



VIRGINIA POLYTECHNIC INSTITUTE  
AND STATE UNIVERSITY

**Revision Date  
June 2017**

# X-Ray Safety Program



Environmental Health and Safety  
Radiation Safety  
540-231-5364



# X-Ray Safety Program

Environmental Health and Safety  
Health and Safety Building  
675 Research Center Dr.  
Blacksburg, VA 24061

Phone (540) 231-5364 Fax (540) 231-3944

dcon@vt.edu  
<http://www.ehss.vt.edu>

# Revision Status

Contact(s)	Implementation Date	Revision Number	Comments
Doug Smiley Radiation Safety Officer	May, 1986	1.0	Program revised for Document Display System
Doug Smiley Radiation Safety Officer	October, 1986	2.0	Program revised with minor wording changes and addition of section 7.7, Repair and Alignment Procedures.
Doug Smiley Radiation Safety Officer	January, 1990	3.0	Program revised with minor wording changes and addition of section 8.2, Training for Cabinet X-Ray Systems.
Doug Smiley Radiation Safety Officer	September, 2008	4.0	Major program revision to be consistent with Radioactive Material Program as needed and to reflect minor wording changes.
Doug Smiley Radiation Safety Officer	March, 2011	5.0	Minor program revision to update training instructions in Radiation Safety Training section, add cautions about personal nuclear medicine procedures under Personnel Monitoring section and add Organizational Chart to Appendix section.
Doug Smiley Radiation Safety Officer	September, 2014	6.0	Minor program revision to update Radiation Safety Committee functions in Radiation Safety Organization section, update instructions in Radiation Safety Training section, update purchasing instructions in X-Ray Equipment section, remove all references to film for diagnostic radiographs and add X-Ray Emergency Procedures and Emergency Contacts to Appendix section.
Donald Conner Radiation Safety Officer	June 2017	7.0	Minor program revision to change the inspection frequency to three years for Analytical and Cabinet X-Ray systems, to modify the Organizational Chart, and to make a number of non-substantive changes.

X-Ray Safety Program .....	i
Environmental Health and Safety .....	i
Introduction .....	7
Radiation Safety - Organization .....	7
Radiation Safety Committee .....	7
Environmental Health and Safety Department .....	9
Radiation Safety Officer .....	9
X-Ray Equipment .....	10
Classification of Users .....	10
Responsibility of Laboratory Authority .....	10
Responsibilities of Workers .....	11
Obtaining an Authorization .....	11
Radiation Safety Training .....	11
Obtaining X-ray Equipment .....	12
Disposal of X-ray Equipment .....	13
Request by Workers for Inspections .....	13
Disciplinary Procedures .....	13
Violations and Penalties .....	13
Variances .....	15
Radiation Exposure Protection .....	15
Radiation Exposure Limits .....	15
ALARA .....	16
Personnel Monitoring .....	16
Specific Requirements .....	18
Exposure Records .....	18
Pregnant Radiation Workers .....	18
X-Ray Examinations of Pregnant or Potentially Pregnant Women .....	19
Posting .....	20
Removal of Notices .....	20
Inspections .....	20
Emergency Procedures .....	20
Diagnostic X-ray Equipment .....	21
Patient Protection .....	21
Personnel Protection .....	22
Stationary Units .....	22
Portable and Mobile Units .....	22
Holders .....	22
Radiation Limits .....	23
Equipment Requirements .....	23
Stationary, Portable, and Mobile Units .....	24

Fluoroscopic Systems .....	24
Operator's Booth .....	24
Structural Requirements .....	25
Control Placement .....	25
Viewing Requirements.....	25
Records .....	25
Surveys and Inspections .....	25
Analytical X-ray Equipment .....	26
Open and Enclosed-Beam Analytical Systems.....	26
Additional Requirements for Open-Beam Systems .....	26
Additional Requirements for Enclosed-Beam Systems .....	27
Operating Procedures .....	28
Radiation Limits .....	28
Surveys .....	28
Repair and Alignment Procedures.....	29
Cabinet X-ray Systems .....	29
Requirements for Cabinet X-ray Systems .....	29
Operating Procedures .....	30
Radiation Limits .....	30
Surveys .....	30
Miscellaneous X-ray Equipment.....	30
Posting .....	31
Warnings and labels .....	31
Operating Procedures .....	31
Radiation Limits .....	31
Personnel Monitoring.....	31
Potential X-ray Exposure from Magnetic-Effect Tubes .....	31
Surveys .....	32
Terms and Definitions .....	32
More Information .....	35
APPENDICES .....	36
APPENDIX 1: Organizational Chart.....	36
APPENDIX 2: X-ray Emergency Procedures.....	37
APPENDIX 3: Emergency Contacts .....	38

## **Introduction**

### **Purpose**

The X-ray Safety Program is designed to provide the information needed for university personnel to work safely with equipment and procedures that generate x-ray radiation.

### **Scope**

The program details Virginia's Department of Health, Office of Radiological Health and Virginia Tech requirements for equipment procurement and validation, procedure developments, and education of personnel.

### **Application**

X-ray equipment is used in different areas and therefore, varied groups of personnel are covered by this program. That includes:

- Medical professionals and researchers using diagnostic units
- Faculty, staff and students involved in analytical research

Any questions for clarification of use should be directed to the University Radiation Safety Office.

## **Radiation Safety - Organization**

The Radiation Safety Committee is the highest decision making body for all radiation safety matters at Virginia Tech. This committee reports to the Vice President for Research and Innovation. The Department of Environmental Health and Safety (EHS) administers the university's radiation safety policies on a daily basis, through its Radiation Safety Group. EHS reports to the Vice President for Administration. Refer to the Organizational Chart in Appendix 1.

### **Radiation Safety Committee**

The university has established the Virginia Tech Radiation Safety Committee (RSC) as a University Operational Committee with the authority to regulate the safe use of ionizing radiation by university personnel. The RSC develops rules for this purpose and oversees their implementation.

The Vice President for Research and Innovation appoints members of the RSC. The Radiation Safety Officer is an *ex officio* member. A representative of the Vice President for Research and Innovation administrative unit is an *ex officio* member representing university top management. At least two persons trained and experienced in the safe use of radioactive materials, one person trained and experienced in the safe use of x-ray producing equipment, and other members, as

necessary, are appointed on the basis of their experience with radiation. An individual with administrative experience and responsibilities serves as Chairman of the Committee. Members of the RSC shall serve a three-year term and may be reappointed for additional terms. A member who misses three consecutive meetings without approval of the Chairman for adequate cause will be removed from the Committee.

A meeting of the RSC will be held at least quarterly. The Chairman shall call additional meetings as necessary. Minutes of the meetings shall be recorded and distributed to selected persons and maintained for the duration of the license. A quorum shall consist of at least one-half of the members and must include the Chairman, the Radiation Safety Officer, and the top management representative or their designees. Decisions of the RSC shall be based upon approval of a majority of the members present. In the event of a tie, the Chairman may vote.

The RSC may delegate its authority to the Chairman (or whoever the Chairman designates in writing as an alternate), and to the Radiation Safety Officer. The delegates would have the authority to act in the RSC's behalf on such occasions that arise between normal meeting dates that do not warrant a special meeting of the full Committee. An example would be the approval of an authorization amendment, such as the addition or deletion of personnel in an individual laboratory.

The RSC shall:

- Review and approve all applications for use of radiation devices and radioactive material by university personnel.
- Review and approve radiological hazard analyses of new procedures used by investigators. Each new procedure or experiment must include:
  - ✓ purpose
  - ✓ description
  - ✓ analysis of the possible radiation levels produced by the experiment
  - ✓ hazards associated with the performance of the experiment
- Approve each use of unsealed radioactive material at temporary job sites and monitor the user's operations with these materials and equipment.
- Ensure any modifications or improvements it considers necessary in the interest of radiation safety or compliance with federal, state, or internal regulations are implemented.
- Review the radiation protection program content and implementation on an annual basis.
- Administer disciplinary actions for violations by an *ad hoc* disciplinary subcommittee composed of:
  - ✓ RSC Chairman (unless an alternate is designated in writing to avoid a potential conflict of interest)
  - ✓ Radiation Safety Officer
  - ✓ Individuals with experience relevant to the incident (can be from outside of the RSC)
- Review lab licenses, research protocols, and amendments to licenses or protocols after submission by the Principal Investigator (PI) to the RSO for review as follows:
  - ✓ The RSO or designee (e.g. a member of the RSC) will perform an initial review of the lab license, research protocol, or amendment, soliciting from



- the PI any corrections or clarifications deemed necessary to allow for an adequate review of the procedures and safety precautions.
- ✓ The RSO will forward electronic copies of the pre-reviewed application materials to all Committee members for an initial Member Review Preference (MRP) assessment of the application. Members will have 5 working days to respond to the RSC, indicating:
    - that one or more questions/concerns need to be addressed;
    - that the protocol should be held for review and discussion at a convened RSC meeting; or,
    - that the submission may be reviewed and approved by a Designated Member Review (DMR) process.
    - The absence of a response from an RSC member within 5 working days will be construed as allowing for DMR review.
  - ✓ The RSC will delegate its authority for final review and approval of the application to the DMR reviewer. The DMR reviewer may be the Chair, the RSO, or any other member of the RSC so designated by the Chair. The DMR reviewer has the authority to provide final approval on behalf of the RSC. However, the DMR reviewer cannot unilaterally disapprove an application – if the DMR reviewer indicates that she/he cannot approve an application, then that application must be reviewed and acted upon at a convened RSC meeting, with final action determined by a majority vote of the members present at the meeting.
  - ✓ For non-substantive changes, e.g., addition or deletion of personnel in an individual laboratory, approval can be done administratively by the Chair or the RSO, and do not require MRP, DMR, or convened RSC meeting action.

## **Environmental Health and Safety Department**

The Department of Environmental Health and Safety is charged with the responsibility for the coordination of all safety and environmental safety programs at the university not specifically assigned elsewhere. The Radiation Safety Office is a part of this department.

### **Radiation Safety Officer**

The Radiation Safety Officer (RSO), a staff member of EHS, who by reason of education, training, and experience, is qualified to advise others in the safe use of ionizing radiation and to supervise the health physics program of the University.

The Radiation Safety Officer shall:

- be responsible for personnel monitoring, training, maintenance of exposure records, radioactive material inventories, survey methods, waste disposal and inspections to assure compliance with radiological safety practices,
- approve in writing all activities and procedures that involve actual or potential exposure of personnel to radiation or the release of radioactive materials to the environment, and ensure such activities are brought before the Committee for review and approval,

- conduct radiological hazard analyses on all new procedures used by laboratories,
  - be available to consult with all users of ionizing radiation and give advice in radiological safety practices,
  - suspend any operation causing, or believed capable of causing, an excessive radiation hazard as rapidly as possible,
  - ensure radiation safety violations are treated according to the Disciplinary Procedures Section of this program document,
  - perform routine and special radiation surveys as considered necessary in the interest of radiation safety,
  - provide the RSC a quarterly resume of incidents, inspections, material received, an inventory of radioactive material, summary of exposures and a list of authorized users of radioisotopes,
  - provide the RSC a quarterly report on X-ray laboratories to include a summary of exposures, a current list of authorized users, and any abnormal occurrences, and
  - complete duties in a timely manner
- ✓

## **X-Ray Equipment**

The following rules set the requirements for the safe use of diagnostic, analytical, cabinet and miscellaneous X-ray systems at Virginia Tech. These rules are in conformity with the radiation safety standards promulgated by the Commonwealth of Virginia.

### **Classification of Users**

1. Laboratory Authority  
A Laboratory Authority may purchase, possess, and use X-ray producing equipment and is directly responsible for the equipment and users on the authorization.
2. Principal User  
A principal user works under the indirect supervision of a Laboratory Authority and may supervise users and request amendments.
3. User or Operator  
An operator uses X-ray equipment under the indirect supervision of a Laboratory Authority or principal user. A user cannot request amendments and has no supervisory power.
4. Holder  
A holder is authorized only to hold patients, cassettes, or animals during an X-ray exposure.

### **Responsibility of Laboratory Authority**

Laboratory Authorities are responsible for the safe operation of the X-ray equipment under their control. They will ensure that:

- Users are adequately instructed in safe operating procedures and are skilled in the safe use of the equipment.
- Users have received training in radiation safety as considered necessary by the Radiation Safety Committee.
- Written safety rules and procedures are provided to all users of the equipment, including any restrictions of the operating techniques required for the safe operation of the system.
- All X-ray equipment under their control is registered with the Radiation Safety Office.
- The equipment, facility and the use of the equipment meets the applicable Federal, State and local regulations as prescribed by the Radiation Safety Office.
- Users wear the appropriate personnel monitoring devices.
- The Radiation Safety Office is notified of any changes in the equipment, facility, or personnel using the equipment.

## **Responsibilities of Workers**

Those who work with X-ray producing equipment, both staff members and students, have the following responsibilities:

- Follow safe operating procedures for the use of the equipment.
- Observe the rules presented in this manual for the safe use of ionizing radiation.
- Immediately notify the Laboratory Authority or the Radiation Safety Office of any defects or deficiencies in radiation protection devices and procedures.
- Maintain radiation doses at a level that is as low as reasonably achievable (ALARA).

## **Obtaining an Authorization**

An individual wishing to become a Laboratory Authority shall submit an application form "Authorization to Use X-ray Producing Equipment" to the Radiation Safety Office. A Laboratory Authority is permitted to possess X-ray producing equipment.

The application will be submitted to the Radiation Safety Committee for review. The applicant will receive a copy of the application signed by the chairman and the Radiation Safety Officer.

## **Radiation Safety Training**

All individuals who wish to operate diagnostic, analytical, or cabinet X-ray systems, or who will be used as holders for diagnostic systems, shall receive instruction in and demonstrate ability in:

1. General properties of ionizing radiation
2. Principles of radiation detection
3. Radiation hazards associated with the use of the equipment
4. Biological effects of ionizing radiation

5. Procedures to minimize exposure
6. Virginia Tech's radiation safety requirements
7. Emergency procedures

Ability shall be demonstrated by passing a written examination administered by the Radiation Safety Office.

In addition to training provided by the RSO, experienced personnel must provide machine specific hands-on training

**Exceptions to radiation safety training will not be granted because of previous training, experience, or education.**

## **Procedure for Completion of Training**

All X-Ray radiation safety training is available on-line. To access the training go to the following web address: [http://www.ehss.vt.edu/programs/RAD\\_blackboard.php](http://www.ehss.vt.edu/programs/RAD_blackboard.php)

- Once there register for the particular training needed and follow the instructions.
- 
- Click on the "launch" button to access the training material and quiz ([www.ehss.vt.edu/train](http://www.ehss.vt.edu/train)).

The successful completion of the radiation safety training does not automatically authorize you to use X-ray equipment. You must be added to an approved authorization by an amendment submitted by a principal user of a laboratory, or in the case of new faculty members, by the submission of an application to use X-ray producing equipment.

## **Obtaining X-ray Equipment**

Only a Laboratory Authority or Principal User can order X-ray equipment.

All orders for X-ray producing equipment are to be purchased through the HokieMart system. Special account codes must be used to ensure appropriate reviews are conducted. The following codes apply:

- 22419 X-Ray Equipment (EHS Approval) - Include expenses for x-ray equipment (e.g., diffraction (XRD), fluorescence (XRF), electron microscopes, micro-CT, ESCA, XPS) costing less than \$2000 per unit.
- 22414 X-Ray Equipment (EHS Approval) - Include expenses for same x-ray equipment as in #22419 above costing \$2000 or more per unit.
- 22426 Medical and Dental Equipment (EHS Approval) - Include expenses for medical, dental and veterinary x-ray equipment (e.g., c-arms, portables, fluoroscopy, CT, bone densitometer) costing less than \$2,000 per unit.

- 22421 - Medical and Dental Equipment (EHS Approval) – Include expenses for same x-ray equipment as in #22426 above costing \$2,000 or more per unit.

The purchaser must consult with the Radiation Safety Office concerning the adequacy of the facility where the equipment will be used.

Donated equipment must be approved by the Radiation Safety Officer prior to the equipment's arrival on-site.

The purchaser is to notify the Radiation Safety Office on receipt of the equipment and provide the information necessary to register the unit with the Commonwealth of Virginia.

Radiation Safety personnel will conduct a system and area survey for all analytical, cabinet and miscellaneous equipment during the initial operation of all equipment. Diagnostic units must be certified by a State approved Certified Expert before use.

## **Disposal of X-ray Equipment**

Any X-ray equipment no longer being used must be disposed of through the Virginia Tech Surplus Property program. Contact the RSO of intent to dispose of equipment and to ensure the State is informed of the disposal.

## **Request by Workers for Inspections**

Any worker who believes there is a violation of the rules and regulations presented in this program document may request an inspection of that facility by notifying the Radiation Safety Officer. The worker's name will be kept anonymous. During inspections the safety officer may confer privately with workers. Workers may bring to the attention of the safety officer of any past or present condition they believe may have contributed to or caused a violation. No licensee shall dismiss or in any manner discriminate against a worker because a complaint was filed with the Radiation Safety Office.

## **Disciplinary Procedures**

Failure to follow the radiation safety guidelines found in this document may result in disciplinary procedures initiated against a Laboratory Authority or responsible individual. Penalties for violations will be assessed at the discretion of the RSO and the Radiation Safety Committee.

## **Violations and Penalties**

**Class I** - Administrative or procedural deficiency of a relatively minor nature, e.g., failure to maintain survey records properly, failure to wear a required personnel monitoring device. If three citations are issued within a 1-year period, operations

under an Authorization will automatically be suspended, pending a review by the Radiation Safety Disciplinary Subcommittee.

- A Notice of Concern (NOC), issued by the Radiation Safety Officer, will explain the nature of a violation and the potential for incurring further disciplinary actions. At the discretion of the Radiation Safety Officer, the NOC can be issued as a warning or as the first citation. A copy of the NOC will be kept on file.
- First Citation - A letter of reprimand will be issued by the Chairman of the Radiation Safety Committee and will be copied to the department head.
- Second Citation - An immediate cessation of operation under an Authorization will be required, normally in effect for two weeks. This action may be changed, pending a review by the Radiation Safety Disciplinary Subcommittee. A letter of reprimand will be issued by the chairman of the Committee and will be copied to the department head and dean of the college involved.
- Third Citation - An immediate cessation of operation under an Authorization will be required, pending review of the incident by the Radiation Safety Disciplinary Subcommittee. A suspension letter will be sent by the Chairman of the Committee and will be copied to the department head, dean of the college involved and the Vice President for Research. After a period of no more than one year, the Committee will review reinstatement of the Authorization.

**Class II** - Major violations are those that could result in excessive radiation exposures to personnel, or willful and repeated negligence, e.g., loss of radioactive material due to negligence; improper use of ionizing radiation, materials or devices in such a way as to lead to potential injury or liability. An immediate cessation of operation under an Authorization will be required, pending review of the incident by the Radiation Safety Disciplinary Subcommittee. A suspension letter will be sent by the Chairman of the Committee and will be copied to the department head, dean of the college involved and the Vice President for Research.

A preliminary determination of the class of violation will be made at an interim meeting of the Radiation Safety Officer and the Chairman of the Radiation Safety Committee. A review of Class I first violations will take place at the next regularly scheduled meeting of the Radiation Safety Committee. A meeting of a Disciplinary Subcommittee will be convened by the chairman as soon as practicable for Class I second and third violations and for Class II violations.

The Disciplinary Subcommittee will determine the appropriate action to take for all Class I violations for second and third offenses and for Class II violations. The Disciplinary Subcommittee is empowered to impose the disciplinary actions decided upon. However, the Radiation Safety Committee will review the decisions of the Subcommittee at the next regularly scheduled meeting or the chairman will call a meeting as soon as practicable upon an appeal by the individual cited. The Radiation Safety Committee may approve or modify the actions of the Disciplinary Subcommittee as the final authority on radiation safety matters at the University.

The results of any disciplinary actions taken by the Radiation Safety Disciplinary Subcommittee, after their consideration of the incident, and of any appeals made to the Radiation Safety Committee will be sent to the same individuals to whom the original materials were sent.

## **Variations**

A Laboratory Authority may apply to the Radiation Safety Committee for an exemption from the requirements of this program.

The request must include the reason the variance is being sought; and alternative methods that will be used to ensure that the health and safety of personnel and the environment will not be compromised.

The application for a variance is to be sent to the Radiation Safety Office or the chairman of the Radiation Safety Committee. The request will normally be acted on at the next scheduled meeting of the committee. A special meeting may be called by the Chairman if it is believed necessary. The Laboratory Authority may be present at the meeting to discuss their request for the variance.

## **Radiation Exposure Protection**

Although occupational radiation doses at Virginia Tech are very low and current occupational limits provide a very low risk of injury, the Administration at Virginia Tech recognizes that it is prudent to avoid unnecessary exposure. It is therefore the policy of Virginia Tech to reduce occupational exposures to a level that is as low as reasonably achievable (ALARA). This will be accomplished through sound radiation protection planning and practice, and a commitment to policies that promote vigilance against unsafe practice.

## **Radiation Exposure Limits**

No person will be permitted to receive a radiation dose in one calendar year in excess of those listed in this section.

### **Occupational Limits**

<b>Type of Individual</b>	<b>Region of the Body</b>	<b>Limit (per year)</b>
Adults (18 years or more)	Total effective dose equivalent (TEDE) Whole body; head, trunk, gonads, arms above the elbow or legs above the knee; external and internal dose	5,000 mrem
	Lens dose equivalent (LDE)	15,000 mrem

	Lens of the eye	
	Shallow dose equivalent (SDE) Skin of body; extremities - hand, elbow, arm below the elbow, foot, knee, leg below the knee	50,000 mrem
Declared pregnant worker	TEDE	500 mrem per pregnancy
Minors (under 18 years of age)	TEDE	500 mrem
	LDE	1,500 mrem
	SDE	5,000 mrem
General Public	TEDE	100 mrem

Radiation levels in unrestricted areas shall not exceed 2 mrem in any one hour or 100 mrem/yr

## ALARA

The university is committed to keeping radiation exposures **As Low As Reasonably Achievable** (ALARA). Under the ALARA program the following exposure levels require investigation. Level I values are 10% of the occupational limits and Level II values are 25% of the limits.

### ALARA Investigation Levels

Type of Individual	Region of Body	Level I (per year)	Level II (per year)
Adults	TEDE	500 mrem	1,250 mrem
	LDE	1,500 mrem	3,750 mrem
	SDE	5,000 mrem	12,500 mrem
Declared pregnant worker	TEDE	50 mrem per pregnancy	125 mrem per pregnancy
Minors	TEDE	50 mrem	125 mrem
	LDE	150 mrem	375 mrem
	SDE	500 mrem	1,250 mrem
General Public	TEDE	10 mrem	25 mrem

The RSO will review and record results of personnel monitoring at least once for each calendar quarter.

The following actions will be taken:

- For personnel dose less than Investigational Level I:
  - no further action will be taken unless deemed appropriate by the RSO
- For personnel dose equal to or greater than Investigational Level I but less than Investigational Level II:
  - RSO will review the appropriate dose results
  - Report the results of the reviews at the first RSC meeting following the quarter when the level was exceeded
  - RSC dose review comparing the doses of others performing similar tasks as an index of ALARA program quality
  - The review will be recorded in the RSC minutes
  - No further action will be taken unless deemed appropriate by the RSC
- For personnel dose equal to or greater than Investigational Level II:
  - RSO will investigate into the causes and take any necessary action



- RSO will provide an investigation report, actions taken, and a copy of the individual's exposure record to the RSC at its first meeting following completion of the investigation
- Details of these reports will be recorded in the RSC minutes

Investigational Levels may be established to levels above those listed in this section and involves the following:

- establish a new level for an individual or group that it is consistent with good ALARA practices
- document the justification
- RSC review and approval of all revisions

## Personnel Monitoring

The need for a personnel monitoring device will be determined by the Radiation Safety Office. That office will supervise the ordering, distribution, and collection of personnel monitoring devices. All personnel who enter an area where it is likely they will receive greater than 10% of the maximum occupational dose limit shall wear a personnel monitoring device. When badges are not required, individuals may request a badge if there are concerns.

Whole-body personnel monitoring devices will be worn routinely on the shirt pocket or collar. The position of the monitoring device shall remain constant during a reporting period.

Personnel monitoring devices shall not be worn in the pocket or obstructed in any manner.

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

Personnel monitoring devices shall not be deliberately exposed to radiation except under the supervision of the Radiation Safety Officer.

When a lead apron or thyroid shield is worn, the monitoring device shall be worn on the outside of the protective device at the collar. There is one exception when a person is issued a monitoring device to be worn at the waist underneath a lead apron.

Pregnant radiation workers shall wear a whole-body personnel monitoring device during the pregnancy.

**Caution – if you travel by air, put personnel monitoring badges in carry-on luggage instead of checked luggage. Checked luggage receives significant x-ray exposure during screening when compared to the very low x-ray exposure received by carry-on luggage being screened.**

**Personnel monitoring devices are not to be worn during non-occupational exposures such as medical X-rays.**

**Caution - personal nuclear medicine procedures can cause non-occupational exposures to be recorded on monitoring devices so before undergoing any**

**nuclear medicine procedures, contact the Radiation Safety Officer to discuss special steps needed.**

## **Specific Requirements**

### 1. Diagnostic Systems

All users shall wear a whole-body monitoring device. Fluoroscopy users will also wear a ring badge.

### 2. Analytical Systems

Users of open-beam analytical X-ray equipment that conduct alignment of the system whenever the beam is accessible are required to wear a ring and body badge. Badges are not required for users of closed systems.

### 3. Cabinet Systems

All users shall wear a whole-body badge unless an area badge is positioned to monitor where operators are located.

### 4. Miscellaneous Systems

Personnel monitoring is not required.

## **Exposure Records**

The Radiation Safety Office will maintain exposure records and will notify workers at least annually of their exposure to radiation. The office will provide a radiation exposure report to the worker or another employer, at the request of the worker.

The Radiation Safety Office will supply the worker with a written report if a dose over 10% of the occupational limits is received.

## **Pregnant Radiation Workers**

A worker has the option to formally declare a pregnancy to their supervisor in order to take advantage of reduced occupational exposure limits for the entire term of the pregnancy. This declaration is voluntary and can be kept confidential. The RSO is available to answer any questions that may arise whether or not a formal declaration of pregnancy is made. To become a declared pregnant worker the supervisor needs the following information:

- Estimated date of conception
- Expected date of birth

Declared pregnant radiation workers shall:

1. Wear a whole-body personnel monitoring device if working with penetrating X or gamma radiation sources.

2. Wear a second whole-body monitoring device under a lead apron at waist level, when a lead apron is required to be worn.
3. Not be required to hold patients, animals, or DR cassettes during an X-ray exposure.
4. Be informed of her radiation exposure on a quarterly basis.

Pregnant radiation workers (undeclared) should:

1. Notify the Radiation Safety Officer as soon as her pregnancy is known (confidentiality can be maintained).
2. Limit her exposure to less than 500 mrem during the pregnancy.
3. Keep her exposure to the very lowest practical level by reducing the amount of time spent in a radiation area, increasing the distance from a radiation source, and using shielding.

The RSO will issue a fetal monitoring badge that can be worn under outer clothing.

## **X-Ray Examinations of Pregnant or Potentially Pregnant Women**

A sign bearing the words (or similar words) "Caution: If you are pregnant or think you are pregnant, please inform the technician before X-rays are taken" shall be conspicuously posted in the X-ray room.

Before ordering X-rays of the abdominal or pelvic area of a fertile woman, the examining physician will order a pregnancy test.

1. The results of the pregnancy test will be placed on the X-ray request form.
2. If the patient is pregnant and there is an urgent need for the X-ray examination, the physician must advise the patient about the benefits derived from the exam versus the risk to her unborn child.
3. The physician must grant permission on the X-ray request before X-rays of the abdominal or pelvic area of a pregnant woman can be performed.

The X-ray technician will check the order for the results of the pregnancy test before taking X-rays of the abdominal or pelvic area of a fertile woman. If a pregnancy test has not been performed, the technician will refer the patient back to the examining physician.

The physician's approval to X-ray pregnant women is not required when X-rays of areas other than the abdominal or pelvic area are ordered, provided the abdomen is shielded on all sides by 0.25 mm lead equivalency.

The abdominal and pelvic area of fertile women shall be covered with a lead apron of 0.25 mm lead equivalency when X-rays are ordered for areas other than the abdominal or pelvic region.

Women in their childbearing years who participate in research studies involving bone density (DXA) scans will be required to undergo a pregnancy test, and receive a negative result (not pregnant), before a scan is performed. The Laboratory Authority must ensure that the results are obtained. Women who are pregnant will be advised

to consult with their personal physician as to the advisability of their continued participation in the study, and if cleared by their physician, they may undergo the scan. The Laboratory Authority must ensure the clearance is received.

## **Posting**

Each area or room where fixed diagnostic, analytical, or cabinet X-ray equipment is located shall be conspicuously posted with:

1. A sign bearing the radiation symbol and the words (or similar words) "CAUTION: X-RAYS" on the door.
2. State Form RH-F-12 "Notice to Employees - Standards for Protection Against Radiation: Notices, Instructions and Reports to Workers; Inspections."
3. Procedures to be followed if there is a radiological emergency.
4. List of x-ray operators only for Diagnostic units.

Each area or room where mobile X-ray equipment is used shall be temporarily posted with a "Caution: X-Rays" sign.

No area posting is required for miscellaneous X-ray producing equipment.

## **Removal of Notices**

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

## **Inspections**

All licensed activities are subject to inspection by the Radiation Safety Office. Inspections may be announced or unannounced and will be conducted at least every year. Some diagnostic units are inspected less frequently (e.g. 3 years for bone density and most veterinary use units). Analytical and cabinet x-ray systems are inspected at least every 3 years and administrative checks are made each year. Miscellaneous x-ray systems are inspected at least every five years and administrative checks are made every year.

A written report specifying any deficiencies will be sent to the Laboratory Authority who must correct the deficiencies as soon as possible, unless a variance or an extension of time has been granted by the Radiation Safety Committee. A Laboratory Authority who disagrees with the deficiencies specified in the report may appeal in writing to the Chairman of the Radiation Safety Committee and request a hearing before the Committee.

## **Emergency Procedures**

Emergency Procedures (Appendix 2) which includes telephone numbers and the laboratory line of authority, must be posted in the lab and shared with everyone who works in the space. The Emergency Contacts (Appendix 3) must be posted on the entrances to the lab.

## PHONE NUMBERS

1. Radiation Safety Office – 540-231-5364
2. Virginia Tech Police - 911 (540-382-4343)
3. Rescue Squad - 911 (540-382-4343)

Note: If using a cell phone to dial 911, remember to identify your location for the operator

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

1. Immediately turn off the equipment.
2. Call the Radiation Safety Office (8 a.m. - 5 p.m.), or call the Virginia Tech Police (after 5 p.m. and on weekends).
3. Notify one person from the laboratory line of authority.
4. Remain in the area until the Radiation Safety Officer or designee arrives.

If a serious injury occurs, unrelated to radiation exposure, notify the Rescue Squad immediately.

The Radiation Safety Officer will do the following:

1. Investigate the incident and approximate the exposure to the individual.
2. Notify the following University Officials: Radiation Safety Committee Chairman and the Department Head where the incident occurred and/or the individuals involved are based.

## **Diagnostic X-ray Equipment**

The following rules are to ensure the safe operation of human-use and veterinary-use diagnostic X-ray equipment at Virginia Tech. These rules are in conformity with the radiation safety standards promulgated by the Commonwealth of Virginia.

### **Patient Protection**

The following rules are to protect patients from exposure to ionizing radiation, except that which is intended for diagnostic purposes.

1. All exposures for diagnostic purposes shall be specifically and individually ordered by a licensed Medical Doctor or a Doctor of Veterinary Medicine.
2. The useful beam shall be collimated to cover only the area of clinical interest.
3. Humans shall not be exposed for training, demonstration, or other non-healing arts purposes.
4. Exposure of individuals for Healing Arts Screening is prohibited unless approved by the Radiation Safety Committee and the Virginia Department of Health, Office of Radiological Health.
5. Procedures shall be used to keep patient exposure at a minimum, while still obtaining the necessary diagnostic information.

- The radiation exposure to the patient must be the minimum required to produce good diagnostic images.
6. For human-use units, other than fluoroscopy, the X-ray tube must be at least 30 cm (approximately 1 ft.) from the patient.
  7. The source-to-patient distance must be at least 38 cm for image-intensified fluoroscopic units.
  8. Gonad shielding of at least 0.25 mm lead equivalency must be used on human patients of reproductive age, if the gonads are in the primary beam and the shielding does not interfere with the diagnostic procedure.
  9. Aluminum filtration shall be placed in the primary beam to reduce the quantity of soft X-rays to the patient.

## **Personnel Protection**

The following rules are to protect operators, holders, and other people from exposure to ionizing radiation.

### **Stationary Units**

1. The operators of human-use units must stand behind the protective barrier at the controls during the exposure. The operators of veterinary-use units should stand behind the protective barriers at the controls during the exposure.
2. An operator who is required to be in the X-ray room to take an exposure of an animal must stand at least 6 feet from the useful beam and the animal.
3. Only individuals required for the radiographic procedure are to be in the room during the exposure.
4. All individuals present in the X-ray room during an exposure must be protected from the primary beam by at least 0.5 mm lead equivalency and from scatter radiation by at least 0.25 mm lead equivalency (lead gloves and aprons as appropriate).
5. Access to the X-ray room must be secured during the exposure.

### **Portable and Mobile Units**

1. Operators shall stand at least 6 feet from the X-ray tube head and wear a lead apron of at least 0.25 mm lead equivalency.
2. The area or room where the equipment is being used shall be temporarily posted with a "Caution -- X-rays" sign.
3. Bystanders must stand at least 12 feet from the X-ray tube head and the patient being X-rayed.
4. Mobile X-ray units shall not be hand held.
5. The primary beam shall not be directed at bystanders.

### **Holders**

When a patient or DR cassette must be provided with auxiliary support during an X-ray exposure:

1. Mechanical holding devices must be used whenever possible.

2. No individual shall be used routinely as a holder, to the exclusion of others who could be used.
3. Personnel used as holders must be protected from the primary beam by at least 0.5 mm of lead equivalency, and from scatter radiation by at least 0.25 mm of lead equivalency (lead gloves and aprons as appropriate).
4. Every effort should be made to position the holder so that no part of the body will be struck by the primary beam.
5. Pregnant workers will not be required to be used as holders.

## **Radiation Limits**

1. Leakage radiation from the tube head shall not exceed 100 mrem/hr at 1 meter.
2. Radiation given off by parts other than the tube head shall not exceed 2 mrem/hr at 5 cm.
3. All walls, ceilings, doors, and floor areas shall be equivalent to or provided with sufficient protective shielding to ensure that radiation levels in unrestricted areas do not exceed 2 mrem in any one hour or 100 mrem/yr.

## **Equipment Requirements**

The control panel shall contain the following legible and accessible warning statements:

1. "WARNING: This X-ray unit may be dangerous to patient and operator unless safe exposure factors and operating conditions are observed."
2. "CAUTION: This equipment produces radiation when energized, to be operated only by qualified personnel."

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

- 0.5 mm aluminum equivalent for machines operating up to 50 kilovolts peak (kVp),
- 1.5mm aluminum equivalent for machines operating between 50-70 kVp, and
- 2.5 mm aluminum equivalent for machines operating above 70 kVp.

The tube housing assembly support shall ensure that the tube housing remains stable during the X-ray exposure.

The technique factors to be used during an exposure shall be visible before the exposure begins.

On battery-powered equipment, visual means shall be provided on the control panel to show the charge of the battery.

A source-to-image distance (SID) indicator must be provided and be accurate to within 2% of the indicated SID.

## **Stationary, Portable, and Mobile Units**

A means for step-less adjustment (e.g. variable aperture collimator) of the size of the X-ray field shall be provided.

Means shall be provided to visually define the perimeter of the X-ray field.

The X-ray field shall not exceed the visually defined field by greater than 2%.

A method shall be provided to show when the axis of the X-ray beam is perpendicular to the plane of the image receptor.

The exposure shall be ended at a preset time interval, product of current and time, number of pulses, or radiation exposure to the image receptor.

The X-ray control shall provide a visual indication of X-ray production and an audible signal when the exposure is finished.

The X-ray control for stationary systems shall be permanently mounted in a protected area.

## **Fluoroscopic Systems**

X-ray production shall be controlled by a dead-man switch.

The on-time of the fluoroscopic tube shall be controlled by a timing device, which ends the exposure after 5 minutes.

An audible signal shall signal the completion of the preset on-time. This signal will remain on until the timing device is reset.

Protective barriers of at least 0.25 mm. lead equivalency shall be used to attenuate scatter radiation from above the table top (e.g. drapes, bucky-slot covers). This shielding is in addition to the lead apron worn by personnel.

Scattered radiation from under the table shall be attenuated by at least 0.25 mm lead equivalency.

The fluoroscopic imaging assembly shall be provided with a primary protective barrier, which intercepts the entire cross section of the useful beam.

The X-ray tube used for fluoroscopy shall not produce X-rays unless the barrier is in position to intercept the entire useful beam.

## **Operator's Booth**

The operator's booth shall have at least 7.5 square feet of unobstructed floor space in the booth. The booth may be of any shape with no dimension less than 2 feet. The booth is to be located or constructed so that the direct beam and unattenuated direct scatter radiation cannot reach the operator.



## **Structural Requirements**

The booth walls shall be at least 78 inches high and permanently fixed. A door or panel that is permanently part of the booth must be interlocked. Sufficient shielding shall be provided to prevent occupational limits from being exceeded.

## **Control Placement**

The X-ray control shall be fixed within the booth at least 40 inches from the edge of the booth wall closest to the examining table.

The placement of the control shall allow the operator to use most of the viewing window.

## **Viewing Requirements**

The booth must have a window that will allow the operator to view any occupant in the room and any entry into the room. Access doors that cannot be viewed by the operator must be interlocked.

The window shall have an area of at least 1 square foot with the lower edge at least 4.5 feet from the floor. The edge of the window shall be at least 18 inches from the edge of the booth. The glass shall have the same lead equivalency as the walls of the booth.

## **Records**

The Laboratory Authority shall maintain the following records and information:

1. An X-ray log containing the patient's name, type of examination, and the date of the examination.
2. Maximum ratings and technique factors of the equipment.
3. Model and serial number of all components.
4. Tube rating charts and cooling curves.
5. Assembler report for certifiable units.
6. Records of calibrations, maintenance, and modifications.
7. Aluminum equivalent filtration of the useful beam, including any routine variations.
8. VDH X-Ray Machine Certification form
9. Virginia Tech license, amendments, surveys and inspections.

## **Surveys and Inspections**

Radiation safety and equipment performance surveys shall be performed by a Qualified Expert annually on human-use units and at least every 3 years on bone density or veterinary-use units.

A survey for leakage radiation shall be performed following any maintenance, modification or relocation of the system.

Radiation surveys of areas adjacent to the X-ray producing facility and in the booth will be performed after installation of new equipment or the relocation of a unit.

1. The survey shall include a scale drawing of the areas adjacent to the X-ray room and an estimate of their occupancy.
2. The drawing shall include the type and thickness of the walls or their lead equivalency.

Reports of all surveys and inspections will be maintained in the Radiation Safety Office.

## **Analytical X-ray Equipment**

The following rules govern the use of analytical X-ray equipment at Virginia Tech. These rules comply with the radiation safety standards promulgated by the Commonwealth of Virginia and with the radiation safety standards recommended by the American National Standards Institute (ANSI).

### **Open and Enclosed-Beam Analytical Systems**

The following are requirements for both open-beam and enclosed-beam analytical X-ray systems.

#### 1. Warning Lights

An easily visible warning light labeled "X-RAY-ON" shall be located near any switch that energizes an X-ray tube. It is to be illuminated only when the tube is energized. This light shall be of a fail-safe design.

#### 2. Labeling

All analytical X-ray equipment shall be labeled with a conspicuous sign or signs that bear the radiation symbol and the words (or similar words):

1. "CAUTION - HIGH-INTENSITY X-RAY BEAM" on the X-ray source housing.
2. "CAUTION - RADIATION - THIS EQUIPMENT PRODUCES RADIATION WHEN ENERGIZED" near any switch that energizes an X-ray tube.

#### 3. Beam trap

A beam trap or other primary beam shield shall be provided to intercept the primary beam.

### **Additional Requirements for Open-Beam Systems**

#### 1. Safety device

An interlocked safety device, which prevents entry of any part of the body into the primary beam or causes the beam to shut off, shall be provided on all open-beam systems.

A Laboratory Authority may seek an exemption from this requirement by applying to the Radiation Safety Committee. The application shall include:

1. A description of the safety devices evaluated and why they cannot be used.
2. A description of the alternative method that will be used to minimize the possibility of an accidental overexposure.
3. Procedures that will be used to alert personnel to the absence of a safety device.

## 2. Warning devices

Open-beam systems shall be provided with the following warning devices:

1. X-ray tube status (ON-OFF) located near the X-ray source housing, if the primary beam is controlled in this manner; and/or,
2. Shutter status (OPEN-CLOSED) located near each port on the X-ray source housing, if the primary beam is controlled in this manner.

These devices shall be readily visible and properly labeled as to their purpose. Warning devices shall have fail-safe characteristics.

## 3. Shutters

Shutters at unused ports shall be secured in the closed position to prevent accidental opening.

## 4. Ports

Each port on the X-ray source housing shall be equipped with a shutter that cannot be opened unless a collimator or other device has been connected to the port, if the system was installed after January 1, 1980.

### **Additional Requirements for Enclosed-Beam Systems**

#### 1. Chamber

The X-ray tube housing, sample detector, and analyzing crystal shall be enclosed in a chamber (or coupled chambers) that prevents entry of any part of the body.

#### 2. Ports

Access ports to the sample chamber shall be of a fail-safe design that prevents X-ray generation or entry of the X-ray beam into the chamber when any port is opened.

## Operating Procedures

1. Procedure Manual - Normal operating procedures shall be written and available to all analytical X-ray equipment users. Analytical X-ray equipment shall not be operated differently from that specified in the procedure manual unless written permission has been obtained from the Radiation Safety Committee.
2. Bypassing Safety Device - A safety device shall not be bypassed unless written approval has been obtained from the Radiation Safety Officer. This approval shall be for a specified time. When a safety device has been bypassed, a conspicuous sign shall be placed on the X-ray housing bearing the words (or similar words), "SAFETY DEVICE NOT WORKING."

## Radiation Limits

### Enclosed-beam systems

The exposure rate during normal operations shall not exceed 2.5 mrem/hr at a distance of 5 cm from the protective chamber walls.

### Open-beam systems

The exposure rate at the maximum rated current and voltage with all shutters closed shall not exceed 2.5 mrem/hr at a distance of 5 cm from the X-ray tube housing.

### Generator Cabinet

The exposure rate at a distance of 5 cm from the surface of the X-ray generator cabinet shall not exceed 0.25 mrem/hr.

The local parts of an analytical X-ray system shall include sufficient shielding and be so located and arranged so exposure rates in unrestricted areas do not exceed 2 mrem in any one hour or 100 mrem/yr.

## Surveys

Radiation surveys shall be performed and documented by the Radiation Safety Office:

1. On installation of the equipment and at least once every 3 years thereafter to monitor leakage radiation.
2. Following any change in the initial arrangement, number or type of local parts.
3. Following any maintenance that requires the disassembly or removal of a local part.
4. During the performance of maintenance and alignment procedures that require the presence of a primary beam and the disassembly or removal of a local part.
5. When a visual inspection of the local parts reveals an abnormality.
6. Annually there will be an administrative review to verify location and instrument status.

Each area or room containing open-beam analytical X-ray equipment shall be equipped with a suitable radiation survey instrument.

## **Repair and Alignment Procedures**

The following safety precautions **shall** be taken to reduce risks during repair and alignment procedures when interlocks are defeated:

1. The Radiation Safety Officer must approve alignment procedures, other than those recommended by the manufacturer.
2. Alignment procedures must be written and available to all users.
3. The main switch, rather than the safety interlocks, shall be used to shut down the equipment.
4. No X-ray tube shall be used without a suitable housing to restrict the radiation to a well-defined beam.
5. A sign stating "Safety Device Not Working" must be posted on the equipment when the interlocks have been defeated for alignment purposes.
6. If the dose rate in an unrestricted area is exceeded during the repair or alignment procedure, temporary barriers must be set up and the area must be properly posted. The area shall be kept under surveillance until normal operations have been restored.
7. After re-assembly, the X-ray equipment shall be checked for leakage radiation by the Radiation Safety Officer or the user.

The following safety precautions **should** be taken to reduce risks:

1. Alignment procedures recommended by the manufacturer should be used.
2. The smallest practical voltage and current should be used during the alignment procedure.
3. Long-handled tools and extension devices should be used to reduce the risk of the hand entering the beam.
4. Protective glasses should be worn during alignment procedures.
5. Temporary shielding should be added to reduce scattered radiation levels to a minimum.
6. Two-person teams should be used during alignment procedures. One person should make the adjustments while the other person watches for safety problems.

## **Cabinet X-ray Systems**

The rules in this section apply to cabinet X-ray systems. These requirements are in conformity with Title 21 of the Code of Federal Regulations, Part 1020 (21 CFR 1020), and the **Rules and Regulations for the Use of Ionizing Radiation in the Commonwealth of Virginia**.

### **Requirements for Cabinet X-ray Systems**

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

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

A control, other than the safety interlock, shall be provided to resume X-ray generation following X-ray interruption by a safety interlock.

Two independent means shall be provided to indicate when X-rays are being generated. One may be a milliamp meter labeled to indicate X-ray tube current, the other indicator shall consist of an easily seen warning light labeled "X-RAY ON."

A clearly legible and visible label bearing the statement: "CAUTION: X-RAYS PRODUCED WHEN ENERGIZED" shall be posted near the controls that energize the X-ray tube.

## **Operating Procedures**

Normal operating procedures shall be written and available to all cabinet X-ray equipment users. Cabinet X-ray systems shall not be operated differently from that specified in the procedure manual unless written permission has been obtained from the Radiation Safety Committee.

## **Radiation Limits**

Radiation emitted from a cabinet X-ray system shall not exceed an exposure rate of 0.5 mrem/hr at any point 5 cm from the external surface at the maximum rated current and voltage.

A cabinet X-ray system shall contain sufficient shielding and be located so exposure rates in unrestricted areas do not exceed 2 mrem in any one hour or 100 mrem/yr.

## **Surveys**

Radiation surveys shall be performed and documented by the Radiation Safety Office:

1. When the equipment is installed and at least once every 3 years thereafter to monitor leakage radiation.
2. After maintenance or system relocation.
3. Annually there will be an administrative review to verify location and instrument status.

## **Miscellaneous X-ray Equipment**

The rules in this section apply to the following miscellaneous X-ray producing equipment: electron microscopes, electron microphones, luminoscopes, and cold-cathode gas discharge tubes. These provisions do not apply to television receivers or video display terminals. These requirements are in conformity with title 21 of the

Code of Federal Regulations, Part 1020, and the **Rules and Regulations for the use of Ionizing Radiation in the Commonwealth of Virginia.**

## **Posting**

No area posting is required for miscellaneous X-ray equipment.

## **Warnings and labels**

A clearly legible and visible label bearing the statement: "CAUTION: THIS EQUIPMENT PRODUCES X-RAYS INCIDENTAL TO ITS PRIMARY FUNCTION - TO BE OPERATED BY QUALIFIED PERSONNEL ONLY" shall be posted on all miscellaneous X-ray producing equipment.

In addition to the above requirement, cold-cathode gas discharge tubes shall bear the following labels:

1. A label stating the maximum safe operating voltage.
2. A label that identifies the correct polarity of the terminals.

## **Operating Procedures**

Operating procedures shall be written and available to all users.

## **Radiation Limits**

Radiation emitted from electron microscopes, electron microprobes, and luminoscopes shall not exceed an exposure rate of 0.5 mrem/hr at 5 cm from the external surface.

Radiation exposure from cold-cathode gas discharge tubes shall not exceed 10 mrem/hr at 30 cm from the external surface averaged over 100 square centimeters.

All miscellaneous X-ray producing equipment shall contain sufficient shielding, and be located and operated so exposure rates in unrestricted areas do not exceed 2 mrem in any one hour or 100 mrem/yr.

## **Personnel Monitoring**

Personnel monitoring is not required for users of miscellaneous X-ray producing equipment.

## **Potential X-ray Exposure from Magnetic-Effect Tubes**

Magnetic-effect tubes demonstrate that cathode rays carry an electrical charge that can be deflected by a magnetic field. These tubes may produce X-rays incidental to their intended use and should be used with caution. Where there is a source of electrons, a target, sufficiently high voltage, and tube gas pressure within the proper

range, X-ray production will occur. X-ray output from magnetic-effect tubes, however, is unpredictable and intermittent. Under identical operating conditions it may vary from one tube to another; one tube may be an X-ray producer while another may not. X-ray production may vary during a given period of operation or from day to day for the same tube.

Since the educational benefits derived from these tubes are gained by visual observation of their operation, unshielded operation of these tubes is required; with the subsequent potential for student and operator exposure. To keep exposures to a minimum, requirements for the safe use of these tubes are as follows:

1. Magnetic-effect tubes must be used only for demonstrations conducted by the instructor.
2. The instructor should stand as far as practical from the tube during the demonstration.
3. Only the instructor shall operate a magnetic-effect tube.
4. Bystanders should stand at least 8 feet from an operating tube.
5. Tubes must always be operated with the correct polarity and the lowest practical current and voltage.
6. Operating time is to be kept to a minimum.

## **Surveys**

Radiation surveys shall be performed and documented by the Radiation Safety Office:

1. For electron microscopes, electron microprobes, and luminoscopes:
  1. When installed and at least once every five years thereafter to monitor leakage and area radiation levels.
  2. After system relocation or maintenance.
  3. Annually there will be an administrative review to verify location and instrument status.
2. For cold-cathode gas discharge tubes:
  1. Every 3 months when used routinely.
  2. Before use when used intermittently.

## **Terms and Definitions**

### **Access panel**

A panel that is designed to be opened for maintenance purposes to permit access to the interior of the cabinet.

### **Aluminum equivalent**

The thickness of type 1100 aluminum alloy affording the same attenuation as the material in question.

### **Analytical X-ray equipment**

Equipment used for X-ray diffraction and fluorescence analysis, (excludes cabinet X-ray systems, electron microscopes and diagnostic X-ray equipment).

### **Automatic exposure control**

A device that automatically controls one or more technique factors in order to obtain a required quantity of radiation.



**Beam-limiting device**

A device that provides a means to restrict the dimensions of the X-ray field.

**Cabinet X-ray system**

X-ray system with the X-ray tube installed in an enclosure, which is intended to contain the object being irradiated, provide radiation attenuation, and exclude personnel from its interior during X-ray generation.

**Certified components**

Parts of X-ray systems that are subject to regulations adopted under the Radiation Control for Health & Safety act of 1968.

**Cooling curve**

The graphical relationship between heat units stored and cooling time.

**Dead-man switch**

A switch that can only be kept ON by continuous pressure.

**Diagnostic X-ray system**

An X-ray system designed for irradiation of a human or animal for the purpose of diagnosis or visualization.

**Digital radiographic (DR) cassette**

Very sensitive screens that have replaced film for imaging where the image is directly recorded in computer systems.

**Diffraction beam**

A beam composed of mutually reinforcing scattered X-rays.

**Direct scattered radiation**

Scattered radiation that has been deviated in direction only by the object exposed to the useful beam.

**Enclosed beam configuration**

An analytical X-ray system in which all possible X-ray paths are fully enclosed.

**Fail-Safe design**

A design feature that guarantees that the beam port shutters close or prevent appearance of the primary beam in the event of failure of a safety or warning device.

**Gonad shield**

A protective barrier for the testes or ovaries.

**Half-value layer**

The thickness of a material that attenuates the beam of radiation to one-half of its original value.

**Healing arts screening**

The testing of humans using X-ray equipment for the detection or evaluation of health problems, when such tests are not specifically and individually ordered by a medical doctor.

**Heat unit**

A unit of energy equal to the product of the peak voltage, current, and seconds.

**Image intensifier**

A device that converts an X-ray pattern into a corresponding light image of higher energy density.

**Image receptor**

A device, such as a digital radiographic cassette, that transforms incident X-ray photons into a visible image.

**Inherent filtration**

Filtration of the useful beam provided by the permanently installed parts of the tube housing.

**Miscellaneous X-ray equipment**

Equipment that produces X-rays secondary to its primary function.

**Kilovolt peak (kVp)**

The maximum value of the potential difference across the X-ray tube during an exposure.

**Lead equivalent**

The thickness of lead affording the same attenuation as the material in question.

**Leakage radiation**

Radiation, except the useful beam, emanating from the tube housing.

**Local components**

Includes areas that are struck by X-rays, such as radiation source housings, port and shutter assemblies, collimators, sample holders, cameras, goniometers, detectors and shielding; but not including power supplies, transformers, amplifiers, readout devices and control panels.

**Milliamperere second (mAs)**

The product of tube current and exposure time.

**Mobile equipment**

X-ray equipment mounted on a permanent base with wheels.

**Open-beam configuration**

An analytical X-ray system in which some part of the body could accidentally be placed in the primary or diffracted beam path.

**Portable equipment**

X-ray equipment designed to be hand-carried.

**Primary beam**

X-rays that pass through an aperture of the source housing by a direct path from the X-ray tube.

**Protective apron**

An apron made of radiation-attenuating materials.

**Protective barrier**

A barrier of radiation-attenuating materials used to reduce radiation exposure. The types of protective barriers are:

- Primary - material placed in the useful beam, excluding filters, to reduce radiation exposure.
- Secondary - barrier that attenuates leakage and scattered radiation.

**Qualified expert**

Individuals, who have demonstrated by training and experience to the satisfaction of the State, that they possess the knowledge and training to measure ionizing radiation, to evaluate safety techniques, and to advise others regarding radiation safety needs.

**Safety interlock**

Device that is intended to prevent the generation of X-rays when a door or access panel is opened.

**Scattered radiation**

Radiation that has been deviated in its direction during passage through an object.

**Stationary equipment**

X-ray equipment that is installed in a fixed position.

**Technique factors**

The condition of operation that is the peak tube potential in kV and either the tube current in mA and exposure time in seconds, or the product of the tube current and exposure time in mAs.

**Tube rating chart**

The set of curves that specify the rated limits of operation of the tube in terms of the technique factors.

**Unrestricted area**

An area, access to which is neither limited nor controlled by the licensee or registrant for purposes of protection of individuals from exposure to radiation.

**Useful beam**

Radiation that passes through the tube housing port and the aperture of the beam-limiting device when the exposure switch is activated.

**Variable aperture**

A beam-limiting device that allows for stepless adjustment of the X-ray field.

**X-ray source housing**

That portion of an analytical X-ray system that contains the X-ray tube.

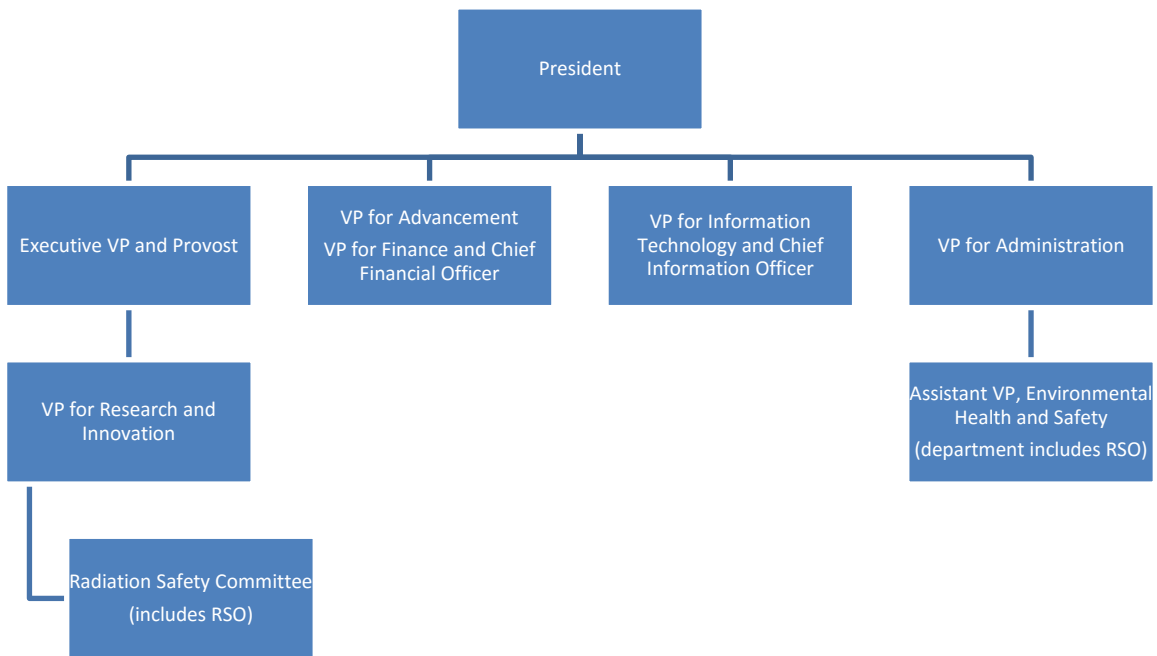
**More Information**

If you have read through all the material, have explored all avenues and still have a question or need a policy clarified, contact:

- Donald Conner, 540-231-5364, [dcon@vt.edu](mailto:dcon@vt.edu), Radiation Safety Officer
- Cynthia Strader, 540-231-2699, [cynth@vt.edu](mailto:cynth@vt.edu)

**APPENDICES**

**APPENDIX 1: Organizational Chart**



**APPENDIX 2: X-ray Emergency Procedures**

**X-RAY EMERGENCY PROCEDURES**

**Individuals who suspect that they have been exposed to the direct beam from any x-ray producing equipment shall:**

**Immediately turn the equipment off.**

**Call the Radiation Safety Office at 231-5364, before 5:00 pm or the Virginia Tech Police at 911 after 5:00 pm and weekends.**

*If using a cell phone to dial 911, remember to identify your location for the operator.*

**Notify one person from the laboratory line of authority.**

**Remain in the area until the arrival of the Radiation Safety Officer or their designee.**

*Off-campus sites should use the campus non-emergency number, (540) 382-4343, to contact VT support personnel as needed.*

**EMERGENCY CONTACTS**

	Name	Office Address	Office Telephone	Home Telephone
Laboratory Authority				
Secondary Contact				
Other Contact				
Other Contact				

**Emergency Telephone Numbers**

**8 am to 5 pm**

**After 5, weekends**

**VT Radiation Safety Office**

**1-5364 (540.231.5364)**

**911**

**VT Hazardous Material Safety**

**1-8758 (540.231.8758)**

**911**

**Police**

**911**

**911**

**Rescue Squad**

**911**

**911**

**Fire**

**911**

**911**

### APPENDIX 3: Emergency Contacts

In Case of Emergency Call 911

## EMERGENCY CONTACTS

	Name	Office Address	Telephone	
			Office	Home
Principal Investigator(s)				
Secondary Contact				
Other Contact				

Emergency Telephone Numbers	8 am–5 pm	After 5 pm, Weekends
Radiation Safety	231-5364	
Hazardous Material Safety	231-2982 or 231-8758	
Biological Safety	231-5864 or 231-3361	
VT Police/Rescue		
Blacksburg Fire Department		

*If using a cell phone to dial 911, remember to identify your location for the operator*

**OFF-CAMPUS SITES SHOULD USE 911 FOR LOCAL EMERGENCY RESPONSE**

*Use the non-emergency number, (540) 382-4343, for information and to contact VT support personnel as needed.*

*Facility-specific safety manual (e.g., Chemical Hygiene Plan, Biosafety Manual) is located:*

*Safety Data Sheets and Material Safety Data Sheets (SDS/MSDSs) are located:*

Effective Date: \_\_\_\_\_