636.

7.2 INTERNAL RADIATION DOSIMETRY

A. The Radiation Safety Division shall monitor occupational exposure to radiation and shall provide and require the use of internal radiation dose assessments for:

1. Adult radiation workers likely to receive, in one year, an intake in excess of 10% of the applicable Annual Limit on Intake in Appendix B of 10 CFR 20.1001-20.2401, according to 15A NCAC 11.1607.

2. Minors and declared pregnant workers likely to receive, in one year, a committed effective dose equivalent in excess of 0.05 rem (0.5 millisievert).

B. For purposes of assessing committed effective dose equivalent, the Radiation Safety Division shall utilize the following measurements:

1. Concentrations of radioactive materials in the air or water in the work zone; or

2. Quantities of radioactive materials in the body; or

3. Quantities of radioactive materials excreted from the body; or

4. Any combination of these measurements.

C. The Radiation Safety Division will perform an internal dose assessment to radiation workers upon written request by the individual or as needed.

7.2.1 Criteria Requiring Internal Dose Assessment

The annual activity limits requiring internal dose assessment were derived from the CRC Handbook for Radiation Protection Programs (Brodsky 1992).

A baseline thyroid scan will be established for all new personnel who will be involved in the use of radioiodine. Thyroid scans will be performed for all lab persons who work directly with one millicurie or greater of unsealed radioiodine (specifically I-125) in a given experimental application within 10 working days of use and within 3 working days for radioiodine (specifically I-131).

Declared Pregnant Workers: Thyroid scans will be performed monthly for declared pregnant workers who work directly with unsealed radioactive iodine, in any quantity, to monitor uptake and to assess any internal dose. The frequency of analysis may be increased at the direction of the Radiation Safety Officer.

Table 2: Annual activity limits requiring internal dose assessment (adapted from Brodsky 1992).

Radionuclide	Type of Confinement	Annual Activity Level (Volatile)	Annual Activity Level (Non-Volatile)
^{3}H	Chemical Fume Hood	400 Ci	4000 Ci
	Open lab bench	40 Ci	400 Ci
	Special operation (unknown ventilation)	4 Ci	40 Ci
^{125}I or ^{131}I	Chemical Fume Hood	200 mCi	2000 mCi
	Open lab bench	20 mCi	200 mCi
	Special operation (unknown ventilation)	2 mCi	2 mCi
Dispersible Alpha Source	Chemical Fume Hood	200 mCi	2000 mCi
	Open lab bench	20 mCi	200 mCi
	Special operation (unknown ventilation)	2 mCi	20 mCi
Dispersible Beta/Gamma Source	Chemical Fume Hood	100 Ci	100 Ci
	Open lab bench	10 Ci	10 Ci
	Special operation (unknown ventilation)	10 Ci	10 Ci

* NC State University follows the above information as a guide; currently, thyroid bioassays are required after the use of 1 mCi or greater of I-125 (within ten working days) and I-131 (within 3 working days).

7.3 SUMMATION OF EXTERNAL AND INTERNAL DOSE

A. The Radiation Safety Division shall demonstrate compliance with the applicable dose limits (e.g. Total Effective Dose Equivalent or Total Organ Dose Equivalent) by summing the external and internal doses, if required. The dose equivalents for the lens of the eye, the skin, and the extremities are not included in the summation.

B. If the only intake of radionuclides is through inhalation, the total effective dose equivalent is not exceeded if the sum of the deep dose equivalent divided by the total effective dose equivalent limit, and one of the following, does not exceed unity:

1. the sum of the fractions of the inhalation ALI for each radionuclide: or

2. the total number of derived air concentration-hours (DAC-hours) for all radionuclides divided by 2000; or

3. the sum of the calculated committed effective dose equivalents to all significantly irradiated organs or tissues calculated from bioassay data using appropriate biological models and expressed as a fraction of the annual limit.

C. If the occupationally exposed individual receives an intake of radionuclides by oral ingestion greater than 10% of the applicable oral ALI (15A NCAC 11.1605c) Radiation Safety Division shall account for this intake in the committed effective dose equivalent, as necessary.

D. The Radiation Safety Division shall evaluate, to the extent practical, and account for intakes through skin absorption or wound injection. The Radiation Safety Division shall account for this intake in the committed effective dose equivalent, as necessary.

8. SURVEYS, POSTINGS, AND INSTRUMENTATION

8.1 LABORATORY SURVEYS BY PRINCIPAL INVESTIGATORS

Good housekeeping practices within the laboratory are fundamental to maintaining a safe environment. To ensure that radiation exposure does not result in a hazard to others, each Principal Investigator should perform appropriate surveys for external radiation and contamination following each procedure when the radioactive material is used. Radiation surveys serve to identify and quantify radiological hazards and document regulatory compliance.

In general, "surveys" may be divided into two general categories.

1. **Area Radiation Surveys** - quantifies the ambient radiation fields in and around the laboratory. The purpose is to ensure that radiation field levels are in compliance. These surveys are generally performed by Radiation Safety Personnel.

2. **Contamination Surveys** - quantifies removable and fixed radioactive material contamination in and around the laboratory. The purpose is to prevent or identify personnel contamination and monitor the efficacy of existing radiation safety measures.

8.2 LABORATORY AREA RADIATION SURVEYS

Laboratories using beta and gamma-emitting radionuclides (e.g. ^{32}P. ^{51}Cr, ^{86}Rb, ^{22}Na, or ^{137}Cs) should perform area radiation monitoring with an appropriate portable survey instrument. Any laboratory using other alpha, beta and gamma-emitters must also perform contamination surveys, analyzed in an appropriate instrument (e.g. liquid scintillation counter or gamma counters) to ensure the absence of radioactivity.

A. Work areas and equipment monitoring should be carried out by means of a portable radiation survey meter. The laboratory should also be surveyed routinely. All radioactive material work areas, bench and tabletops, sinks, drains, traps, floors, *etc.* are to be included in this survey. Radiation levels >3 times background should be further examined, decontaminated if necessary and/or properly posted.

B. Principal Investigators must have access to a survey meter that is appropriate for the radionuclide used.

C. If contamination of the body or clothing is suspected, monitoring of the suspected parts and decontamination, if necessary, shall be conducted immediately. Contact the Radiation Safety Division for assistance.

8.3 LABORATORY CONTAMINATION SURVEYS

Contamination surveys are readily accomplished through "wipe tests". Wipe tests are a method of determining the presence of removable contamination and must be performed in addition to any area radiation surveys required. Principal Investigators should require performance of surveys of the work area after each procedure involving unsealed sources of radioactivity.

Principal Investigators are required by the Radiation Safety Committee to document laboratory wipe tests at least once a *calendar* month in each of their laboratories where radioactive material is used. Monthly wipe test records are subject to inspection at any time and are part of the routine safety audit program performed by the Radiation Safety Division. Documentation need only be retained for one wipe survey per month. Wipe tests should be performed with the frequency given by the following schedule.

A. Monthly in areas where fewer than 50 mCi per protocol of dispersible radioactive materials are used.

B. If the laboratory is merely storing radioactive material, a survey shall be performed in or around the radioactive material storage area only to assure the primary vial is not damaged or breached causing contamination.

C. If the laboratory has no radioactive material in storage and no radioactive material usage occurred during the month, a record of this status, called a "Statement of No Use", should be created and filed with the other surveys.

The following additional wipe tests are not required, but highly recommended and do not need to be documented and retained.

A. Daily or after each operation in areas where 100 mCi per protocol or more of dispersible radioactive materials are used.

B. Weekly in areas where 50 mCi to 100 mCi per protocol of dispersible radioactive materials are used.

8.3.1 Laboratory Contamination Survey Procedure

Contamination surveys (e.g. wipe tests) should be performed as follows:

A. A cotton swab or filter disc may be used for wiping each location. Protective gloves should be worn while performing contamination surveys. Vigorously wipe the location-of-interest with the swab or filter paper disc. Any radioactive material loosely deposited on the surface of the location

should be transferred to the wiping medium.

B. Wipe tests should be taken at strategic locations throughout the laboratory, each covering an area (where possible) of approximately 100 cm^2. Typically, eight (8) to fifteen (15) wipes are taken. Larger laboratories may require more wipes. Areas to consider for testing include the following:

1. work benches reserved for radionuclide use
2. fume hoods (especially the accessible front area and handle)
3. sinks and adjacent areas
4. radioactive material storage containers
5. refrigerator or freezer handles
6. light switches and telephones
7. floor areas surrounding radioactive material use
8. laboratory equipment (centrifuge, balances, racks, or incubators)
9. locations where contamination is likely

C. For wipe tests that must be documented (e.g. monthly), the wipe location must be documented and the wipe analyzed on equipment capable of measuring the levels and types of radiation anticipated in the lab (e.g. liquid scintillation counter and/or gamma counter).

D. **Decontamination Action Level**: While any excess activity should be removed when discovered, areas with wipe test results of 500 dpm/100 cm^2 or greater of removable contamination for beta- and gamma-emitting radionuclides must be decontaminated until further wipe tests show results below this threshold. In general, radioactive material contamination should warrant investigation into contributing sources.

8.3.2 Laboratory Contamination Survey Records

A. A copy of the monthly wipe test results should be retained in the laboratory. For convenience, Principal Investigators are provided binders in which to retain all required documents.

B. Laboratory wipe test results should be retained in the laboratory for review during routine safety audits and review during inspections performed by the

Radiation Protection Section. To eliminate significant accumulation of paperwork, the Radiation Safety Division will notify the Principal Investigator when previous survey records may be removed (in general, every 2-3 years which corresponds with RPS inspections). The Radiation Safety Division should be contacted prior to the disposal of records to ensure compliance.

8.3.3 Documentation of Laboratory Contamination Surveys

Schematic diagrams of work areas are used to identify the locations where wipe test samples are taken. Space for such diagrams is provided on the Principal Investigator Laboratory Wipe Test Report (RS-9). The form is located in the Forms section of this manual and NC State Radiation Safety Webpage. Photocopies of each diagram are advantageous for future use. This form should be used to document wipe test samples.

A. Although the most important feature of any wipe test is the results of the sample analysis (e.g. removable activity detected), such data is not useful if other tracking information is not available. Therefore, each wipe test record (lab map or counting equipment printout) shall contain the following information:

1. Building and room number of laboratory wipe tested.

2. Month that the wipe test is being performed.

3. Name of the person performing the wipe tests.

4. Date of survey.

5. Principal Investigator's name.

6. Model, type, and serial number of counting equipment used.

7. Type of counting device (e.g. gamma or LSC).

8. Energy range where samples are counted.

9. Background count rate.

10. Efficiency of counter at region counted is preferable. May be omitted if equipment can automatically convert to dpm.

11. Identification of the location of each wipe taken.

12. Wipe test results printed from counter, in dpm or cpm, though dpm

is preferable. The dpm value may be calculated using the following formula:

$$DPM = \frac{\left[CPM - Background\right]}{Efficiency}$$

13. Actions taken regarding contamination (e.g. decontamination and rewipe documentation).

8.4 RADIATION NOTICES, SIGNS, AND LABELS

The following information must be available to all employees who receive, possess, use, or transfer sources of radiation at NC State. The following documents must be posted or referenced in conspicuous places in sufficient work areas:

A. *North Carolina Regulations for Protection Against Radiation, 15A NCAC*

B. The radioactive material license, certificates of registration, conditions or documents incorporated into the license, and supplemental amendments;

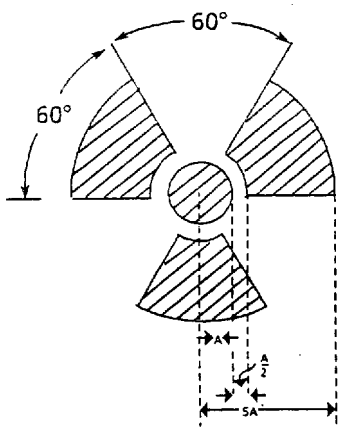
C. The operating procedures applicable to work under the license or registration;

D. Any outstanding notice of violation, order, or response stemming from regulatory inspection activities; and

E. The Agency Form, "Notice to Employees".

8.4.1 Posting Requirements

The following symbol shall be used for describing radioactive materials. The symbol shall use the colors magenta, purple, or black on a yellow background.



8.4.2 Types of Postings

The following postings must be appropriate for the indicated hazard and conspicuous.

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

B. **Caution High Radiation Area** - any area, accessible to individuals, in which levels could result in an individual receiving a dose equivalent in excess of 100 mrem in 1 hour at 30 centimeters from the source of radiation or from any surface that the radiation penetrates.

C. **Grave Danger Very High Radiation Area** - any area, accessible to individuals, in which levels could result in an individual receiving an absorbed dose in excess of 500 rad in one hour at 1 meter from a source of radiation or from any surface that the radiation penetrates.

D. **Caution Airborne Radioactivity Area** - any room or area in which airborne radioactive materials exist in concentrations in excess of levels specified in the 15A NCAC 11.

E. **Caution Radioactive Material** - should be posted at all doors or entrances to rooms or areas in which licensed radioactive materials are used or stored (excluding natural uranium, thorium, ^{63}Ni, and other exempt sources).

F. Additional postings shall be dictated by the level of hazard, degree of control in the area, and available facilities.

8.4.3 Labeling Containers and Radiation-Producing Machines

Prudent laboratory practice warrants labeling of all containers (e.g. flasks, beakers, jars, tubes) with some type of conspicuous label identifying the contents.

A. In order to prevent contamination of employees, general public, and future experiments, the Radiation Safety Committee recommends labeling containers regardless of the contained activity.

B. The Principal Investigator should ensure that unattended containers with activities exceeding the following limits are labeled with "Caution Radioactive Material" and the radiation symbol (Section 8.4.1).

Table 3: Quantities of selected licensed materials requiring labeling.

Radionuclide	Activity Requiring Labeling (μCi)
^{3}H	1000
^{14}C	1000
^{22}Na	10
^{32}P	10
^{33}P	100
^{35}S	100
^{125}I	1
^{45}Ca	100
^{86}Rb	100
^{51}Cr	1000

C. The Principal Investigator shall ensure that each container of licensed material is labeled with sufficient information to permit employees handling or using the container to minimize radiation exposures.

D. The Principal Investigator shall ensure that radioactive postings or labels are defaced, removed, or obscured prior to disposal of empty uncontaminated containers for unrestricted use.

E. The Principal Investigator shall ensure that each radiation-producing machine is labeled in a conspicuous manner advising individuals that radiation is produced upon energizing.

8.4.4 Exemptions and Exceptions to Posting

A. Containers, which are in transit and packaged and labeled in accordance with U.S. Department of Transportation regulations, are not required to be posted

B. Precision-manufactured equipment (e.g. centrifuge rotors), which may be damaged or unusable, is not required to be labeled. In this case, the contaminated equipment may be labeled on a secondary surface in order to convey the potential hazard

C. Installed or process equipment (e.g. pipes or tanks) are not required to be labeled or posted

D. A room or area is not required to be posted with a caution sign due solely to the presence of a sealed source. The radiation level must exceed 0.005 rem per hour at 30 centimeters from the sealed source container or shielding

8.5 INSTRUMENTATION

Radiation detectors at NC State may be categorized as follows:

1) **Quantitative** - These radiation survey instruments are operated in a manner to produce absolute quantities (e.g. effluent monitoring or package receipt surveys). The response of these instruments determines regulatory compliance with a dose, contamination, shipping, or release limit. Calibration techniques used by Radiation Safety will employee calculation of radiation detection efficiencies to determine the efficacy of meters.

2) **Qualitative** - These radiation detectors are operated in a manner to merely determine the presence or absence of radioactive materials. These instruments are not utilized in determining regulatory compliance with applicable dose limits.

8.5.1 Radiation Detector Calibration Requirements

A. Radiation detectors used for quantitative measurements shall be calibrated at intervals not to exceed 12 months

B. Radiation detectors used for qualitative measurements should be calibrated or response-checked at intervals not to exceed 12 months

C. Radiation detectors may be calibrated by the Radiation Safety Division, the instrument manufacturer, or a licensed or registered calibration service provider

D. Quantitative radiation detectors, which are serviced or repaired, shall be recalibrated following the repair. Recalibration is not essential for minor changes, which will not affect the instrument response characteristics (e.g. battery replacement)

E. Radiation detectors used for quantitative measurements shall be calibrated for the type of radiation encountered and the energies appropriate for use at an accuracy within ±20% of a reference value. The detection efficiencies will be recorded for comparison and reference during routine laboratory practices and audits

8.5.2 Requirements for Possessing a Detector

A. Each Principal Investigator should possess or have access to a radiation detector, which is appropriate for the potential hazard in their laboratory (radionuclides or radiation producing device).

B. Principal Investigators possessing high-energy beta- or gamma-emitting radionuclides should possess or have access to a portable radiation detector.

C. Users authorized for less than 0.5 mCi of ^{3}H, ^{14}C, ^{35}S, ^{63}Ni, or ^{33}P (i.e. any low-energy beta-emitting radionuclide) are not required to possess a portable radiation detector. The Principal Investigator should have access to a detector sufficient for quantifying the degree of laboratory contamination.

D. Users authorized for only ^{63}Ni in gas chromatographs or natural uranium or thorium compounds of 3 kilograms (6.6 pounds) or fewer are not required to possess a radiation detector.

E. Principal Investigators possessing only sealed sources presenting a minimal radiation exposure hazard are not required to possess a radiation detector.

F. Principal Investigators using I-125 RIA kits only presenting minimal radiation exposure hazards are not required to possess a radiation detector.

8.5.3 Guidelines for Using Radiation Detectors

A. Radiation detectors shall be used in accordance with manufacturer specifications or procedures. Failure to adequately follow these guidelines may result in erroneous readings

B. Before using a radiation detector in the field, the detector should be checked for operability and the detector response should be evaluated

C. Thin or open window probes should be operated in a manner that prevents contamination of the detector face

D. High radiation fields may not be accurately detected with GM probes due to electronic effects. Use caution when evaluating radiation fields with a GM probe

E. Low-energy beta-emitting radionuclides are not efficiently detected using a portable radiation detector. In general, this class of radionuclides should be evaluated using a liquid scintillation counter

F. Low-energy x-ray sources (e.g. ^{125}I) are most efficiently detected using a thin-window NaI scintillation probe

9. LABORATORY SAFETY AUDITS BY THE RSD

In order to assist and support the safe use of radioactive material at NC State, the Radiation Safety Division conducts routine audits of Principal Investigator activities. These audits may be classified as follows:

A. **Authorization Review** - This audit evaluates the Principal Investigator's emergency contact information, laboratory locations, radioactive material inventory, laboratory personnel and training, portable radiation survey instrument availability and calibration, and radioactive waste disposal issues. This audit is intended to evaluate the conditions and parameters of the radioactive material authorization set by the Radiation Safety Committee. The frequency of the review is once per calendar year.

B. **Laboratory Safety Evaluation** - This on-site audit is performed by the Radiation Safety Division at the Principal Investigator's facility. This audit should evaluate emergency response information, postings and labeling, facilities, records, RAM handling and use, RAM storage and security, radioactive waste disposal, personnel dosimetry, laboratory radiation levels, and other safety issues as needed. The frequency of the audit is four times per calendar year unless otherwise indicated by the Radiation Safety Officer or the Radiation Safety Committee.

The Principal Investigator is ultimately responsible for compliance with safety and health issues in facilities under their jurisdiction. The intent of safety audits and subsequent items of non-compliance is to notify the Principal Investigator of potential safety issues in the research environment.

The frequency of on-site audits may be accelerated due to enforcement actions recommended by the Radiation Safety Committee, significant increases in radioactive material use, a request by the Principal Investigator, or other safety conditions warranting additional oversight.

9.1 INSPECTION CRITERIA

The on-site radiation safety audits performed by the Radiation Safety Division evaluate potential radiological hazards, determine the concentrations and quantities of radioactive material, and ensure compliance with applicable regulatory issues in the research environment. The on-site audit is an essential tool for evaluating safety in the laboratory. To this end, the Radiation Safety Committee or Radiation Safety Officer may accelerate the on-site audit schedule if prudent judgment obligates such action.

The following items are incorporated in this document to outline the breadth of the routine inspection criteria. Necessary parameters will be added or deleted without

notification. In addition, not all items will be evaluated for each research facility. The degree of radiological hazard will guide inspection criteria.

A. Emergency response information

B. Appropriate postings and labeling

C. Facilities Review

D. Records and Inventory Review

E. RAM Use and Handling Review

F. RAM Security or Storage Review

G. Radioactive Waste Disposal Review

H. Radiation Dosimetry Review

I. Laboratory Radiation Survey

J. Other conditions, as necessary.

9.2 RESULTS OF INSPECTIONS

Audits conducted by the Radiation Safety Division will be used to determine the Principal Investigator's compliance with North Carolina Department of Environment and Natural Resources, Radiation Protection Section, regulations and conditions outlined in this document. The Radiation Safety Division will retain the audit record. Permanent records of laboratory inspections will be available for inspection at any time by the Principal Investigators, the Radiation Safety Officer, members of the Radiation Safety Committee, or representatives of the North Carolina Department of Environment and Natural Resources, Radiation Protection Section.

Laboratory safety audit findings will be directed to the Principal Investigator. Items of non-compliance will generally require prompt rectification by the responsible parties. A summary of on-site audit activities conducted by the Radiation Safety Division will be presented to the Radiation Safety Committee via programmatic information.

9.2.1 On-site Audits with No Observed Deficiencies

Audits conducted by the Radiation Safety Division, which result in no items of non-compliance, will be deemed successful. No response or clarifying documentation will be required.

9.2.2 On-site Audits with Observed Deficiencies

Items of non-compliance observed during audit activities will be conditionally handled accounting for the degree of hazard present in the facility, severity to employee health and safety, technological feasibility, or other mitigating circumstances. Audits conducted by the Radiation Safety Division which result in items of non-compliance may require the following:

A. Verbal response by laboratory personnel;

B. Follow-up audit by the Radiation Safety Division;

C. Written response by laboratory personnel;

D. Written response and supporting documentation by the Principal Investigator;

E. Consultation with the Radiation Safety Officer;

F. Non-compliance hearing before the Radiation Safety Committee; or

G. Immediate intervention by the Radiation Safety Officer when imminent concern for safety and health exist.

9.2.3 Findings of Repeated Observed Deficiencies

Items of non-compliance, which consistently appear in Principal Investigator's facilities, warrant additional consideration from the Radiation Safety Division. Repeated items of non-compliance will be conditionally handled accounting for the degree of hazard present in the facility, severity to employee health and safety, and other mitigating circumstances. Escalated enforcement actions will be addressed via the Radiation Safety Officer and the Radiation Safety Committee on an individual basis. Repetitive violations can result in heightened inspection frequencies, suspension of ordering privileges, suspension of protocol approval, deactivation of license or other measures deemed appropriate.

9.3 PROCEDURE FOR ADDITION OF A RADIOACTIVE MATERIAL LABORATORY

The prospective Principal Investigator shall provide labeled drawings of facilities with the original applications as the Radiation Safety Division as part of the application review process evaluates each facility.

A. The new applicant for radioactive material use in the research environment should specify facility information with the Radiation Safety Committee on

the initial Radioactive Material Use Application (RS-01 and RS-02). An established Principal Investigator may conditionally add laboratories by filing a Radioactive Material Protocol Amendment (RS-5), a completed Authorization Review, or written notification with the RSD. These requests will be reviewed by the Radiation Safety Officer for provisional approval and the Radiation Safety Committee for final approval.

B. The Radiation Safety Division should review applicable facility issues during an "opening" laboratory evaluation including but not limited to:

1. Emergency response information;
2. Appropriate posting and labeling;
3. Facility review and evaluation;
4. Shielding review and evaluation;
5. RAM use and handling review;
6. RAM storage and security;
7. Radioactive waste disposal review;
8. Laboratory radiation survey; and
9. Other conditions, as necessary.

C. Upon successful completion of an opening survey, the new laboratory will be added to the Principal Investigator's list of approved radioactive material use areas.

D. Notifications of amendments to authorization parameters (excluding personnel changes and contact information) are provided to the Radiation Safety Committee for review and approval.

9.4 PROCEDURE FOR DECOMMISSIONING A RADIOACTIVE MATERIAL LABORATORY

A radioactive material laboratory may be decommissioned through the request of the Principal Investigator, the Department Chair or Dean, the Radiation Safety Officer or the Radiation Safety Committee.

A. The Radiation Safety Division shall review applicable facility issues during a decommissioning laboratory evaluation including but not limited to:

1. Emergency response information;
2. Appropriate posting and labeling;
3. Facility review and evaluation;
4. Radioactive source and waste review;
5. Laboratory radiation survey; and
6. Other conditions, as necessary.

B. Prior to vacating any facility or releasing areas or equipment for unrestricted use, the Radiation Safety Division or the Principal Investigator shall ensure that radioactive contamination has been removed to levels as low as reasonably achievable. In no case shall the licensee vacate a facility or release areas or equipment for unrestricted use until surface contamination levels are below the activity limits specified in 15A NCAC 11.

C. In the event of long-lived (e.g. half-life exceeding 300 days) non-removable radioactive material contamination existing on equipment or facilities which will continue to be used in the research environment which does not pose a significant exposure potential, the contamination shall be labeled with appropriate identifying and cautionary information and retained in the laboratory. The location of the non-removable radioactive material contamination shall be maintained for ultimate disposal in conjunction with the decommissioning plan per 15A NCAC 11.

D. Following a successful decommissioning audit by the Radiation Safety Division, the laboratory will be removed from the Principal Investigator's radioactive material jurisdiction and responsibility.

10.0 RELEASE OF ANIMAL PATIENTS CONTAINING RADIOPHARMACEUTICALS

The following applicable release condition must be met for an animal patient containing radioactive material:

A. Any animal to whom more than 30 millicuries of a radiopharmaceutical is administered shall be confined to an approved inpatient facility and shall not be released from confinement until the activity of the administered radiopharmaceutical in the patient is less than 30 millicuries or the dose rate at one meter from the patient is less than 5 millirem per hour;

B. The veterinarian/approved PI will have ultimate responsibility and oversight on patient release criteria and recordkeeping.

C. All bedding materials, animal holding facilities, and animal excrement will be properly removed, cleaned and disposed of via NC State radioactive material waste release procedures.

10.1 USE OF DOSE CALIBRATORS

Dose calibrators used for determining patient dosage should be calibrated in accordance with the manufacturer's instructions and the following schedule:

A. Daily for constancy, when in use.

B. Quarterly for linearity over the range that it is normally used.

C. Annually for complete calibration.

The user should maintain a logbook of calibrations.

10.2 POSITRON-EMITTING RADIONUCLIDES - SPECIAL PRECAUTIONS

A. Tracers will arrive at the facilities and will remain stored in an appropriate area, properly shielded until it is time for injection into the patient or the investigator is ready for use.

B. Appropriate lead shielding should be maintained when preparing, storing, or using positron-emitting radionuclides.

C. Minimize exposure by utilizing available protective equipment and minimizing handling time. Traditional lead-shielded syringes provide little attenuation for the 511 keV photons, and may hinder the administration process. Novel plastic-shielded syringes attenuate the high-energy positrons emitted. Such protective devices should be considered in order

to reduce employee exposures while maximizing patient care activities.

D. Routinely survey clinical facilities using positron-emitting radionuclides with a survey meter. The survey frequency for these laboratories will be conditionally determined accounting for radionuclides and activities utilized, available facilities, technological advances, or other mitigating circumstances.

E. Keep sources used for attenuation correction or standardization behind lead shielding at all times excluding use.

F. In the event of a radioactive material spill, follow standard emergency response or decontamination procedures stated in Section 13, ”Incidents and Emergencies”. Contact the Radiation Safety Division for assistance with response, decontamination, and radiation level quantification.

11. SEALED SOURCES OF RADIOACTIVE MATERIAL

A sealed source of radioactive material is defined as radioactive material that is permanently bonded or fixed in a capsule or matrix designed to prevent release and dispersal of the radioactive material under the most severe conditions that are likely to be encountered in normal use and handling. Sources fabricated by individuals or organizations that are not registered and approved by the Sealed Source and Device Registry maintained by the U.S. Nuclear Regulatory Commission are not considered sealed sources. Radioactive sources, which are not registered and approved, should be treated as unsealed sources and subject to the handling precautions and requirements for open radionuclides.

11.1 GENERAL REQUIREMENTS

A. Each sealed source, unless otherwise exempt, shall be tested for leakage or contamination and the test results available before the sealed source is put into use unless a certificate from the transferor indicates that the sealed source has been successfully leak tested within the required leak test interval.

B. Each sealed source that is not designed to emit alpha particles is tested for leakage or contamination at intervals not to exceed six months or at alternative intervals approved by the NC RPS.

C. Each sealed source that is designed to emit alpha particles is tested for leakage or contamination quarterly, or at intervals approved by the NC RPS.

D. If a sealed source is required to be surveyed for leakage or contamination and the source is damaged or suspected of leaking, the sealed source shall be surveyed for leakage or contamination.

E. Tests for leakage for all sealed sources, except radium brachytherapy sources, shall be capable of detecting the presence of 0.005 microcurie (11,100 dpm) of radioactive material on a test sample. Test samples should be taken from the sealed source or the surfaces of the storage container where contamination might accumulate.

F. Analysis for sealed source leak tests should be performed by the Radiation Safety Division under the guidance of the Radiation Safety Officer. Authorized vendors or the source manufacturer may perform additional sealed source tests.

G. The following shall be considered indication that a sealed source is leaking:

1. The presence of 0.005 microcurie (11,100 dpm) or greater of removable contamination originating from the source tested;

2. The presence of removable contamination resulting from the decay or 0.005 microcurie or more of radium.

H. Upon determination that a sealed source is leaking, the Radiation Safety Division will remove the leaking source to prevent personnel contamination. The leaking source will be either appropriately repaired or disposed of.

I. The Radiation Safety Division must notify the NC RPS if a sealed source is determined to be leaking. A written report of a leaking source shall be submitted to the NC RPS within five working days of the determination that the source is leaking.

11.2 EXEMPTIONS

Tests for leakage or contamination are not required on the following sealed sources:

A. Sealed sources containing only radioactive material with a half-life less than 30 days;

B. Sealed sources containing only radioactive material as a gas;

C. Sealed sources containing 100 microcurie or less of beta- or photon-emitting material or 10 microcurie or less of alpha-emitting material;

D. Sealed sources containing only ^{3}H;

E. Seeds of ^{192}Ir encased in nylon ribbon; and

F. Sealed sources which are stored, not being used and identified as in storage.

12. INSTRUCTION AND TRAINING

Written safety procedures established for laboratory operations and a copy of the *Radiation Safety Manual* must be available to laboratory personnel at all times. All applicable persons working in the laboratory will be required to familiarize themselves with these procedures and practice them. In addition, it is incumbent upon the Principal Investigator or the laboratory supervisor to ensure that such persons are familiar with established safety procedures. Applications for authorization to use radioactive materials and requests to add new personnel to a project require persons associated with the project to indicate such familiarity was established.

Periodically, the Radiation Safety Division offers instruction sessions or seminars in the fundamentals of laboratory radiation protection to technicians, applicants for radioactive materials use, and other interested persons. It is emphasized that completion of a formal course in radiation safety does not absolve a Principal Investigator of the obligation for instructing technicians in the principles of good radiation safety practices.

Persons performing radioactive material protocols must complete one or more of the following options:

A. Provide to the Radiation Safety Division a copy of a certificate or letter of completion for a course on radiation safety from another institution, no earlier than 2 years of completion; or

B. Successfully complete an examination on radiation safety given by the Radiation Safety Division, administered at the conclusion at the Principles of Radiation Safety Class and.

C. Successfully complete a radiation safety refresher training (materials and x-ray) course every four years or at an interval suggested by the Radiation Safety Officer or Radiation Safety Committee.

Additional training classes shall be offered by the Radiation Safety Division and may be required for protocols using certain radioactive materials or Principal Investigators with radiation-producing devices.

13. INCIDENTS AND EMERGENCIES

13.1 GENERAL INFORMATION

The North Carolina State University Emergency Response Plan provides a clearly defined protocol and corresponding support mechanism to protect NC State personnel and property in emergency situations. The scope of this plan is to define emergency situations, specific preventive and response procedures to avoid and cope with emergencies in a safe, orderly and efficient manner, protecting the personnel and facilities at NC State. Emergency situations include any circumstances that threaten NC State personnel and/or property.

13.2 MINOR SPILLS

A. Notify the Radiation Safety Division of the spill. The following information is necessary:

1. Laboratory location of the spill;
2. Identity of the caller;
3. Extent of personnel injuries;
4. Radionuclide involved;
5. Amount of radioactive material involved (in μCi or mCi); and
6. The chemical or physical form.

B. If the spill occurs:

1. **During working hours** - call Radiation Safety 515-2894
2. **After working hours** - call Campus Police 911

C. Attend to the spill as soon as possible.

D. Use appropriate personal protective equipment (e.g. gloves, laboratory jacket, etc.).

E. Once the affected area has been blotted dry, scrub the contaminated area with soap and water. Continue this process until the contamination is less than 500 dpm/100 cm^2 of the removable contamination. If the contaminated area cannot be reduced to these levels, the area should be covered with an impervious material (e.g. diaper paper) to prevent further

contamination. If the spill produces radiation fields exceeding 2 mrem per hr at one foot from the source, appropriate shielding material should be placed on the area. If shielding is not feasible, access to the spill zone should be restricted. All areas of non-removable contamination should be labeled with cautionary information, and personnel in the area should be notified. The Radiation Safety Division is available to supervise personnel concerning decontamination of surfaces, appropriate shielding, and restriction of access.

F. In the case of contaminated wounds, rinse with running water and soap. (Do not scrub contaminated skin). Cover with sterile dressing and seek medical attention at once.

13.3 Major Spills or Radiation Emergencies

Radiation emergencies, as is applicable for NC State, are incidents which involve actual or suspected exposure to uncontrolled sources of radioactivity that cause or threaten to cause an external dose in excess of five (5) rem to the whole body, or gross radioactive personnel contamination resulting in ingestion, inhalation, injection, or skin absorption of radioactive material leading to comparable risk.

A. Call Campus Police at 911

B. Provide the following information to Campus Police:

1. Laboratory location of the spill or emergency
2. Identity of the caller
3. Extent of personnel injuries
4. Radionuclide involved
5. Amount of radioactive material involved (in μCi or mCi)
6. The chemical or physical form

C. Life-saving or first aid measures should take precedence over radiation hazards and decontamination efforts

D. Stand clear of a contaminated area. Radiation Safety will perform clean up, decontamination and surveys of the area

13.4 LABORATORY FIRES

In the event of a laboratory fire involving radioactive materials, the following procedure is recommended:

A. Report the fire by calling 911. The following information should be given:

1. Identify yourself and phone number
2. Exact location of fire (building, laboratory number of the specific area)
3. Extent of personnel injuries
4. Type of fire (electrical, flammable liquid, trash, *etc*.)
5. Extent of fire (severity of fire and smoke)

B. Close laboratory doors to contain the fire as you leave the laboratory area

C. Activate the fire alarm system at the nearest pull-station as you exit to the stairwell

D. Evacuate to safe area after exiting through the stairwell

13.5 MISCELLANEOUS INCIDENTS AND EMERGENCIES

The following may constitute an incident or emergency:

A. Loss or theft of any radioactive material or radiation-producing device

B. High or potentially high radiation exposure to an employee or member of the general public

C. Intake of radioactive material by inhalation, ingestion, skin absorption, or injection through the skin or wound

D. Deceptive or potentially deceptive exposure of a dosimeter

E. Personnel contamination that cannot be removed after two washes with soap and water

F. Spills involving significant activities of ^{125}I or ^{131}I with the potential for inhalation

G. Removable contamination in unrestricted areas (e.g. hallways, offices, vehicles, etc.), which exceed the limits outlined in 15A NCAC 11

H. Radiation fields in unrestricted areas that exceed the limits specified for members of the general public in 15A NCAC 11

I. Accidental or unmeasured releases of radioactive material to the environment

J. Fire or floods which threaten to release radioactive material to the environment or which threaten to expose emergency response personnel

K. An on-site transportation accident involving radioactive material

L. Personnel injuries that may involve radioactive material contamination of the wound

M. Additional situations deemed pertinent by the Radiation Safety Committee or Radiation Safety Officer

14. RECORDKEEPING

14.1 GENERAL REQUIREMENTS

A. The Radiation Safety Division shall maintain all required records in units and subdivisions of curie, rad, rem, roentgen, or disintegrations per minute, where appropriate and/or feasible. Other units may be used when necessary.

B. All units shall be clearly indicated on required records.

C. The Radiation Safety Division should make distinctions among quantities and values entered on required dosimetry records (e.g. total effective dose equivalent, total organ dose equivalent, shallow dose equivalent, eye dose equivalent, deep dose equivalent, or committed dose equivalent).

D. Required records shall include the date and identification of the individual making the record, and, as applicable, identification of the survey instrument(s) used, and an exact description of the survey location.

E. Records of receipt, transfer, and disposal of sources of radiation shall uniquely identify the radiation source.

F. All required laboratory documents must be retained for three years, unless otherwise specified by Radiation Safety. Record retention rates for documents not specified will be determined on a case-by-case basis.

15. NUCLEAR REACTOR

A 1 MW nuclear reactor, located in Burlington Engineering Laboratory, is a special resource for education, research and service. A Safety Analysis Report describes the nuclear and radiation safety of the reactor facility. A license for operating the reactor, issued by the Nuclear Regulatory Commission, requires compliance with license conditions, applicable federal regulations and the facility Technical Specifications.

The Protocol process, as described in this manual, permits operations associated with surveillance, maintenance, and the experiments associated with education, research and service. Those who use the various experimental facilities and the reactor staff must comply with the applicable Protocol conditions. Users and unescorted personnel are allowed in the facility provided they have completed the training described in the facility procedures. Visitors are allowed in the facility, as long as an individual who has unescorted privilege assess privileges, as described in the facility procedures, escorts them.

The reactor facility is unique in comparison with other laboratories on campus where radioactive materials or sources are used. The unique aspects of the reactor facility occasionally require deviations from the radiation safety requirements given in this manual, but are specified in other reactor related documents approved by the Reactor Safety and Audit Committee (RSAC) and the Radiation Safety Committee (RSC). These documents include the Protocols as described in this manual, license support materials, and facility specific Health Physics procedures.

1. GLOSSARY OF TERMS

These terms as well as others can be located in 15 NCAC 11.0104.

ABSORBED DOSE: The amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material.

ABSORPTION: The phenomenon by which radiation imparts some or all of its energy to any material through which the radiation passes.

ACCELERATOR: A device for imparting kinetic energy to charged particles, such as electrons, protons, deuterons, and helium ions. Common types of accelerators are the cyclotron, synchrotron, synchrocyclotron, betatron, linear accelerator, and Van de Graff electrostatic generator.

ACTIVITY: The number of nuclear disintegrations occurring in a given quantity of material per unit time.

ACUTE EXPOSURE: Term used to denote a relatively high radiation exposure of short duration.

ALARA: Acronym for the radiation protection philosophy that radiation exposures and effluents to the environment should be maintained "As Low As Reasonably Achievable". The U.S. Nuclear Regulatory Commission requires that ALARA be considered in the design of all experiments where radioactive material is used.

ALARA LEVEL: Administrative action level of 2.5% of any applicable dose limit.

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

ALPHA RAY: A stream of fast moving helium nuclei (alpha particles), a strongly ionizing and weakly penetrating radiation.

ANGSTROM (A): Unit of measure of wavelengths equal to 10^{-10} meter or .01 nanometers (millimicrons).

ANODE: Positive electrode; an electrode to which negative ions are attached.

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

ATOMIC NUMBER: The number of protons in the nucleus of an atom.

ATTENUATION: The process by which a beam of radiation is reduced in intensity

when passing through materials.

AUTORADIOGRAPH: Record of radiation from radioactive material in an object, made by placing the object in close proximity to a photographic emulsion.

BACKGROUND RADIATION: Ionizing radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic rays and natural radioactivity is always present. There may also be background radiation due to the presence of radioactive substances in other parts of the building, in the building material itself, etc.

BACKSCATTER: The deflection of radiation by scattering processes through angles greater than 90 degrees with respect to the original direction of motion.

BEAM: A unidirectional or approximately unidirectional flow of electromagnetic radiation or particles: A *USEFUL BEAM* in radiology is that part of the primary radiation that passes through the aperture, cone, or other collimator.

BECQUEREL (Bq): SI Unit of radioactivity. One Bq equals one nuclear transformation/second. One microcurie is equivalent to 37,000 Bq (37 kilobecquerels) (kBq).

BETA PARTICLE: Charged particle emitted from the nucleus of an atom, having a mass and charge equal in magnitude to that of the electron.

BIOASSAY: Monitoring of personnel for the uptake of radioactive material in the body.

BIOLOGICAL HALF-LIFE: The time required for the body to eliminate one-half of an administered dose of any substance by regular processes of elimination. This time is approximately the same for both stable and radioactive isotopes of a particular element.

BONE SEEKER: Any compound or ion, which migrates in the body preferentially into bone.

BREMSSTRAHLUNG: Electromagnetic (X-ray) radiation associated with the deceleration of charged particles passing through matter. Usually associated with energetic beta emitters, (e.g., phosphorus-32).

CALIBRATION: Determination of variation from standard, or accuracy, of a measuring instrument to ascertain necessary correction factors.

CALORIE: Amount of heat necessary to raise the temperature of one gram of water 1' C (from 14.5' to 15.5' C).

CATHODE: Negative electrode; electrode to which positive ions are attracted.

COLLIMATOR: A device for confining the elements of a beam within an assigned solid angle.

CONTAMINATION, RADIOACTIVE: Deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence may be harmful. The harm may be in vitiating the validity of an experiment or a procedure, or in actually being a source of excess exposure to personnel.

COULOMB: A unit of electrical charge in the practical system of units. A quantity of electricity equal to 3×10^9 electrostatic units of charge.

COULOMB/KILOGRAM (C/kg): SI Special unit of radiation exposure. 1 coulomb/kilogram is equivalent to 3,876 Roentgens.

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

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

CURIE: The quantity of any radioactive material in which the number of disintegrations is 3.700×10^{10} disintegrations per second. Abbreviated Ci.

CYCLOTRON: A particle accelerator, which uses a magnetic field to confine a positive ion beam to a plane while an alternating electric field accelerates the ions in a spiral path. An RF voltage is applied between one or two hollow semicircular electrodes called dees at the frequency at which the ions rotate (which is constant in the conventional cyclotron). As the voltage between the dees alternates, particles are accelerated as they enter and leave the dees.

DAUGHTER: A synonym for a decay product of a radioactive parent-nuclide.

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

DE MINIMIMS: Literally, *"de minimis non curat lex"* meaning, the law does not concern itself with trifles; hence, too small (or low) to be of concern.

DISINTEGRATION: A spontaneous nuclear transformation (radioactive) characterized by the emission of energy and/or mass from the nucleus. When large numbers of nuclei are involved, the process is characterized by a definite half-life.

DOSE: A general term denoting the quantity of radiation or energy absorbed in a specified mass. For special purposes, it must be appropriately qualified, (e.g., absorbed dose).

DOSE, ABSORBED: The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. The unit of absorbed dose is the rad, which is 10^{-5} J/gram.

DOSE EQUIVALENT: A quantity used in radiation protection expressing all radiation on a common scale for calculating the effective absorbed dose. The unit of dose equivalent is the rem, which is numerically equal to the absorbed dose in rads multiplied by certain modifying factors such as the quality factor, the distribution factor, etc. Further descriptions may be associated with dose equivalent, including shallow and deep, referring to depth in tissue.

DOSE RATE: Dose delivered per unit time.

DOSIMETER: An instrument used to detect and measure an accumulated dose of radiation. In common usage, it is a pencil size ionization chamber with a built-in, self-reading electrometer or other measuring deceive used for personnel monitoring.

DOT: Department of Transportation (U.S.).

EFFICIENCY (Counters): A measure of the probability that a count will be recorded when radiation is incident on a detector. Usage varies considerably so it is well to make sure which factors (window, transmission, sensitive volume, energy dependence, etc.) are included in a given case.

ELECTROMAGNETIC RADIATION: Electromagnetic waves consist of oscillating electric and magnetic fields.

ELECTRON: Negatively charged elementary particle that is a constituent of every neutral atom. Its unit of negative electricity equals 4.8×10^{-10} electrostatic units or 1.6×10^{-19} coulombs. Its mass is 0.000549 atomic mass units.

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

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

ENERGY DENSITY: The intensity of electromagnetic radiation per unit area per pulse

expressed as joules per square centimeter.

ERYTHEMA: An abnormal redness of the skin due to distention of the capillaries with blood. Many different agents-heat, drugs, ultraviolet rays, or ionizing radiation can cause it.

EXCITATION: The addition of energy to a system, thereby transferring it from its ground state to an excited state. Excitation of a nucleus, an atom, or a molecule can result from absorption of photons or from inelastic collisions with other particles.

EXPOSURE: A measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the mass of air in the volume element. The special unit of exposure is the roentgen.

FILM BADGE: A packet of photographic film used for the approximate measurement of radiation exposure for personnel monitoring purposes. The badge may contain two or more films of differing sensitivity, and it may contain filters that shield parts of the film from certain types of radiation.

FLUX: For electromagnetic radiation, the quantity of radiant energy flowing per unit time. For particles, the number of particles or photons flowing per unit time.

GAMMA RAY: Very penetrating electromagnetic radiation of nuclear origin. Except for origin, identical to X-ray.

GEIGER MUELLER (GM) COUNTER: Highly sensitive gas-filled detector and associated circuitry used for radiation detection and measurement.

GENETIC EFFECT OF RADIATION: Inheritable changes, chiefly mutations, produced by the absorption of ionizing radiations. On the basis of present knowledge these effects are purely additive, and there is no recovery.

GRAY (Gy): SI unit of absorbed dose. 1 Gy is 1 Joule of energy deposited per kilogram of absorber. 1 Gy is equivalent to 100 rad.

HALF-LIFE, EFFECTIVE: Time required for a radioactive nuclide in a system to be diminished 50 percent as a result of the combined action of radioactive decay and biological elimination.

$$\text{Effective half-life} = \frac{\text{Biological halflife x Radioactive halflife}}{\text{Biological halflife} + \text{Radioactive halflife}}$$

HALF-LIFE, RADIOACTIVE: Time required for a radioactive substance to lose 50 percent of its activity by decay. Each radionuclide has a unique half-life

HALF VALUE LAYER (Half thickness): The thickness of any specified material necessary to reduce the intensity of an X-ray or gamma ray beam to one-half its original value.

HARDNESS: A relative specification of the quality or penetrating power of x-rays. In general the shorter the wavelength, the harder the radiation.

HEALTH PHYSICS: A term in common use for that branch of radiological science dealing with the protection of personnel from harmful effects of ionizing radiation.

HIGH RADIATION AREA: Any area, accessible to personnel, in which there exists radiation at such levels that a major portion of the body could receive in any one hour a dose in excess of 100 millirems. High Radiation Areas must be posted and must be equipped with specified control devices, alarms, etc.

HOOD, FUME: A hood for handling unconfined radioactive materials that provides adequate containment in a hood or box and independent air exhaust from the work area.

INVERSE SQUARE LAW: The intensity of radiation at any distance from a point source varies inversely as the square of that distance. For example, if the radiation exposure is 100 R/hr at 1 inch from a source, the exposure will be 0.01 R/hr at 100 inches.

IODINATION: To combine or treat with iodine or a compound of iodine.

ION: Atomic particle, atom, or chemical radical bearing an electrical charge, either negative or positive.

IONIZATION: The process by which a neutral atom or molecule acquires either a positive or a negative charge.

IONIZATION CHAMBER: An instrument designed to measure the quantity of ionizing radiation in terms of the charge of electricity associated with ions produced within a defined volume.

IONIZING EVENT: Any occurrence of a process in which an ion or group of ions is produced.

IONIZATION, SPECIFIC: The number of ion pairs unit length of path of ionizing radiation in a medium, (e.g., per centimeter of air or per micron of tissue).

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

ISOTOPES: Nuclides having the same number of protons in their nuclei, and hence having the same atomic number, but differing in the number of neutrons, and therefore in

the mass number. Almost identical chemical properties exist between isotopes of a particular element.

JOULE (J): Unit of energy. It is equal to 1 watt/second or 4.19 calories.

JOULE/cm^2 (J/cm^2): Unit of energy density used in measuring the amount of energy per area of absorbing surface, or per area of a laser beam. It is a unit for predicting damage potential of a laser beam.

keV: The symbol for one thousand electron volts.

LABELED COMPOUND: A compound consisting, in part, of molecules labeled by radioactive material. By observations of radioactivity or isotopic composition this compound or its fragments may be followed through physical, chemical, or biological processes.

LASER: Light amplifications by stimulated emission of radiation.

LASER REGION: A portion of the electromagnetic spectrum, which includes the ultraviolet, the visible light, and the infrared.

LEAK TEST: A test for leakage from sealed radioactive sources (usually a wipe test) when received and on a periodic basis.

LEAKAGE RADIATION: The radiation that escapes through the protective shielding of an X-ray tube or teletherapy unit.

LIQUID SCINTILLATION COUNTER (LSC): See SCINTILLATION COUNTER.

MeV: The symbol for one million electron volts.

MICROWAVE: An electromagnetic wave having a wavelength in the microwave region, usually in the frequency range above 1000 megahertz.

MICROWAVE REGION: A portion of the electromagnetic spectrum, the covers the approximate frequencies of 300 to 300,000 megacycles per second, with the corresponding wavelengths of approximately 1 meter to 1 millimeter.

MILLIROENTGEN (mR): A submultiple of the roentgen equal to one one-thousandth (1/1000th) of a roentgen. (See Roentgen)

MILLIWATT (mW): A submultiple of the watt equal to one/thousandth of a watt.

MONITORING, RADIOLOGICAL: Periodic or continuous determination of the amount of ionizing radiation or radioactive contamination present in an occupied region as

a safety measure for purposes of health protection. Area monitoring is routine monitoring of the level of radiation or of radioactive contamination of any particular area, building, room, or equipment. Personnel monitoring is monitoring any part of an individual, the individual's breath, the individual's excretions, or any part of the individual's clothing. (See Radiological Survey)

MULTICHANNEL ANALYZER (MCA): An instrument used with a GM tube for pulse height analysis in numerous counting channels.

NATURAL RADIATION: The radioactivity exhibited by more than fifty naturally occurring radionuclides.

NUCLEAR REGULATORY COMMISSION (NRC): Federal agency established by the Atomic Energy Act of 1954 and the Energy Reorganization Act of 1974 to regulate the use of radioactive material through its Licensing, Inspection and Enforcement, and Standards Development activities.

NEUTRON: Elementary particle with a mass approximately the same as that of a hydrogen atom and electrically neutral. It has a half-life in minutes and decays in a free state into a proton and an electron.

NUCLIDE: A species of atom characterized by its mass number, atomic number, and energy state of its nucleus, provided that the atom is capable of existing for a measurable time.

OUTPUT POWER AND OUTPUT ENERGY: Power is used primarily to rate C.W. lasers since the energy delivered per unit time remains relatively constant (output measured in watts). However, pulsed lasers that have a peak power significantly greater than their average power, produce effects that may best be categorized by energy output per pulse. Pulsed energy output is usually expressed in joules.

PARTICLE ACCELERATOR: A device for imparting large kinetic energy to electrically charged particles such as electrons, protons, deuterons, and helium ions. Common types of particle accelerators are direct voltage accelerators (including Van de Graaf, Cockcraft-Walton, Dynamitron, resonant transformer, and insulating core transformer), cyclotrons (including synchrocyclotrons and isochronous cyclotrons), betatrons, and linear accelerators.

PLATED SOURCE: Radioactive material permanently deposited on a surface or matrix such that there is no window or other covering between the radioactive material and the open air. (Essentially a "sealed source" with a zero thickness window).

POWER DENSITY: The intensity of electromagnetic radiation present at a given point. Power density is the average power per unit area usually expressed as milliwatts per square centimeter.

PRINCIPAL INVESTIGATOR: An individual member of the teaching or research faculty or professional staff who has been approved by the Radiation Safety Committee to use or supervise the use of radioactive material under conditions specified in an application for authorization. All transactions involving radioactive material must be made in the name of a Principal Investigator.

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

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

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

QUALITY FACTOR (QF): Linear Energy Transfer dependent factor by which absorbed doses are multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiations, the biological effectiveness of the absorbed dose. As a rule of thumb, QF is 1 for X-rays, gamma rays, and Beta particles with E_{max}<0.003 **MeV**, 1.7 for Beta particles with E_{max}>0.003 **MeV**, 10 for neutrons and protons >10 MeV (30 for eyes), 10 for Beta particles, and 20 for heavy recoil nuclei.

RAD: Acronym for "Radiation Absorbed Dose". The unit used to describe dose in terms of energy deposited in any absorber. 1 rad ≈ 100 ergs/gram.

RADIATION: 1. The emission and propagation of energy through space or through a material medium in the form of waves, for instance, the emission and propagation of electromagnetic waves, or of sound and elastic waves. 2. The energy propagated through a material medium as waves; for example, energy in the form of electromagnetic waves or of elastic waves. The term "radiation" or "radiation energy" when unqualified, usually refers to electromagnetic radiation. Such radiation commonly is classified according to frequency as Hertzian, infrared, visible (light), ultraviolet, x-ray, and gamma ray. 3. By extension corpuscular emissions, such as alpha and beta radiation, or rays of missed or unknown type, as cosmic radiation.

RADIATION AREA: Any area, accessible to personnel, in which there exists radiation at such levels that a major portion of the body could receive in any one hour a dose in excess of 5 millirems, or in any 5 consecutive days a dose in excess of 100 millirems.

RADIATION SAFETY OFFICER (RSO): An officer who is responsible for investigating incidents, monitoring, and implementing policies on matters relating to radiation safety and is the Radiation Safety Committee's authorized representative regarding radiation protection within NC State. The RSO is also Director of the Radiation Safety Division at NC State.

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

RADIOACTIVITY: Process whereby certain nuclides undergo spontaneous disintegration in which energy is liberated, generally resulting in the formation of new nuclides. The process is accompanied by the emission of one or more types of radiation.

RADIOISOTOPE: Nuclides having the same number of protons in their nuclei; and hence, the same atomic number, but differing in the number of neutrons, and therefore in the mass number. Almost identical chemical properties exist between isotopes of a particular element.

RADIOLOGICAL SURVEY: Evaluation of the radiation hazards incident to the production, the use or the existence of radioactive materials or other sources of radiation under a specific set of conditions. Such an evaluation customarily includes a physical survey of the disposition of materials and equipment, measurements or estimates of the levels of radiation that may be involved, and a sufficient knowledge of processes using or affecting these materials to predict hazards resulting from expected or possible changes in materials or equipment.

RADIONUCLIDE: A species of atom characterized by the constitution of its nucleus. The nuclear constitution is specified by the number of protons (Z), the number of neutrons (N), and the energy content; or alternatively, by the atomic number (Z), by the mass number A=(N+Z), and by the atomic mass. To be regarded as a distinct nuclide, the atom must be capable of existing for a measurable time. Thus, nuclear isomers are separate nuclides, whereas promptly decaying excited nuclear states and unstable intermediates in nuclear reactions are not so considered.

RADIOSENSITIVITY: Relative susceptibility of cells, of tissues, of organs, or of organisms to the injurious action of radiation. The term may be applied to chemical compounds, or any other substances.

RADIOTOXICITY: Term referring to the potential of an isotope to cause damage to living tissue by absorption of energy from the disintegration of the radioactive material introduced into the body.

RAD: The special unit of absorbed dose.

RAM: Abbreviation for radioactive material.

RELATIVE BIOLOGICAL EFFECTIVENESS (RBE): For a particular living organism or part of an organism, the ratio of the absorbed dose of a reference radiation that produces a specified biological effect to the absorbed dose of the radiation of interest that produces the same biological effect.

REM: The special unit of dose equivalent. The dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the quality factor, by the distribution factor, and by any other necessary modifying factors.

RESPIRATOR: A device worn over the nose and mouth to protect the respiratory tract from contaminated atmospheres.

RESTRICTED AREA: Any area, access to which is controlled for purposes of protection of individuals from exposure to radiation and radioactive materials. While any area except areas used for living quarters may be designated as a restricted area, every area in which there are radiation levels, which, if an individual were continuously present in the area, could result in his receiving a dose in excess of two millirems in any one hour, or radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of 100 millirems in any seven consecutive days *must* be established as a restricted area.

ROENTGEN (R): The quantity of x or gamma radiation such that the associated corpuscular emission per 0.001293 grams of dry air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign. The roentgen is the special unit of exposure.

SCATTER: Change of direction of sub-atomic particle or photon as a result of a collision or interaction. MULTIPLE: Scattering of a particle or photon in which the final displacement is the vector sum of many, usually small displacements.

SCINTILLATION COUNTER: A counter in which light flashes produced in a scintillator by ionizing radiation are converted into electrical pulses by a photomultiplier tube and counted.

SEALED SOURCE: Radioactive material permanently enclosed inside a capsule or other holder such that there is no contact between the radioactive material and the open air. Sealed sources must be tested for leakage at intervals specified in the NRC license.

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

SI: Abbreviation for the international system of units. The terms gray, sievert, becquerel, and coulomb per kilogram are all SI units.

SIEVERT (Sv): SI unit of absorbed dose to the human body in terms of biological effect. (sievert is gray x QF.) 1 Sv is equivalent to 100 Rem.

WHOLE-BODY EXPOSURE: Exposure to ionizing radiation of the whole body or

trunk and major blood-forming organs.

APPENDIX I - RADIATION SAFETY FOR X-RAY PRODUCING DEVICES

EMERGENCY PROCEDURES

In event of an emergency, call:

Radiation Safety (before 5 p.m.) at 515-2894
Campus Police (after 5 p.m. and on weekends) at 911

Emergency telephone numbers should be available to everyone in the lab, posted near the telephone or outside the entrances to the lab.

Individuals who suspect that they have been exposed to the direct beam from any X-ray producing equipment must:

a) Immediately turn off the equipment
b) Notify their Supervisor and Principle Investigator
c) Call the emergency numbers listed above
d) Remain in the area until help arrives, if applicable to situation

The Radiation Safety Officer, or designee, will do the following:

a) Investigate the incident
b) Estimate the exposure to the individual.
c) Make the appropriate notifications.

1. X-RAY SAFETY: PURPOSE AND SCOPE

This document is designed to supplement the Radiation Safety Manual in support of the safe and effective use of x-ray producing equipment, including imaging/diagnostic x-ray equipment, electron microscopes, analytical x-ray equipment and cabinet x-ray equipment. This manual addresses specific actions and procedures required of its users as they function within the administrative, technical, and physical environments encountered at NC State.

This manual is *not* intended to replace the official regulations as enforced by the North Carolina Radiation Protection Section and the North Carolina Regulations for Protection Against Radiation, 15A NCAC 11. It will, however, provide valuable guidance and information related to NC State practices, policies and procedures for Principal Investigators. All Principal Investigators and their staff should become familiar with the 15A *NCAC 11* sections that may apply to their particular applications. As a North Carolina Licensee, NC State shall comply with all applicable provisions of .0100, .0200, .0300, .0500, .0800, .1000, .1100, .1600 of NCAC.

1.1 RESPONSIBILITIES

1.1.1 Radiation Safety Committee

The Radiation Safety Committee is responsible for formulating policy about the use of radiation sources and for regulating their use in compliance with State of North Carolina regulations and NC State policy. In this regard, the committee serves as the primary regulatory body for the institution in all matters related to the use of radiation-producing devices.

1.1.2 Radiation Safety Officer

The Radiation Safety Officer (RSO) is responsible for investigating incidents, monitoring and implementing established policies on matters relating to radiation safety and is the Radiation Safety Committee's authorized representative regarding radiation protection within NC State. The Radiation Safety Officer may designate an Associate Radiation Safety Officer, or equivalent, pending appropriate qualifications pertaining to these assigned duties. The Radiation Safety Officer grants authorization to procure and use any radiation producing devices.

1.1.3 Principal Investigator

A Principal Investigator (PI) is an individual who by virtue of position, training and experience is designated by NC State Radiation Safety Officer as a user of radiation producing devices. In order for an individual to qualify as a principal investigator, he/she must be a faculty member at NC State. This authorization permits the procurement and use of radiation producing devices within a defined protocol or work activity under the

supervision of the authorized user provided that the materials are used within the guidelines of safe practice, and within the rules, regulations and recommendations of the Radiation Safety Committee and NC State policy.

The Principal Investigator is responsible for the safe operation of the radiation producing equipment under his/her control. Responsibilities include the following:

A. Ensure that all x-ray equipment under PI's control is registered with the Radiation Safety Division and that the authorization protocol is current as to the use of the equipment

B. Ensure that all personnel operating the x-ray unit are registered with Radiation Safety and have completed required radiation safety training

C. Ensure that written safety rules and procedures are provided to all personnel who operate the equipment, including any restrictions of the operating techniques required for the safe operation of the system

D. Ensure that all personnel operating the x-ray device are instructed in safe operating procedures and are skilled in the safe use of the equipment

E. Ensure that the equipment, facility and the operators of the device meet the applicable Federal, State and local regulations

F. Ensure that all personnel who operate the x-ray producing equipment wear the appropriate radiation monitoring devices, store the devices in appropriate locations, and promptly exchange them for new devices on a scheduled replacement basis

G. Ensure that Radiation Safety is promptly notified of any changes in the equipment, facility, or personnel using the equipment

1.1.4 Radiation Worker

Those who work with x-ray producing devices, both staff members and students, assume the following responsibilities:

A. Submit Forms RS-3, "Radiation Worker Registration Form" and RS-4, "Dosimetry Service Assessment and Exposure History Form"

B. Follow safe operating procedures for the use of the x-ray equipment

C. Wear the assigned personnel monitoring device as required, store it in the appropriate place, and promptly exchange it for new devices on a scheduled replacement basis

D. Observe the rules presented in the Radiation Safety Manual and this handbook for the safe use of x-ray equipment

E. Notify the Principal Investigator and the Radiation Safety Division of any defects or deficiencies in x-ray devices, procedures or facilities

F. Follow the emergency protocol and immediately notify the Principal Investigator and Radiation Safety division if he/she suspects they have been exposed to the direct beam of an x-ray producing device

2. APPLICATION TO OBTAIN A RADIATION-PRODUCING DEVICE

Any person planning to obtain or construct a radiation-emitting device, including diagnostic x-ray machines, electron microscopes and analytical x-ray equipment, should submit the appropriate information to the Radiation Safety Division before obtaining the device. **Form RS-10,** "Radiation Producing Device Authorization Form", should be completed and submitted to the Radiation Safety Division for review. Information requested with this form includes:

A. A description of the device. Specify the types, energies and levels of radiation anticipated, model number, manufacturer and serial number

B. Beam currents, workload (*i.e.*, hours per week), and a description of how the device will be used

C. Operating and safety procedures for the device. Include documentation procedures for training new staff or students

D. A sketch of the facility showing adjacent rooms and their use. The purchaser must consult with the Radiation Safety Division concerning the adequacy of the facility shielding where the equipment will be used. Facilities are required to have a shielding plan review, prior to installation

E. Portable monitoring instruments that are available. Each project is expected to provide any necessary survey instruments. The Radiation Safety Division can be used as a resource when selecting appropriate survey instruments or providing short-term instrumentation

F. A brief resume of the pertinent training and experience of the Principal Investigator for the equipment

The Radiation Safety Officer will review the proposed plans and facilities for safety and compliance with regulations and will evaluate the need for and type of radiation badges required. The Radiation Safety Officer will grant authorization to procure and use the x-ray equipment. A report will be given to the Radiation Safety Committee of any new acquisitions of x-ray equipment. The Radiation Safety Officer will work with the PI on all facility requirements, conduct the shielding plan review and obtain approval from the NC Radiation Protection Section prior to construction or installation. Radiation Safety staff will conduct a radiation leakage and area survey following installation and prior to the initial operation of the equipment. This post-installation survey must be performed after initial installation, relocation, or any renovations or alterations to the machine to assure radiation safety.

All radiation-producing machines shall be registered with the NC Radiation Protection Section (NCRPS). Radiation Safety registers such machines on behalf of NC State. The purchaser must notify the Radiation Safety Division upon receipt of the equipment and provide the necessary information for registering the unit with the NC

Radiation Protection Section. The equipment must be registered with the state agency within 30 days of initial operation.

3. REPORTING CHANGES

All radiation-producing devices to be sent to surplus, donated or transferred to another NC State facility or other business, must be inspected by the Radiation Safety Division before leaving the institution or current location.

The Radiation Safety Division must be notified if a machine is to be moved from its approved location or placed into storage. Moving to another location requires prior approval of the new location and a change on the Registration with the NC Radiation Protection Section.

Under some circumstances, a device may be posted as "Out of Service" by Radiation Safety to prevent its use. No attempt to energize or otherwise use the device should be made without prior notification of and approval from the Radiation Safety Division.

3.1 CHANGES IN USERS AND STAFF

For changes in staff working under a Principal Investigator, Form RS-5 should be filed with the Radiation Safety Division. New staff members shall submit forms RS-3 and RS-4, and complete the Principles of X-Ray Safety Course, provided by Radiation Safety. Personnel dosimetry devices will be issued following successful completion of the training course. Departing workers should be instructed to return dosimetry for a final reading. All staffing/student changes should be submitted to Radiation Safety via RS-5 forms.

3.2 ABSENCE OF PRINCIPAL INVESTIGATOR

3.2.1 Temporary Absences

For temporary absences and sabbaticals, a Principal Investigator may designate another investigator to supervise the project. *Form RS-12 should be submitted to the Radiation Safety Officer prior to departure for approval.* Alternatively, the Principal Investigator or Department head may request, in writing, assistance from the Radiation Safety Officer and the Radiation Safety Committee to designate an alternate Principal Investigator, or the project may be rendered temporarily inactive.

3.2.2 Permanent Absence

When a Principle Investigator departs the University, the department should notify Radiation Safety. Another investigator may assume responsibility of the device and staff by submitting the required PI application forms (RS3, RS4, RS10).

4. TRAINING REQUIREMENTS

All individuals who will operate an x-ray device or have the potential to be exposed to the x-ray beam must be trained on basic x-ray safety principles, NC State policies and procedures as well as the safe operating procedures for the device. Machine specific training must occur prior to operation of the device by the individual. It is the responsibility of the Principal Investigator to provide specific training on the safe operation of the x-ray equipment before the individual is allowed to operate the equipment without supervision. Training by the Principal Investigator, or his/her designee, for all new users on the safe use of the x-ray equipment must be documented. *An example training form is included in this document and can be used to record hands on training, or similar documentation must be kept.*

The Radiation Safety Division offers monthly training courses for users of radiation producing devices. All individuals must complete the Radiation Safety Division training course, *Principles of X-Ray Safety*, within 30 days of operation of any x-ray device. If x-ray safety training has been completed within the past two years at another institution, and proper documentation is provided to the Radiation Safety Division, NC State training may not be required.

Refresher training is required every four years and is available to all users via the World Wide Web.

4.1 X-RAY USE IN CLASSROOM INSTRUCTION

Provisions must be made for students to complete the basic radiation safety training prior to hands-on operation of an x-ray device.

Students using x-ray equipment as part of a classroom requirement and who will be under the direct supervision of a Principal Investigator must complete radiation safety training and receive dosimetry before operating the device.

5. RADIATION CONTROL MEASURES

X-ray production in the operation of radiation producing devices is a source of external radiation exposure. An integral part of a radiation protection program is ensuring doses received by an individual are **A**s **L**ow **A**s **R**easonably **A**chievable (ALARA).

A. Time - Decreasing "exposure time" reduces personnel dose linearly

B. Distance – Radiation dose rate follows the "inverse square law". The "inverse square law" states that radiation intensity from a point source varies inversely as the square of the distance from the source. Thus, doubling the distance from a source, reduces the exposure to ¼ its original value. Increasing distance between personnel and the radiation source is an effective means of reducing the dose

C. Shielding – Absorbing materials or shields can be incorporated to reduce exposure levels. The specific material and thickness is dependent upon the amount and type of radiation involved. Lead shielding is generally used for diagnostic and other low-energy x-rays. The Radiation Safety Division will assist in designing and specifying appropriate shielding

D. Exposure – Reducing the intensity, or quantity, of the radiation used, the dose can be reduced. The exposure is influenced by both the strength of the x-ray beam, determined by kVp, and the quantity of photons produced, influenced by mAs

6. PERSONNEL DOSIMETRY

Personnel monitoring devices (badges, ring TLDs, pocket dosimeters, etc.) are provided by the Radiation Safety Division to measure an individual's radiation exposure from x-ray sources**.** Individuals who have the potential of receiving greater than 10% of the maximum occupational dose limit must wear a radiation dosimeter or personal monitoring device. The Radiation Safety Division will determine the need for dosimetry. The Radiation Safety Division will supervise the ordering, distribution, and collection of personnel monitoring devices. RSD will also maintain the exposure records and notify individuals of dose rates that exceed limits as defined by ALARA.

Whole-body radiation monitoring devices may be worn on the waist, shirt pocket or collar as directed by the Radiation Safety Officer. When a lead apron or thyroid shield is worn, the monitoring device must be worn on the outside of the protective device on the collar.

Analytical x-ray users are assigned a ring badge to monitor extremity and skin dose. The ring badge should be worn on the appropriate hand and finger, the one with the greatest potential of exposure from the x-ray beam. X-ray imaging users (diagnostic) are assigned a body badge and may also be assigned a ring badge, depending on the type of work involved. Cabinet X-ray unit users will be assigned whole-body badges. Guidelines for the proper use of monitoring devices include:

A. Only the individual assigned the radiation monitoring device(s) shall wear it; Never wear another users device

B. Radiation monitoring devices are not to be worn during non-occupational exposures such as personal medical or dental x-ray procedures, or when passing through airport security devices

C. When not in use, radiation monitoring devices must be stored in an area where they will not be exposed to ionizing radiation above background levels

D. Radiation monitoring devices must not be deliberately exposed to radiation

E. Damaged or broken devices should immediately be reported to the Radiation Safety Division

F. Radiation monitoring devices must be promptly exchanged when new devices become available, either on a monthly or quarterly schedule

Pocket dosimeters are available and may be worn for specific reasons as determined by the Radiation Safety Officer. They are not intended for long term use by

one individual**,** and should not be used by badged individuals when they are working in their assigned areas.

7. DECLARED PREGNANT WORKERS

Pregnant workers must declare the pregnancy in writing to the Radiation Safety Officer or designee. Each worker will receive an information packet, counseling and a waist dosimeter after the declaration is made.

A. The fetal dosimeter should be worn at waist level and under a lead apron if an apron is used in the work environment. If a lead apron needs to be worn, the dosimeter should be worn under the lead apron at the waist level

B. Minimize exposure by reducing the amount of time spent in a radiation area, increasing the distance from a radiation source, and using shielding

C. Pregnant workers should not hold patients, animals, or film cassettes during an x-ray exposure

8. ANALYTICAL X-RAY EQUIPMENT

Analytical x-ray equipment, as defined by NCRPS regulations, is equipment used for x-ray diffraction or fluorescence analysis. Hazardous radiation from an analytical x-ray system may come from the following sources:

A. The primary beam

B. Leakage or scatter of the primary beam through cracks in defective, or poorly fitted equipment components

C. Penetration of the primary beam through the tube housing, shutters or diffraction apparatus

D. Secondary scatter emission from the sample or other material exposed to the primary beam

E. Diffracted or fluorescence x-rays

F. Radiation generated by vacuum tube rectifiers in the high voltage power supply

8.1 REQUIRED POSTINGS AND LABELS

8.1.1 Warning Lights

An easily visible warning light labeled "**X-RAY-ON**" must be located near any switch that energizes an x-ray tube and must also be located outside the room housing the device. It is to be illuminated only when the tube is energized. This light must be of a fail-safe design-a design feature that causes beam port shutters to close, or otherwise prevents emergence of the primary beam, upon the failure of a safety or warning device. Under certain circumstances it may be difficult to comply with this requirement and a variance may be requested from NC Radiation Protection Section. The following information must be provided to the Radiation Safety Division in order to obtain a variance:

A. A description of the safety devices evaluated and why they cannot be used

B. A description of the alternative method that will be used to minimize the possibility of an accidental overexposure

C. Procedures that will be used to alert personnel to the absence of a safety device

D. Posting on the equipment indicating the specific safety device is not functional

8.1.2 Labeling

The following signs or labels are required for analytical x-ray equipment. NC State Radiation Safety Division will provide these labels for posting. The labels must be conspicuous and bear the radiation symbol as described in the Radiation Safety Manual, Section 8.4.1 and the words (or similar words):

"**CAUTION – HIGH-INTENSITY X-RAY BEAM**" on the x-ray source housing.

"**CAUTION – RADIATION – THIS EQUIPMENT PRODUCES RADIATION WHEN ENERGIZED**" near any switch that energizes an x-ray tube.

"**CAUTION – X-RAY EQUIPMENT**" in each area or room containing analytical x-ray equipment.

"**CAUTION RADIATION – THIS DEVICE MAY NOT BE ALTERED, MOVED, TRANSFERRED, OR DISPOSED OF WITHOUT PRIOR APPROVAL FROM NC STATE RADIATION SAFETY DIVISION" –** on each analytical x-ray machine.

8.1.3 Removal of Notices

Any sign, notice, warning or label, applied by the Radiation Safety Division, to equipment or the facilities of a licensed PI must not be removed, defaced, or concealed without written permission from the Radiation Safety Officer.

9. OPERATING PROCEDURES

Normal operating procedures must be written and available to all analytical x-ray equipment users. Written operating procedures must include:

A. methods of controlling radiation exposure

B. method and frequency of conducting radiation safety surveys

C. method of controlling access to the unit

D. method of locking/securing the unit both when in use and not in use

E. method of alignment

F. method and condition for personnel monitoring

G. emergency procedures/notification requirements in the event of an accident

H. method for maintaining required records

I. procedures for inspection and maintenance

Additional precautions may include warning signs and/or communication with other lab personnel.

Analytical x-ray equipment must not be operated differently from that specified in the procedure manual unless written permission has been obtained from the Radiation Safety Officer. Radiation Safety must approve deviation from the manufacturer's recommended alignment procedures that are included in the operating procedures.

9.1 SAFETY PRECAUTIONS

The following safety precautions are be taken to reduce risks during repair and alignment procedures:

A. The main switch, rather than the safety interlocks, must be used to shut down the equipment

B. No x-ray tube will be used without a suitable housing to restrict the radiation to a well-defined beam

C. A sign stating "Interlocks Not Working" must be posted on the equipment when the interlocks have been defeated for alignment purposes. Prior approval must be obtained from the NCRPS via Radiation Safety before

defeating safety interlocks

D. Reduce the beam current (mA) and the beam energy (kV) to the lowest possible settings. This will keep the x-ray beam exposures rates low

E. Long-handled tools and extension devices should be used to reduce the risk of the hand entering the beam

F. Radiation monitoring should be maintained during alignment or maintenance procedures

G. Two-man teams should be used during alignment procedures. One person should make the adjustments while the other person watches for safety problems

H. Unrestricted areas should be properly posted and temporary barriers set up if the acceptable dose rate in that area is exceeded during repair or maintenance. The area must be under surveillance until normal operations have been restored

I. After re-assembly, for alignment or any other repair, or if there is a change in the initial arrangement, the Radiation Safety or the user must check the x-ray equipment for leakage radiation. The results of this survey must be documented

9.2 RADIATION LIMITS

The exposure rate at the maximum rated current and voltage with all shutters closed must not exceed 2.5 mrem in one hour at a distance of 5 cm from the x-ray tube housing.

The exposure rate at a distance of 5 cm from the surface of the x-ray generator cabinet must not exceed 0.04 mrem in one hour.

The analytical x-ray system must include sufficient shielding and be so located and arranged so that exposure rates in unrestricted areas, those areas not under control by the P.I., do not exceed 2 mrem in any one-hour or 100 mrem in a year.

9.3 ADDITIONAL REQUIREMENTS FOR OPEN-BEAM SYSTEMS

An interlocked safety device, which prevents entry of any part of the body into the primary beam and/or causes the beam to shut off, must be provided on all open-beam systems. A Principal Investigator may seek an exception from this regulation and/or permission to override the safety interlocks by providing the Radiation Safety Division with the following information:

A. A description of the safety devices evaluated and why they cannot be used

B. A description of the alternative method that will be used to minimize the possibility of an accidental overexposure

C. Procedures that will be used to alert personnel to the absence of a safety device

A request will be made, on behalf of the PI, by the Radiation Safety Division to the NC Radiation Protection Section for an exception to the regulation.

9.4 WARNING DEVICES

Open-beam systems must be provided with the following warning devices that are fail safe, readily visible and properly labeled as to their purpose:

A. X-ray tube status (ON-OFF) located near the x-ray source housing, if the primary beam is controlled in this manner

B. Shutter status (OPEN-CLOSED) located near each port on the x-ray source housing, if the primary beam is controlled in this manner

C. Shutters at unused ports must be secured in the closed position to prevent accidental opening. Each port on the x-ray source housing must be equipped with a shutter that cannot be opened unless a collimator or other device has been connected to the port, if the system was installed after January 1, 1980

A safety device must not be bypassed unless written approval has been obtained from the Radiation Safety Officer. This approval must be for a specified time. When a safety device has been bypassed, a conspicuous sign must be placed on the x-ray housing bearing the words (or similar words), "SAFETY DEVICE NOT WORKING."

10. SAFETY AUDITS AND TESTING

10.1 PRINCIPAL INVESTIGATOR TESTING REQUIREMENTS

Open beam analytical x-ray units must be tested at least annually, preferably quarterly, by the P.I., to ensure that warning lights and safety interlocks are operating properly. If a unit has not been used, the tests are not required, but the absence of testing must be documented. An entry indicating that the unit was out of service for that period is to be made. These tests must be performed prior to the next use of the unit. The documentation of testing must be kept for 3 years and located in the room with the x-ray unit for review by inspecting personnel.

10.2 RADIATION SAFETY DIVISION AUDITS

In order to assist and support the safe use of x-ray equipment at NC State, the Radiation Safety Division conducts routine audits of Principal Investigator activities. These audits may be classified as follows:

A. Authorization Review - This audit evaluates the Principal Investigator's emergency contact information, x-ray unit locations, laboratory personnel and training, and portable radiation survey instrument availability and calibration. This audit is intended to evaluate the conditions and parameters of the authorization set by the Radiation Safety Committee. The frequency of the review is once per calendar year

B. X-Ray Safety Evaluation - This on-site audit is performed by the Radiation Safety Division at the Principal Investigator's facility. This audit should evaluate compliance with regulations as outlined in this manual. The frequency of the audit is once per calendar year unless otherwise indicated by the Radiation Safety Officer or the Radiation Safety Committee

The Principal Investigator is ultimately responsible for compliance with safety and health issues in facilities under their jurisdiction. The intent of safety audits and subsequent items of non-compliance is to notify the Principal Investigator of potential safety issues in the research environment.

The frequency of on-site audits may be accelerated due to enforcement actions recommended by the Radiation Safety Committee, significant increases in use, a request by the Principal Investigator, or other safety conditions warranting additional oversight.

10.3 REQUIRED RECORDS

The Principal Investigator is responsible for ensuring that the following records are completely and accurately kept and made available for inspection by the Radiation Safety Division:

A. The Radiation Safety Division must keep records of "hands on" training by the PI or designee for inspection. The PI should also have copies of the certificates provided to each worker upon completion of the Principles of X-Ray Safety course

B. An equipment use log must be kept to include date & time, operator name or initials, and operating voltage and current

C. Inspections of all safety warning lights and interlocks must be documented and kept on file for 3 years

11. CABINET X-RAY SYSTEMS

The additional rules in this section apply to cabinet x-ray systems only:

A. A key-activated control must be provided to ensure that x-rays will not be generated when the key is removed

B. Each door of a cabinet x-ray system must have a minimum of two safety interlocks. Each access panel must have at least one safety interlock

C. A control, other than the safety interlock, must be provided to resume x-ray generation following x-ray interruption by a safety interlock

D. Two independent means must be provided to indicate when x-rays are being generated. One may be a milliamp meter labeled to indicate x-ray tube current; the other indicator must consist of an easily seen warning light labeled "X-RAY ON"

E. A clearly legible and visible label bearing the statement: "CAUTION: X-RAYS PRODUCED WHEN ENERGIZED" must be posted near the controls that energize the x-ray tube

11.1 RADIATION LIMITS

Radiation emitted from a cabinet x-ray system must not exceed an exposure rate of 0.5 mrem/hr at any point 5 cm from the external surface at the maximum rated current and voltage. A cabinet x-ray system must contain sufficient shielding and be located so exposure rates in unrestricted areas do not exceed 2 mrem in any one-hour and 100 mrem/yr.

12. DIAGNOSTIC X-RAY EQUIPMENT

The following rules are to ensure the safe use of human and veterinary diagnostic X-ray equipment at NC State University. These rules are in conformity with the radiation safety standards recommended by the NC RPS.

12.1 PATIENT PROTECTION

The following rules are to protect both human and animal patients from exposure to ionizing radiation, except that which is intended for diagnostic purposes.

A. A licensed Medical Doctor or Doctor of Veterinary Medicine will specifically and individually order all exposures
B. Humans must not be exposed for training, demonstration, or other non-healing art purposes. Except for Student Health Services, NC State University is not licensed for exposure of humans for healing arts screening
C. Appropriate measures must be used to keep patient exposure at a minimum, while still obtaining the necessary diagnostic information
D. The useful beam must be collimated to focus only on the area of clinical interest
E. The film screen combo must be the fastest speed possible for the specific exam, yet be consistent with the diagnostic purpose
F. The radiation exposure to the patient must be the minimum required to produce good diagnostic images
G. The source-to-patient distance must be at least 38 cm for image-intensified fluoroscopic units
H. Gonadal shielding of at least 0.25 mm lead equivalency must be used on human patients of reproductive age, if the gonads are in the primary beam and the shielding does not interfere with the diagnostic procedure
I. A pregnancy test should be performed on women of child-bearing age before taking x-rays of the abdominal or pelvic area
J. Aluminum filtration must be placed in the primary beam to reduce the quantity of soft x-rays to the patient

12.2 WORKER PROTECTION

12.2.1 Stationary Units

A. The operators must stand behind the protective barrier at the controls during the exposure
B. An operator who is required to be in the x-ray room to take an exposure of an animal must stand at least 6 feet from the useful beam and the animal.
C. Only individuals required for the radiographic procedure are to be in the room during the exposure

D. All individuals present in the x-ray room during an exposure must be protected from the primary beam by at least 0.5 mm lead equivalency and from scatter radiation by at least 0.25 mm lead equivalency. Use of lead aprons and fluoroscopy shielding is sufficient
E. Access to the x-ray room should be secured during the exposure

12.2.2 Portable and Mobile Units

A. Operators must stand at least 6 feet from the x-ray tube head and wear a lead apron of at least 0.25 mm lead equivalency
B. Bystanders must stand at least 12 feet from the x-ray tube head and the object being radiographed
C. Mobile x-ray units should not be hand held. If a hand held unit is used, distance and appropriate shielding is imperative
D. The primary beam must not be directed toward bystanders

12.2.3 Holders

Use of people to hold a patient, animal, or film cassette during an x-ray exposure is not encouraged. However, when the use of a "holder" is necessary the following considerations must be followed:

A. Mechanical holding devices or auxiliary support must be considered and used whenever possible (sandbags, tape, cassette holders, etc)
B. No individual, to the exclusion of others, should be required to provide routine service as a holder
C. Personnel used as holders must be protected from the primary beam by at least 0.5 mm of lead equivalency, and from scatter radiation by at least 0.25 mm of lead equivalency. Lead aprons may be used to provide sufficient shielding
D. Every effort should be made to position the holder so that no part of their body will be exposed to the primary beam
E. Pregnant workers must not be required to serve as holders
F. Personnel dosimetry is required for all individuals associated with patient holding and should be worn on the external surface of the lead apron

12.3 SHIELDING REQUIREMENTS

A. The walls, ceilings, doors, and floor areas of rooms housing diagnostic units must be provided with sufficient protective shielding (lead or lead equivalent materials). Radiation Safety is responsible for appropriate shielding design and submitted all necessary documentation to NC Radiation Protection Section

B. Shielding in the form of protective housing, is required for diagnostic x-ray producing devices

C. Radiation given off by parts other than the tube head must not exceed 2 mrem/hr at 5 cm. Leakage radiation from the tube head must not exceed 100 mrem/hr at 1 meter. Scatter radiation from shielding materials into unrestricted areas must not exceed 2 mrem/hr or 100 mrem/yr

12.4 EQUIPMENT REQUIREMENTS

The control panel must contain the following legible and accessible warning statements:

A. "CAUTION: This equipment produces radiation when energized, and is to be operated only by qualified personnel"
B. Diagnostic Units Only: "WARNING: This x-ray unit may be dangerous to patient and operator unless safe exposure factors and operating conditions are observed"

The total filtration permanently mounted in the useful beam must not be less than:

A. 0.5 mm aluminum equivalent for machines operating up to 50 kilovolts peak (kVp)
B. 1.5 mm aluminum equivalent for machines operating between 50-70 kVp
C. 2.5 mm aluminum equivalent for machines operating above 70 kVp

The tube housing assembly support must ensure that the tube housing remains stable during the X-ray exposure.

The technique factors to be used during an exposure must be visible before the exposure begins.

A visual means to show the charge of the battery on battery-powered equipment must be provided on the control panel.

A source-to-image distance (SID) indicator must be provided and be accurate to within 2% of the indicated SID.

12.4.1 Stationary, Portable, and Mobile Units:

A. A means for stepless adjustment of the size of the x-ray field must be provided, (e.g. variable aperture collimator)
B. Means, such as a light, must be provided to visually define the perimeter of the x-ray field. The x-ray field must not exceed the visually defined field by greater than 2%

C. The axis of the x-ray beam must be perpendicular to the plane of the image receptor
D. The means to limit the exposure time must be present. For example, the exposure may be controlled by a preset timer, the product of current and time (mAs), number of pulses, or radiation exposure to the image receptor
E. The x-ray control must provide a visual indication of x-ray production and an audible signal when the exposure is finished
F. The x-ray control for stationary systems must be permanently mounted in a protected area. Waiver from this requirement must be determined and approved by Radiation Safety prior to construction and installation

12.4.2 Fluoroscopic Systems:

A. A dead-man switch must control x-ray production
B. The "on-time" of the fluoroscopic tube must be controlled by a timing device, which ends or alarms when the exposure exceeds 5 minutes. An audible signal must signal the completion of the preset on time. This signal will remain on until the timing device is reset
C. The x-ray tube used for fluoroscopy must not produce x-rays unless a barrier is in position to intercept the entire cross section of the useful beam. The fluoroscopic imaging assembly must be provided with shielding sufficient that the scatter radiation from the useful beam is minimized
D. Protective barriers of at least 0.25 mm lead equivalency must be used to attenuate scatter radiation above the tabletop (e.g. drapes, bucky-slot covers). This shielding is in addition to the lead apron worn by personnel. Scattered radiation under the table must be attenuated by at least 0.25 mm lead equivalency shielding.

12.4.3 Operator's Booth:

A. The operator's booth should have at least 7.5 square feet of unobstructed floor space
B. The booth may be of any shape with no dimension less than 2 feet
C. The booth is to be located or constructed so that the direct beam and unattenuated direct scatter radiation cannot reach the operator
D. The booth walls must be at least seven (84") feet high and permanently fixed
E. A door or access panel that is permanently part of the booth must be interlocked
F. Sufficient shielding must be provided to prevent occupational limits from being exceeded

12.4.4 Control Panel Placement:

A. The X-ray control panel must be fixed within the booth at least 40 inches from the edge of the booth wall closest to the examining table
B. The placement of the control must allow the operator to use most of the viewing window

12.4.5 Viewing requirements:

A. The booth must have a window that will allow the operator to view any occupant in the room and any entry into the room. Access doors that cannot be viewed by the operator must be interlocked
B. The window must have an area of at least 1 square foot with the lower edge at least 4.5 feet from the floor. The edge of the window must be at least 18 inches from the edge of the booth. The viewing glass materials must have the same lead equivalency as the walls of the booth

13. RECORDS

The Principal Investigator must maintain the following records and information:

A. An X-ray log containing the patient's name, type of examination, and the date of the examination

B. Maximum ratings and technique factors of the equipment

C. Model and serial number of all components

D. Tube rating charts and cooling curves

E. Assembler report for certifiable units

F. Records of calibrations, maintenance, and modifications

G. Aluminum equivalent filtration of the useful beam, including any routine variation

H. Approved Protocols, amendments, surveys and inspections

14. SURVEYS AND INSPECTIONS (DIAGNOSTIC X-RAYS ONLY)

A. A qualified expert must perform radiation safety and equipment performance surveys at least annually on human-use units and at least every 3 years on veterinary-use units

B. A survey for leakage radiation must be performed following any maintenance, modification or relocation of the system

C. X-ray equipment and area surveys will be performed after installation of new equipment or the relocation of a unit

D. The survey must include a scale drawing of the areas adjacent to the x-ray room and an estimate of their occupancy

E. The drawing must include the type and thickness of the walls or their lead equivalency

F. Reports of all surveys and inspections will be available for review by the Radiation Safety Division and NC RPS

15. MISCELLANEOUS X-RAY EQUIPMENT

The rules in this section apply to the following miscellaneous x-ray producing equipment: electron microscopes, ESCA spectrometers, electron microphones, luminoscopes, and cold-cathode gas discharge tubes. These provisions do not apply to television receivers or video display terminals. These requirements are in conformity with NC RPS regulations.

15.1 POSTINGS

No area posting is required for miscellaneous X-ray equipment.

15.2 WARNINGS AND LABELS

A clearly legible and visible label bearing the statement: "CAUTION: THIS EQUIPMENT PRODUCES X-RAYS INCIDENTAL TO ITS PRIMARY FUNCTION - TO BE OPERATED BY QUALIFIED PERSONNEL ONLY" must be posted on all miscellaneous X-ray producing equipment.

In addition to the above requirement, cold-cathode gas discharge tubes must bear the following labels:

A. A label stating the maximum safe operating voltage

B. A label that identifies the correct polarity of the terminals

15.3 RADIATION LIMITS

A. Radiation emitted from electron microscopes, electron microprobes, ESCA spectrometer, and luminoscopes must not exceed an exposure rate of 0.5 mrem/hr at any accessible location on the external surface

B. Radiation exposure from cold-cathode gas discharge tubes must not exceed 10 mrem/hr at 30 cm from the external surface averaged over 100 square centimeters

C. All miscellaneous x-ray producing equipment must contain sufficient shielding, and be located and operated so exposure rates in unrestricted areas do not exceed 2 mrem/hr, or 100 mrem/yr

D. Personnel Monitoring: Personnel monitoring is not required for users of miscellaneous x-ray producing equipment

15.4 POTENTIAL X-RAY EXPOSURE FROM MAGNETIC-EFFECT TUBES

Magnetic-effect tubes demonstrate that cathode rays carry an electrical charge that can be deflected by a magnetic field. These tubes may produce x-rays incidental to their intended use and should be used with caution. Where there is a source of electrons, a target, sufficiently high voltage, and tube gas pressure within the proper range, x-ray production will occur. X-ray output from magnetic-effect tubes, however, is unpredictable and intermittent. Under identical operating conditions it may vary from one tube to another; one tube may be an x-ray producer while another may not. X-ray production may vary during a given period of operation or from day to day for the same tube.

Since the educational benefits derived from these tubes are gained by visual observation of their operation, unshielded operation of these tubes is required; with the subsequent potential for student and operator exposure. To keep exposures to a minimum, requirements for the safe use of these tubes are as follows:

A. Magnetic-effect tubes must be used only for demonstrations conducted by the instructor

B. The instructor should stand as far as practical from the tube during the demonstration

C. Only the instructor must operate a magnetic-effect tube

D. Bystanders should stand at least 8 feet from an operating tube

E. Tubes must always be operated with the correct polarity and the lowest practical current and voltage

F. Operating time is to be kept to a minimum

15.5 RADIATION SAFETY SURVEYS

Radiation surveys must be performed and documented by the Radiation Safety Division upon installation, relocation and following any maintenance or tube replacement.

16. TERMS AND DEFINITIONS	
Access panel	A panel designed to be opened for maintenance purposes to permit access to the interior of the cabinet.
Aluminum equivalent	The thickness of type 1100 aluminum alloy affording the same attenuation as the material in question.
Analytical X-ray equipment	Equipment used for x-ray diffraction and fluorescence analysis (excludes cabinet x-ray systems, electron microscopes and diagnostic x-ray equipment).
Automatic exposure control	A device that automatically controls one or more technique factors in order to obtain a required quantity of radiation.
Beam-limiting device	A device that provides a means to restrict the dimensions of the x-ray field.
Cabinet X-ray system	X-ray system with the x-ray tube installed in an enclosure, which is intended to contain the object being irradiated, provide radiation attenuation, and exclude personnel from its interior during x-ray generation.
Certified components	Parts of x-ray systems that are subject to regulations adopted under the Radiation Control for Health & Safety act of 1968
Cooling curve	The graphical relationship between heat units stored and cooling time.
Dead-man switch	A switch that can only be kept ON by continuous pressure.
Diagnostic X-ray system	An x-ray system designed for irradiation of a human or animal for the purpose of diagnosis or visualization.
Diffracted beam	A beam composed of mutually reinforcing scattered x-rays.
Direct scattered radiation	Scattered radiation that has been deviated in direction only by the object exposed to the useful beam.
Enclosed beam configuration	An analytical x-ray system in which all possible x-ray paths are fully enclosed.
Fail-Safe design	A design feature that guarantees that the beam port shutters close or prevent appearance of the primary beam in the event of failure of a safety or warning device.
Gonad shield	A protective barrier for the testes or ovaries.
Half-value layer	The thickness of a material that attenuates the beam of radiation to one-half of its original value.
Healing arts screening	The testing of humans using x-ray equipment for the detection or evaluation of health problems, when such tests are not specifically and individually ordered by a medical doctor.
Heat unit	A unit of energy equal to the product of the peak voltage, current, and seconds.
Image intensifier	A device that converts an x-ray pattern into a corresponding light image of higher energy density.
Image receptor	A device, such as a fluorescent screen or radiographic film, transforming incident x-ray photons into a visible image
Inherent filtration	Filtration of the useful beam provided by the permanently

	installed parts of the tube housing
Miscellaneous X-ray equipment	Equipment that produces x-rays secondary to its primary function
Kilovolt peak (kVp)	The maximum value of the potential difference across the x-ray tube during an exposure
Lead equivalent	The thickness of lead affording the same attenuation as the material in question
Leakage radiation	Radiation, except the useful beam, emanating from the tube housing
Local components	Includes areas that are struck by x-rays, such as radiation source housings, port and shutter assemblies, collimators, sample holders, cameras, goniometers, detectors and shielding; but not including power supplies, transformers, amplifiers, readout devices and control panels
Milliampere second (mAs):	The product of tube current and exposure time
Mobile equipment	X-ray equipment mounted on a permanent base with wheels
Open-beam configuration	An analytical x-ray system in which some part of the body could accidentally be placed in the primary or diffracted beam path
Primary beam	X-rays that pass through an aperture of the source housing by a direct path from the x-ray tube
Protective apron	An apron made of radiation-attenuating materials
Protective barrier	A barrier of radiation-attenuating materials used to reduce radiation exposure. The types of protective barriers are: 1. Primary – material placed in the useful beam, excluding filters, to reduce radiation exposure 2. Secondary - barrier that attenuates leakage and scattered radiation
Qualified expert	An individual, who has demonstrated by training and experience to the satisfaction of the State, that he/she possesses the knowledge and training to measure ionizing radiation, to evaluate safety techniques, and to advise others regarding radiation safety needs
Safety interlock	Device that is intended to prevent the generation of x-rays when a door or access panel is opened
Scattered radiation	Radiation that has been deviated in its direction during passage through an object
Stationary equipment	X-ray equipment that is installed in a fixed position
Technique factors	The condition of operation that is the peak tube potential in kV and either the tube current in mA and exposure time in seconds, or the product of the tube current and exposure time in mAs
Tube rating chart	The set of curves that specify the rated limits of operation of the tube in terms of the technique factors
Useful beam	Radiation that passes through the tube housing port and the aperture of the beam-limiting device when the exposure switch is

	activated
Variable aperture	A beam-limiting device that allows for stepless adjustment of the x-ray field
X-ray source housing	That portion of an analytical x-ray system that contains the x-ray tube