CONTROL AND ACCOUNTABILITY OF RADIATION GENERATING EQUIPMENT

1.0 PURPOSE

To provide instructions for the registration, use, operation, control, and accountability of x-ray generating devices on the campus of the Georgia Institute of Technology (Georgia Tech).

2.0 SCOPE

This procedure is applicable to the Georgia Tech campus in its entirety and to all operations involving x-ray generating devices except those which produce radiation from radioactive materials and x-ray generating devices designed and used for medical uses on humans. Typical x-ray generating devices include devices in shielded rooms (Appendix B), shielded cabinets devices (Appendix C), open installations (Appendix D), and electron microscopes (Appendix E). This procedure also extends to cover any apparatus capable of emitting x-rays as an unwanted byproduct (Appendix F). Particle accelerators are considered separately.

3.0 RESPONSIBILITIES

3.1 The President of Georgia Tech has charged the Radiation Safety Officer (RSO) with the responsibility of administering the program for control and accountability of x-ray generating devices and radioactive materials.

3.2 The Radiation Safety Committee (RSC) is responsible for approving policies governing the registration, use, operation, control, and accountability of x-ray generating devices. Applications for acquisition of x-ray generating devices must be approved by the RSC prior to equipment purchase or acquisition. Applications for use of x-ray generating devices must be approved by the RSC prior to use.

3.3 The Radiation Safety Officer (RSO) is responsible for the Radiation Protection Program of the entire campus including determining compliance with rules and regulations of the State of Georgia, the Georgia Tech Radiation Safety Policy Manual, and the conditions under which the Authorized User (AU) obtained approval from the RSC.

3.4 The Office of Radiological Safety (ORS) is responsible for providing radiation protection services such as personnel monitoring, periodic equipment surveys, maintenance of records required by the State of Georgia, and consultation on the safe use of x-ray generating devices. The ORS is authorized to enter any room housing an x-ray generating device

anywhere on the Georgia Tech campus at any time for the purpose of determining compliance with the State of Georgia regulations for personnel health and safety.

3.5 The Authorized User (AU) is responsible for informing the ORS of a new x-ray generating device before purchase or acquisition, filling out the required paperwork in a timely manner, and having the x-ray generating device surveyed before its first use.

4.0 REFERENCES/REQUIREMENTS

4.1 Requirements and Specifications

4.1.1 Radiation Safety Policy Manual, Georgia Institute of Technology

4.1.2 State of Georgia Rules and Regulations for X-ray, Chapter 290-5-22

4.1.3 ANSI/HPS N43.3-2008

4.1.4 X-ray Shutter Service Policy

4.2 Related Procedures

4.2.1 Procedure 9310, Posting of Radiological Control Areas and Materials

4.2.2 Procedure 9316, Personnel Dosimetry

4.3 Equipment/Materials Required

4.3.1 Form A (RS-019a)

4.3.2 Form B (RS-019b)

4.3.3 Quarterly Check Form (RS-136)

4.4 Other

4.4.1 None

5.0 PROCEDURAL STEPS

5.1 Obtaining Authorized User Status

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5.1.1 A prospective AU must complete the paperwork and training as described in section 5.2 of this procedure to become a Radiation Worker before the approval of a Form A.

5.1.2 The prospective AU must complete an Application for Authorized User Status for Acquisition and Use of X-Ray Producing Equipment form (Form A). This form may be obtained from the ORS. The completed application shall be forwarded to the RSO for review.

5.1.3 The RSO shall review the application and if appropriate, schedule an interview with the prospective AU to evaluate the facilities available (e. g., shielding requirements), training and experience of the applicant, survey equipment available, and the details of the work to be performed.

5.1.4 Radiation protection requirements shall be established for users of x-ray generating devices as appropriate for each specific x-ray generating device, the nature, duration and scope of use, and the exact location(s) of use.

5.1.5 Upon review and concurrence with the application by the RSO, the application shall be forwarded to the RSC for approval. RSC approval will be signified by the signature of the Chairman and the RSO on the application form.

NOTE: Since the RSC may meet only once per quarter, the Chairman of the RSC is empowered to signify an interim approval of the application. In such instances, the application will be presented to the entire body of the RSC at its next scheduled meeting.

NOTE: Upon the approval of a Form A for AU Status, the AU shall also provide to the ORS a key to the room(s) where the x-ray generating device will be used and/or stored.

5.1.6 The procedure as described in the approved Form A along with any modifications incorporated during the review process shall become the conditions under which the AU and his personnel are authorized to use the x-ray generating device.

5.2 **Obtaining Radiation Worker Status**

5.2.1 To provide Georgia Tech with a record of the training and experience of persons working with radiation, each individual (including faculty, staff, and students) who will be working with x-ray generating devices shall file a Radiation Worker Registration Form (Form B) with the ORS.

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EXEMPTION: There will be no requirement for Radiation Worker Registration Forms to be filed for each student attending a regularly scheduled laboratory class that utilizes an x-ray generating device. However, students operating the x-ray generating device will be required to have a Form B filed with the ORS.

5.2.2 On a periodic basis, the ORS shall arrange training sessions in x-ray safety.

5.2.3 X-ray safety training shall be completed before the Radiation Worker may operate the x-ray generating device. The AU shall maintain a record of all training for each operator. Such records shall be made available for inspection.

5.2.4 The AU shall assure that all x-ray generating devices under his control are operated only by Radiation Workers who have completed the x-ray safety course through the ORS.

5.2.5 The AU shall be responsible for providing device specific training for individuals working with x-ray generating devices under his sponsorship to ensure that the health and safety of these individuals will be safeguarded. This includes demonstrating familiarity with the terms of the authorization as approved by the RSC. This training shall be documented by the AU or his designee in a training log that is to be maintained in the laboratory.

5.2.6 **Personnel Monitoring**

5.2.6.1 Personnel monitoring shall be performed in accordance with the requirements contained in the Georgia Tech Radiation Safety Policy Manual and Procedure 9316 titled “Personnel Dosimetry”.

5.2.6.2 Each individual who receives, or is likely to receive, a whole body dose in excess of 10% of the limits set forth in 10 CFR 20, or who enters a Radiation Area shall be provided a personal dosimeter. These devices shall be provided by the ORS.

5.2.6.3 When a personal dosimeter is provided, it shall be worn appropriately by the individual to whom it is assigned when in the vicinity of the x-ray generating device.

5.3 **Acquisition of X-ray Generating Devices**

5.3.1 An approved Form A is required before acquisition of an x-ray generating device.

5.3.2 Georgia Tech Procurement requires RSO approval before processing orders for x-ray generating devices.

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5.4 **Receipt of X-Ray Generating Devices**

NOTE: The ORS must register any x-ray generating device to be used on the Georgia Tech campus within 7 days of acquisition with the Georgia Department of Human Resources, Division of Radiological Health.

5.4.1 When an x-ray generating device is delivered to the Georgia Tech campus, the responsible AU shall verify and document that the manufacturer of the x-ray generating device has provided manuals and instructions which shall include at a minimum the following technical and safety information:

5.4.1.1 Voltage, current and duty cycle ratings of the x-ray generation equipment,

5.4.1.2 Adequate instructions concerning any radiological safety procedures and precautions which may be necessary because of unique features of the system, and

5.4.1.3 The schedule of maintenance necessary to keep the system in compliance with approved regulations.

5.4.2 **Caution Signs, Labels and Signals**

5.4.2.1 Posting of "Radiation Areas" or "High Radiation Areas" shall be in accordance with the instructions contained in Procedure 9310, Posting of Radiological Control Areas and Materials.

5.4.2.2 Control panels of equipment capable of producing radiation when operated shall be appropriately labeled with a permanent label visible to the operator so as to inform individuals that such equipment produces radiation when operated. These labels shall be provided by the ORS.

EXAMPLE: CAUTION X-RAYS - This Equipment Produces X-Rays When Energized

5.4.2.3 A warning light with the notation **"X-RAY ON"** or equivalent shall be located on the control panel and shall light only when the x-ray tube is activated.

5.4.2.4 Audible or visible signals shall be provided in the vicinity of installations to provide warning that the equipment is on and that x-rays are being produced and should be activated prior to any exposure.

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5.4.3 A radiation survey shall be performed by the ORS upon installation of the x-ray generating device before the x-ray generating device is placed into routine use.

5.5 **Normal Operation**

5.5.1 **Requirements**

5.5.1.1 Written operating and emergency shut down procedures shall be established for each unit and shall be posted in a conspicuous location near each x-ray generating device including any restrictions or constraints which are imposed to ensure safe operation of the particular device.

5.5.1.2 A key-operated primary control switch shall be provided such that x-ray production shall not be possible with the key removed. Any exception to this requirement requires the approval of the State of Georgia Department of Human Resources. Petition for exception shall be made through the ORS.

5.5.1.3 Safety glasses shall be provided by the AU and recommended for use by operators, assistants, and maintenance personnel.

5.5.1.4 A logbook shall be kept for each x-ray generating device, and shall include the following information:

5.5.1.4.1 Name of operator

5.5.1.4.2 Date, time in, time out

5.5.1.4.3 Voltage and current settings

5.5.1.4.4 Maintenance performed or problems with the device

5.5.2 **Safety Systems (Interlocks) if Applicable**

5.5.2.1 Interlocks shall **NOT** be used to de-activate the x-ray tube, except in an emergency or during testing of the interlock system. If the interlock was activated, it shall be possible to restore the machine to full operation only from the control panel.

5.5.2.2 Interlocks shall **NOT** be bypassed for operation of the device at any time.

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5.5.2.3 Any time a temporary alteration to safety devices, such as to interlocks or shielding during maintenance or repair, is planned or anticipated, the ORS shall be notified prior to initiation of any action. Work must be done by manufacturer certified personnel.

5.5.3 Radiation surveys shall be conducted annually by the ORS.

5.6 **Change of Operating Conditions**

5.6.1 Any AU who wishes to make any change (including change of location) to his approved Form A shall formally request the change in writing. The proposed change shall be reviewed and approved by the RSO before the change can go into effect.

5.6.2 Only manufacturer certified personnel shall be permitted to install, repair, or make other than routine modifications to the x-ray generating apparatus and the tube housing-apparatus complex.

5.6.3 The AU shall notify the ORS that a radiation survey is needed under any of the following conditions:

5.6.3.1 A change in the arrangement, number or type of components in the system,

5.6.3.2 Any maintenance requiring the disassembly or removal of a component in the system,

5.6.3.3 During the performance of maintenance and alignment procedures if the procedures require the presence of a primary x-ray beam when any component in the system is disassembled or removed, or

5.6.3.4 Any time a visual inspection of the local components in the system reveals an abnormal condition.

5.7 **Unit Out of Service**

5.7.1 When the use of an x-ray generating device is discontinued, the keys that operate the x-ray generating device will be removed and stored in a secure place by the AU. The ORS will be notified and will tag the x-ray generating device out of service. The device shall remain tagged out of service until another individual becomes an approved AU for the device or the AU notifies the ORS of the change in status. A radiation survey shall be conducted by the ORS before the device is put into routine use.

5.8 **Disposal**

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5.8.1 Any AU who wishes to dispose of his x-ray generating device shall notify the ORS in writing well ahead of such action. X-ray generating devices can only be discarded by:

5.8.1.1 Transferring the unit to a Georgia Department of Human Resources (GA DHR) approved registrant, or

5.8.1.2 Rendering the unit dysfunctional by removal of the tube head.

6.0 **RECORDS**

6.1 Any record generated as a result of implementation of this procedure shall be maintained as permanent records of Georgia Institute of Technology.

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Appendix A – Definitions

accessible area: Any area where the body or a part of the body may be exposed to radiation without necessitating a shutdown of the radiation source.

as low as reasonably achievable (ALARA): Making every reasonable effort to maintain exposures to radiation as far below the dose limits as practical, taking into account the state of technology, the economics of improvements in relation to benefits to health and safety, and other societal and socioeconomic considerations.

Authorized User (AU) - An AU is a Georgia Tech faculty or staff member whose use of radiation generating equipment has been approved by the Radiation Safety Committee. An AU is normally in charge of a research project involving an x-ray generating device or is responsible for a course with a laboratory in which an x-ray generating device is used. Students are not eligible to apply for AU status.

collimator: A device used to limit the size, shape, and direction of the primary beam.

controlled area: A specified area in which access of personnel to radiation or radioactive material is controlled. A controlled area should be under the supervision of a person who has knowledge of the appropriate radiation protection practices, including pertinent regulations, and who has responsibility for applying them.

exposure (X): A measure of the ionization produced in air by x-rays or gamma rays of energies less than or equal to 3 MeV. It is the sum of the electrical charges of all of the ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in the air, divided by the mass of the air in the volume element. The SI unit of exposure is coulomb per kilogram (C kg–1). The conventional special name for exposure is the roentgen (R), where 1 R = 2.58 × 10–4 C kg–1. Though the conversion is slightly dependent on photon energy, for the purposes of this Standard, an exposure of 100 R corresponds to an air kerma of approximately 0.878 Gy (1 R ≈ 0.878 rad in air).

Note: “exposure” is also used colloquially to express contact with a radiation field. Its use as either the technical term above or in the more conversational sense should be obvious by context.

exposure rate: Exposure per unit time. In the case of a pulsed x-ray–generating device, the exposure rate is considered to be the time-weighted average over a full cycle, not an instantaneous rate.

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high radiation area: Any area, accessible to individuals, in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 0.001 Sv (0.1 rem) in one hour at 30 cm from the radiation source or from any surface that the radiation penetrates.

interlock: An electromechanical device that automatically precludes access to an area of radiation hazard either by preventing entry or by automatically removing the radiation hazard.

ionizing radiation: Any electromagnetic or particulate radiation capable or producing ions, directly or indirectly, by interaction with matter, including x- and gamma rays or alpha, beta, and neutron particles.

leakage radiation: All radiation, except the useful beam, coming from the x-ray generating device or source housing.

primary radiation: Radiation coming directly from the x-ray tube target or from the sealed source.

radiation area: Any area, accessible to individuals, in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 0.05 mSv (0.005 rem) in one hour at 30 cm from the source or from any surface that the radiation penetrates.

radiation detection instrument: A device that will provide audible and/or visual indication of the presence and magnitude of radiation. A radiation detection instrument, for example, may be either a traditional hand-held radiation survey meter or a personal alarming ratemeter that is worn on a worker.

radiation protection survey: Evaluation of the radiation hazards in and around an installation. It customarily includes a physical survey of the arrangement and use of the equipment and measurements of the exposure rates under the full range of expected operating conditions.

radiation source: An apparatus or a material emitting, or capable of emitting, ionizing radiation in its current configuration.

radiation survey meter: A type of radiation detection instrument used to assess radiation levels for purposes of documentation or to identify and quantify specific radiation levels.

radiation worker: An individual whose work is normally performed in a controlled area, or whose duties involve exposure to radiation and who is subject to appropriate radiation protection controls.

rem: The conventional special unit of dose equivalent. One rem = 0.01 Sv, or 1 Sv = 100 rem.

roentgen (R): The conventional special unit of exposure. One roentgen equals $2.58 \times 10–4$ C kg–1 of air. Though the conversion is slightly dependent on photon energy, for the purposes of this Standard, an exposure of 100 R corresponds to an air kerma of approximately 0.878 Gy (1 R $\approx$ 0.878 rad in air).

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scattered radiation: Radiation that has been scattered as a result of interaction with matter and has usually been reduced in energy and intensity.

shield or shielding: Attenuating material used to reduce the transmission of radiation.

uncontrolled area: Any area to which access is not managed to protect individuals from exposure to radiation and/or radioactive material.

useful beam: That part of the primary and secondary radiation that passes through the aperture, cone, or other device used for collimation.

workload (W): A measure, in suitable units, of the amount of use of radiation equipment. For the purpose of this Standard the workload is expressed in milliampere-minutes per week for x-ray generating devices and roentgens per week at one meter from the source for gamma-ray sources and high-energy equipment (such as linear accelerators, betatrons, etc.).

x-ray generating device : A device that generates characteristic x-rays or bremsstrahlung radiation. For the purpose of this standard, this definition only includes photon radiation up to 10 MeV. There are two categories of x-ray generating devices, intentional and incidental.

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Appendix B - Shielded Room Installations

1.0 Setup

1.1 **Shielding**

1.1.1 Shielding drawings and specifications for a new facility or for modifications to be made in an existing facility shall be submitted for review and approval prior to construction or modification.

1.1.2 X-ray tubes shall be provided with protective housing(s) appropriate to the nature of the research to afford adequate protection to personnel.

1.1.3 The AU shall provide each installation with such primary protective barriers and/or secondary protective barriers as are necessary to assure compliance with the Georgia Tech ALARA levels as stated within the Georgia Tech Radiation Protection Program.

1.1.4 The ORS shall be involved in each stage of the installation of the shielding and x-ray generating device. The final assessment of the adequacy of the design and construction of structural shielding shall be based on a radiation survey conducted by the ORS after the installation is completed. If the radiation survey shows any deficiencies, additional shielding and/or modifications shall be provided by the AU and installed to the satisfaction of the ORS.

1.2 **High Radiation Areas**

1.2.1 Each high radiation area shall be arranged in such a way that an individual can quickly leave that area.

1.2.2 Each entrance or access point to a high radiation area shall be:

1.2.2.1 Equipped with a control device which shall cause the x-ray generating device to turn off automatically upon entry into the area, such as interlocked doors; or

1.2.2.2 Maintained locked except during periods when access to the area is controlled.

1.2.3 The dose equivalent at any accessible uncontrolled area shall not exceed 0.02 mSv (2 mrem) in any one hour at 30 cm (1 foot) from the outside surface of the enclosure.

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NOTE: No radiation beam limiting or collimating devices or filters shall be used during tests to determine shield adequacy unless these devices are normally attached to the source housing or x-ray tube assembly during use.

NOTE: The beam direction shall be positioned and oriented such that the highest exposure rate will be encountered in the area under evaluation provided that such positioning and orientation will serve a practical purpose in normal use.

1.2.4 No person, either within the controlled area or in the uncontrolled areas of the installation, shall be exposed to more than the maximum permissible dose equivalent.

1.2.5 Additional occupancy restrictions may be required to ensure that the annual dose equivalent to personnel in uncontrolled areas is maintained as low as reasonably achievable (ALARA).

1.3 Safety Systems

1.3.1 Suitable means of egress, so that any person may escape the interior of the room without delay, or an effective means within the room for preventing or terminating production of the x-rays, and which cannot be reset from the outside of the room.

1.3.2 For radiography x-ray generating devices, each door of a shielded room shall have a minimum of two operative safety interlocks. One but not both of the required interlocks shall be such that a door opening results in physical disconnection of the energy supply circuit to the high voltage generator and shut down of x-rays.

2.0 Operation

2.1 A suitable and functioning survey instrument, calibrated for the energy used, shall be available for use at each installation.

2.2 Follow operating procedure in approved Form A. Changes or new projects require a new Form A.

2.3 Radiation Surveys

2.3.1 Radiation surveys shall be performed quarterly by the AU or performed by a Radiation Worker on his behalf, and documented for the ORS using RS-136.

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APPENDIX C – Cabinet XRD/XRF/Radiographic

The term cabinet analytical x-ray generating device refers to x-ray diffractometers (XRDs), x-ray fluoroscopes (XRFs), and any type of cabinet x-ray generating device where the data is collected via a computer cable.

The term cabinet radiographic x-ray generating device refers to a cabinet x-ray generating device where the data is collected via film or an image receptor placed in the cabinet.

1.0 General Safety Provisions

1.1 Setup

1.1.1 Written operating and emergency procedures pertaining to radiation safety shall be established for each x-ray generating device and shall be posted in a conspicuous location near the x-ray generating device.

1.2 Routine Operation

1.2.1 AU shall not permit the routine operation of any equipment that would require an individual to expose any part of his body to the primary beam.

1.2.2 All x-ray generating devices shall be housed in interlocked and shielded protective housing, and the protective enclosures and equipment shall be kept in good repair.

1.2.3 A suitable and functioning survey instrument, calibrated for the energy used, shall be available for use at each installation.

1.2.4 Interlocks shall not be used to deactivate the x-ray tube except in an emergency or during testing of the interlock system; it shall be possible to restore the machine to full operation only from the control panel.

1.2.5 Radiation surveys, including tests of all safety devices such as interlocks, shutters and warning lights shall be performed quarterly by the AU or performed by a Radiation Worker on his behalf, and documented for the ORS using RS-136.

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1.2.6 Radiation originating within the high voltage power supply (i.e., transformers and rectifiers) shall not exceed 0.5 mrem in one hour at a distance of 5 centimeters from the power supply at every specified rating.

1.3 Maintenance

1.3.1 Only manufacturer certified personnel shall be permitted to install, repair, or make modifications to the x-ray generating device and the tube housing apparatus complex. A maintenance log book shall be kept. As a minimum, the following information must be logged each time maintenance is done, i.e., Date, person doing maintenance, description of work done.

1.3.2 The AU shall have the interlock and shutter systems of all x-ray generating devices in his possession that depend on an interlock and shutter system to prevent exposure of human being to x-ray disassembled and fully inspected by manufacturer certified personnel every five years. The documentation of these inspections shall be a prerequisite for continued operation of the x-ray generating device on the Georgia Tech campus.

2.0 Analytical X-Ray.

2.1 General Safety Provisions

2.1.1 Each analytical system shall be so arranged as to restrict the entry of parts of the body into the primary beam. This may be accomplished by using such arrangements as adequate barriers or interlocks.

2.1.2 The analytical x-ray device shall be provided with a protective barrier which absorbs the useful beam behind the specimen under examination.

2.1.3 The coupling between the x-ray tube and the collimator of the diffractometer, camera, or other accessory shall prevent radiation from escaping the coupling.

2.1.4 All tube head ports which are not in use shall be secured in the closed position in a manner which will prevent casual opening. Port covers shall offer the same degree of protection as is required of the tube housing.

2.2 Warning Lights, Signs, Labels

2.1 A sign or label shall be placed on or adjacent to each x-ray tube housing and shall be clearly visible to any individual who may be working in close proximity to the primary beam path.

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The sign or label shall read **"CAUTION - HIGH INTENSITY X-RAY BEAM."** These labels shall be provided by the ORS.

2.2 A warning light with the notation "X-RAY ON," shall be located on the control panel and:

2.2.1 Shall light only when the x-ray tube is activated; and

2.2.2 Shall be wired in series with the primary electrical circuit so that if the warning light is inactivated x-ray generation is not possible.

2.3 When the primary x-ray beam is completely enclosed the radiation level shall be less than 2 mrem/hour at 25 centimeters from the apparatus at every specified tube rating.

3.0 **Radiographic**

3.1 General Safety Provisions

3.1.1 The x-ray source and all objects exposed thereto must be contained within a permanent enclosure.

3.1.2 A control shall be provided that will enable the operator to initiate and terminate the production of x-rays by means other than the safety interlock system or main power control.

3.1.3 It shall not be possible to extend any part of the human body through a port into the primary beam.

3.1.4 Radiation exposure shall not exceed 0.5 mR in any one hour at a distance of five cm (2 in) from any point on the external surface of the cabinet or of any component outside the cabinet when operated under any conditions for which the machine is designed.

3.2 Safety Systems and Interlocks

3.2.1 Each door of a cabinet x-ray system shall have a minimum of two operative safety interlocks. One but not both of the required interlocks shall be such that a door opening results in physical disconnection of the energy supply circuit to the high voltage generator, and such disconnection shall not be dependent upon any moving part other than the door. The Authorized User shall:

3.2.1.1 Maintain records that verify the existence of dual interlocks,

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3.2.1.2 Maintain records of any repairs made on the dual interlocks, and

3.2.1.3 Certify to the Office of Radiological Safety that modifications have not been made to the dual interlocks that are not consistent with manufacturer's design specifications. Such certification shall be made as a part of the Form A.

3.2.2 For cabinet x-ray systems designed for entry by an individual during the normal course of use of the machine, there shall also be provided:

3.2.2.1 Audible and visible warning signals (preferably of the rotating or flashing beacon type) within the cabinet which must be activated for at least 20 seconds immediately prior to the first initiation of x-radiation production; and

3.2.2.2 A visible signal within the cabinet which shall remain operative for the entire duration of x-ray production. It shall be automatically initiated prior to x-ray production and terminated with the exposure; and

3.2.2.3 Suitable means of egress, so that any person may escape the interior of the cabinet without delay, or an effective means within the cabinet for preventing or terminating production of the x-radiation, and which cannot be reset from the outside of the cabinet.

3.2.2.4 The audible signal shall be activated if an interlocked access to the exposure area is opened and the radiation exposure rate exceeds 100 mR/hr. The signal shall be audible to the operator of the radiation source and to the person entering the exposure area. The audible signal shall be of a frequency or sound pressure level that can be heard over background noise. During normal operations, constant use of audible signals that may be heard outside of the enclosure is discouraged due to the potential desensitization of workers toward responding to alarms.

3.2.2.5 For installations using x-ray generating devices, the following recommendation may be used instead of using the warning signals. Each personnel access to the exposure room shall have a minimum of two interlocks. At least one of the required interlocks shall be such that opening of any x-ray enclosure room door results in physical disconnection of the energy supply circuit to the high-voltage generator, and this disconnection shall not depend upon any other moving part other than the door.

3.2.2.6 Installations using x-ray generating devices that produce radiation levels in excess of 500 Rad/hr at 1 m (39.4 in) from the radiation source shall employ both audible and visible warning signals. This requirement does not apply to installations in which the very high radiation area is not an accessible area.

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APPENDIX D - Open Installations (radiographic / XRF)

1.0 **General Safety Provisions**

1.1 **Radiation Surveys**

1.1.1 A suitable and functioning survey instrument, calibrated for the energy used, shall be available for use at each installation.

1.1.2 Radiation leakage from the tube housing shall not exceed 25 mrem in one hour at 5 centimeters from the surface of the tube housing at any specified tube rating.

1.1.3 Radiation originating within the high voltage power supply (i.e., transformers and rectifiers) shall not exceed 0.5 mrem in one hour at a distance of 5 centimeters from the power supply at every specified rating.

1.1.4 When the primary x-ray beam is completely enclosed the radiation level shall be less than 2 mrem/hour at 25 centimeters from the apparatus at every specified tube rating.

1.2 The AU shall have the interlock and shutter systems of all x-ray generating devices in his possession that depend on an interlock and shutter system to prevent exposure of human being to x-ray disassembled and fully inspected by manufacturer certified personnel every five years. The documentation of these inspections shall be a prerequisite for continued operation of the x-ray generating device on the Georgia Tech campus.

1.3 Each port on the radiation source housing shall be equipped with a shutter that cannot be opened unless a collimator, or a coupling and recording device with beam absorber, has been connected to the port.

2.0 **Setup**

2.1 **Warning lights, etc.**

2.1.1 Sufficient warning lights or other equally conspicuous signals that operate only when the primary x-ray beam is released from the beam ports shall be provided in such a manner as to alert individuals to the potential radiation hazard. These signals shall be labeled so that their purpose is easily identified.

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2.2 **High Radiation Areas**

2.2.1 Each high radiation area shall be arranged in such a way that an individual can quickly leave that area.

2.2.2 Each entrance or access point to a high radiation area shall be:

2.2.2.1 Equipped with a control device which shall cause the x-ray generating device to turn off automatically upon entry into the area; or

2.2.2.2 Maintained locked except during periods when access to the area is controlled.

2.2.3 The dose equivalent at any accessible uncontrolled area shall not exceed 0.02 mSv (2 mrem) in any one hour at 30 cm (1 foot) from the outside surface of the enclosure.

NOTE: No radiation beam limiting or collimating devices or filters shall be used during tests to determine shield adequacy unless these devices are normally attached to the source housing or x-ray tube assembly during use.

NOTE: The beam direction shall be positioned and oriented such that the highest exposure rate will be encountered in the area under evaluation provided that such positioning and orientation will serve a practical purpose in normal use.

2.2.4 No person, either within the controlled area or in the uncontrolled areas of the installation, shall be exposed to more than the maximum permissible dose equivalent.

2.2.5 Additional occupancy restrictions may be required to ensure that the annual dose equivalent to personnel in uncontrolled areas is maintained ALARA.

3.0 **Operating Procedure**

3.1 **Exposure Rate Barriers**

3.1.1 During the initial exposure, radiation levels should be measured around the perimeter of the controlled area and the perimeter adjusted as required. Surveys should be conducted for each new operating condition and the perimeters adjusted accordingly. The area of operation should be monitored periodically.

3.1.2 Measurement of radiation levels for a radiation survey must be performed using a suitable calibrated radiation survey meter. A radiation survey meter must also be

conducted when there is potential for non-uniform exposure to personnel, such as may occur during machine maintenance or work in an x-ray generating device target area.

3.1.3 When approaching the radiation source, following the conclusion of an exposure, the operator shall use a suitable calibrated and operable radiation detection instrument to verify that the source is in its fully shielded condition or that the x-ray tube has been de-energized.

3.1.4 Radiation areas shall be identified and suitably posted with caution signs. A fence, rope or other suitable personnel barrier shall be erected along a 5 mR/hr contour line.

3.1.5 High radiation area shall be identified and suitably posted with "Danger (or Caution): High Radiation Area" warning signs at the distance measured or calculated to produce a radiation level of 1 mSv (100 mrem) in any one hour.

3.2 **Monitoring Devices**

3.2.1 Suitable personnel monitoring devices for the energy used shall be provided and shall be used by persons in the area. One device shall be a personal dosimeter issued by the ORS in accordance with Procedure 9316.

3.2.2 A personal alarming dose rate meter may be worn to approach the work area if the device is appropriately calibrated, set at an appropriate level to detect the presence of the source (e.g., 0.02 mSv/hr (2 mrem/hr)), and has been source-checked prior to use. The radiation in the work area must be reasonably uniform so that the device responds to radiation exposure to any part of the body. It may not be used to measure radiation levels, nor may it be used to indicate the presence of the source for potential non-uniform exposure, such as may occur during machine maintenance or work in an x-ray generating device target area.

3.3 **Control of Exposed Areas**

3.3.1 The operator of radiation sources shall coordinate the planned operation with the area supervisor so that personnel are made aware of the potential radiation hazards.

3.3.2 All persons shall be removed from the radiation area before irradiation is begun. The operator shall perform a visual check of the controlled area to ensure it is free of all unauthorized personnel immediately prior to activating or exposing the radiation source. The operator shall be the last person to exit the area.

CONTROL AND ACCOUNTABILITY OF RADIATION GENERATING EQUIPMENT

3.3.3 During each radiographic operation, either the Authorized User or designee shall maintain direct vigilance of the operation to insure against unauthorized entry into the radiation area. Surveillance of the exposure area shall be maintained during operation, either by visual or by other reliable means to ensure that no person enters the area.

3.4 Written records of personnel exposure, safety procedures, and scaled drawing of the 5 mR/hr contour line shall be at the work site.

4.0 **Unaccompanied Use or Storage**

4.1 The operator shall be in immediate attendance at all times when the equipment is in operation except when the area is locked to protect against unauthorized or accidental entry.

4.2 The x-ray generating device itself, or the place in which the machine is stored, shall be locked in order to prevent unauthorized use.

4.3 When an x-ray system is left unattended, the control console shall be locked and the key removed to prevent unauthorized use. The exposure device or source housing shall be secured to prevent unauthorized access and removal or theft of the device.

4.4 All radiation sources and radiation protection equipment shall be inspected each day prior to use. Source and equipment checks shall be documented.

CONTROL AND ACCOUNTABILITY OF RADIATION GENERATING EQUIPMENT

APPENDIX E – Electron Microscopes

1.0 The high voltage power supply, which accelerates electrons in excess of 5 keV in electron microscopes, causes electron microscopes to be potential sources of ionizing radiation.

2.0 All equipment shall be operated in such a manner as to provide adequate protection to meet 10 CFR 20 radiation protection standards.

3.0 The dose rate at any readily accessible point 5 centimeters (2 inches) from the surface of such equipment shall not exceed 0.5 mR/hr.

CONTROL AND ACCOUNTABILITY OF RADIATION GENERATING EQUIPMENT

APPENDIX F - By-Product X-Ray Radiation

1.0 **Sources of X-rays**

1.1 Any apparatus capable of emitting x-rays as an unwanted by-product is regulated by the State of Georgia. (OCGA 290-5-22-.06)

1.2 The high voltage power supply, which accelerates electrons in excess of 5 keV in electron microscopes, causes equipment to be potential sources of ionizing radiation.

2.0 **General Safety Provisions**

2.1 All equipment shall be operated in such a manner as to provide adequate protection to meet 10 CFR 20 radiation protection standards.

2.2 Electronic equipment should not have a dose rate at any readily accessible point 5 cm (2 inch) from the surface of the equipment in excess of 0.5 mR/hr.

2.3 Additional appropriate safety provisions will be determined by the RSO. Shielding may be required to meet Georgia Tech ALARA levels.