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APPENDIX

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I. Introduction

A. Radioactive Material License and ALARA

The use of licensed radioactive material is regulated by the Ohio Administrative Code (OAC) as it relates to the Ohio Department of Health (ODH), and by the U.S. Nuclear Regulatory Commission (NRC) under 49 CFR. Most of the sections, as they pertain to the use of ionizing radiation at Ohio University, are as follows:

1. 3701-39 Standards for Radioactive Materials Licensees

2. 3701:1-38 General Radiation Protection Standards for Sources of Radiation

3. 3701:1-40 Licensing Requirements for By-Product and Accelerator Produced Radioactive Materials

4. 3701:1-50 Packaging and Transportation of Radioactive Materials

5. 3701:1-52 Radioactive Materials Standards - Irradiators

6. 49 CFR Parts 171-178 - Transportation.

The Ohio University Radiation Safety Program is designed to ensure compliance to all University, State and Federal policies, codes and regulations and to keep occupational dose to members of the public As Low As Reasonably Achievable (ALARA).

B. General Responsibilities of the Radiation Safety Committee

The Radiation Safety Committee is responsible for establishing procedures and policies for the procurement, use and disposal of all radioactive materials and other sources of ionizing radiation on the Ohio University campus. The Committee is responsible for developing and/or adopting safety codes to protect University personnel and the public. University personnel will be responsible for following procedures, policies, and safety codes established by the Committee. The Committee will examine the adequacy with which these procedures, policies, and safety codes have been followed.

The Committee is responsible for receiving and approving the applications of staff members to use radioactive materials and other sources of ionizing radiation. The Committee will examine and approve the qualifications of personnel using radioactive material or other sources of ionizing radiation, the proposed usage, procedures, and facilities (see Appendix 30 for details on evaluation categories). The Committee will establish a continuous inventory and inspection records of all radioactive material and other sources of ionizing radiation and the facilities where radioactive materials are used. The University will employ a Radiation Safety Officer and necessary staff to

serve in a liaison capacity between the Committee and the staff members using radioactive material or sources of ionizing radiation. The Radiation Safety Officer and staff will perform the necessary inspections to insure the adequacy with which the procedures, policies, and codes established by the Committee have been followed. If unsafe practices involving radioactivity and/or radiation are observed, the Radiation Safety Officer has the authority to require cessation of such practices of the projects using such practices until a review has been made by the Committee. The Radiation Safety Committee will meet at least once per quarter to discuss matters relating to the use of radioactive isotopes and ionizing radiation. Matters of the Committee meeting shall be recorded and kept in a file under the direction on the Chair of the Committee. See Appendix 31 for composition of the Radiation Safety Committee members.

The Radiation Safety Committee will review the performance of the Radiation Safety Office and the Radiation Safety Officer. The results of the evaluation will be sent to the Vice President for Finance and Administration (see Appendix 31 for Committee members).

C. General Responsibilities of the Radiation Safety Officer

The Radiation Safety Officer is responsible to the Radiation Safety Committee and is independent of any college, division or department in administrating the rules of the Committee.

The Radiation Safety Officer is appointed by the Associate VP Risk Management and Safety on the recommendation of the Vice President for Finance and Administration and the Radiation Safety Committee. The Ohio Department of Health will be notified of the appointment.

In the absence of the Radiation Safety Officer (such as leave, illness, travel, etc.) an Alternate Radiation Safety Officer shall be appointed by the Associate VP Risk Management and Safety upon recommendation by the Radiation Safety Officer or by the Radiation Safety Committee Chair if the RSO is not present.

Any change considered significant by the RSO or RSC of an approved experiment that may involve additional radiological hazards must be reviewed by the Radiation Safety Committee and will be considered as a new application for the use of radioisotopes.

If no increase in safety hazards exists, the Radiation Safety Officer can approve the project and will report to the Radiation Safety Committee at its next meeting. The Committee requires adherence to the safety practices set forth in Sections I through X at all times.

The Radiation Safety Officer is responsible for monitoring radiological safety and health on the University campus in accordance to the regulations of the Radiation Safety Committee.

The Radiation Safety Officer also assists and advises campus personnel on matters of radiological safety in such a manner as to assure a minimum of delay and inconvenience in their experimental work.

The Radiation Safety Office will be directed by the Radiation Safety Officer. The RSO reports through the Associate VP Risk Management and Safety to the Vice President for Finance and Administration where budget and personnel will be administered. Some of the specific duties of the Radiation Safety Office are shown in Appendix 19.

The Radiation Safety Officer will review the following reports: monthly film badge, bioassay results, monthly laboratory surveys, monthly inventory of radioactive waste in Radiation Safety Office storage, summary of sealed sources checked and equipment calibration results.

D. Responsibilities of the Applicant

1. General

The applicant must furnish information requested by the Committee and the Radiation Safety Officer at the original and/or subsequent time requested, regarding the usage of radioisotopes and the procedures expected to be used. A "cold run" demonstration of the anticipated procedures may be required.

After initial approval of the application, the applicant must present for the approval of the Committee any planned change in the use of radioisotopes beyond the approval of the Committee, Appendix 27.

The applicant must report to the Radiation Safety Officer as quickly as possible any accident involving radioactive isotopes. This is not a disciplinary action, but for the protection of the individual involved through an efficient decontamination.

No radioactive source may be taken off campus other than as expressed on the application or upon approval given by the Radiation Safety Officer or authorized representative. He/she is responsible for the adherence to safety practices in Sections II through X of this manual and the appropriate policy, code or regulation (RSH, Appendix 16).

If an individual has received radiation exposure during his association with a previous company or institution, the exposed person shall complete the "Radiation Exposure History Form" located in Appendix 22.

2. Training for Individuals Working In or Frequenting Restricted Areas (Authorized Users and Authorized Radiation Workers)

   The Radiation Safety Program will include the intent of OAC 3701:1-38 (see Appendix 16). The training requirements of Individuals Working in Restricted Areas are shown in Appendix 8. The frequency of training for individuals working in restricted areas, will be the initial training prior to working in a restricted area and an Annual Refresher. The Annual Refresher could include, for example, radiation video tapes/orientation by the radiation staff on specific radiation topics. The annual training will be assessed based on the needs of the individuals working in radiation laboratories.

3. Training for Individuals (Facilities/Administrative personnel, Tour Groups, Contractors, Visitors, etc.) Who Have Occasion to Enter a Restricted Area

   All individuals who have any occasion to enter a restricted area, or area within a restricted area designated as requiring on to be trained, must be instructed in radiation hazards as well as other hazards present. The instruction will be the responsibility of the licensee (see Appendix 18 for Occasional Visitor Orientation (OVO) information). A list of individuals, who have been instructed, will be sent by the licensee to the Radiation Safety Office on the prescribed form (Appendix 18).
   Special attention should be given to the custodial workers concerning cleaning, waste collection and emergency procedures. In addition, clerical personnel should be instructed with an emphasis on the receipt of packaged radioactive materials, radiation precautions in restricted areas, visitors and emergency procedures.

4. Radiation Safety Workers - Training by Licensed Supervisor (Authorized User)

   a. When radiation workers are working under the supervision of an Authorized User, the Authorized User will work directly with the new staff until the authorized user is confident in the worker's abilities and understanding of Ohio Administrative Code (OAC), license provisions and "in-house" safety instructions. The Authorized User is responsible for documenting the staff member's completion of his/her instruction and certification of the worker's use of materials with limited supervision, i.e., not under his/her physical presence.

   b. Approximately once each quarter, a Radiation Safety Newsletter will be developed and sent to each individual working in radiation laboratories using radioactive materials. The Authorized User will be responsible to provide evidence of the worker having received and read the newsletter.

5. Pregnancy Training

Section OAC 3701:1-38-10, "Notices, Instructions, and Reports to Workers" requires that all individuals working in or frequenting any portion of a restricted area be instructed in the health protection problems associated with exposure to radioactive materials or radiation, in precautions or procedures to minimize exposure, and in the regulations that they are expected to observe. Ohio University "Instruction Concerning Prenatal Radiation Exposure" is based on NRC Regulatory Guide 8.13 (see Appendix 11), "Requirements for Radiation Safety Orientation for Pregnancy and Radiation Safety Orientation For Pregnancy" form.

6. License Renewal

Five years after the initial approval of a particular application, the Authorized User must renew their License. The renewal is for the purpose of updating the "description of use," the inventory of radiation workers and deleting projects no longer active. The five-year renewal is found in Appendix 17.

7. Reporting

The following reports are a requirement of our license and must be submitted in a timely manner. It is the PI's responsibility to assure coverage of these reporting requirements in his/her expected/unexpected absence. Submission of these required documents after the due date may result in review of your authorization to use radioactive materials by the Radiation Safety Committee.

a. Occasional Visitor Orientation

Occasional Visitor Orientations (OVO) must be given to all visitors who enter your lab area. Upon completion of the OVO, record the individual's name, department or institution, date of OVO, and trainer's initials. Request for the annual submission of the Occasional Visitor Orientation Record (Appendix 18) are made by the end of Spring. The completed form must be returned to the Office of Radiation Safety **within 10 days of the request**.

b. Film Badge/Bioassay, Missing

Explanation for a missing bioassay or film badge must be submitted within 7 days of the request.

c. ORITS

Response to the monthly email request for review and approval of Monthly Inventory Balance Summary and radioactive isotope usage is required within 10 days of request.

II. Application for Use of Radioactive Materials

The minimum qualifications for an applicant are previous training and experience with radiation commensurate with the types and amounts of radioactive materials he/she wishes to use. Inexperienced applicants should contact Risk Management and Safety for training and assistance.

A. Broad Scope Radioactive Material License (Appendix 1)

Ohio University's Ohio Department of Health Broad Scope License requires all individuals requesting Use of Radioactive Byproduct Material to be licensed by the Ohio University Radiation Safety Committee. The applicant must complete one signed original and provide twenty-five copies of the form "Application for Permission to Obtain and Use Radioactive Isotopes" (See Appendix 2 for sample form) to the RSC. The application must include broad outlines of the program which are as descriptive as possible. See Appendix 3 for A Guide for Filling Project Application for Radioactive Materials. A person who has been approved to obtain and use radioactive materials is responsible for safe handling of all radioisotopes he receives. He is also responsible for maintaining current records of receipts, usage, including all radiation (meter) and removable contamination (wipe) surveys and waste disposal of all radioisotopes in his possession.

B. Guide to Completing the Application for Permission to Obtain and Use Radioactive Isotopes

1. Call Risk Management and Safety (593-1666) and ask to speak to someone in Radiation Safety regarding the use of radioisotopes. Appropriate information will be sent to you.

2. Read the pertinent sections of the Radiation Safety Manual prior to completing the application.

3. Read "A Guide for Filling Project Applications for Radioactive Materials" (Appendix 3).

4. Additional information you will need to complete the application is as follows:

    a. Appendix 4 - Common Radionuclides, Energies and Half-Lives

    b. Appendix 5 - Dose Rate/Shielding

    c. Appendix 6 - Glossary

d. Appendix 7 - Facility Selection Criteria

e. See Section I. D. (RSH) General Responsibilities of Applicant

f. See section X Radiation Safety Handbook, Required Forms To Be Completed by applicant or licensee.

5. Some questions/comments you should consider in completing your application are:

a. Is there a possibility the radioactive material could become airborne? If so, explain fully.

b. What type of daily monitoring for surface contamination will you be using?

c. How much waste will you accumulate (solid, liquid)? How much waste will you dispose down the sanitary sewer system?

d. Note: there is an optional "Radiation Safety Orientation for Pregnancy" (See Appendix 11).

III. Use of Radioactive Materials (General)

The federal, state, and university regulations and procedures which generally apply to all radioisotopes are set forth in this Section.

A. Procurement of Radioactive Materials through BobcatBUY or Requisition for Individual (One-Time Only) Purchase

When radioactive materials are purchased with University or grant funds, the following procedures must be followed.

1. **Follow the instructions for BobcatBUY first. (See Appendix 12)**

2. A Requisition form (Appendix 12) is available on the Ohio University Division of Finance web site: http://http://www.ohio.edu/finance/procuretopay/forms.cfm. This form must be used to request a one-time-only purchase of radioactive materials and filed in such a timely manner to allow the Budget Office, Purchasing, and the Radiation Safety Office to complete their processes. The completed form must:
   a. Include Project numbers, radioisotopes and associated chemical forms

   b. In the "Ship To" section list: Alan E. Watts, RSO, University Service Center 142, Athens, OH 45701"

   c. Be sent to Risk Management and Safety for approval prior to being sent to Purchasing

3. When the requisition is approved by the Radiation Safety Officer, it will immediately be sent to General Accounting and Financial Reporting Office (or Grant Accounting).

4. When a Purchase Order is generated by the Purchasing Department, the Radiation Safety Office will enter the information into the Online Radioactive Isotope Tracking System (ORITS).

5. The package containing radioactive materials order will be received by Risk Management and Safety, opened and examined for damage and/or contamination. The order will be logged and placed in the Radioactive Materials Inventory. The order will then be delivered to the purchaser. Any adjustments, replacements, or special handling will be performed by Risk Management and Safety.

B. Procurement of Radioactive Materials through BobcatBUY and Requisition for Blanket Purchase Orders

The Radiation Safety Committee has approved the following procedure when ordering radioactive material off a blanket purchase order:

1. **Follow the instructions for BobcatBUY first. (See Appendix 12)**

2. Complete the Requisition form (Appendix 12) as stated in Section A 2-4 above with the exception of listing information requested for a blanket purchase order.

3. Using the Online Radioactive Isotope Tracking System (ORITS), complete and submit the "place an order" form. This accomplishes two purposes: (1) traces all orders to assure proper arrival and (2) assures someone is in the RMS Office to expedite delivery of the material. You must be authorized to access ORITS. Contact 593-1666 for further information.

4. Notify the vendor to ship radioactive material to Risk Management and Safety, 49 Factory St, #42 University Service Center.

5. If you receive an order directly (was not delivered to RMS), call RMS immediately. Please, DO NOT OPEN the container.

C. Purchase by Purchasing (P) Cards

Purchasing cards cannot be used to purchase radioactive materials.

D. Requirement for Ordering Radioactive Materials

If, in the opinion of the Radiation Safety Office, an authorized user is continually delinquent in providing necessary information (e.g., verification of ORITS Monthly Inventory Balance Summary) to Risk Management and Safety as required by policy,

the Radiation Safety Office will provide a letter to the individual indicating no further ordering of radioactive material will be permitted until such delinquent matters are resolved. At such time the matter is cleared by the Radiation Safety Officer, a letter will be sent to the licensee that the next order will be permitted and can continue as long as their records are not delinquent. (Radiation Safety Committee approved 4/29/91 and re-approved 5/22/06)

E. Gifts and Loans of Radioactive Materials

Any radioactive materials received by any faculty or staff member for use at the University and at no cost to the University will be considered a gift. Any radioactive materials which are received by any faculty or staff member on loan from any source outside the University for use at the University will be considered a loan of radioactive materials. Gifts and loans must be processed as follows:

1. Prior to making any commitment to accept a gift or loan, contact the Radiation Safety Office (RMS). The material must be included on the Ohio University Broad Scope License before we can receive and use the radioisotope.

2. The individual who will receive the material must be licensed to obtain and use the material by the Radiation Safety Committee (see Section II of this Handbook).

3. If conditions 1 and 2 are fulfilled, the material must be sent to Risk Management and Safety as with purchased materials and processed accordingly.

F. Transfers of Radioactive Materials

Risk Management and Safety is responsible for all transfer of radioactive materials to, from and within the University. The Radiation Safety Officer must approve <u>all</u> transfers prior to movement. All transfers must be recorded with Risk Management and Safety.

G. Requirement for Caution Signs and Labels

All signs and labels required by this section must bear the conventional radiation symbol in magenta or purple or black on a yellow background. Signs and labels are available from Risk Management and Safety.

1. Each area or room where an amount of licensed radioactive material is used or stored, which exceeds 10 times the quantity of such material specified in OAC Appendix A of rule 3701:1-38-18, must be conspicuously posted with a sign, or signs, bearing the radiation caution symbol and the words: "CAUTION OR DANGER RADIOACTIVE MATERIALS."

2. Each "Radiation Area" must be conspicuously posted with a sign bearing the radiation caution symbol and the words: "CAUTION RADIATION AREA." A exists a radiation level, from any source, such that an individual could receive in any one hour a dose to the whole body of 5 millirem (0.05 mSv) or more at 30 cm from the source of radiation.

3. Each "High Radiation Area" must be conspicuously posted with a sign bearing the radiation caution symbol and the words: "CAUTION OR DANGER HIGH RADIATION AREA." A "High Radiation Area" is defined as any area accessible to personnel in which there exists a radiation level, from any source, such that an individual could receive in any one hour a dose to the whole body in excess of 100 millirem (1.0 mSv) at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

4. Each Very High Radiation Area must be conspicuously posted with a sign bearing the radiation symbol and the words: "GRAVE DANGER, VERY HIGH RADIATION AREA." A grave danger, very high radiation area is defined as an area where an individual could receive 500 rad (5 Gy) or more in one hour at one meter from a radiation source or any surface through which the radiation penetrates.

5. Each area or room in which radioactive materials are dispersed in the air in the form of dusts, mists, vapors, or gases, must be conspicuously posted with a sign bearing the radiation caution symbol and the words: "CAUTION OR DANGER AIRBORNE RADIOACTIVITY AREA."

6. Each area or room in which X-Ray machines are permanently installed must be conspicuously posted with a sign bearing the radiation caution symbol and the words: "CAUTION X-RAYS."

7. Labeling of Containers: Each container of radioactive material must be 1abeled with a durable clearly visible label which identifies the contents of the container. The label must bear the radiation caution symbol , the words "CAUTION OR DANGER RADIOACTIVE MATERIAL" and the isotope, total activity, and date. A label is not required on a container when it is continuously attended or secured by the responsible individual. Containers holding licensed materials less than quantities in Appendix A of 3701:1-38-18 or when concentrations are less than specified in Table 3 of Appendix C of 3701:1-38-12, do not require labeling.

8. Labeling of Equipment: Each radiation-generating machine must be labeled in a manner which cautions individuals that radiation is produced when the machine is being energized.

9. Such areas or rooms, noted in numbers 1-6 & 8 of this section, must also be posted with an Ohio Department of Health "Notice to Employees."

H. Handling and Processing Techniques

A copy of the "Laboratory Rules" shall be posted in each laboratory using non-sealed radioactive materials (See Appendix 13).

1. Eating, drinking, smoking, and the application of cosmetics are prohibited in any area where radioactive materials are used.

2. Pipetting by mouth suction is prohibited in any area where radioactive materials are used. Propipettes or syringes should be used.

3. Eye protective devices must be worn in all laboratories where there is a possibility of eye injuries.

4. Protective gloves should be worn during all handling operations where contamination is a potential hazard. After use, disposable gloves should be discarded in the dry radioactive waste containers. If reusable gloves are worn, the gloves should be thoroughly washed with soap and water while still worn on the hands and dried with paper towels (the towels are discarded in the dry radioactive waste container). The gloves should then be checked with a laboratory monitor for contamination, and if clean, should be removed and left inside-out until reuse.

5. After removing either type of gloves, the hands should be thoroughly washed with soap and water, dried, and checked for contamination with a laboratory monitor.

6. If, in the course of work, personal contamination is suspected, a survey with a suitable instrument should be made immediately. If contamination is found, refer to Appendix 14.

7. Whenever practicable, perform all laboratory operations over trays and/or disposable, absorbent paper.

8. If a spill should occur, refer to Section VIII. (RSH).

9. Try out all new procedures and manipulations by practicing with non-radioactive materials.

10. Operations with dry, volatile, or gaseous radioactive materials or any other process that could lead to production of airborne radioactivity, must be performed in an adequately ventilated fume hood or a glove-box.

11. Radioactive wastes must be disposed of as outlined in Section III. J.

12. The time required to handle any container of radioactive material should always be kept to a minimum.

13. Unauthorized transfer or removal of any radioactive materials from any building or the campus is prohibited.

I. Storage of Radioactive Materials

Unattended radioactive materials must be stored in a location inaccessible to unauthorized persons.

1. The storage container must be labeled with the isotope total activity, date, and name of the person responsible.

2. Radioactive materials in storage must be shielded such that radiation levels in adjacent unrestricted areas are less than 2 millirem per hour.

3. Flammable organic solvents must not be stored near radioactive materials.

4. See Section III. J. for Radioactive Waste Storage.

5. See Section VI. F. for Accelerator.

J. Radioactive Waste Disposal

The step by step process of determining if a waste is hazardous and/or radioactive, packaging instructions, policy and procedure and more are in Appendix 15. An actual copy of the disposal request form and the label are in Appendix 23.

Basic Philosophy

Handle all hazardous waste, including radioactive material, in a safe manner and clearly communicate the hazards in the work space by signage, labeling and training. It is Risk Management and Safety's desire to work in a cooperative manner to provide a safe working environment for Ohio University and provide professional services to authorized users and their staff.

Topics of Concern

Radioactive waste disposal has become more complicated with the mixed waste issue involving the U.S. Environmental Protection Agency (EPA). The hazardous portion of the mixed waste is regulated by EPA and the radioactive portion is regulated by ODH.

This means it is necessary for a radioactive material user to be able to identify a hazardous waste and a radioactive waste. In the typical material user's laboratory, the constituents are available to create mixed waste. All possible steps should be taken to prevent the creation of mixed waste.

A second major topic of concern has to do with long term storage of radioactive waste. One of the most dangerous things to store for long periods of time are containers of liquid waste. It is therefore very crucial that all possible steps be taken to eliminate the generation of liquid radioactive waste or dispose of it via the sanitary sewer. The amount of water soluble radioactive material that can be disposed of is based on the quantity of sanitary sewage released to the sanitary sewers. There is a dilution that must be achieved, before it is acceptable to dispose of radioactive waste in this manner. It is fortunate that we receive low amounts of radioactive material in comparison to the sewage released from our buildings. Specified activities of water soluble radioactive waste may be disposed of via the sanitary sewer, per laboratory, as stated in the lab rules (Appendix 13). The amount of activity has a 10 fold safety factor built into it. By doing this, the need to do a calculation every time waste is disposed of in this manner is eliminated.

This does provide flexibility to increase an authorized user's sanitary sewer disposal limit from the specified activity stated in the lab rules (Appendix 13). Due to the problems associated with containing, transporting and storing liquid radioactive waste, and in support of ALARA, users of materials shall request permission from the Radiation Safety Committee to increase their limit for sanitary sewer disposal to maximize the management of liquid radioactive waste via the sanitary sewer disposal instead of collecting and packaging it for disposal. The RSO or designated responsible person will provide a calculation to verify that such disposal is in accordance with OAC 3701:1-38-12, Appendix C. Emergency or one time disposal permission may be granted via a phone call to the RSO or designated responsible person. The phone call and the calculation must be documented and placed in the file of the authorized user.

A third topic of great concern is waste minimization and segregation. Minimization of waste generation should be standard practice in the laboratory. Reducing waste generation reduces exposure to all downstream handlers, transporters and storers, besides substantially reducing the cost of waste disposal. Waste segregation means keeping the waste from unnecessarily being mixed with any other material. This would include keeping the different isotopes separate. A 55 gallon drum of P-32 waste will be decayed off in 5 months; if you mix S-35 waste with it, it will take 29 months to decay off; if you mix H-3 with it, it will take 124 years to decay off.

A fourth topic of great concern is the user's choice of radioactive material. A material user should give favorable thought to using a radioactive material that has a short half-life. This reduces the time for decay to background and therefore eliminates many problems associated with radioactive waste with a long half-life. There is a wealth of

experience in using radioactive material by researchers at Ohio University, please contact our RSO and discuss material use and/or get further contacts.

A fifth topic of great concern is surface contamination. To ensure your radioactive material is not spread to other parts of the University, it is important to ensure the outside of any package being offered for shipment or pickup for disposal has been surveyed and is free of removable surface contamination.

A sixth topic of great concern is airborne contamination. From actual experience, it has been demonstrated that NaI will become airborne in its free state. Everyone in a workspace will be exposed unless proper precautions are taken. Once attached to other compounds, the potential has been demonstrated to be much less. Literature indicates that certain forms of S-35 will act similarly. Please be careful and read the literature thoroughly. It is not permissible, professional or ethical to make available an off gassing waste or material to anyone without their knowledge. If you are requesting disposal of a questionable material, it will be necessary to show by air monitoring that the material is not off gassing.

A seventh topic of great concern is spill protection. Due to the vast problems that spills may cause, including shutting down buildings for extended periods of time, it is extremely important to have secondary containment. When planning a procedure and storing material, ask yourself this question, "How would the spill be contained?"
In summary**,** it is in the interest of ALARA that low level radioactive waste be managed in a manner to reduce exposures as much as possible. This is why we do not compact waste (reduces handling and potential for airborne exposures), encourage maximizing sanitary sewer disposal, (to reduce exposures associated with packaging, transporting and storing), survey packaging (to eliminate potential for spread of contamination and therefore exposure) and maintain control of our waste for extended periods of time for treatment by decay (to reduce exposure associated with transporting and storing at other facilities).

You, the authorized user, are the most important link in a successful radioactive waste disposal program. The source of waste generation is the point at which key decisions are made. The steps that you take to make this a successful program are very much appreciated.

K. Release of Radioactive Material to Air and Sanitary Sewer System

1. Sanitary Sewer System

   Effluents may be discharged to public sanitary systems provided the quantity of radioactivity in any one month, if diluted by the average monthly quantity of water released by the installation, will not result in an average concentration exceeding OAC 3701:1-38-12, Appendix C. Any disposal other than specified in the Laboratory Rules shall be approved by the Radiation Safety Committee.

4. External Monitoring - Survey of Areas and Radiation Signs

If indicated, all areas in which exposure could occur shall be surveyed and the appropriate radiation sign located to indicate the hazard present. See Section III. G. Requirements for Caution Signs and Labels.

Regulations state each authorized user shall monitor occupational exposure to radiation and require the use of individual monitoring devices for adults likely to receive 500 mRem/yr. or 50 mRem/yr. for declared pregnant women and minors.

5. Internal Monitoring

The Bioassay Program: A review will be completed of the described experimental procedure as written in the licensed application to determine the probability of ingestion, inhalation and/or absorption. Regulatory Guide 8.20 "Applications of Bioassay for 1-125 and 1-131," and Guide for Bioassay Requirements for Tritium (10/19/77) (AB/REA) will be used by the Radiation Safety Committee to determine the bioassay requirements for each application. Action points and corresponding actions as described in Guide 8.20 and Bioassay Requirements for Tritium will be used. If there is a positive action level, the worker will be removed until an evaluation is completed. A positive assay for 1-125 and/or 1-131 is described in Guide 8.20.

If a probability exists that radioactive material can become airborne, bioassays (urine) will be completed. The frequency will depend on the use. If quantities greater than 10 mCi are used at any one time (non-sealed), bioassays will be performed at least once per month and at greater frequency if deemed necessary. If a person worked with radioactive materials since the last bioassay and a sample is not provided, the form as shown on Appendix 28 will be sent (to the supervisor) for an explanation as to why a urine sample was not given. An e-mail message requesting the reasoning for not providing the bioassay sample may be utilized as well. A urine sample may be required if the excuse is determined to be insufficient.

Urine samples are measured with a liquid scintillation counter. Thyroid uptake for I-125 and/or 1-131 are analyzed using a single channel analyzer and/or an appropriate NaI detector.

The requirement for air sampling will be based on the Regulatory Guide 8.25 "Air Sampling in the Workplace." In general, any licensee who handles or processes unsealed or loose radioactive materials in quantities that during a year will total more than 10,000 times the ALI for inhalation, should evaluate the need for air sampling.

In summary, OAC 3701:1-38-12, in part says, that each authorized user shall monitor exposures to adults likely to receive in 1 year, an intake in excess of 10 percent of the applicable ALI(s). It is recognized that a bioassay is a retrospective assessment of intake.

*The dose to the embryo/fetus is per gestation period, not an annual limit.

IV. Use of Radioactive Materials (Research and Instructional Programs)

A. Use of Sealed or Plated Radioactive Sources

In addition to the general regulations outlined in Section III, the following regulations apply to the use of sealed or plated radioactive sources.

1. Most sealed or plated radioactive sources, which are used for a variety of counting experiments, have a total activity of less than 10 micro Curies. Such sources may be handled with the fingers if care is taken not to touch the active surface of the source and to minimize the handling time.

2. If at all possible, sealed or plated radioactive sources, which have a total activity greater than 10 micro Curies, must be handled remotely with forceps, tongs, etc., and the handling time must be kept to a minimum. Remote handling tools range in length from about 10 cm. to 1 m. A general rule to follow is - the greater the activity, the longer the remote handling tool.

3. When handling radioactive sources, one should hold them away from the body and never near the eyes. Sources must never be carried around in a pocket.

4. At the end of each laboratory period, radioactive sources must be returned to their normal storage location and secured. The laboratory instructor must verify that all sources are present and accounted for.

B. Use of Liquid Radioactive Materials

Most liquid radioactive materials used are H-3, C-14, P-32, I-125 and S-35 labeled organic compounds in solution form. In addition to the general regulations outlined in Section III, the following regulations apply to the use of liquid radioactive materials.

1. No unnecessary personal materials are to be brought into the laboratory in order to avoid the possibility of contaminating them. Leave such items outside the laboratory.

2. Work in the laboratory must be performed under the direction of the laboratory supervisor or authorized user (AU) and in accordance with standard, approved laboratory procedures.

C. Alpha Emitting Isotopes

Alpha particles are emitted by many of the radioactive isotopes of the heavy elements. The alpha emission usually coincides with gamma rays. The primary alpha particle and gamma ray energies, and the radioactive half-life of several isotopes are given in the following table:

Isotope	Primary Alpha Particle Energies	Primary Gamma Ray Energies	Radioactive Half-Life
Po-210	5.30 MeV	-----	138 days
Ra-226	4.78 MeV	0.187 MeV	1620 yrs.
Th-228	5.42, 5.34 MeV	0.084 MeV	1.91 yrs.
Th-232	4.00 MeV	0.060 MeV	1.39×10^{10} yrs.
U-238	4.19 MeV	0.048 MeV	4.5×10^{9} yrs.
Pu-239	5.15, 5.13 MeV	0.051, 0.013 MeV	24,360 yrs.
Am-241	5.48, 5.44 MeV	0.060 MeV	458 yrs.

Alpha particles are completely absorbed by about one inch of air at STP. Thus, they present no external radiation hazard. If alpha emitting radioactive materials are present inside the body, they may be a serious hazard. Alpha-gamma emitting isotopes should be handled the same as beta-gamma emitting isotopes.

D. Neutron Sources

There are no radioisotopes that emit neutrons directly, with the exception of spontaneous fission of some isotopes of heavy elements. There are, however, a number of nuclear processes in which neutrons are produced indirectly. The most common one is the alpha-neutron reaction with beryllium. The alpha source, half-life, and neutron yield for some common alpha-neutron sources are given in the following table:

Alpha Sources	Half-Life	Yield (neutrons/sec./Curie)
Po-210-Be	138 days	2.5×10^{6}
Ra-226-Be	1,620 yrs.	$1.0\text{-}1.5 \times 10^{7}$
Pu-239-Be	24,360 yrs.	2.2×10^{6}

All alpha-neutron sources emit gamma rays either coincident with the alpha emission or as a result of the alpha-neutron reaction. Thus, neutron sources should be handled the same as beta-gamma emitting isotopes.

V. Use of Radioactive Materials (Biological and Chemical)

In addition to the general regulations outlined in Section III, the following regulations apply to the biological and chemical use of radioactive materials.

A. Administration of Radioactive Materials to Animals

1. Radioactive materials are to be administered only to animals that are owned by Ohio University, approved by the Institutional Animal Care Use Committee (IACUC) and housed through Lab Animal Resources (LAR).

2. Cages must be labeled with the appropriate warning signs. The isotope, quantity, date of administration, and name of the person responsible must be given on the label.

3. Arrangements must be made in advance for the collection of radioactive excreta such as to minimize contamination of cages and surrounding areas.

4. If the isotope and quantity administered are such that significant quantities of radioactivity are released during animal respiration, metabolic cages fitted with suitable filters may be required.

5. Dead radioactive animals and radioactive excreta are considered biological radioactive waste and must be disposed of in accordance with the regulations specified in Section III. J.

B. Biological and Chemical Procedures That May Release Airborne Radioactivity

1. Chemical reactions or radioactive decay may produce radioactive gases, e.g., I-131, I-125 released from acid solutions, or noble gases such as radon, krypton, and argon. Other gases that may be produced by chemical reactions are $^{14}CO_2$, $^{35}S0_2$, $^{3}H_2$, or $^{3}H_20$ vapor.

2. Biological metabolism by plants or animals may produce $^{14}CO_2$.

3. Ion exchange, e.g., ^{3}H exchange with H_2 in the atmosphere.

4. Use of I-125 - Volatilization of iodine is the most significant problem with I-125. Opening a vial of NaI^{I25} at high radioactive concentration can cause droplets to become airborne. Solutions containing iodide ions should not be made acidic nor stored frozen. Both lead to formation of volatile elemental iodine. Some iodo-compounds can gradually penetrate certain types of gloves. It is advisable to change gloves often unless it has been determined that the gloves are impervious to the compound being used. To render any spilled I-125

chemically stable, the area of the spill should be treated with alkaline sodium thiosulfate solution prior to commencing decontamination.

5. Use of Sulfur-35

Sulfur-35 may be difficult to distinguish from Carbon-14 because the beta emissions are of similar energy. If both C-14 and S-35 are being used in the same area, establish controls which are conservative for both nuclides.

Some Sulfur-35 compounds, including methionine, generate volatile fractions particularly during lyophilization or incubation. Check for airborne and surface contamination. Charcoal and copper turnings are effective in absorbing and minimizing airborne contamination.

C. Other Precautions /Comments in Using Radioactive Materials for Biological and Chemical Use

1. Phosphorus-32 (P-32) is the highest energy radionuclide commonly encountered in research laboratories and requires special care. If milli Curie quantities are used, ring dosimeters shall be worn. The use of lead-impregnated rubber gloves is also recommended. The shielding materials of choice are low density substances such as Plexiglas. The absorption of beta particles by high density materials gives rise to X-radiation. Some lead shielding may be required in addition to the Plexiglas when milli Curies of P-32 are being handled.

2. Tritium (H-3), because of its low beta energy, cannot be monitored directly (survey meter). Therefore, special care is needed to keep the working environment clean. Regulatory monitoring by wipe testing (smears) is required in areas where H-3 is used. External contamination, although not causing a radiation dose itself, should be kept as low as possible as it can lead to an internal uptake. Contamination can also interfere with experimental results.

VI. Tandem Accelerator

A. Responsibilities

1. Background

The general purpose of these regulations is to establish standards and procedures to assist in minimizing the hazards associated with the use of radioactive materials and the Tandem Accelerator. The regulations in this handbook apply to all individuals who in any way are associated with nuclear and/or extra nuclear radiation within the Accelerator area and are under jurisdiction and control of Ohio University. The administration of these regulations will be vested in the

University Radiation Safety Committee, appointed and empowered by the University President.

The establishment and support of an effective radiation safety program is the responsibility of the Radiation Safety Committee and the Tandem Accelerator Laboratory Committee (TALC). With the two groups working together, they shall establish the areas and levels of authority for the actual conduct of the program.

Any radiation safety program has to establish a balance between minimizing risks and maximizing the use of the facility and at the same time shall cause negligible interference with the work in the facility. The establishment and support of operating and radiation safety procedures in Accelerator operation and maintenance is of utmost importance. The purpose of the program is to assure:

a. That an adequate organization is established to formulate advise and implement safety policy.

b. That the Accelerator facility provides an environment for safe conduct of experiments and to eliminate damage caused by any equipment malfunction.

2. General Responsibilities of the Radiation Safety Committee:

The Radiation Safety Committee has the responsibility of establishing procedures and policies for procurement, use, and disposal of all radioactive materials and sources of ionizing radiation on the Ohio University campus. The Committee will also be responsible for developing safety codes which will establish permissible radiation levels to protect University personnel and the public. University personnel will be responsible for adequately performing these safety procedures. The Committee will examine the adequacy in which these safety practices are performed.

3. General Responsibilities of the Tandem Accelerator Laboratory Committee (TALC):

Accelerator personnel must furnish all information concerning radiation, requested by the TALC and the Radiation Safety Officer at the original and/or subsequent time requested.

The members of TALC, along with the Radiation Safety Committee, will assure that there is an adequate radiation safety program for the Accelerator facility. The program will be designed to protect personnel from injury and shall:

(1) maintain safe working conditions, (2) enable Ohio University to satisfy its statutory and legal obligations, and (3) instruct Accelerator personnel in safe attitudes and practices.

4. General Responsibilities of the Radiation Safety Officer:

The Radiation Safety Officer is responsible to the Radiation Safety Committee, and is independent of any college, division or department in administering the rules and regulations of the Radiation Safety Committee. In the absence of the Radiation Safety Officer (such as leave, illness, travel, etc.) an Alternate Radiation Safety Officer shall be appointed by the Associate Vice President Risk Management & Safety upon recommendation of the Radiation Safety Officer or the Chair of the Radiation Safety Committee, if the RSO is not present.

Any change in Accelerator experimentation that may involve additional radiological hazards must be reviewed by the Radiation Safety Officer. The radiation problems and decisions concerning the remedy of the problem shall be reported to the Radiation Safety Committee. The responsibilities of the Radiation Safety Officer, if indicated, shall include the following categories:

a. Inventory and control of radiation sources, targets, and other activated materials

b. Observation and control of radiation hazards

c. Radiation waste storage and disposal

d. Radiation monitoring procedures

e. Instruction of personnel in observation of rules and monitoring procedures

f. Maintenance of records related to exposures and accumulated doses received by the personnel

g. Periodic routine survey of the Accelerator installation

h. Survey of new experimental setups

i. Survey of unusual conditions including conditions during maintenance operations

j. Advise in establishing radiation safety rules and regulations

k. Establish radiation emergency procedures

l. Calibration of portable radiation survey meters and fixed radiation monitoring equipment

5. General Responsibilities of the Accelerator Operator:

The Accelerator operator is responsible for operating the Accelerator in such a manner that will not endanger the health and safety of Accelerator personnel. The Accelerator operator is also responsible for enforcing the rules and regulations as specified in the Radiation Safety Handbook and accelerator handbooks. The operator shall adhere to the Standard Operating Procedures for Accelerator personnel as described in Section VI. A. 6 (next section).

6. Standard Operating Procedures for Accelerator Personnel:

a. General Responsibilities

1) At any time during machine operation, any person wishing to enter the vault, small target room, large target room or machine compressor room, must obtain approval from the operator. In addition, the operator must make sure that the individual requesting entrance is wearing a film badge.

2) If a radiation safety violation occurs, it must be reported to the Chair of the TALC and the Radiation Safety Officer.

b. The Accelerator operator is responsible for the following:

1) Prior to activating the Tandem Accelerator, the operator must inspect the vault, small target room, large target room, upstairs machine and compressor room, to clear all personnel from those areas.

2) Lock upstairs door to machine room.

3) Close all doors to vault, small target room and large target room as needed. A visual inspection of interlock door lights shall be made to assure that doors are secure.

c. Responsibilities in Enforcing Radiation Safety Regulations:

1) The operator must be familiar with the Accelerator Emergency Procedures (as indicated during the safety orientation) and the Radiation Safety Handbook and shall comply with those requirements.

2) The operator shall enforce the Accelerator Visitor Policy as it pertains to restricted areas.

d. Responsibility in Recording Information:

1) The operator shall record all data requested in the Health Physics log book. The strip recording tape shall represent radiation exposure data for the time period of 24 hours (12:00 a.m. to 12:00 a.m.).

2) If a shut-down occurs as a result of tripping the radiation safety interlock system, a full written explanation must be included on the back of the daily Health Physics log book.

7. Visitor Policy

a. Introduction

All visitors who wish to enter the vault or target areas, when the Accelerator is in operation, shall be required to wear a film badge. Visitors shall be accompanied by a member of the Accelerator staff whenever they enter the vault or target areas. At these times, when the Accelerator is turned off, visitors may be accompanied into the restricted areas without film badges unless the Accelerator personnel or Radiation Safety Officer know of circumstances (e.g., residual radioactivity) which would make such entry unwise. All visitors must receive an Occasional Visitor Orientation as to potential hazards present and/or other concerns and their names must be documented. See Appendix 18.

b. Key Policy

If an Accelerator key to a restricted area is needed, the following procedures must be followed:

1) You must attend and successfully complete the Radiation Safety Orientation and Accelerator Orientation.

2) A "Request For Accelerator Key" must be completed by the individual needing the key and signed by the Chair of TALC or Chair of Physics and Astronomy. The request is sent to Risk Management & Safety for assignment of a key. Upon termination of the Accelerator facility usage, the key shall be returned to the Chair of TALC or Chair of Physics and Astronomy and in turn, to RMS.

c. Future Modification

As experience indicates, the Ohio University Radiation Safety Handbook Regulations may be amended by the Radiation Safety Committee.

B. Description of Accelerator Areas, Radiation Fixed Monitoring System, Audible, Visual Warning Devices, Shut-Down Control Panel Test, and Shut-Down and/or Accumulated Count Reset

1. Introduction

The arrangement of rooms, permanent shielding walls, and doors in the Edwards Accelerator Laboratory are shown in Appendix 10. Doors E, F,G, H, and I are keyed separately from all other doors in the building. They use a key that only key holders may have that is issued on the authority of the RSO/IRRP. These doors give access to Controlled Spaces where either ionizing radiation from radioactive sources and/or ionizing radiation generated by the accelerator may be present.

The areas of potential radiation hazard are (see Appendix 10 for schematic):

Room 122 Accelerator Vault
Room 120 Small Target Room
Room 121 Large Target Room
Room 121A Target Preparation Room
Room 113 Control Room
Room 225 Mechanical Room

Traffic in and out of these areas shall be controlled by the on duty Accelerator operator. Their decision concerning permissible entry into these areas may be appealed to the Radiation Safety Officer. In the absence of the RSO, the decision of the operator shall be final.

The rooms designated (number 111, 114, 115, 116) are expected to be free of accelerator- produced radiation and radioactive isotopes or activated components may not be stored in them.

Radioactive isotopes may be used and stored temporarily in room 101.

Access to rooms in the rest of the building will be by separate keys issued on the authority of the Chair of Physics and Astronomy.

2. Fixed Monitoring System

A fixed monitoring system is installed in the areas of largest potential hazard, i.e., Rooms 116, 120, 121, 122 (Room 121A shall be considered as part of Room 121 for the remainder of this Handbook).

The purpose of the fixed monitoring system is to provide for delayed automatic shutdown of the Accelerator beam beginning when a door to a hazardous area is opened. The delay time is inversely proportional to the radiation level in that area except in a limiting case in which Accelerator shutdown becomes instantaneous upon opening the door. Thus, limited monitored access to reasonably low-level radiation areas may be achieved, with consent of operator, without interruption of an experiment in progress. The radiation-sensitive element of the system is a BF_3 plus Argon-filled ionization chamber. The chamber has a thin outer coating of cadmium and a thick jacket of polyethylene chosen so that the relation between meter reading and dose rate shall be known for each target position. The maximum allowable integrated dose for an 8-hour period shall be defined as 20 mRem at 1.5 meters from the target.

Monitor currents will be converted to metering signals which drive "allowable entry time" meters at the appropriate doors. All door meters have a duplicate at the main control console for operator inspection. A current integrator locked at the control integrates the current from any active monitor if the door surrounding the monitor is open. If more than one monitor is alive to the integrator, a priority circuit automatically selects the monitor with the highest level for integration.

The digital display across the top has two functions. The three digits on the left are the cumulative dose, in counts, collected by the unsecured detectors. This value resets to zero every 24 hours. The cumulative dose is also tracked by the strip chart recorder at the bottom of the unit, and is also recorded by the data logging system, and resets to zero every 8 hours. The six digits on the right are the clock in 12 hour time. It should reflect the approximate time, and the accumulated dose should be resetting at midnight, 8am, and 4 pm. The toggle switch to the right of the digital display should normally be in the run position to count time. The Stop and Set positions are used when adjusting the clock time and the 8 and 24 hour reset point.

The Radiation Monitor has an audible warning alarm, it produces a steady, high pitched whistle. This alarm will sound when there is a power supply failure on one of the detectors, or when the accumulated dose has reached 80% of the maximum dose allowed in an 8 hour shift. The latter situation will also illuminate the 80% warning light on the front of the unit. The audible alarm for the 80% warning will silence after about 30 seconds but the light will remain on. The audible alarm for a power supply failure will sound until the problem is fixed. An 80% warning should cause the operator to pause the experiment and consult with the Radiation Safety Officer, or accelerator staff, to study the situation and modify operations in order to prevent a shutdown on accumulated counts.

There are two conditions which will cause the Radiation Monitor to send a

shutdown request to the Shutdown Module.

The first is based on instantaneous rate. A rate greater than 100 mRem/hr on an unsecured detector will cause this type of shutdown. Provided that no individual was exposed, the operator may silence the shutdown alarm and resume operations after the situation has been corrected and the event has been recorded on the shutdown log (form found in Testing, Calibration, and Shutdown book) and in the electronic log book.

The second condition is based on accumulated counts. Reaching 200 counts (20 mRem) in an 8 hour cycle will cause this type of shutdown. Two persons are required to reset the Radiation Monitor from an accumulated dose shutdown, one has to press the T3 button in the rear, and the other has to press the two buttons on the front. A full written explanation (form found in Testing, Calibration, and Shutdown book) must be completed and added to the Health Physics Daily Log Book. The event must be recorded in the shutdown log and the electronic log book. The Radiation Monitor shall never be reset unless there is absolute assurance that no personnel have received the dose registered on the digital counter. An investigation must be made, documented, and action taken to prevent recurrence of this type of shutdown.

3. Safety Interlocks and Warning Devices

   a. Interlock System

      Interlocks are electrical circuits which act to turn off electrical power if a hazardous situation exists. Each interlock is intended to furnish protection to personnel or equipment in the event of a specific malfunction or improper operating condition. Accelerator personnel shall not depend on a door interlock to turn off the beam. It should always be remembered that these interlocks seldom act directly to remove the hazard but rather through intermediate relay circuits. Also, relay or switches may fail so that these interlocks are not completely dependable. <u>It should never be assumed that the interlocks have removed the hazard</u>.

   b. Warning Devices

      Prior to beam, an audible and visual signal will be activated for the purpose of notifying individuals to leave all high radiation areas.

4. Calibration of Fixed Monitoring System

   The Radiation Safety Officer or an individual approved by the Radiation Safety Officer shall perform the calibration of the fixed monitoring system. Calibration of the fixed monitoring system will be accomplished by the following method.

a. Neutron Calibration

A PuBe Source will be used to calibrate neutron detectors to a known dose equivalent rate or flux at particular distances from the source.

b. Gamma Calibration

A Cs-137 Source will be used to calibrate gamma detectors to a known exposure rate at a particular distance from the source.

c. Position of Fixed Monitoring System

During the operation of the Accelerator, the detectors will be located approximately 3 meters from the source of radiation. The radiation field at one-half the distance from the source will be used as a basis for determining the amount of accumulated dose to cause Accelerator shutdown.

Therefore, the calibration of the fixed detector will be determined at the 1.5 meter position. A record of the responses will be recorded for each detector.

5. Accelerator Shutdown Module

This is the device that shuts down the accelerator, and sounds an alarm, when it receives a shutdown command from a connected device. There are two devices that provide a shutdown command to this module; the Fixed Monitoring System (on rate or accumulated dose) for human safety and the E1 alarm panel for mechanical protections. When a shutdown command is received this module:

1) Turns off the Pelletron power center in the Vault causing the chains and upcharge power supplies to go off.

2) Sounds an audible alarm. (abrasive, pulsating sound)

3) De-energizes the LE faraday cup causing the cup to go to the "IN" position.

The module is also responsible for controlling the flashing red warning lights and start up claxon. When it senses a chain start it activates the flashing red light circuit and sounds the claxon for 5 seconds. When it senses that the chains are off it deactivates the flashing red light circuit. In order to reset a shutdown alarm condition the operator must first clear the condition that caused one of the connected devices to request a shutdown, and then proceed to the back of the

cabinet and press the RESET button on the back of the module. There is also a TEST button on the back of the module that will create a shutdown request. Press the RESET button to end the test. The module has a series of indicator lights on the control console to inform personnel of the module's current status. Definitions of the indications may be found in alarm systems documentation.

6. Accelerator Shutdown and/or Accumulated Count Reset

If the main control panel is reset to zero accumulated counts, a full written explanation must be completed and attached to the "Health Physics Daily Log Sheet." The main control panel should never be reset unless there is an absolute assurance that no personnel have received the dose equivalent registered on the digital counter.

If the main control panel is to be reset, use the following procedures:

a. Activate the reset buttons. This will reset the accumulated counts to zero and zero time to the existing integral hour (e.g., will reset 4:25 p.m. to 4:00 p.m.

b. Run clock to approximately 8:10 a.m. and activate the reset buttons. This will reset zero time to 8:00 a.m.

c. Run clock to exact time of day.

Remember that there are two time cycles which reset (8 hour and 24 hour). The reset buttons on the main control panel resets the 24 hour cycle and must always be set to 8:00 a.m.

7. Emergency Off (EMO) switches

Every high radiation area is equipped with at least one EMO switch in readily visible locations. Each switch remains locked in the closed position when pressed. An activated switch's button must be rotated to release and reset. Activation of an EMO will cause the Pelletron AC Power Center to go into a power off condition, disabling the chain drive motors and upcharge power supplies, as well as shutting off the accelerator control power and all electrostatic common beam line components.

8. Beam Warning System

All areas that will experience high radiation levels, when beam and target conditions lead to such levels, are equipped with an audible and visual warning system which will activate for 15 seconds when the Low Energy Faraday Cup is lifted to inject beam into the Accelerator. The 15 second warning system

activation will operate every time the LE cup is commanded to the OUT position, independent of whether or not the beam and target conditions will produce detectable radiation. The warning devices consist of a yellow speaker housing with a strobe light across the front. The audible warning will be variable, but always distinctly different from all other audible alarm and warning sounds in the building.

High Radiation Mode:
A "HIGH RAD MODE" switch is located on the Faraday Cup Control Module. When this switch is in the "OFF" position the LE cup will lift instantaneously and the audible and visual warning will be active for 15 seconds. When this switch is in the "ON" position there will be a 15 second delay between pushing the LE Cup "OUT" button and the actual lifting of the LE Cup, as well as the 15 second audible/visual warning.

The Operator shall place the HIGH RAD MODE switch in the "ON" position when:

- The experiment conditions are known to produce measurable radiation
- Any time measurable radiation appears on any of the fixed monitors
- Any time there is uncertainty in the radiation that will result from the experiment conditions

The Operator may place the HIGH RAD MODE switch in the "OFF" position when:

- The experiment conditions are known to NOT produce measurable radiation
- When an experiment is tuned and running and no radiation has been detected in any of the fixed monitors.

C. Portable Radiation Monitors

1. Introduction

While the fixed radiation monitoring system has been designed to provide accurate indication of the radiation hazard in certain areas and to provide for automatic shutdown of the Accelerator in the event of possible overexposure, it is recognized that the system is in no way a substitute for good judgment.

It is always possible for an experimenter to approach a radiation source (targets, slits, etc.) to distances which are small compared to the source-to-monitor distance. In this case, the monitoring system would under-estimate their actual exposure.

It is also possible that the radiation level in a given area could increase suddenly due, perhaps, to the failure of some automatic device. For these and other

reasons, it is necessary to provide the additional monitoring equipment described below.

2. Portable Survey Meters (Neutron, Gamma, Beta)

As part of the permanent equipment of the laboratory, at least two types of monitors shall be provided. A neutron survey meter (Victoreen Model 488A, or Ludlum Model 15) which are sensitive to neutrons in the energy range from 1 to 15 MeV shall be located in the control room. Small gamma-ray sensitive devices with audible warning signals shall also be located in the control room.

All persons entering an area where the beam is on or has been on, shall be accompanied by Accelerator Personnel equipped with a Direct Reading Dosimeter. Accelerator personnel will survey the area, if needed, prior to group entry.

All personnel shall be aware of the lack of sensitivity of these direct reading dosimeters to neutrons and shall be requested to investigate unfamiliar situations with the portable neutron survey meters.

In addition to the monitors described above, the laboratory possesses one beta-gamma survey meter (Victoreen 440 RF), which will be insensitive to possible RF fields and three Bicron Model 50 Geiger-Mueller probed instruments.

3. Calibration of Equipment

Responsibility for the calibration of the radiation monitors shall rest with the Radiation Safety Officer who shall possess and maintain suitable standards and techniques for such calibration. Repair and maintenance of both the portable and the fixed monitoring systems shall be performed by the Accelerator electronics technician. The calibration records will be kept in the control room.

D. Personnel Monitors

1. Film Badges

In order to comply with the listed maximum exposures for individuals who enter controlled areas, the following regulations shall be adhered to:

a. Accelerator and Maintenance Personnel

All Accelerator and maintenance personnel who enter the vault or target areas while the machine is activated shall wear film badges. If the machine is not activated, and individuals, Accelerator and/or maintenance personnel, enter an area under such circumstances that they receive or are likely to receive a

dose in excess of 10 millirem in one week, they shall wear film badges. If the above conditions do not exist, film badges will not be required. It should be recognized that it is good practice to always wear your film badge within the Accelerator facility. This could help eliminate the possibility of "forgetting."

b. Film badge

1) Accelerator not operating - no film badge required unless special hazard requires it.

2) Accelerator operating - film badge is required if visit is to the vault and target rooms.

Permission from operator is required for target room entry, upstairs equipment room or roof entry.

3) Visitor Film Badge card – when a visitor is required to have a film badge the following information must be obtained:

1. Name_____Date_____
(individual and institution)
2. (Group No. Persons)_____
3. Individual Visiting_____
4. Reason for Entry_____
5. Location In Acc. Visiting_____
6. Entry Time_____Exit Time_____
7. Film Badge No. (if Needed) _____

Operator Signature_____

A visitor is defined as any individual who has not been authorized to obtain a key. They must complete the visitor's card (tours or open houses - each group must furnish the number of persons, institution requesting visit, date, entry time).

E. Permissible Exposure Limits, Area Surveys and Radiation Signs

1. Introduction

This section, permissible exposure limits, specifies the maximum exposure an individual may receive during a certain time interval.

The listed maximum permissible exposure limits means that an individual shall not receive an exposure in excess of these limits. Individual exposure will be

classified into three categories: permissible levels of radiation occupational exposures, nonoccupational exposures, nonoccupational exposure rate limits.

Areas within the restricted area will be classified into two different categories:

a. Residential Quarters

Controlled Residential Quarters include the thin film laboratory, target preparation room, student laboratory, control room, and compressor room. Visitors may be permitted within these areas, if accompanied or approved by a member of the Accelerator staff. Visitors shall be made aware of possible hazards within the controlled Residential Quarters.

b. Instrument Vault and Target Areas

2. Occupational Exposure Limits

No individual shall receive an exposure over what is specified in the following :

Annual Limit Whole Body Total Effective Dose Equivalent this is the sum of the Deep Dose Equivalent and the Committed Effective Dose Equivalent	5 rem (0.05 Sv)
Committed Dose Equivalent is the dose to any organ or tissue other than the lens of the eye	50 rem (0.5 Sv)
Lens (Eye) dose equivalent	15 rem (0.15 Sv)
Shallow dose equivalent to the skin	50 rem (0.5 Sv)
Shallow dose equivalent to the extremities	50 rem (0.5 Sv)
Other organs	50 rem (0.5 Sv)
Minors-Trained as Authorized Radiation Worker (10% of the annual limit specified for adult workers)	0.5 rem (5.0 mSv)
*Embryo/Fetus (Exposure during the entire pregnancy due to the occupational exposure of a declared pregnant woman).	0.5 rem (5.0 mSv)

3. Nonoccupational Exposure Limits

Individual Members of the Public	0.1 rem (1 mSv)

4. Nonoccupational Exposure Rate Limits

From external sources in any unrestricted area in any one hour	0.002 rem (0.02 mSv)

5. Survey of Areas and Radiation Signs

   If indicated, all areas which exposure could occur shall be surveyed and the appropriate radiation sign (see III. G. RSH) located to indicate the hazard present.

6. Internal Monitoring, see Section III. K. 5. for details.

   *The dose to the embryo/fetus is per gestation period, not an annual limit

F. Storage and Use of Activated Components

1. Induced Radioactivity in Materials

   a. Targets and Accelerator

      The target, which is being intentionally irradiated, will usually become radioactive. Any other material which the beam strikes or which is exposed to intense secondary radiation may also become radioactive. Radiation from these sources will not normally be a personnel hazard until personnel enter target rooms and the vault for maintenance, target changes, or routine adjustments. A survey of these areas should be made to evaluate the radiation hazard before or as they are being entered.

   b. Airborne Radioactive Materials

      Radioactive materials may become airborne by the following means:

      1) Beam passes through air

      2) Radioactive gases produced internally in the targets

      3) Powder targets

2. Handling Activated Materials

   a. Classified into Two Groups

1) Radiation emitted by radioactive material external to the body

2) Radiation emitted by radioactive material in contact with the skin or clothing or ingested or inhaled.

b. Before handling, or working with or around any activated materials, safe levels should be determined to establish safe handling procedures.

c. Any material which is suspected of radioactivity (e.g., previously bombarded targets) should be monitored to determine the level of any type of radiation present. Whenever radioactive material is to be handled, personnel shall wear plastic or surgical gloves and wash their hands thoroughly after the work. See Decontamination Procedures, Section VIII.

d. Radioactive materials, which are powdered, tend to flake, and/or are chemically reactive shall be handled in hoods or glove boxes in which adequate ventilation is provided.

3. Storage of Radioactive Material

a. Activated Materials

All radioactive items and bombarded targets shall be placed in a suitable safe area and labeled. Any nuts, bolts, and other small objects, removed during maintenance operations on the Accelerator, shall be placed in marked containers. These objects may be certified for reuse, if the level of induced activity does not create a hazard.

b. Routine Check Sources

All routine check sources, when not in use, shall be stored in suitable shielded containers. These containers shall be appropriately labeled (e.g., type of source, activity).

4. Machining Activated Materials

a. There shall be no machining of radioactive materials or components of the Accelerator, which have become radioactive, unless approved by the Radiation Safety Officer and follow guidelines established by the Radiation Safety Committee.

5. Vacuum Pump Exhaust, Vacuum System Maintenance and Cooling

a. Exhaust from Accelerator vacuum pumps may contain toxic and radioactive gases. The radioactive gases may be absorbed in the vacuum system as a result of leakage from targets or from target failure.

b. Special cautions should be taken when opening a vacuum system for decontamination or service. The contaminated parts to be serviced shall be removed in plastic bags. All service work, or repairs on components shall be performed in hoods or well ventilated areas. Similar practices should be made with cooling systems.

6. Gas Target System, see Appendix 24 for Rules and Procedures For Operation of the Tritium Gas System.

VII. Use of Radiation Machines

Qualified faculty whose instructional and research programs require the use of radiation producing machines may submit an Application for Use of Radiation Machines to the Radiation Safety Officer. A person who has been approved by the Radiation Safety Committee to use a radiation machine is responsible for the safe use of all radiation producing machines in their possession. They are also responsible for maintaining accurate records of "on" time and other pertinent data. A licensed operator or their responsible, trained assistant must be present whenever a radiation machine is in operation.

Application for Use of Radiation Machines

The minimum qualifications for an applicant are previous training and experience with radiation commensurate with the topic(s) of radiation machines they wish to use. Inexperienced applicants should contact the Radiation Safety Office.

A. X-Ray Diffraction Machines

Radiation exposures from X-Ray diffraction machines can be extremely hazardous. Dose rates in the primary beam can exceed 100,000 R/minute. Any part of the body momentarily placed in the beam would receive enough radiation to cause serious radiation burns. X-Ray diffraction machines must be operated in accordance with the following regulations:

1. Operators of X-Ray Diffraction Machines

No individual will be permitted to operate any X-Ray diffraction machine until such person has:

a. Received an acceptable amount of training in radiation safety

b. Demonstrated competence to use the machine and radiation survey instruments which will be employed

c. Received the approval of the person licensed to possess and use the machine; The operator of the X-Ray diffraction machine will be responsible for all operations associated with that equipment, including radiation safety. In particular they will:

1) Keep radiation exposure to themselves and others as low as practical

2) Be familiar with safety precautions and procedures as they apply to each machine he/she operates

3) Notify Risk Management and Safety of known or suspected abnormal radiation exposures to themselves or others

2. Operating Procedures

a. The operator should be in immediate attendance at all times when the machine is in operation.

b. When not in operation, the machine must be secured in such a way as to be inoperable to unauthorized personnel.

c. Personnel must not expose any part of their bodies to the primary beam.

d. Only properly trained personnel are permitted to install, repair, or make other than routine modifications to the X-Ray generating apparatus and tube housing.

e. Procedures and apparatus utilized in beam alignment should be designed to minimize radiation exposure to the operator. Particular attention should be given to viewing devices to assure that lenses and other transparent components attenuate the radiation beam to minimal levels. When alignment involves working near the open primary X-Ray beam, the beam current should be reduced in order to lower exposure rates. If a fluorescent alignment tool is used, dimming the room light will permit a significant reduction in beam current. The fluorescent alignment tool should be long enough to permit the operator's hand to be kept at a safe distance from the beam. The operator should be familiar with the manufacturer's recommended alignment procedures and copies of these should be available for reference.

f. If, for any reason, it is necessary to alter safety devices such as bypassing interlocks or removing shielding, such actions must be performed under the

supervision of the licensed user and must be terminated as soon as possible and safety devices reinstalled.

g. Radiation exposures to individuals must be so controlled that the specified limits in Section III. K. are not exceeded.

3. Personnel Monitoring

An operator of X-Ray diffraction machines should wear personnel monitoring devices (a ring and film badge), if appropriate, whenever they are operating or near an operating machine. The ring badge should be worn on the finger most likely to be exposed.

4. Area Monitoring

Radiation protection surveys must include monitoring for stray or scattered radiation in the immediate vicinity of the X-Ray machine. Radiation protection surveys must be made routinely and must be made after each modification of apparatus.

5. High Voltage Hazards

The high voltage power supply of X-Ray machines can be particularly hazardous. Personnel must never tamper with high voltage equipment. Only properly trained personnel are permitted to install, repair, or modify high voltage equipment.

6. Safety Engineering

a. Either easily visible flashing lights or equally conspicuous signals that operate only when the primary X-Ray beam is on should be provided in such a manner as to alert personnel to the potential hazard. The signal must be labeled so that its purpose is easily identified.

b. Each tube housing apparatus should be arranged as to prevent the entry or parts of the body into the primary X-Ray beam or cause the primary beam to shut off upon entry into its path.

c. A shutter status (open or closed) indicator should be provided, on or adjacent to the tube housing, which will automatically indicate the position of each shutter.

d. A sign or label bearing the words "Caution-Radiation - This Equipment Produces X-Radiation When Energized" or words having similar intent, must be placed near any switch which energized an X-Ray tube and

adjacent to each X-Ray tube housing. It should be located so as to be clearly visible to any person who may be working near the primary radiation beam.

e. A red warning light with the notation "X-Ray On," or equivalent, should be located on the control panel and should light only when the X-Ray tube is activated. A similar light should be mounted on or near tube housing.

f. The coupling between the X-Ray tube and the collimator of the diffractometer, camera or other accessory must prevent stray X-Rays from escaping the coupling.

g. Safety interlocks should be employed on tube head ports or shielding whenever feasible.

h. All safety devices (interlocks, shutters, warning lights, etc.) must be tested periodically to insure their proper operation. Records of such tests should be maintained.

i. For other safety engineering, accident prevention, and hazard elimination problems contact Risk Management and Safety.

B. Medical X-Ray Machines

Medical X-Ray equipment installations should be listed in four separate categories: Fluoroscopic, Fixed Radiographic, Mobile Radiographic, and Dental.

1. Fluoroscopic

All fluoroscopic equipment installations shall comply to regulations as specified in the OAC 3701:1-66-07.

2. Fixed Radiographic

a. A diagnostic-type protective tube housing shall be used (See definition in Appendix A, NCRP Report No. 33).

b. Suitable devices (diaphragms, cones, adjustable collimators), capable of restricting the useful beam to the area of clinical interest shall be provided to define the beam and shall provide the same degree of attenuation as that required of the tube housing. Such devices shall be calibrated in terms of the size of the projected useful beam at specified source-film distances (See VII. B. 3. b.). For chest photo-fluorographic equipment, the collimator shall restrict the beam to dimensions no greater than those of the fluorographic screen.

c. Radiographic equipment, particularly multi-purpose machines, should be equipped with adjustable collimators containing light localizers that define the entire field. Rectangular collimators are preferable. Means should be provided to produce a visible indication of adequate collimation and alignment on the developed X-Ray film. The field size indication on adjustable collimators shall be accurate to within one inch for a source-film distance of 72 inches. The light field shall be aligned with the X-Ray field with the same degree of accuracy.

d. The aluminum equivalent of the total filtration in the useful beam shall be not less than shown below. See also Section VII. B. 3. a. For dental radiography, see NCRP Report No. 35.

Operating kVp	Minimum Total Filter (Inherent plus added)
Below 50 kVp	0.5 mm aluminum
50-70 kVp	12.5 mm aluminum

e. A device shall be provided which terminates the exposure at a preset time interval or exposure. The operator should be able to terminate the exposure at any time.

f. The exposure switch, except for those used in conjunction with "spot-film" devices in fluoroscopy, shall be so arranged that it cannot be conveniently operated outside a shielded area.

g. The control panel shall include a device (usually a milliameter) to give positive indication of the production of X-Rays whenever the X-Ray tube is energized.

h. The control panel shall include devices (labeled control settings and/or meters) indicating the physical factors (such as kVp, mA, exposure time or whether timing is automatic) used for the exposure.

i. Machines equipped with beryllium window X-Ray tubes shall contain keyed filter interlock switches in the tube housing and suitable indication on the control panel of the added filter in the useful beam if the total filtration permanently in the useful beam is less than 0.5 mm aluminum equivalent. The total filtration permanently in the useful beam shall be clearly indicated on the tube housing.

Comment: Beryllium window X-Ray tubes with no added filtration emit low energy X-Rays at very high exposure rates. It is particularly important, therefore, that the operator be able to tell by a glance at the control panel how much added filter, if any, is present.

j. Beryllium window X-Ray tubes should not be used on multipurpose radiographic equipment.

k. The aluminum equivalent of the table top when a cassette tray is used under the table top, or the aluminum equivalent of the front panel of the vertical cassette holder, shall not be more than 1 mm at 100 kVp.

l. Equipment to be operated in areas where explosive gases may be used should have the approval of Underwriter's Laboratory for such use[1].

[1]Information may be obtained from Underwriter's Laboratory, 207 E. Ohio St. Chicago, IL 60611.

3. Performance Standards for Radiographic Units

a. If the filter in the machine is not accessible for examination and the total filtration is unknown, the half-value layer of the useful beam should be measured. Recommendation VII. B. 2. d. may be assumed to have been met if the half-value layer is not less than 0.6 mm aluminum when the X-Ray tube is operated at 49 kVp, or not less than 1.6 millimeters aluminum at 70 kVp, or not less than 2.6 millimeters aluminum at 90 kVp. For other tube potentials, the measured half-value layers should not be less than the corresponding values specified by an asterisk (*) in Table 2, Appendix B for dental radiography. See NCRP Report No. 35.

Comment: The purpose of the filter is to absorb, preferentially, the lower energy (longer wavelength) portions of the X-Ray spectrum which would otherwise be absorbed by the patient without significantly contributing to the information reaching the film. In general, the greater the amount of filtration, the greater the average energy of the X-Ray beam, and the smaller the dose to the patient for a given exposure to the X-Ray film. However, depending on kVp, the rate of dose reduction with increasing filtration diminishes rapidly and practical considerations place an upper limit on the amount of filtration that is reasonable in a given type of radiological examination. For the great majority of X-Ray examinations, one filter will suffice. Since relatively few examinations (such as mammography) are carried out below 50 kVp, most radiographic equipment should have two or more millimeters of added aluminum filtration securely fixed in the tube housing.

b. The size of the X-Ray beam projected by fixed aperture cones and collimators (except those housed for stereo-radiography) should not exceed the dimensions of the X-Ray film by more than 2 inches for a source-film distance (SFD) of 72 inches or 1 inch for a source-film distance of 36 inches as illustrated in Figure 1.

c. In general, modern diagnostic tube housing incorporate sufficient attenuating material to limit the leakage radiation to that permitted in the definition of a diagnostic-type protective tube housing and it usually is unnecessary to perform leakage tests in the field on modern X-Ray machines. When in doubt, however, the following method for testing for leakage radiation is recommended:

With the window of the housing blocked with at least 10 HVL of absorbing material (e.g., lead), the leakage radiation should be measured with the X-Ray tube operating at its maximum voltage and at its maximum current for continuous operation at that voltage. When this method of testing is not practical, the test may be made at higher current, provided that careful consideration is given to the limitation of operating time imposed by the heat capacity of the tube or target as determined from the manufacturer's tube rating and cooling charts. Small areas of reduced protection are acceptable in evaluating the maximum exposure rate provided the average reading over 100 square centimeters at one meter distance does not exceed 100 mR per hour (normalized to maximum current for continuous operation).

4. Guidelines for the User - Radiographic Units

a. Particular care should be taken to limit the useful beam to the smallest area consistent with clinical requirements and to align accurately the X-Ray beam with the patient and film. See VII. B. 3. b.

Gonadal shielding should be used for the patient when appropriate, but never as a substitute for adequate beam collimation and alignment.

1) When a patient must be held in position for radiographic mechanical supporting or restraining, devices should be used. If the patient must be held by an individual, that individual shall be protected with appropriate shielding devices such as protective gloves and apron. In addition, the patient should be so positioned that no part of the body will be struck by the useful beam and maintain the body as far as possible from the edge of the useful beam.

b. Only persons whose presence is necessary shall be in the radiographic room during exposure. All such persons shall be protected.

c. The radiographer shall stand behind the barrier provided for protection during radiographic exposures.

d. Special care should be taken to ensure adequate filtration in multi-purpose machines.

Comment: For soft tissue radiography such as mammography, operating potentials considerably below 50 kVp may be required. In performing such examinations on multi-purpose machines, it is usually necessary to reduce the amount of filtration. It is important, however, that the appropriate filter be replaced before proceeding with exposures requiring normal filtration.

e. Particular care shall be taken to ensure adequate filtration in any machine equipped with a beryllium window tube. Adding an appropriate filter is required to provide the filtration values recommended in Section VII. B. 1. d. See also VII. B. 1. i. and j.

5. Mobile Radiographic

All mobile radiographic equipment installations shall comply to regulations as specified in the OAC 3701:1-66.

6. Dental

All dental X-Ray equipment installations shall comply to regulations as specified in the OAC 3701:1-38-66.

C. Electron Microscopes

1. Personnel operating the microscope should be considered radiation workers, and as such, should wear film badges or thermoluminescent dosimeters, when appropriate.

2. The room containing the electron microscope should be considered a controlled area, and as such:

a. Should be posted with a sign having the equivalent of "Caution-X-Rays"

b. The electron microscope should be labeled with a sign having the equivalent of "Caution, X-Rays -- This Equipment Produces X-Rays When Energized."

3. Electron microscopes should be considered the same as any radiation producing equipment and as such, should be surveyed by the Radiation Safety Officer:

a. Whenever the filament is changed,

b. After the microscope is serviced or cleaned, and

c. At periodic intervals designated by the Radiation Safety Officer

4. The authorized user should be responsible for notifying the Radiation Safety Officer whenever:

   a. Conditions of use change,

   b. The microscope is serviced, and

   c. When new operators use the microscope

5. Possible Microscope Physical Deficiencies

   In the literature, numerous physical deficiencies and improper operational practices were discovered. These deficiencies and operational practices contributed to emission of unnecessary and previously undiscovered radiation. Some of the physical deficiencies are as follows:

   a. The anode was not properly shielded, thus allowing radiation to leak from the top of the microscope.

   b. Leaded glass in the viewing port was cracked so that the operator's hand and head could be unnecessarily exposed.

   c. The heat sink was inverted so that the electrons diverged instead of converged from the anode.

   d. The heat sink aperture was unnecessarily large so that the beam of radiation was broader than required.

   e. An objective aperture which was 2 1/2 times larger than allowed in the design of the microscope was mislabeled by the vendor and used by the operator. Therefore, the beam of electrons was 2 1/2 times larger than expected, and the x-radiation emitted from the microscope was 2 1/2 times greater than necessary.

   f. The face plate located at the viewing window was aluminum instead of brass. Therefore, the less dense aluminum did not attenuate the X-Rays as well as the brass and caused the emission of unnecessary X-Rays.

6. Improper Operational Procedures

   The following operational procedures contributed to the emission of unnecessary radiation:

a. The electron microscope was used with no aperture restriction. Often, this is the result of the preceding operator not checking to see which aperture had been installed. As a result, the radiation beam was unnecessarily large.

b. The setup procedure routinely used to optimize the performance of the electron microscope, may produce radiation readings at the outside surface of some electron microscopes. The setup procedure included having the beam at crossover with low magnification (the smaller the magnification, the greater the radiation emitted), and having the beam spread at low current (which also increased radiation emitted).

c. In general, operators were ignorant of the fact that improper operation of an electron microscope could cause radiation exposure.

D. Other X-Ray Machines

The regulations for X-Ray diffraction machines apply in general to all other X-Ray machines. Contact Risk Management and Safety for further information.

E. Neutron Generators

1. Associated with the Neutron Generator is a number of potential health hazards, none of which are serious, provided intelligent precautionary measures are employed. The potential hazards are listed below.

   a. Neutrons produced by bombardment of a tritium or deuterium target with deuterons or tritium

   b. Tritium evolvement from targets

   c. Tritium escape from ion source region

   d. Tritium loss during source filling

   e. X-Rays associated with the accelerated ion beam

   f. Delayed radiation induced by neutron activation of components in the drift tube section of the generator

   g. Electrical shock

2. Tritium Targets

Tritium is a radioactive element, decaying with half-life of about 12.3 years by emitting a low energy β^- particle (18 keV) to form ^3He. Tritium is considered to be dangerous when ingested into the system because it exchanges readily with hydrogen in the body. The Derived Air Concentration (DAC)* in air, as

*This is the maximum concentration for a working year (2000 hrs.) and chronic occupational exposure control. DAC = (ALI / 2.4 x 10^9) uCi/m.

specified by the OAC 3701:1-38-12, Appendix C, is 2 x 10^{-5} uCi/ml. The tritium targets normally used with the neutron generator contain 1-5 Curie of tritium and consist of tritium absorbed in titanium which is evaporated onto a metal "backing" material. The targets are discs typically 1-1 /4" in diameter. The backing material, which is usually copper, but can be molybdenum or other metals, ranges in thickness from 0.010 inches to 0.030 inches, and the titanium film is about 0.5 to 1.0 mg/cm^2 thick. High concentration tritium targets are available which contain as high as 16 to 18 Curies/in^2. The titanium film for these targets range in thickness from 5 to 25 mg/cm^2. Using a target containing 1 Curie of tritium and operating with 600 uA of deuteron beam, the yield of 14 MeV neutrons drops to half value after 2 to 3 hours of continuous operation. This drop off is exponential, decreasing by a factor of two every two hours. The target half-life, which is the time required for the yield to drop to half value, increases with decreasing beam current and is about 1 hour at 1.0 MA and 8 to 10 hours at 100 uA. Part of this drop off is due to the build-up of a carbon film on the surface of the target which increases the effective thickness of the target to incident 150 kV deuterons. Present indications are that most of the drop off is due to tritium gas which is released from the target as a result of heating by the incoming beam.** Most of the tritium released from the target will be removed from the system by the vacuum pumps, a small amount being absorbed on components inside the vacuum system. All vacuum fore pumps should be vented to the outside and periodic smear tests should be made on various components in the drift tube section of the generator (particularly the target assembly). It would be advisable to have available near the target a radioactive air monitor which is equipped with an alarm that alerts the operator when the tritium content in the target vicinity is above the maximum permissible level. Such devices are commercially available. Venting the roughing pump on models equipped with an ion pump is not necessary since most of the tritium is absorbed in the pump elements. Care should be exercised, however, in handling components when disassembling the pump. Consider the situation where the generator is operating with a 1 Curie target at a beam current of 600 uA. If we take the worst possible case and assume that the decrease in neutron yield is due entirely to the release of tritium and none of the tritium is absorbed in the vacuum system, approximately 0.5 Curies will be released into the atmosphere in two hours. Suppose now that the Neutron Generator is equipped with an oil diffusion pump and is operated in a room 20 ft. x 30 ft. x 30 ft. If the fore pump is not vented to the outside and the

room is sealed with no exhausts, the air in the room will contain an average tritium concentration of ~ 1 x 10^{-3} Curies/ml after two hours of operation.***

**A Beam current of 1.0 mA at 150 kV bombarding energy produces 150 Watts of energy, which must be dissipated by the target assembly.

***Actually, much of the tritium is trapped in the pump oils, and care should be exercised in handling and disposing these used oils.

Obviously, the above illustration is intended only to serve as a very rough guide. It does, however, point out the fact that a potential hazard does exist and emphasizes the desirability of exhausting the vacuum fore pump to the outside for units equipped with an oil diffusion pump. The high concentration targets contain as much as 18 Curies of tritium but present no greater hazard than the 1 Curie because of the rate at which tritium is released from the two targets is about the same. In other words, the half-life of high concentration targets is much greater. As pointed out previously, components inside the vacuum system can become contaminated by tritium absorbed in the walls. In one decontamination operation, vacuum components in the drift tube section of machine were ultrasonically cleaned and 1285 micro Curies of activity was found in the cleaning water. This operation was performed after the machine had been run for 170 hours at a beam current of 400 uA. This illustrates the need for making occasional smear tests and exercising ordinary prudence in handling vacuum components. The tritium targets emit low energy beta rays and present no particular hazard unless the tritiated surface is allowed to come into direct contact with parts of the body. Tweezers and/or gloves should be used in handling targets to prevent tritium from coming into contact with the hands.

3. X-Rays

X-Rays are produced in the generator by electrons which drift into the accelerating tube and are accelerated to the upper terminal where they strike metal objects and produce Bremsstrahlung X-Rays which have a maximum energy of 150 keV. The electrons are produced by a small amount of positive beam which strikes the walls of components in the drift section and accelerating tube. The intensity of these "back streaming" electrons is reduced substantially by a ring magnet which surrounds the drift tube at a point just below the accelerator base plate. The magnet deflects the "drifting electrons" before they have an opportunity to enter the accelerating tube. The intensity of X-Rays produced by back streaming electrons will depend on the vacuum condition and the amount of positive beam being accelerated. X-Ray production generally is higher for poor vacuum and high beam currents. A survey made with a proton beam of 600 µA and a normal operating vacuum (~ 1 x 10^{-5} mm Hg) showed that at various points one meter away from the H.V. terminal, the X-Ray dose varied

from about 1 mR/hr. to 25 mR/hr. In some cases, 50 to 100 mR/hr. has been measured. The measured dosage at the target is always well below tolerance, because it is shielded from the upper terminal by the accelerator base plate. The only time that X-Rays will present a potential hazard is when the machine is being tested using a proton beam on a blank target and no neutrons are being produced, (e.g., during installation). During such an operation it is desirable to shield the operator console from the upper terminal (primary source of X-Rays) with about a 1/4" of lead or the equivalent. When neutrons are being produced, the shielding required for the neutrons will stop all X-Rays.

4. Delayed Radiations Induced in Accelerator Components

Components in the accelerator will become activated by 14 MeV neutrons produced at the target. For practical considerations, activities induced in the target holder assembly and the target backing material are all that need to be considered. The target holding cap is made of aluminum and weighs about 55 grams. Most of the activity is produced through the Al27 (n,p) Mg27 reaction. The radioisotope, Mg27, emits 0.84 MeV and 1.02 MeV gamma rays and has a half-life of 9.5 minutes. If the machine is operated at an average output of 4 x 10^{10} n/sec. for one hour, the activity of the aluminum cap will be about 2 milli Curies which corresponds to a dose rate of 200 mR/hr. at a distance of 10 cm from the target. This activity decreased with a 9.5 minute half-life. Another reaction which can give rise to gamma rays is the A127 (n,p) Na24 reaction. Na24 emits 1.37 MeV and 2.75 MeV gamma rays and has a half-life of 14.9 hours. After a 1 hour bombardment, this reaction produces activity in the aluminum cap which corresponds to a dose of about 30 mR/hr. at a distance of 10 cm from the target. The copper backing material of the tritium targets will become activated. The backing is 0.010 inches thick and 1.25 inches in diameter. Two reactions contribute to the activity: Cu63 (n,2n) Cu62, and Cu65 (n,2n) Cu64. Both Cu62 and Cu64 are positron emitters (β^+) with half-lives of 9.7 minutes and 12.6 hours respectively. Approximate calculations show that after a one hour bombardment using an average neutron output of 4 x 10^{10} n/sec., the dose due to the annihilation gamma rays at 10 centimeters is about 60 mR/hr. Based on the above considerations, the total gamma ray dose for a one hour bombardment and an output of 4 x 10^{10} n/sec. is estimated to be about 200 to 300 mR/hr. at a distance of 10 cm from the target. This activity will, of course, decrease with time after the end of bombardment. The contribution due to activities produced in other components of the accelerator system will be small compared to that produced in the water cap and target material. The activity from a target holder made from stainless steel, rather than aluminum, would be much less, about 30-50 mR/hr. at 10 cm for a one hour bombardment. Stainless steel target holders are available on special request.

The dose values given above, which are very rough estimates, show that considerable radioactivity will be induced in the accelerator components. This

suggests that components should be surveyed (particularly the target assembly) before they are handled. It should be mentioned that activity induced in the target cooling water is not significant. Only a 7 second activity in oxygen can be produced and this decays very rapidly.

5. Electrical Shock

   There are two potential sources of serious electrical shock: the 1500 Volt power supply which is connected to the deflector plates in the post acceleration pulsing system, and the 150 kV accelerating voltage. The 1500 Volt supply has a current output of 100 mA and hence can produce serious effects. Protective caps are placed on the deflector plate feed-throughs to prevent accidental shock while adjusting the deflection plates. There are high voltage hazards present.

VIII. Emergency Procedure/Radioactive Material Spills

A. Contamination of the Laboratory

All spills of radioactive material must be cleaned promptly. The responsibility for cleaning up the spill rests on the individual working in the area involved and responsible for the spill. Under no circumstances should an untrained person attempt to examine or clean up a spill of radioactive material. Please call Radiation Safety at any step for assistance, if necessary, @ 593-1666. No spill /accident is too small for outside help.

The following general procedures should be followed when dealing with spills of radioactive material:

Major Spills - Those spills involving significant radiation hazards to personnel shall be decontaminated under the direct supervision of the Radiation Safety staff or appointed individual.

1. Notify all personnel not involved with the spill to vacate the area at once. Have an evacuee notify Radiation Safety of the incident.

2. Affected persons should limit their movement to confine the spread of contamination.

3. Stop further spread/contain the spill. If the material is liquid, place an absorbent material such as paper towels, tissues, sponges, etc. over the spill to prevent its spread. If the material spilled is powdered solid, attempt to contain its spread by covering the area with a protective barrier such as a drip tray, empty beaker, dampened material (paper or towels). If appropriate, close doors and windows, turn off room ventilation fans to prevent the spread of the powdered material.

4. Remove contaminated clothing at once, if necessary. Flush contaminated skin areas thoroughly with water. See Personnel Decontamination Procedures below. Use emergency showers and eye washes, if necessary.

5. Be sure the hood is on to draw the contamination out of the lab, close doors and windows, if appropriate. If possible, shut off ventilating equipment that may transport contaminated air from the contaminated area to other parts of the building. Remember that the fire alarm can be used for emergency purposes to vacate the building, if necessary.

6. Cordon off the contaminated area, place appropriate warning sign and vacate.

7. Assemble in a nearby safe or clean area and begin monitoring and decontamination of affected persons. Do Not Leave the Area unless adequately decontaminated or with the permission of Radiation Safety.

8. The person responsible for the spill shall prepare a report of the incident and follow up procedures for the Radiation Safety Office.

9. Record pertinent information in the survey logbook.

Minor Spills - Spills involving little or no radiation hazard to personnel may be decontaminated by laboratory personnel under the direction of the laboratory supervisor. Wear a film badge and ring dosimeter and appropriate protective clothing including rubber gloves and lab coat.

1. Contain the spill: If the material is a liquid, place an absorbent material such as paper towels, tissues, sponges, etc. over the spill to prevent its spread. If the material spilled is powdered solid, attempt to contain its spread by covering the area with a protective barrier such as a drip tray, empty beaker, dampened material (paper or towels). If appropriate, close doors and windows, turn off room ventilation fans.

2. Inform others of the spill: Adjust your response to the seriousness of the spill. Instruct those personnel present in the room at the time of the spill to remain in an evacuation area to prevent contamination spread. Evacuated personnel should not eat, drink, or smoke until they are monitored and found free of contamination.

3. Decontaminate the area: Plan ahead. Provide adequate protection and supplies for personnel involved in the contamination. Cover cleaned areas with plastic or paper to prevent its recontamination. Place all contaminated items in the proper waste containers.

4. Monitor the area: Using appropriate survey techniques, monitor the progress of the decontamination. Monitor all personnel and materials before releasing them to clean areas. Monitor to levels stated in how to decommission the lab (see Appendix 14). Record spill and follow-up procedures taken into logbook.

B. Personnel Decontamination Procedure

Decontamination procedures can begin while waiting for Radiation Safety or transfer to Hudson Health Center or O'Bleness Hospital.

Always try to decontaminate yourself (clothing) first before considering removing any articles of clothing. If you must do so, be sure to leave all contaminated items in the lab. Upon realizing that you are contaminated, seek out help from coworkers, so that they can make telephone calls (Radiation Safety, emergency services, etc.), get cleaning supplies, turn on water faucets, handle the survey meter to monitor cleanup efforts, etc., so that the spread of contamination can be minimized.

Skin or External Contamination

To properly decontaminate personnel, it is necessary to first define the area of contamination by means of proper monitoring techniques. Special emphasis should be placed on the location of any hot spots on the individual. The mildest methods of cleansing should be attempted first, progressing to more harsh methods when necessary to avoid abrading the skin. Cleansing methods in order of harshness are as follows:

1. Flushing with water
2. Soap and warm water
3. Mild abrasive soap (Lava soap), soft brush, and water
4. Detergent
5. Mixture 50% powered detergent and 50% cornmeal
6. Complexing solution (such as EDTA)
7. Solvent, i.e. scintillation fluid
8. Mild organic acid (citric acid)

Chemical treatment is to be used only when absolutely necessary, and then only under the direction of Radiation Safety.

After removal of contamination, individuals should take a thorough shower with special attention to washing the hair, hands, and fingernails.

In all personnel decontamination procedures, every effort should be made to prevent the spread of contamination.

Remember to always call Radiation Safety as soon as possible whenever personnel contamination is involved.

C. Contaminated Wounds

When the skin is lacerated by glassware or injured by hypodermic needles or other instruments containing radioactive materials, immediately wash the wounded area thoroughly under a stream of cold water. If bleeding is not severe, allow bleeding to cleanse the wound. If the radioactive material is unusually toxic, call Radiation Safety and Poison Control for advice. Common treatment is to apply pressure to the injured extremity or a pressure point tightly enough to occlude the veins without stopping the arterial pulse.

D. Ingestion of Radioactive Material

Notify Radiation Safety immediately after the incident for assistance. Accidental ingestion or swallowing of radioactive material should be treated like other types of poisoning. Please seek the advice of a physician and/or the Poison Control Center (1-800-222-1222) prior to initiating any treatment. Some, but not all poisons are treated by ingesting large volumes of water with or without emetics, followed by throat stimulation to induce vomiting.

E. Inhalation of Radioactive Materials

Notify Radiation Safety immediately after the incident for assistance. Accidental inhalation of gaseous or particulate radioactive materials should be treated by intentional coughing. Deep breathing of clean, non-radioactive air may also enhance the normal elimination process.

F. High Radiation Exposure

In the event of an accident involving the possibility of exposure to a high dose of radiation (> 1000 mRem) contact Radiation Safety immediately.

G. Lost/Stolen Radioactive Sources

If sealed or unsealed radioactive materials are lost, stolen or misplaced, contact Radiation Safety immediately. The longer the material is missing, the more difficult it will be to locate, and greater the potential hazard to personnel. Caution must be exercised when recovering lost material to avoid unnecessary personnel exposure.

All emergencies such as fire, lost or stolen radioactive material, accidental uptake of radioactive material, radiation injury, etc., require the same basic responses as described above**.** The proper authorities should be notified at once of such incidents and will act with other authorities to control emergencies of this nature. Any spill which can potentially cause injury to a person or property must be reported to Risk Management and Safety.

H. Decontamination of Tools, Equipment and Areas

Preliminary decontamination work can be performed first and should be done dry. It includes scraping off grease, removing adhesive tape and labels, brushing/blowing of powdered material. Remember that contamination may be spread further so perform this step with caution or eliminate it if necessary. Most equipment can be decontaminated by simply using soap and water and a sponge or paper towel. Dishwashing soap, laundry soap (Tide works well), or commercial decontamination soaps (Radcon, Radiac Wash, etc.) are all good for decontamination procedures. After using soap and water, contaminated equipment can be treated with more harsh chemical and physical methods. Start by using the least harsh methods first. Some examples of acids and other chemical agents include chromic, sulfuric, nitric, phosphoric and citric acids and sodium hydroxide, and acetone. Both chemical and physical methods can deteriorate the surface of the equipment. Proceed with caution. Call Radiation Safety for advice at any point along the process. Some of the decontaminating chemicals are powerful and toxic in their own way and can pose severe non-radiological hazard. Equipment that is used more than once, for only radioactive procedures, must have *Caution Radioactive* tape or labels attached to identify their use. This equipment should be stored separately from non-radioactive use equipment. In a few cases it may be cost effective to dispose of equipment that cannot be decontaminated.

Metal objects may sometimes be decontaminated with dilute solution of 10 % sodium citrate or ammonium bifluoride. The use of strong acids on metal tools may corrode them.

Plastics may be decontaminated with ammonium citrate, dilute acids or organic solvents.

Equipment must be decontaminated prior to the removal from the lab. After trying soap and water, glassware can be decontaminated using more powerful oxidizing or chelating agents. Chromic acid cleaning solution or nitric acid are common decontaminants of glass. If contamination cannot be removed, discard the glassware into radioactive waste. Be sure the glass is packaged to preclude injury to future handlers of the waste.

I. Emergency Procedure/User Emergency Telephone Numbers/Campus Safety Emergency Numbers

1. General Procedure

   Serious Injury, Minor Injury and Overexposure

   a. Notify the appropriate authorities:

Risk Management & Safety	593-1666
Radiation Safety Laboratory	593-1661
Alan Watts (Office/Cell)	593-4176/517-5075
David Ingram (Office/Home)	593-1705/594-7511
Crystal Brooks (Office/Cell)	597-2950/330-903-0506
SEOEMS Ambulance to O'Bleness Hospital	911
Poison Control Center	1-800-222-1222
Campus Care (Student Health)	593-1660
Ohio University Police Department (24 hours)	593-1911

a. If there is a serious injury with or without contamination or serious overexposure with or without contamination, transfer the injured without delay to O'Bleness Hospital.

b. If there is contamination with minor injury, remove clothing and begin decontamination. Transfer the person to Hudson Health Center or O'Bleness Hospital.

J. Laboratory Decommissioning

The main decommissioning objective at Ohio University is to decommission each laboratory/facility when an individual license is terminated. This will allow each laboratory/facility to be decommissioned immediately and minimize possible accidental exposures.

(See Appendix 14, Laboratory Decommissioning for details.)

IX. Radiation Safety Services

The Risk Management and Safety, Radiation Safety Office, provides a number of services to faculty, staff, and students in an effort to maximize the usefulness of radioactive materials in research and instructional programs while minimizing radiation hazards.

A. Procurement of Radioactive Materials and Radiation Machines

Risk Management and Safety is available to assist licensed users in procurement of radioactive materials and radiation machines as described in Section III. A. & VII. Risk Management and Safety also maintains a comprehensive file of catalogs of radioactive materials and supplies.

B. Request New Lab Space and Transfers of Radioactive Materials/Transfers of Employees from AU to AU

Risk Management and Safety is responsible for all transfers of radioactive materials to and from the Ohio University, to and from any branch of the University, to and from individuals on campus, and to and from separate buildings on the campus. All incoming shipments of radioactive materials, including transfers, are received at Risk Management and Safety, processed, and delivered to the receiver. Anyone who desires to move radioactive materials from one building to another must notify RMS. Employees, who initially went through the Radiation Safety Orientation with one AU (Authorized User) and later transfer to another AU, must complete the Employee Transfer Form. The AU must also sign this form saying they are responsible for this person.

C. Personnel Monitoring

1. Film Badge Service

   Personnel monitoring devices are issued to individuals, using radioisotopes or radiation machines, who are likely to receive an exposure greater than one tenth the allowable yearly dose. Luxel: beta, gamma, and X-Ray whole body badges (designated as "Pl"), and neutron, beta, gamma, X-Ray whole body badges (designated as "Jl"), and ring badges (designated as "U3") can be ordered by completing a "Film Badge/Bioassay Request Form" (Appendix 26) and sending it to Risk Management and Safety. Each user must transfer funds each quarter to Risk Management and Safety for the cost of the badges. The Jl, Pl and U3 badges are distributed approximately the lst week of each month.

2. Bioassay

   If indicated, personnel working with non-sealed quantities of radioactive materials are required to submit urine samples for analysis. Initiate the bioassay service by submitting the Film Badge/Bioassay Request Form (Appendix 26).

D. Surveys and Wipe Tests

Routine surveys for radioactive contamination are conducted by the Radiation Safety Officer or a Radiation Safety technician. Surveys are completed once per month or more often if required by the nature of operations. The laboratory supervisor or Authorized User is called if contamination is observed.

E. Decontamination

The Radiation Safety Officer is required to supervise major decontamination of laboratories, equipment, and personnel. Refer to Section VIII for instructions to be followed in the case of decontamination. DO NOT ATTEMPT DECONTAMINATION WITHOUT THE APPROVAL OF RISK MANAGEMENT AND SAFETY. Some contamination problems require special procedures and

equipment. Minor decontamination may be handled by laboratory personnel under most circumstances. RMS is available to provide assistance for any contamination event.

F. Leak Tests of Sealed Sources

Risk Management and Safety will perform all required sealed source leak tests. Persons responsible for the sealed sources will be informed of test results, if contamination is found.

G. Survey Instrument Calibration

Risk Management and Safety will perform all required survey instrument calibration. Major maintenance and repairs will be the responsibility of the person who owns the instrument. Calibration will be completed annually at a minimum.

H. Radiation Machine Surveys

X-Ray diffraction, medical, and dental X-Ray machines are routinely surveyed for stray or scattered radiation and checked for proper operation. A report of the survey is sent to the licensed user. The user must notify Risk Management and Safety of any major modifications so that a resurvey can be conducted.

I. Radioactive Waste Disposal

See Section III. J. for details.

J. Radiation Safety Lectures

The Radiation Safety Officer is prepared to give radiation safety lectures and/or demonstrations to any class or group as required

K. Consultant Service

The Radiation Safety Officer is available for consultation on any problems regarding radiation safety or use of radioactive materials or radiation machines. The RSO will also provide training to inexperienced license applicants when required.

X. Required Forms to be Completed by the Applicant or Authorized User, or Services to be Requested

A. Application for Permission to Obtain and Use Radioactive Isotopes

This form is to be completed and approved by the Radiation Safety Committee prior to ordering and using radioactive isotopes. See Section II. B.

B. Release of Decayed (non-radioactive) Solid Waste to Ordinary Refuse

This form is to be completed for every container of radioactive waste that has been held until the radioactive material (half-life of 120 days or less only) decays to less than 0.05 uCi and is going to be released as ordinary refuse as a result. All criteria for release of decayed (non-radioactive) waste to ordinary refuse, as discussed on the form, must be met. See Appendix 25 for form.

C. Radioactive Waste Disposal Request

If there is a need for radioactive waste disposal by transfer to Risk Management and Safety, complete the form and send to Risk Management and Safety. See Section III. J. (Appendix 23) for details or use the following link:
http://www.ohio.edu/riskandsafety/docs/radwaste_form.xls

D. Radiation Exposure History Form

Each individual who has worn dosimetry to monitor exposure with a previous company or institution must complete the Radiation Exposure History Form. See Appendix 22 for sample form.

E. Film Badge/Bioassay Request Form

This form is to be used when there is a need to request a film badge, terminate a film badge, initiate or terminate a bioassay, reactivate a film badge or to temporarily stop a bioassay or film badge. See Appendix 26.

F. Individuals Who Have Occasion to Enter a Restricted Area (Radiation Laboratory)

See Appendix 18 for a form along with Occasional Visitor Orientation information.

G. License Renewal

Every 5 years all authorized projects must be renewed by the Authorized User. See Appendix 17.

H. Radiation Safety Orientation Request

If you would like to request a Radiation Safety Orientation or reactivate your authorization as a radiation worker, please see Appendix 8.

I. Radiation Safety Orientation for Pregnancy

See Appendix 11 and RSH, Section I. D. 5. "Pregnancy Training," for additional information.

J. Transfer Forms

See Section IX. B. for information about requesting new lab space and transfers of radioactive material as well as transfers of employees from AU to AU. See Appendix 20 for the transfer forms.

K. Usage, Transfer, Waste Log & Survey Record for Radioactive Material (RAM) Form

This is a "suggested use" form for keeping track of those items listed in the form. See Appendix 27.

L. Faculty and Parental Responsibility for Minors Under the Age of 18 in Ohio University Laboratories Form

Minors under the age of 18, who are not registered Ohio University students and not employed by the university, that are permitted in a radioactive material use lab by the faculty member, will be required to submit this completed form to the Radiation Safety Office at Risk Management and Safety prior to the minor's initial entry into the lab. See appendix 28.