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**APPENDIX A GENERAL INFORMATION**

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**REFERENCES**
THE RADIATION SAFETY COMMITTEE

PURPOSE OF THE RADIATION SAFETY COMMITTEE

The purpose of the University of Delaware Radiation Safety Committee is the promotion of the best practice in safe handling and use of radioactive materials and radiation producing devices. Occupational radiation exposures to individuals and the environment are to be maintained as low as is reasonably achievable. The purview of the Committee is the University campus, regional facilities, affiliated institutions, and University properties throughout the State of Delaware and University research vessels in national and international waters.

The establishment of a Radiation Safety Committee is required by federal regulations before an institution will be licensed for "broad scope" use of radionuclides in research and development.

Federal and state government regulations for radionuclides and x-ray producing equipment shall be implemented by the Committee in association with individual radiation users, department heads, and the administration of the University.

Radiation, as used herein, includes x-rays, gamma rays, alpha and beta particles, high speed electrons, neutrons, protons, and other nuclear particles; but not sound, microwaves or radio waves, or visible, infrared, or ultraviolet light.

ORGANIZATION OF THE RADIATION SAFETY COMMITTEE

The Radiation Safety Committee shall be appointed by the Provost of the University.

Membership shall consist of faculty and professional staff experienced in handling radionuclides, the use of radiation producing devices, the practice of radiation protection, or those who have a desire to institute safe practices with regard to radiation. The Radiation Safety Officer shall be the representative of management.

The activities of the Committee are directed by the chairperson; who is appointed by the Provost of the University upon recommendation of the Committee.

The business of the Committee is administered through the Department of Occupational Health & Safety which is directed by the Radiation Safety Officer. The Radiation Safety Officer is a full-time professional staff member appointed to this position based on experience, education and qualifications in the area of Radiation Safety and with the recommendation of the Radiation Safety Committee. The Radiation Safety Officer serves as Executive Secretary of the Radiation Safety Committee.

Meetings of the Committee shall be called by the chairperson at his/her discretion, not less than once per calendar quarter or on petition by any member of the Committee.
A quorum of the Committee to conduct business shall consist of at least three members plus the Radiation Safety Officer.

The Radiation Safety Officer and the chairperson shall conduct the interim business of the Committee subject to the approval of the Committee at the next scheduled meeting.

1.3. **RESPONSIBILITIES OF THE RADIATION SAFETY COMMITTEE**

1.3.1. Assume the responsibility for radiation safety aspects for all University programs involving radioactive materials or radiation producing devices.

1.3.2. Review and grant permission for, or deny the use of radioactive materials or radiation producing devices within the University. Approval is necessary before a project involving these materials or devices can be initiated. A majority vote of the Committee is required for approval.

1.3.3. Review and prescribe special conditions, requirements, and restrictions that may be necessary for safe handling of radioactive materials and radiation producing devices. These may include oral or written examination, additional training of personnel, physical examination (e.g. blood test, urine test, etc.), upgrading of facility (hoods, ventilation, shielding, etc.), evaluation of airborne radioactivity, designation of use areas within the laboratory, proper caution signs, proper disposal methods, proper handling procedures and procedures to be followed after spills or other radiation accidents.

1.3.4. Serve as a liaison with the Delaware State Office of Radiation Control and the United States Nuclear Regulatory Commission in matters of registration, licensing and radiation safety.

1.3.5. Receive and review periodic and/or urgent reports from the Radiation Safety Officer regarding:

A. Results of area monitoring.

B. Personnel exposures.

C. Accidents in handling, storage or use of radionuclides or x-ray producing equipment.

D. Loss or theft of radionuclides and x-ray producing equipment.

E. Records of radionuclide and x-ray producing equipment procurement and disposal.
1.3.6. Recommend and/or initiate remedial action up to and including termination of permits and authorizations of personnel and confiscation of radioactive materials or radiation producing devices where safe procedures are not followed under an authorized project or where procedures are not in compliance with government and University regulations. Authorize resumption of operations, stopped by the Radiation Safety Officer when the operations are in compliance with regulations.

1.3.7. Recommend modifications to operating and maintenance procedures, and review and recommend in advance of construction of new buildings or alterations or remodeling of existing buildings, proper ventilation, flow rates and filtration for fume hoods, shielding, construction material, furniture and finishes for laboratories and rooms in which the use and storage of radioactive materials or radiation producing devices is contemplated. The Department of Occupational Health & Safety shall carry out the Committee's responsibility in this area to ensure the concept and philosophy of "as low as is reasonably achievable" (radiation exposure to personnel and environment) is carried out.

1.3.8. Keep Department Chairpersons, Permit Supervisors, Authorized Users and other academic and administrative officers advised of changes in rules and recommendations of various government agencies concerned with radiation safety and the safe use of radioactive materials and radiation producing devices.

1.3.9. Keep a written record of actions taken in approving or disapproving the use of radioactive materials and radiation producing devices and other transactions, communications, and reports involving the work of the Committee.

1.3.10. Delegate to the Radiation Safety Officer the authority to review, grant or deny temporary permits for use of radioactive materials and radiation producing devices. Temporary permits shall be approved or denied at the next regularly scheduled Committee meeting.

1.3.11. Arrange for and/or conduct an annual management audit of the Radiation Safety Program.

1.4. APPEAL OF COMMITTEE ACTIONS

Appeals of actions taken by the Radiation Safety Committee should be directed to the Chairman of the Radiation Safety Committee.

2.0. THE RADIATION SAFETY OFFICER

2.1. AUTHORITY OF THE RADIATION SAFETY OFFICER

The authority of the Radiation Safety Officer is derived from the Office of the Provost. The Radiation Safety Officer is a member and the authorized
representative of the Radiation Safety Committee regarding radiation protection and control within the University.

The Radiation Safety Officer, or his/her authorized representative has the authority to stop all operations with radioactive materials or radiation producing devices where a potential hazard or violation of federal, state or University rules and regulations exist. Resumption of operations may take place only upon authorization from the Radiation Safety Committee.

The Radiation Safety Officer shall determine the conditions necessary for maintaining occupational radiation exposures "as low as is reasonably achievable".

2.2. RESPONSIBILITIES OF THE RADIATION SAFETY OFFICER

The Radiation Safety Officer has the responsibility for ensuring adherence to all regulations of the United States Nuclear Regulatory Commission (U.S.N.R.C.), state and local agencies, and other applicable codes and regulations and shall advise and assist the Radiation Safety Committee regarding regulations issued by or subscribed to by the Radiation Safety Committee.

2.2.1. Implement the organization, administration and management of the Radiation Safety Program of the University of Delaware.

2.2.2. Interpret regulations which govern the use of sources of ionizing radiation and disseminate information on radiation safety.

2.2.3. Develop and maintain a manual of Radiation Safety regulations and procedures for the University of Delaware.

2.2.4. Supervise all radiation protection programs and develop and maintain these programs.

2.2.5. Review research protocols and applications for the use of sources of ionizing radiation. Make recommendations to the Radiation Safety Committee.

2.2.6. Coordinate the dosimetry service, maintain personnel exposure records, and give timely notification of exposures to supervisors as well as individuals exposed.

2.2.7. Review all requests for procurement of radionuclides to assure compliance with limitations for possession and use.

2.2.8. Procure, receive and arrange delivery and shipment of all radioactive materials coming to or leaving the University.

2.2.9. Maintain records of procurement and receipt of all radioactive materials and radiation producing devices.
2.2.10. Supervise the radioactive waste disposal program.

2.2.11. Instruct groups of employees and students on proper procedures for handling radioactive materials, radiation in restricted areas, health protection problems associated with exposure to radiation, exposure precautions, protective devices and applicable portions of the Commission's regulations.

2.2.12. Maintain radionuclide disposal records and records of disposal, transfer, or shutdown of any radiation producing devices.

2.2.13. Conduct periodic radiation surveys and wipe tests in use and storage areas.

2.2.14. Conduct alpha scintillation meter surveys when applicable (e.g. radium storage areas) and provide instrumentation for overseeing the decontamination of alpha-contaminated areas or equipment.

2.2.15. Conduct surveys on and register all radiation producing devices.

2.2.16. Perform leak tests and physical inventories on sealed sources of radionuclides.

2.2.17. Maintain running inventory of radionuclides and sealed sources.

2.2.18. Assume the responsibility for storage of sources and materials not in use.

2.2.19. Assume the responsibility for calibration of monitoring and surveying equipment.

2.2.20. Verify and report to appropriate authorities any radiation incident which may have resulted in injury to, or contamination of, personnel or damage to property.

2.2.21. Note and take steps in order to correct radiation safety problems.

2.2.22. Conduct periodic laboratory audits.

2.2.23. Perform other duties related to radiation safety.

3.0. UNIVERSITY REGULATIONS GOVERNING THE USE OF RADIATION PRODUCING DEVICES

The rules and regulations contained in this section are derived from the Delaware Radiation Control Regulations, 16 Delaware Code 7405. Failure to comply with these rules and regulations can result in fines, imprisonment, or both, or other sanctions as provided by law in addition to actions taken by the Radiation Safety Officer, the Radiation Safety Committee or the University Administration.

3.1. DEFINITIONS
A. Analytical X-Ray Equipment: A group of components utilizing x-rays to determine the elemental composition or to examine the microstructure of materials.

B. Enclosed Beam X-Ray System: An analytical x-ray system in which all possible x-ray paths are fully enclosed as specified in Section 8.3.

C. Facility: Any location, room, laboratory, or area in which a radiation producing device is housed, except for a radiation producing device that is not operable.

D. Local Components: Parts of an analytical x-ray system and areas that are struck by x-rays such as radiation source housings, port and shutter assemblies, collimators, sample holders, cameras, goniometers, detectors and shielding, but do not include power supplies, transformers, amplifiers, readout devices, and control panels.

E. Normal Operating Procedures: Step-by-step instructions necessary to accomplish the analysis. These procedures shall include sample insertion and manipulation, equipment alignment, routine maintenance by the owner, and data recording procedures which are related to radiation safety.

F. Open-Beam X-Ray System: An analytical x-ray system in which an individual could accidentally place some part of his body in the primary beam path during normal operation.

G. Particle Accelerator: Any machine capable of accelerating electrons, protons, deuterons, or other charged particles in a vacuum and of discharging the resultant particulate or other radiation into a medium at energies usually in excess of 1 MeV.

H. Primary Beam: The radiation which passes through an aperture of the source housing by a direct path from the x-ray tube or a radioactive source located in the radiation source housing.

I. Radiation Producing Device: Any device capable of producing radiation except those which produce radiation only from radioactive material.

J. Safety Device: A device which prevents the entry of any portion of an individual's body into the primary beam path or which causes the beam to be shut off upon entry into its path.

3.2. PROCUREMENT OF RADIATION PRODUCING DEVICES

All purchase requests for new radiation producing devices shall be approved by the Department of Occupational Health & Safety. The Department of
Occupational Health & Safety shall evaluate the health and safety implications of each purchase and ensure operating personnel can operate the equipment in a safe manner when the equipment arrives.

Registration of all new radiation producing devices with the State of Delaware Office of Radiation Control shall be completed by the Department of Occupational Health & Safety upon receipt of the equipment.

3.3. TRANSFERS OF RADIATION PRODUCING DEVICES

Any transfers of radiation producing devices to, from or within the University shall be approved by the Department of Occupational Health & Safety. Transfers shall be reported within three weeks of the date of transfer. The following information shall be provided in the report:

A. The name and address of the shipper and receiver.

B. The manufacturer, model and serial number of the equipment.

C. Date of transfer.

3.4. AUTHORIZATION TO USE RADIATION PRODUCING DEVICES

No person shall use any radiation producing devices unless approved by the Radiation Safety Committee.

Radiation Safety Committee approval or denial of an application to use radiation producing devices is based on:

A. Radiation safety training as required by the Radiation Safety Officer and mandated by the Delaware Radiation Control Regulation, 16 Delaware Code 7405 for the applicant.

B. Demonstrated competency in the use of the equipment.

C. Availability of survey equipment for monitoring purposes by the applicant.

D. Adequacy of the facility and equipment for the proposed use and compatibility of the project with other uses of the laboratory.

E. Training and experience of others working with the equipment.

Application forms can be obtained from the Department of Occupational Health & Safety.

3.4.1. Personnel Definitions
A. Permit Supervisor: The faculty or professional staff member who directs the research/teaching project and/or supervises the laboratory in which radiation producing devices are used.

A Permit Supervisor is expected to meet the following requirements:

1. Training: A college degree in science or engineering and training by formal course work or on-the-job training covering:
   a. Principles and practices of radiation protection.
   b. Radiation measurements, standardization and monitoring techniques and measurements.
   c. Mathematics and calculations, basic to the use and measurement of radiation.
   d. Biological effects of radiation.

2. Experience: Generally, the minimum experience required for a Permit Supervisor will be one year's research with the same or a similar radiation producing device.

3. Knowledge of his/her responsibilities as outlined in Section 3.5.

B. Operator: The faculty, professional or salaried staff member, graduate student or undergraduate student who assists the Permit Supervisor or works under the authority of the Permit Supervisor but does not require direct supervision.

An Operator is expected to meet the following requirements:

1. Training: Formal course work or on-the-job training covering the subjects listed under Item 3.4.1.A.1.

2. Experience: Generally, the minimum experience required for an operator is the length of time necessary to demonstrate competency in the safe operation of the equipment.

3. Knowledge of his/her responsibilities as outlined in Section 3.6.

C. Trainee: A person working with radiation producing devices who does not meet the qualifications of an operator and who must work under direct supervision of the Permit Supervisor or an operator. A trainee must have knowledge of his/her responsibilities as outlined in Section 3.6.

3.4.2. Personnel Training Requirements
3.4.2.1. Operators

Training requirements for operators are as follows:

A. Attendance at seminars on Radiation Safety and other subjects as specified under 3.4.1.A.1. presented by the Department of Occupational Health & Safety in conjunction with on-the-job training as specified in 3.4.1.B.2. and working experience under the direct supervision of a Permit Supervisor or appropriate operator; or,

B. On-The-Job training specified in 3.4.1.B.2. and experience operating the same or a similar radiation producing device under direct supervision and instruction of the Permit Supervisor or operator, and instruction covering:

1. Subjects as specified under 3.4.1.A.1.
2. Rules and Regulations of the University of Delaware including precautions and procedures to minimize exposure.
4. Energy of radiation emitted from the devices used.
5. Interaction of radiation with matter.
7. Security requirements and designated work areas in the laboratory.
8. Operation of instruments used to detect radiation.
9. Identification of radiation hazards associated with the use of the equipment.
10. Proper procedures for operating the equipment.
11. Proper procedures for reporting an actual or suspected overexposure.
12. Significance of various radiation warning and safety devices incorporated into the equipment.
13. Responsibilities of Permit Supervisor, Operators, and Trainees at the University of Delaware.
An oral or written examination to evaluate the training of the employee or student may be administered by the Radiation Safety Officer.

3.4.2.2. Other Training Requirements

A. Permit Supervisors and Line Supervisors shall assure all individuals under their supervision who work in an x-ray laboratory attend periodic radiation safety training program. Training shall be provided before an individual works with radiation producing devices.

B. Permit Supervisors and Line Supervisors shall assure all individuals working in or frequenting any facility are kept informed of the radiation in such portions of the facility; are instructed in the health protection problems associated with exposure to radiation, in precautions or procedures to minimize exposure, and in the purposes and functions of protective devices employed; are instructed in, and instructed to observe, to the extent within the worker's control the applicable provisions of the Delaware Radiation Control Regulations for the protection of personnel from exposures to radiation occurring in such areas; are instructed of their responsibility to report promptly to the Department of Occupational Health & Safety any condition which may lead to or cause a violation of the Delaware Radiation Control Regulations or unnecessary exposure to radiation; are instructed in the appropriate response to warnings made in the event of any unusual occurrence or malfunction that may involve exposure to radiation; and are advised as to the radiation exposure reports which workers may request pursuant to 16 Delaware Code 7405. The extent of these instructions shall be commensurate with potential radiological health protection problems in the facility.

3.4.3. Project Approval

The project for which the use of radiation producing devices is requested shall be reviewed by the Radiation Safety Officer and the Radiation Safety Committee for feasibility based on the applicant's experience with the radiation producing device and other information given in the project section of the application for authorization.

3.4.4. Facility Approval

Radiation producing devices may only be used in those facilities which have been approved by the Radiation Safety Officer and the Radiation Safety Committee.

3.4.4.1. Monitoring Instruments

Unless specifically exempted by the Radiation Safety Committee or the Radiation Safety Officer, each Permit Supervisor using radiation producing devices shall
have available and in operating condition a properly calibrated survey or monitoring instrument appropriate to the type and level of ionizing radiation used.

3.4.4.2. Other Radiation Safety Equipment

The Radiation Safety Committee may require the use of other special equipment or devices that it may deem necessary to ensure the safe use of radiation producing devices in a given situation. This may include special shielding, alarms and warning devices and other such apparatus.

3.4.5. Issuance of Authorized Permits

Upon receipt of the application for authorization, the Radiation Safety Officer or his/her representative shall review the training and experience of the applicant(s) and carry out a pre-authorization investigation and inspection of the personnel and facility.

The Radiation Safety Officer may issue a temporary permit as specified in Section 1.3.10.

A temporary permit with "Conditional Approval" may be granted when a Permit Supervisor has experience and training using one type of radiation producing device and requests use of another. At the discretion of the Radiation Safety Committee, "Conditional Approval" may require oral or written examination or other conditions prescribed as specified in Section 1.3.3.

Permanent permits are issued after review and approval by the Radiation Safety Committee.

Permits expire one (1) year after the date issued.

3.4.6. Amendment(s) to Authorized Permits

Amendments will be granted on the same basis as the original application for authorization.

3.4.7. Renewal of Authorization

Prior to the expiration date of the permit, the Department of Occupational Health & Safety will contact the Permit Supervisor concerning renewal. At a scheduled meeting, changes in personnel, facility, project, and/or equipment will be made. Revised applications will be prepared by the Department of Occupational Health & Safety and submitted to the Radiation Safety Committee for authorization.

3.5. RESPONSIBILITIES OF PERMIT SUPERVISOR(S)
Those persons who have been authorized by the Radiation Safety Committee as Permit Supervisors are responsible for the safe use of radiation producing devices by the operators and trainees under their supervision. They shall also:

A. Ensure compliance with the Delaware Radiation Control Regulations, 16 Delaware Code 7405, and University rules and regulations regarding radiation producing devices.

B. Instruct personnel (students and employees) as outlined in Section 3.4.2. of this manual. Documentation of training shall be submitted to the Department of Occupational Health & Safety.

C. Ensure radiation producing devices utilized in undergraduate teaching activities are under the supervision and in the physical presence of an operator approved by the Radiation Safety Committee.

D. Ensure that operators and trainees wear personnel dosimeters as specified by Section 5.0. and follow protective rules for minimizing exposure.

E. Ensure radiation surveys are conducted with each use of the equipment.

F. Ensure protocols provide for adequate safety precautions.

G. Limit the use of the radiation producing devices to operators and trainees under their permit.

H. Limit the use of the equipment to experiments and configurations approved by the Radiation Safety Committee.

I. Bring to the attention of the Radiation Safety Officer any defect or deficiency in radiation protection devices and procedures.

J. Provide an operator for radiological health hazard surveys.

K. Attend seminars on Radiation Safety as required by the Radiation Safety Committee.

L. Communicate to the Radiation Safety Officer all pertinent information regarding changes in their permits (e.g. change in facility, deletion or addition of personnel, changes in equipment configuration, etc.).

M. Cooperate with the Radiation Safety Committee and Radiation Safety Officer on all matters related to radiation safety.

N. Answer in a timely manner communications from the Radiation Safety Committee or Radiation Safety Officer regarding deficiencies or violations of regulations.
O. Develop and maintain in conjunction with the Radiation Safety Officer written emergency procedures for each facility. Emergency procedures shall be posted in a conspicuous location near each radiation producing device. Emergency procedures should list telephone numbers of the Supervisor, Radiation Safety Officer and Health Physicist, and as a minimum include instructions for addressing known or suspected accidents involving radiation exposure.

P. Develop, maintain and make available operating procedures. All exceptions to the normal operating procedures shall be approved by the Radiation Safety Officer.

3.6. RESPONSIBILITIES OF AUTHORIZED OPERATOR(S) AND TRAINEE(S)

Each person who is authorized to use radiation producing devices shall comply with the University rules and regulations contained in this manual and shall:

A. Survey the equipment for leakage radiation with the change of each sample. Results of surveys shall be recorded in the instrument log book.

B. Report immediately to the Permit Supervisor or Department of Occupational Health & Safety the details of any accident or overexposure to radiation.

C. Wear personnel dosimeters as directed and comply with rules concerning dosimeters.

D. Follow protective rules for minimizing personal exposure to x-radiation and keep exposure as low as reasonably achievable.

E. Limit the configurations of the radiation producing devices to those approved by the Radiation Safety Committee.

F. Receive additional education as required.

3.7. PERMISSIBLE RADIATION LEVELS

A. Restricted Areas

Radiation levels in a restricted area shall not be such that an individual could receive in any calendar quarter from any source of radiation in the permitter's possession a dose in excess of the limits specified below:

**Rems Per Calendar Quarter**
Whole body: head and trunk;
active blood-forming organs;
lens of eyes, or gonads.............1 1/4

Hands, forearms, feet and
ankles............................18 3/4

Skin of whole body..............7 1/2

Minors, individuals under 18 years of age, shall not be allowed to receive a
dose in excess of ten percent of the limits stated above.

B. Unrestricted Areas

No radiation producing device facility shall produce radiation in such a
manner as to create in any unrestricted area:

1. Radiation levels which, if an individual were continuously present
   in the area, could result in his/her receiving a dose in excess of 2
   millirems in any one hour; or

2. Radiation levels which, if an individual were continuously present
   in the area, could result in his receiving a dose in excess of 100
   millirems in any seven consecutive days.

4.0. POSTING REQUIREMENTS

Each facility containing radiation producing devices shall be conspicuously posted
with a sign or signs bearing the radiation symbol and the words "Caution - X-Ray
Equipment" or words having a similar intent.

4.1. EXCEPTIONS FROM POSTING REQUIREMENTS

Caution signs are not required to be posted in facilities containing electron
microscopes, or equipment which requires the confinement of the x-ray beam to a
vacuum and any others determined intrinsically safe by the Radiation Safety
Officer.

5.0. PERSONNEL MONITORING

5.1. STATE OF DELAWARE REQUIREMENTS

Finger or wrist dosimetric devices shall be provided to and shall be used by:
1. Personnel using radiation producing devices having an open-beam configuration and not equipped with a safety device.

2. Personnel maintaining radiation producing devices if the maintenance procedures require the presence of a primary x-ray beam when any local component in the radiation producing device is disassembled or removed.

5.2. UNIVERSITY REQUIREMENTS

In addition to the State of Delaware requirements, personal dosimeters are required for University personnel and students using all radiation producing devices except for the following: electron microscopes, equipment which requires the confinement of the x-ray beam to a vacuum and any others determined intrinsically safe by the Radiation Safety Officer.

5.3. DOSIMETER INFORMATION

A. The Department of Occupational Health & Safety issues film and ring badges to individuals who require them. Individuals must fill out a Request for Personnel Dosimeter Form available from the Department of Occupational Health & Safety.

B. The badge, when required, must be worn at all times when the individual is occupationally exposed. It shall be worn in a fashion so as to indicate whole body exposure (breast pocket, collar, or belt) except in the case of ring, wrist, or ankle badges.

C. Badges are issued once per month.

D. The badge is not to be worn when the individual is undergoing diagnostic or therapeutic radiation exposure.

E. When not in use, the badge shall be stored in a location away from radiation (above background), excessive heat or moisture.

F. A badge which is not returned for processing within two weeks of the expiration date of the badge shall be considered lost. If found, the Department will be charged a late fee; or if lost, a lost fee.

5.4. RECORDS AND REPORTS

A. Permanent records of film badge exposures are maintained by the Department of Occupational Health & Safety.

B. In cases where an individual monitored for external exposure receives a monthly exposure equal to or exceeding 100mR, the Department of Occupational Health & Safety will notify the individual through a written
Radiation Exposure Report. The individual shall provide the information requested on the report and return it to the Department of Occupational Health & Safety within five days of its receipt. The report information is necessary for proper exposure evaluation and remedial action. Radiation exposures shall be kept as low as reasonably achievable.

C. The Department of Occupational Health & Safety will provide an individual on an annual basis or upon written request, a copy of his/her external occupational exposure at the University.

D. Individuals who indicate on the University of Delaware Request for Personnel Dosimeter Form that they have had previous occupational exposure which was recorded by a personnel dosimeter at other institutions shall authorize release of such exposure from each of these institutions to the University of Delaware, Department of Occupational Health & Safety.

6.0. DEMONSTRATIONS

A. Demonstrations involving radiation producing devices shall only be given by a permit supervisor or operator.

B. Participants in a course who will be using radiation producing devices for experimentation shall do so only under direct supervision of a permit supervisor or an authorized operator.

C. The Department of Occupational Health & Safety is available to assist in demonstrations or in the education of participants and has readily available training materials which would be appropriate for all x-ray demonstrations and course participants.

7.0. RADIATION EMERGENCIES

Incidents resulting in an overexposure may require immediate notification of State of Delaware Office of Radiation Control. Any person who suspects an overexposure to radiation from any source must report immediately, by phone or in person, to the Radiation Safety Officer. (Any exposure to the whole body in excess of 1.25Rem in a period of 13 weeks or less is regarded as an overexposure for purposes of these regulations.)

7.1. CALL LIST FOR RADIATION INCIDENTS

The following information shall be posted in each facility:

In case of emergency call:
1. Occupational Health & Safety 831-8475 (normal hours)
2. Public Safety 831-2222 (off hours)
3. Fire 911 or 9-911 from a University phone

8.0. ANALYTICAL X-RAY EQUIPMENT

8.1. GENERAL REQUIREMENTS FOR ALL FACILITIES

A. Unused ports on radiation source housings shall be secured in the closed position in a manner which will prevent casual opening.

B. All analytical x-ray equipment shall be labeled with a readily discernible sign or signs bearing the radiation symbol and the words "Caution Radiation - This Equipment Produces Radiation When Energized", or words having a similar intent, near any switch that energizes an x-ray tube if the radiation source is an x-ray tube.

C. An easily visible warning light labeled with the words "X-Ray On" or words having a similar intent, shall be located near any switch that energizes an x-ray tube and shall be illuminated only when the tube is energized. Such warning lights shall have fail-safe characteristics.

D. Each x-ray tube housing shall be so constructed that, with all shutters closed, the leakage radiation measured 5cm from its surface is not in excess of 2.5mRem in one hour at any specified tube rating.

E. Each x-ray generator shall be supplied with a protective cabinet which limits leakage radiation measured 5cm from its surface to 0.25mRem in one hour.

F. The local components of an analytical x-ray system shall be located and arranged and shall include sufficient shielding or access control such that no radiation levels exist in any area surrounding the local component group which could result in a dose to an individual in excess of the following dose limits:

1. Radiation levels which, if an individual were continuously present in the area, could result in his/her receiving a dose in excess of 2 millirems in any one hour; or,

2. Radiation levels which, if an individual were continuously present in the area could result in his/her receiving a dose in excess of 100 millirems in any seven consecutive days.
These levels shall be met at any specific tube rating.

G. X-Ray diffraction equipment should be placed in a room separate from other work areas whenever possible.

8.2. SPECIFIC REQUIREMENTS FOR OPEN-BEAM X-RAY FACILITIES

A. The radiation source housing shall have a warning device which indicates the x-ray tube status (on-off) and/or a warning device indicating the shutter status (open-closed) located near each port. These devices shall be fail-safe.

B. Each port on the radiation source housing shall be equipped with a shutter that cannot be opened unless a collimator or a coupling has been connected to the port.

C. A system barrier shall be provided which prevents the entry of any portion of an individual's body into the primary x-ray beam path and has sufficient inherent shielding so that the dose equivalent received by individuals in the surrounding controlled areas does not exceed the dose limits specified in 3.7.A.

8.3. ADDITIONAL REQUIREMENTS FOR ENCLOSED BEAM SYSTEMS

A. The x-ray tube, sample, detector and analyzing crystal (if used) shall be enclosed in a chamber of coupled chambers that cannot be entered by any part of the body during normal operation.

B. The sample chamber closure shall be interlocked using a failsafe design with the x-ray tube high voltage supply or a shutter in the primary beam so that no x-ray beam can enter the sample chamber while it is open unless the interlock has been consciously and deliberately defeated.

C. If there is more than one port in the radiation source housing all requirements must be satisfied for each port in every source housing associated with the system.

8.4. OPERATING REQUIREMENTS

Only those procedures specified by the manufacturer of the x-ray system shall be used unless an alternate procedure has been specified by the permit supervisor and approved by the Radiation Safety Officer; or, in those cases which do not risk the possibility of personnel exposure, the permit supervisor may at his/her discretion specify alternate procedures.
A. No person shall bypass a safety device unless such person has obtained the approval of the Radiation Safety Officer. Such approval shall be for a specified period of time. When a safety device has been bypassed, a readily discernible sign bearing the words “Safety Device Not Working” or words having similar intent shall be placed on the radiation source housing.

B. Personnel shall not expose any part of their body to the primary radiation beam.

C. Only trained personnel, as approved by the Radiation Safety Officer, shall be permitted to install, repair, or make other alterations to the tube apparatus complex.

D. Safety interlocks shall not be used to de-activate the x-ray beam except in an emergency or during testing of the interlock system. If the interlock system does turn off the x-ray beam, it shall not be possible to resume operation without resetting the beam "On" switch at the control panel.

E. All safety devices (interlocks, shutters, warning lights, etc.) shall be tested once per month to insure their proper operation. Records of such tests shall be maintained.

F. Permanent shielding should be used in preference to temporary shielding. Lead foil should be used carefully, as it is easily distorted and may permit radiation leaks.

8.5. REPAIR AND ALIGNMENT

Most severe injuries occur during non-routine operations such as repair and alignment. It is required that the permit supervisor or experienced operator for an x-ray installation be present when nonroutine operations are to be undertaken, especially if the operation to be performed is a new one for the operator. All persons doing alignment shall wear safety glasses to reduce the risk of accidental exposure to the lens of the eye.

A. No operation involving removal of covers, shielding materials or tube housing; or, modifications to shutters, collimators, or beam stops shall be performed without ascertaining that the tube is off and will remain off until safe conditions have been restored. Power shall be secured at its source by a padlock if possible.

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

C. Alignment procedures recommended by the manufacturer of the x-ray system shall be used when available.
D. Alignment procedures involving risk of overexposure shall not be used unless approved by the Radiation Safety Officer and the Permit Supervisor.

E. If an alignment procedure may result in increasing the dose rate in any area so that the usual designation of that area no longer applies, the person in charge shall notify the Radiation Safety Officer who shall direct the construction of temporary barriers and warning signs, as required, and shall keep the area under radiological surveillance until normal operation has been restored.

F. Repairs shall be carried such that pieces left out during re-assembly will be conspicuous.

G. After re-assembly the x-ray system shall be surveyed by the Radiation Safety Officer or member of his/her staff for any change in the radiological health hazard status. Corrective actions/recommendations shall be implemented prior to the restoration of normal operations. Particular attention should be given to the alignment of shielding, shutters and collimators. Lead parts should be inspected for damage or distortion which could result in radiation leakage and should be mounted in such a way that they will not cold-flow because of their own weight.

H. Procedures and apparatus utilized in beam alignment shall be designed to minimize radiation exposure to the operator:

1. Particular attention shall be given to viewing devices to assure lenses and other transparent components attenuate the radiation beam to minimal levels.

2. When alignment involves working near the open primary radiation beam, the beam current shall be reduced in order to lower the exposure rate.

3. If a fluorescent alignment tool is used, dimming the room light will permit a significant reduction in beam current.

4. The fluorescent alignment tool shall be long enough to permit the operator's hand to be kept a safe distance from the beam.

5. The operator shall be familiar with the manufacturers recommended alignment procedures and copies of these should be available for reference.

8.6. USE OF NON-STANDARD ACCESSORIES
Any device for use with an x-ray tube shall be regarded as a nonstandard accessory unless it is a compatible component manufactured specifically to fit the radiation housing used. Non-standard accessories shall not be aligned or operated until procedures have been approved. A radiation survey shall be performed upon completion of the alignment prior to the start of normal operations.

No new accessories shall be aligned or operated until procedures have been approved and a radiation survey carried out.

9.0. MEDICAL X-RAY UNITS

9.1. USE

The use of x-rays on humans for medical diagnosis shall be under the supervision of a physician licensed by the State of Delaware. The physician shall assure that the x-ray unit is operated only by a registered x-ray technician competent in the safe use of the machine.

9.2. RESPONSIBILITIES

9.2.1. The Director of the Student Health Services is responsible for maintenance of the medical x-ray unit in the condition that it was installed and communicating to and consulting with the Radiation Safety Officer on any changes in the x-ray unit or x-ray room design which may affect radiation exposure to patients, the x-ray technician/technologist or other employees working in the area.

9.2.2. The Radiation Safety Officer is responsible for registration of the x-ray unit with the State of Delaware keeping such registration current, and the radiation safety program associated with the unit including: personnel dosimetry, shielding, periodic surveys, training and education of employees, posting of necessary signs and documents required by the Delaware Radiation Control Regulations.

9.3. FACILITY REQUIREMENTS

9.3.1. Warning Label: The control panel containing the main power switch shall bear the warning statement, legible and accessible to view: "WARNING: This X-Ray Unit May be Dangerous to Patient and Operator Unless Safe Exposure Factors and Operating Instructions are Observed".

9.3.2. Leakage Radiation: The leakage radiation from the diagnostic source assembly one meter in any direction from the source shall not exceed 100mR in one hour when the x-ray tube is operated at its leakage technique factor.

9.3.3. Other Radiation: The radiation emitted by a component other than the diagnostic source assembly shall not exceed 2mR in one hour at five centimeters from any
accessible surface of the component when it is operated in an assembled x-ray system under any conditions for which it was designed.

9.3.4. Mechanical Support of Tube Head: The tube housing assembly supports shall be adjusted such that the tube housing assembly will remain stable during an exposure unless tube housing movement is a designed function of the x-ray system.

9.3.5. Technique Indicators

A. The technique factors to be used during an exposure shall be indicated before the exposure begins. When automatic exposure controls are used, technique factors set prior to the exposure shall be indicated.

B. The requirement in 9.3.5.A. may be met by permanent markings on equipment having fixed technique factors. Indication of technique factors shall be visible from the operator's position.

9.3.6. Beam Quality

A. Half-Value Layer

1. The half-value layer of the useful beam for a given x-ray tube potential shall not be less than the values shown in Table 2.

2. The requirements of 9.3.6.A. will be considered to have been met if it can be demonstrated that the aluminum equivalent of the total filtration in the primary beam is not less than that shown in Table 1.

3. Beryllium window tubes shall have a minimum of 0.5mm aluminum equivalent filtration permanently installed in the useful beam.

4. For capacitor energy storage equipment, compliance with beam quality requirements shall be determined with the maximum quantity of charge per exposure.

5. The required minimal aluminum equivalent filtration shell include the filtration contributed by all materials which are always present between the source and the patient.

B. Filtration Controls

For x-ray systems which have variable kVp and variable filtration for the useful beam, a device shall link the kVp selector with the filter(s) and shall prevent an exposure unless the minimum amount of filtration required in
the above table is in the useful beam for the given kVp which has been selected.

9.3.7. Mechanical Support of Tube Head: The tube housing assembly supports shall be adjusted such that the tube housing assembly will remain stable during an exposure unless tube housing movement is a designed function of the x-ray system.

10.0. VETERINARY UNITS

10.1. EQUIPMENT REQUIREMENTS

10.1.1. The protective tube housing shall limit the leakage radiation at one meter in any direction to 100mR in one hour when the x-ray tube is operated at its maximum settings for tube potential and continuous tube current.

10.1.2. Diaphragms or cones shall be provided for collimating the useful beam to the area of clinical interest and shall provide the same degree of protection as is required of the housing.

10.1.3. The total filtration permanently in the useful beam shall not be less than:

- 0.5mm A for machines operating below 50kVp
- 1.5mm A for machines operating between 50-70kVp
- 2.5mm A for machines operating above 70kVp
### TABLE 1

Filtration Required Vs. Operating Voltage

<table>
<thead>
<tr>
<th>Operating Voltage (KVP)</th>
<th>Total Filtration (inherent plus added) (mm Al equivalent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 50</td>
<td>0.5 millimeters</td>
</tr>
<tr>
<td>50 - 70</td>
<td>1.5 millimeters</td>
</tr>
<tr>
<td>Above 70</td>
<td>2.5 millimeters</td>
</tr>
</tbody>
</table>

### TABLE 2

Half-Value Layer Vs. X-Ray Tube Potential

<table>
<thead>
<tr>
<th>Design Operating Range (Kilovolts Peak)</th>
<th>Measured Potential (Kilovolts Peak)</th>
<th>Half-Value Layer (mm of Al)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 50</td>
<td>30</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>49</td>
<td>0.5</td>
</tr>
<tr>
<td>50 to 70</td>
<td>50</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>1.5</td>
</tr>
<tr>
<td>Above 70</td>
<td>71</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>110</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>130</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>4.1</td>
</tr>
</tbody>
</table>
10.1.4. A device shall be provided to terminate the exposure after a preset time or exposure.

10.1.5. A dead-man type of exposure switch shall be provided with an electrical cord of sufficient length, so that the operator can stand out of the useful beam and at least six feet from the animal during all x-ray exposures.

10.1.6. Structural Shielding: All wall, ceiling, and floor areas shall be equivalent to or provided with applicable protective barriers to assure compliance with Section 3.7.

10.2. OPERATING PROCEDURES

10.2.1. The operator shall stand well away from the useful beam and at least six feet away from the animal during radiographic exposures.

10.2.2. No individual other than the operator shall be in the x-ray room while exposures are being made unless such individual's assistance is required.

10.2.3. If an animal must be held in position during radiography, mechanical supporting or restraining devices should be used. If the animal must be held by a person, appropriate shielding devices such as lead gloves and an apron shall be used. The person shall also be positioned such that no part of his body will be struck by the useful beam. Personnel monitoring is required for all such procedures.

11.0. PARTICLE ACCELERATORS

11.1. FACILITY REQUIREMENTS

11.1.1. Shielding and Safety Design Requirements

A. A qualified expert, specifically accepted by the State shall be consulted in the design of a particle accelerator installation and called upon to perform a radiation survey when the accelerator is first capable of producing radiation.

B. Each particle accelerator installation shall be provided with such primary and/or secondary barriers as are necessary to assure compliance with Section 3.7.

11.1.2. Particle Accelerator Controls and Interlock Systems

A. Instrumentation, readouts and controls on the particle accelerator control console shall be clearly identified and easily discernible.
B. All entrances into a target room or other high radiation area shall be provided with interlocks that shut down the machine under conditions of barrier penetration.

C. When an interlock system has been tripped, it shall only be possible to resume operation by manually resetting controls at the position where the interlock has been tripped, and lastly at the main control console.

D. Each safety interlock shall be on a circuit which shall allow its operation independently of all other safety interlocks.

E. All safety interlocks shall be fail-safe, i.e., designed so that any defect or component failure in the interlock system prevents operation of the accelerator.

F. A scram button or other emergency power cutoff switch shall be located and easily identifiable in all high radiation areas. Such a cutoff switch shall include a manual reset so that the accelerator cannot be restarted from the accelerator control console without resetting the cutoff switch.

11.1.3. Warning Devices

A. All locations designated as high radiation areas, and entrances to such locations shall be equipped with easily observable flashing or rotating warning lights that operate when, and only when, radiation is being produced.

B. Each high radiation area shall have an audible warning device which shall be activated for 15 seconds prior to the possible creation of such high radiation area. Such warning device shall be clearly discernible in all high radiation areas and all radiation areas.

C. Barriers, temporary or otherwise, and pathways leading to high radiation areas shall be identified in accordance with the following requirements:

1. Each high radiation area shall be conspicuously posted with a sign bearing the radiation caution symbol and the words: Caution (or Danger) High Radiation Areas.

2. Each entrance to a high radiation area shall be:

   a) Kept locked except during periods when access to the area is required, with positive control over each individual entry or;

   b) Equipped with a control device which shall limit the radiation dose to any individual to 100mR in one hour or;
c) Equipped with a control device which shall energize a conspicuous visible or audible alarm signal announcing the entry into the high radiation area to the individual and the supervisor.

3. All controls described in 11.1.3.C.2. shall be designed in such a way that no individual will be prevented from leaving a high radiation area.

11.1.4. Operating Procedures

A. Particle accelerators, when not in operation, shall be secured to prevent unauthorized use.

B. The safety interlock system shall not be used to turn off the accelerator beam except in an emergency.

C. All safety and warning devices, including interlocks, shall be checked for proper operability at intervals not to exceed three months. Results of such tests shall be maintained at the accelerator facility for inspection by the Department of Occupational Health & Safety.

D. Electrical circuit diagrams of the accelerator and the associated interlock systems shall be kept current and maintained for inspection by the Department of Occupational Health & Safety and shall be available to the operator at each accelerator facility.

E. If, for any reason, it is necessary to intentionally bypass a safety interlock or interlocks, such action shall be:

1. Authorized by the Radiation Safety Committee and/or Radiation Safety Officer;

2. Recorded in a permanent log and a notice posted at the accelerator control console; and

3. Terminated as soon as possible.

F. A copy of the current operating and the emergency procedures shall be maintained at the accelerator control panel.

G. The accelerator shall only be operated by individuals approved by the Department of Occupational Health & Safety. All trainees shall be physically supervised during all operations.
H. Comply with all applicable responsibilities listed in Sections 3.4.2., 3.5.
and 3.6.

11.1.5. Radiation Monitoring Requirements

A. There shall be available at each particle accelerator facility appropriate
portable monitoring equipment which is operable and has been calibrated
for the appropriate radiations being produced at the facility. Such
equipment shall be tested for proper operation daily and calibrated at
intervals not to exceed one year and after each servicing and repair.

B. A radiation protection survey shall be performed and documented by the
Department of Occupational Health & Safety when changes have been
made in shielding, operation, equipment, or occupancy of adjacent areas.

C. Radiation levels in all high radiation areas shall be continuously
monitored. The monitoring devices shall be electrically independent of the
accelerator control and interlock systems and capable of providing a
remote and local readout with visual and/or audible alarms at both the
control panel and at the entrance to high radiation areas, and other
appropriate locations, so that people entering or present become aware of
the existence of the hazard.

D. All area monitors shall be calibrated at intervals not to exceed one year
and after each servicing and repair.

E. All area surveys shall be made in accordance with the written procedures
established by a qualified expert or the Radiation Safety Officer.

F. Records of all radiation protection surveys, calibration results,
instrumentation tests, and smear results shall be kept current and on file at
the Department of Occupational Health & Safety.
APPENDIX A

General Information

A.1. Nature of the Radiation

Typical acceleration potentials are 25 to 50kVp for diffraction tubes and 25 to 100kVp for those used in fluorescent analysis. There is no theoretical lower limit to the energy of the photons in the white radiation continuum but the intensity below about 5KeV is low and the x-rays are readily attenuated. The continuum can be assumed to extend from 5 to 100KeV with an intensity maximum in the range 20 to 30KeV, depending on the accelerating potential.

Superimposed on this continuum are the lines of the characteristic spectrum of the anode. These constitute less than half of the output in the case of tubes used for diffraction. The energies involved are generally in the range 5.4 to 17.5KeV.

A.2. Sources of Radiation

Hazardous radiation may come from the following sources:

A.2.1. Primary beam is the most hazardous source because of the extremely high exposure rates. Exposure rates are on the order of 400,000 R/min and the beam size is usually less than 1 cm².

A.2.2. Leakage or scatter of the primary beam through cracks in ill-fitting or defective equipment: can produce very high intensity beams (80 R/hr maximum) of possibly small and irregular cross section.

Diffracted beams also tend to be small and irregular in shape. They may be directed at almost any angle with respect to the main beam and can cover a reasonably large area.

These radiations represent a chronic exposure hazard to long term users if not controlled.

A.2.3. Penetration of the primary beam through the tube housing, shutters or diffraction apparatus is slight in well-designed equipment. Adequate shielding is easily attained at the energies commonly used for diffraction and fluorescence analysis.

A.2.4. Secondary emission from the sample or other materials exposed to the primary beam and diffracted rays can be shielded to eliminate their potential hazards. Leak proof joints can be made by having the equivalent of two right angle bends in the equipment at every joint.

A.2.5. Radiation from the high voltage power supply may result from gassy rectifiers. The effective potential is twice the potential applied to the x-ray tube, and the
radiation is very penetrating. This condition can arise at any time and the only effective countermeasure is to shield the assembly that contains the rectifiers and check at least twice a year for radiation leakage.

This is generally not a problem for equipment manufactured after 1974.

A.3. **Biological Effects of X-Radiation**

A.3.1. Acute effects are those resulting from a short exposure to a high dose of x-radiation (approximately 100 rad or more). Biological repair mechanisms do not have time to function before effects appear, within days or weeks.

1. **Low energy (<50KeV):** These effects typically appear as erythema, epilation, pigmentation, dermatitis, ulceration and other skin-surface effects on the upper extremities of the body. These are slow to heal and can lead to cancer. Amputation of one or more fingers is sometimes required.

2. **High energy (>50KeV):** This radiation can penetrate deep into the body and cause damage to the lining of the gastrointestinal tract, blood-forming cells in the bone marrow, and the central nervous system. These effects can lead to death.

A.3.2. Chronic effects are those resulting from many small doses of radiation delivered over a large period of time. Biological repair occurs during the exposure period and effects that appear will take years to develop. Continual exposure over many years may produce observable effects.

1. **Low energy (<50KeV):** These effects are known to appear as skin cancer, cataracts or other surface effects. Normally the damage does not become apparent until as little as six months or as much as ten to twenty years after exposure.

2. **High energy (>50KeV):** The biological damage produced by this radiation may include genetic mutations, various organ cancers (such as bone or thyroid) and leukemia.

A.4. **Dose Limits**

Guidelines for maximum permissible doses of ionizing radiation are established by National Council on Radiation Protection, the International Council on Radiation Protection, and the Nuclear Regulatory Commission. The following table lists the maximum permissible doses (MPD) for operators:

<table>
<thead>
<tr>
<th>Exposed Portion of Body</th>
<th>MPD/Calendar Quarter</th>
<th>MPD/YR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body, gonads, lens of eye</td>
<td>1.25Rem</td>
<td>5.0Rem</td>
</tr>
</tbody>
</table>
red bone marrow

Skin (other hands, forearms, feet and ankles) 7.5Rem 30.0Rem

Extremities (hands, forearms, feet and ankles) 18.75Rem 75.0Rem

Radiation exposure to individuals, either within the radiation controlled area or in its environs, shall be so controlled that the MPD equivalent values as set forth by the NCRP, NRC, State or University regulations are not exceeded.

A.5. **Instruments Required for X-Ray Monitoring**

A.5.1. GM Survey Meter is a very sensitive instrument for detecting extremely low levels of radiation. It is ideally suited for finding leaks in shielding or detecting low intensity scattered radiation. The Geiger Mueller survey meters response is very energy dependent and should not be used to measure dose rates.

A.5.2. An Ionization Chamber Survey Meter measures the rate of energy absorption in the chamber. It is used to accurately measure the exposure rate in order to limit personnel Exposure. Calibration corrections may be required at low x-ray photon energies (less than 6.5KeV), but these energies are an important part of the spectrum only when an iron or chromium anode is used and of little radiological health consequence. The ionization chamber will not give an accurate measurement unless the entire ionization chamber is in the radiation field. This limitation can present a problem when monitoring x-ray machines that emit very small beams of radiation as in diffraction or spectroscopy machines.

A.5.3. Evaluating the Exposure Rate Due to Small Beams

1. Instrumental Methods: An instrument which is calibrated for radiation that exposes the entire active area uniformly will give an erroneously low reading when exposed to a beam having a smaller area and the scale reading must be multiplied by a factor (f), \( f = \frac{\text{Area of detector}}{\text{Area of beam}} \).

Beams as small as 0.01 cm\(^2\) are commonly encountered around single crystal diffraction apparatus and correction factors of 6000 or more may be required for a 3 1/2 inch diameter ionization chamber. In such cases it becomes difficult to detect beams in which the dose rate may be hundreds of times greater than permissible.

To resolve this difficulty in connection with detection and measurement of x-radiation from color television receivers the NCRP has allowed for the
The fact that the smaller the beam the less is the likelihood that the same area of an individual will be repeatedly or continuously exposed. The standard for home television receivers permits the dose rate to be averaged over an area of ten square centimeters. The same practice is acceptable for surveys around x-ray generator cabinets and system barriers, but in the vicinity of x-ray tube housing, beam ports, collimators, and specimen chambers where small, intense beams are likely to be encountered, it is necessary that the area over which the dose rate is averaged be limited to 1 cm$^2$. It is also more likely that the eye-beam orientation will be repeated under these conditions. On this basis it may be assumed that the largest correction factor that will need to be applied will be numerically equal to the sensitive area of the detector in square centimeters.

2. Film Methods: X-Ray film in a low absorption opaque envelope is a useful adjunct to the survey meter in searching for radiation leaks. This method often gives recognizable shadows of features of the x-ray equipment that effectively locate the leak. An estimate of the cross section of the beam can be obtained for use in correcting readings of a survey meter, or the film method itself can be made to give a quantitative estimate of the dose if calibration data are available. An additional advantage of the film is its suitability for integrating over a long period in order to detect very weak beams and to give an indication of the dose averaged over a period of time that includes all the steps of a given procedure. The latter sometimes leads to the detection of a possible hazardous transient situation.

Of special interest to those checking equipment in the field where darkroom facilities may not be available, is a cassette for use with high speed packets (ASA 3000). An air cushion forces the film into contact with a fluorescent screen during exposure. Exposure times are generally shorter than with conventional films, and development facilities are built in, so that the photograph can be viewed after only 15 seconds.

3. Fluorescent Screen Method: Fluorescent screens are occasionally useful, but their low sensitivity generally limits their effectiveness to cases involving a direct beam from the x-ray tube anode. This being the case, the screen should be mounted on a long handle to minimize the risk of exposing the hands. It should be viewed through a lead-glass shield. The sensitivity can be improved by darkening the room completely and allowing 20 minutes or longer for the eyes to become darkadapted.

A.5.4. Calibration: The accuracy of any radiation detector is only as good as its calibration. All radiation survey meters shall be calibrated annually by the Department of Occupational Health & Safety.

A.5.5. The Use of a Check Source: As a means of detecting abrupt changes in sensitivity resulting from component deterioration or hidden damage, a check source should be provided. Iron-55, which decays by electron capture directly to the stable
isotope manganese-55 is suggested for this application. It emits the 5.9 KeV x-ray characteristic of manganese-55. This radiation represents the extreme low energy range of the spectrum encountered in survey work and provides an excellent test of an instrument's capabilities in this most difficult range. A 50uCi source is sufficient to provide exposures in the range 10 -100mR/hr, and its half life (2.7 years) is long enough to insure a reasonable useful life. The source should be mounted in a jig that will insure fixed geometry. If possible, the exposure rate should be established when the survey instrument has been recently calibrated. Thereafter it is only necessary to correct for the activity and, possibly, variations in air absorption due to changes in barometric pressure and relative humidity. The simplicity of the spectrum facilitates making such corrections.
REFERENCES


41. Underestimation of Radiation Exposure from Am-Be Neutron Probe.
