RADIATION SAFETY GUIDE
FOR
ANALYTICAL X-RAY SYSTEM USERS

I  INTRODUCTION

The Minnesota Department of Health has established rules for the registration and safe use of ionizing radiation sources, and because analytical X-ray systems produce ionizing radiation the safety precautions and procedures are to be followed when these systems are used. The specific rules that apply to analytical X-ray users are listed in Chapter 4730, Sections 2510 and 2550 of the State of Minnesota Rules (see Appendix A).

At the University of Minnesota, the Radiation Protection Division (RPD) of the Department of Environmental Health & Safety provides assistance to analytical X-ray users to enable them to maintain compliance with State of Minnesota and University of Minnesota safety requirements. The RPD has developed this radiation safety guide as a means of informing analytical X-ray users of the potential hazards associated with these systems and of the precautions and procedures that are to be followed to minimize these hazards.

All persons who wish to use analytical X-ray systems must first review this guide, and receive hands on training in the proper operation of the unit and its associated safety and warning systems necessary to minimize radiation exposure. This training must be conducted under the supervision of an authorized operator of the analytical unit, and a written record that is signed by the trainee and the authorized operator must be kept on file for review by the RPD and the State of Minnesota safety inspectors. Questions concerning authorized operator requirements and analytical X-ray safety requirements should be directed to the RPD at (612) 626-6002.
Units of Radiation Exposure & Dose

The traditional unit of radiation exposure is the roentgen (abbreviated as R), which is defined as 2.58E-4 coulombs/kilogram of air. One milliroentgen (mR) equals 0.001 roentgen (R). Also, the radiation exposure rate is the number of roentgens per unit time. Typical units of exposure rate are R/min, mR/hr, etc.

The rad is the traditional unit of absorbed radiation dose and is equal to 1 erg/gram of any absorbing material. One millirad (mrad) equals 0.001 rad. The international system (SI) unit for absorbed dose is the gray (Gy). One Gy = 1 joule/kilogram (or 100 rad).

The traditional unit of radiation dose equivalence is the rem. One millirem (mrem) equals 0.001 rem. The SI unit of radiation dose equivalence is the sievert (Sv). One Sv = 100 rem. The rem dose for a particular radiation absorbed dose is equal to the absorbed dose in rad multiplied by the quality factor (QF) for the type of ionizing radiation (rem = rad x QF). The following table gives the approximate QF for various type radiations.

<table>
<thead>
<tr>
<th>Type of Radiation</th>
<th>QF</th>
</tr>
</thead>
<tbody>
<tr>
<td>beta particles</td>
<td>~1</td>
</tr>
<tr>
<td>gamma rays</td>
<td>~1</td>
</tr>
<tr>
<td>X-rays</td>
<td>~1</td>
</tr>
<tr>
<td>protons</td>
<td>~10</td>
</tr>
<tr>
<td>neutrons (&lt;0.025 MeV)</td>
<td>~1</td>
</tr>
<tr>
<td>neutrons (&gt;0.5 MeV)</td>
<td>~10</td>
</tr>
<tr>
<td>neutrons (&gt;10 MeV)</td>
<td>~20</td>
</tr>
<tr>
<td>alpha particles</td>
<td>~20</td>
</tr>
<tr>
<td>other heavy particles</td>
<td>~20</td>
</tr>
</tbody>
</table>

As a general rule, for beta, gamma and X-ray radiations, the following is true,

\[ 1 \text{ roentgen (R)} \equiv 1 \text{ rad} \equiv 1 \text{ rem} \]

Natural Background Radiation

Natural background radiation is received from four primary sources, 1) cosmic, 2) terrestrial, 3) internal body, and 4) indoor radon. The amount of radiation received by an individual will vary with elevation above sea level and geographic location. The average natural background radiation dose in the USA is approximately 300 mrem/year from the following sources:

<table>
<thead>
<tr>
<th>Source of Radiation</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosmic</td>
<td>~ 30 mrem/yr</td>
</tr>
<tr>
<td>Terrestrial</td>
<td>~ 30 mrem/yr</td>
</tr>
<tr>
<td>Internal</td>
<td>~ 40 mrem/yr</td>
</tr>
<tr>
<td>Radon</td>
<td>~ 200 mrem/yr</td>
</tr>
<tr>
<td>Total</td>
<td>~ 300 mrem/yr</td>
</tr>
</tbody>
</table>
II  GENERAL RADIATION SAFETY

Biological Effects of Ionizing Radiation

The physical process of ionization (formation of ions) when it occurs in a biological system will result in chemical and, potentially, biological effects. In the human body these biological effects may become evident as acute effects (only in event of high dose), or as longer-term somatic effects. The following is a brief summary of the types of effects from acute whole body radiation doses in the human body:

<table>
<thead>
<tr>
<th>Effect</th>
<th>Dose (rem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No observable effect</td>
<td>&lt; 25</td>
</tr>
<tr>
<td>Changes in white blood cell count</td>
<td>50</td>
</tr>
<tr>
<td>Nausea, vomiting, blood cell reduction</td>
<td>100</td>
</tr>
<tr>
<td>Illness, blood cell suppression, possible death</td>
<td>200</td>
</tr>
<tr>
<td>Lethal dose for 50% of exposed persons</td>
<td>400</td>
</tr>
<tr>
<td>Lethal dose for 100% of persons</td>
<td>650</td>
</tr>
</tbody>
</table>

The cause of lethality at ~650 rem is the effect on the cells of the blood forming system (the most sensitive cell system in the body). Other cell systems such as the endothelial cells are somewhat less sensitive to radiation, and muscle and nerve cells are relatively resistant to radiation damage. It is generally accepted that cell systems that are rapidly dividing and less differentiated are more sensitive to radiation. For this reason the dose limit for the developing embryo/fetus is lower than the adult dose limit (0.5 rem/9 month gestation vs. 5 rem/yr, respectively).

Dose Effect Limits

Stochastic Effects: an effect in which the probability of occurrence increases with increasing absorbed dose, but the severity in the exposed person does not depend on the magnitude of the absorbed dose. Examples include the probability of the induction of cancer and of the occurrence of genetic effects. Currently, the risk coefficient used for occupational radiation risks is \(4 \times 10^{-4}\) effects (lethal cancer induction) per rem of dose. The National Academy of Sciences’ Committee on the Biological Effects of Ionizing Radiations (BEIR) has stated that the actual risk of effects at low doses (such as typical occupational doses) may be less than this projection, and that the risk may, in fact, be zero. However, until studies can better establish a lower risk and/or a threshold, the stated risk coefficient estimate will continue to be the assumed risk of health effects.

Non-Stochastic Effects: a somatic effect (in the person exposed) which increases in severity with increasing absorbed dose. In general, considerably larger doses are required to cause non-stochastic effects to a degree that seriously impairs health. These effects often have a threshold dose below which no effect is seen. Examples of non-stochastic effects are reddening of the skin (erythema), lens opacification (cataracts) and hair loss (epilation). The following table shows the acute dose above which certain non-stochastic effects have been documented.

<table>
<thead>
<tr>
<th>Single Dose (rads)</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>Cataracts</td>
</tr>
<tr>
<td>350</td>
<td>Temporary epilation</td>
</tr>
<tr>
<td>500-800</td>
<td>Erythema</td>
</tr>
<tr>
<td>1200</td>
<td>Permanent epilation</td>
</tr>
</tbody>
</table>
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Severe radiation exposure and injury to fingers and hands have occurred when proper beam controls were not in place or failed to operate on x-ray diffraction units. The pictures below show the possible effects of very high radiation dose to the hand. Remember that erythema can be induced with an acute dose of greater than 500 rads, and tissue necrosis can occur from an acute dose of 1000 rads.

Effects of high radiation dose to the hand

Principles of Radiation Exposure Control

The radiations emitted by analytical X-ray machines (e.g. electrons, X-rays) may present an external exposure potential to those who operate and/or are in the vicinity of the machine during its operation. If X-ray energies exceed 10 MV there is a potential for neutron production, but because analytical X-ray units operate in the kV range neutron production does not occur. Therefore, with analytical x-ray units, the application of the principles of external exposure control, namely: time, distance, and shielding, are applied to minimize personnel exposure. These principles are described below.

1.  TIME

The radiation dose (D) a person receives is dependent on two factors: the radiation dose rate (DR) at the point where the person is located, and the time (T) the person remains at that location.

\[ D = DR \times T \]

2.  DISTANCE

The exposure rate (E) from a source falls off very rapidly with distance (d) if the source approximates a point source of emission. This relationship of exposure rate and distance from the source can be determined by using the inverse square law given below:

\[ \frac{E_d_1}{E_d_2} = \left(\frac{d_2}{d_1}\right)^2 \]

For example: if the exposure rate at 1 foot is 100 mR/hr, then the exposure rate at 10 feet will 1/100th of the exposure rate at 1 foot, or 1 mR/hr.
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3. SHIELDING

This principle involves the placement of an absorbing or attenuating material between the source of radiation and the exposed person to block or reduce the intensity of the radiation received by the person. The type and thickness of shielding necessary to reduce to radiation to a safe level is dependent on the type of radiation, the energy of radiation and the initial intensity of the radiation. The most common type of shielding used for attenuation of X-ray radiation is lead, or lead impregnated materials such as glass or acrylic. The half-value layer of a material is the thickness of that material needed to reduce the intensity of a particular type and energy of radiation by one half (½). The following table from NCRP Report #49 shows the shielding effectiveness of lead and concrete materials (note: the higher the energy the greater the amount of shielding for the half-value layer).

<table>
<thead>
<tr>
<th>Peak Voltage (kV)</th>
<th>50</th>
<th>70</th>
<th>100</th>
<th>150</th>
<th>200</th>
<th>250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Half-Value Layers (cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>0.006</td>
<td>0.017</td>
<td>0.027</td>
<td>0.030</td>
<td>0.052</td>
<td>0.088</td>
</tr>
<tr>
<td>Concrete (2.4 gm/cm³)</td>
<td>0.430</td>
<td>0.840</td>
<td>1.650</td>
<td>2.240</td>
<td>2.500</td>
<td>2.800</td>
</tr>
</tbody>
</table>

Half-value layers for shielding materials

Comparative Risks

The following table of comparative risks is taken from the NRC Regulatory Guide 8.29, which is entitled, ”Instructions Concerning Risks From Occupational Radiation Exposure”.

Estimated Loss of Life Expectancy from Health Risks

<table>
<thead>
<tr>
<th>Health Risk</th>
<th>Estimate of Life Expectancy Lost (average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking 20 cigarettes a day</td>
<td>6 years</td>
</tr>
<tr>
<td>Overweight (by 15%)</td>
<td>2 years</td>
</tr>
<tr>
<td>Alcohol consumption (U.S. average)</td>
<td>1 year</td>
</tr>
<tr>
<td>All accidents combined</td>
<td>1 year</td>
</tr>
<tr>
<td>Motor vehicle accidents</td>
<td>207 days</td>
</tr>
<tr>
<td>Home accidents</td>
<td>74 days</td>
</tr>
<tr>
<td>Drowning</td>
<td>24 days</td>
</tr>
<tr>
<td>All natural hazards (earthquake, lightning, flood, etc.)</td>
<td>7 days</td>
</tr>
<tr>
<td>Medical radiation</td>
<td>6 days</td>
</tr>
<tr>
<td>Occupational Exposure</td>
<td></td>
</tr>
<tr>
<td>0.3 rem/y from age 18 to 65</td>
<td>15 days</td>
</tr>
<tr>
<td>1 rem/y from age 18 to 65</td>
<td>51 days</td>
</tr>
</tbody>
</table>
Nature of X-rays

X-rays are electromagnetic radiation photons that have sufficient energy per photon to ionize matter. Along with gamma rays and cosmic rays, they are at the short wavelength (high frequency/high energy) end of the electromagnetic (EM) spectrum as shown in the following illustration:

![The Electromagnetic Spectrum](image)

X-rays differ from gamma rays in that gamma rays result from nucleon energy transitions within the nucleus of a radioactive atom, and X-rays result primarily from the interaction of a high energy electron within the positively charged fields of the nuclei of the target material (e.g., copper, molybdenum, tungsten, etc.). X-rays can also be produced as a result of electron shell vacancies in the target atoms caused by the electron beam interaction with orbital electrons. The X-rays that are generated as a result of vacancies in the orbital electron shells are called characteristic X-rays and are mono-energetic. The X-rays generated as a result of the interaction of the electron beam with positively charged nuclei are called bremsstrahlung or braking radiation, and have a continuous energy spectrum with the maximum energy equal to the energy of the accelerated electron beam. The amount of X-ray radiation produced in an electron beam target is proportional to the square of the electron beam energy, and proportional to the atomic number (Z) of the target. Examples of a typical X-ray tube and of a typical X-ray spectrum (showing both the bremsstrahlung spectrum and characteristic X-rays) are shown below.
X-ray Diffraction and Fluorescence Machines

X-ray diffraction units are commonly used to analyze the structure of materials, and X-ray fluorescence units for analyzing the elemental composition of materials. A significant radiation exposure potential exist from these units, especially when the beam pathway is not enclosed. The primary beam exposure rates form an X-ray diffraction unit can be as high as 40,000 R/min at the open beam port, and diffracted beams can be as high as 10’s of R/hr at the target material (ANSI Std. N43.2, Radiation Safety for X-ray Diffraction and Fluorescence Analysis Equipment). Remember, skin erythema is known to occur at a dose of several hundred rads. An erythema dose could be received at an open beam port in less than one second! Therefore, extreme caution and safety controls are needed to assure that no part of the body is exposed to these intense radiation levels. Interlocked beam shutters and shutter-open warning lights are necessary to prevent inadvertent exposure of the hands during beam alignment and sample placement or manipulations.

The following pictures show examples of X-ray diffraction units that have an open beam pathway, a closed beam pathway, warning lights, scatter radiation barriers and interlocks.
Radiation scatter barriers

Scatter barrier interlock
All individuals who are required to have their exposure to ionizing radiation monitored must be trained prior to using the source(s) of radiation. Viewing a series of radiation safety videotapes and successfully completing a questionnaire prepared by the Radiation Protection Division (RPD) will satisfy part of this requirement. The videotapes are available for viewing in the media resource centers of the Diehl Hall library on the Minneapolis campus, the Magrath Library on the St. Paul campus, and the UMD library. The radioactive material permit holder, the supervisor of the individual, or the equipment registrant is responsible for assuring that training is completed and, if applicable, that appropriate personnel dosimeters are obtained before assigning the individual to work with sources of ionizing radiation.

A. U.S. Nuclear Regulatory Commission (NRC) and State of Minnesota Requirements

Federal radiation protection standards and State of Minnesota ionizing radiation rules both require that persons who use sources of ionizing radiation be monitored for radiation exposure if their potential for exposure from external and/or internal radiation sources exceeds the following specified levels:

1. NRC requirements

Monitor external exposure of persons likely to receive a radiation dose from external sources in excess of 10% of the applicable yearly occupational dose limit:

- Total effective dose equivalent: 5,000 mrem
- Lens of the eye: 15,000 mrem
- All other organs including skin and extremities: 50,000 mrem
- Declared pregnant worker: 500 mrem /gestation
- Minors: 500 mrem

Monitor internal exposure of persons likely to receive in one year an intake in excess of 10% of the applicable Annual Limit of Intake (ALI). For a declared pregnant worker or a minor, the requirement applies if they are likely to exceed 1% of the applicable ALI(s).

2. State of Minnesota requirements

Monitor external exposure of persons likely to receive a radiation dose from external sources in excess of 25% of the applicable dose limits (in the time period referenced):

- Total effective dose equivalent: 1250 mrem/calendar quarter
- Lens of the eye: 3,750 mrem/qtr
- All other organs including skin and extremities: 12,500 mrem/qtr
- Declared pregnant worker: 500 mrem /gestation
- Minors: 100 mrem/yr

The dose limit for members of the general public is 100 mrem per year under both NRC and State of Minnesota rules.
B. External Radiation Exposure Monitoring

If required, appropriate radiation dosimeters must be requested and obtained from the RPD before an individual is allowed to use a radiation source. Use the following guidance to determine what, if any, dosimeters are required.

If a person will use a NRC licensed radiation source(s), and the external exposure potential exceeds 10% of the applicable limit(s) listed in A.1 above, the person must be provided and wear the appropriate external radiation dosimeter(s).

**NOTE:** If the radiation source is unsealed, the person may also be required to be monitored for internal radiation exposure if the potential for uptake exceeds the applicable limit. Contact the RPD if you have questions.

In the case where an individual will work only with X-ray equipment or other ionizing radiation producing machines, the State of Minnesota requirement applies. The person must be provided and wear the appropriate external radiation dosimeter(s) if they are likely to receive greater that 25% of the applicable limit(s) listed in Item A.2 above.

**NOTE:** The RPD, under the guidance of the All-University Radiation Protection Advisory Committee (AURPAC), may assign dosimeters to certain individuals or categories of radiation users who do not require a radiation dosimeter under NRC and/or State requirements (e.g., self-shielded gamma irradiator users, radiotracer radioisotope users, etc.). Because persons in these categories are not required to be monitored, it will not be necessary to obtain past exposure histories or to provide termination reports at the end of the period during which a person is monitored.

C. Dosimeters Needed for Ionizing Radiation Sources in Research or Medical Environment

1. Radioactive Material Used in Research

The University of Minnesota has monitored users in the research community for over 40 years, and dosimetry records have established that this group does not require monitoring under the federal and state guidelines listed above. However, the All-University Radiation Protection Advisory Committee has chosen to monitor certain members of this community based on the guidelines listed below. The RPD will review each research protocol and assess dosimetry needs on an individual basis.

It is the University’s policy that all Declared Pregnant Radiation Workers and minors who have authorized access to radioactive material use areas be issued a body dosimeter. Please see the corresponding policy statements for these two categories of radiation workers.

<table>
<thead>
<tr>
<th>Material category</th>
<th>Criteria for dosimeter</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. H-3, C-14, S-35, P-33, Ca-45</td>
<td>No external radiation dosimeter necessary</td>
</tr>
<tr>
<td>b. P-32, Cl-36, Y-90</td>
<td>Body dosimeter if $\geq 0.5$ mCi/stock vial</td>
</tr>
<tr>
<td></td>
<td>Body &amp; ring dosimeter if $\geq 1.0$ mCi/stock vial</td>
</tr>
</tbody>
</table>
c. I-125, Cr-51
   Body dosimeter if $\geq 1.0$ mCi/stock vial
   Body & ring dosimeter if $\geq 2.0$ mCi/stock vial
V PERSONNEL MONITORING AND DOSIMETRY POLICIES

<table>
<thead>
<tr>
<th>Material category</th>
<th>Criteria for dosimeter</th>
</tr>
</thead>
<tbody>
<tr>
<td>d. Cs-137, Co-60, Na-22, Fe-59, Sc-46, Sr-85 Rb-86, Nb-95, I-131, Ce-141</td>
<td>Body dosimeter if $\geq 0.1$ mCi/stock vial</td>
</tr>
<tr>
<td></td>
<td>Body &amp; ring dosimeter if $\geq 0.25$ mCi/stock vial</td>
</tr>
<tr>
<td>e. Gamma irradiators (Cs-137)</td>
<td>Body dosimeter</td>
</tr>
<tr>
<td>f. Soil moisture probes and density gauges</td>
<td>Body dosimeter</td>
</tr>
<tr>
<td>g. Cf-252 neutron irradiation facility</td>
<td>Body and ring dosimeters.</td>
</tr>
</tbody>
</table>

2. **Radioactive Materials Used in Medical Applications**

   a. Nuclear Medicine and brachytherapy                                             | Body and ring dosimeters.                                                              |
   b. Radioisotope therapy patient care                                              | Body dosimeter                                                                         |
   c. Cobalt teletherapy facility                                                    | Body dosimeter                                                                         |

3. **Ionizing Radiation Producing Equipment**

   a. Electron microscopes/microprobes                                              | No external radiation dosimeter necessary                                              |
   b. Cabinet X-ray (Faxitron, etc.)                                                | No external radiation dosimeter necessary                                              |
   c. DEXA (dual energy X-ray scanner)                                              | No external radiation dosimeter necessary                                              |
   d. Dental diagnostic X-ray                                                        | No external radiation dosimeter necessary                                              |
   e. X-ray diffraction & fluorescence                                              | Ring dosimeters                                                                        |
   f. Radiographic diagnostic X-ray                                                 | Body dosimeter                                                                         |
   g. Fluoroscopic diagnostic X-ray                                                 | Body and collar dosimeter                                                              |
   h. Medical accelerators                                                          | Body dosimeter                                                                         |
   i. X-ray irradiators                                                             | Body dosimeter                                                                         |
   j. Particle beam accelerators                                                    | Body dosimeter                                                                         |
                                                                                | Body neutron dosimeter if voltage $> 1$ MV                                              |
D. Procedures to Obtain and Use a Radiation Dosimeter

- Determine if person is required to have a dosimeter (see guidance in Items B & C above). Contact the RPD if assistance is needed (612 626-6002).

- If dosimeter is required, contact the RPD to obtain a radiation dosimeter request card. Examples of the front and back of the request card are shown below.

![Request Card Image]

**Front**

Be sure to provide your Social Security number.

If you use an ionizing radiation producing machine, provide the name of the machine’s registrant on the “Permit Holder” line.

**Back**

If you have been monitored for radiation exposure at another institution, be sure to provide its name, address and phone number.

Sign and date the request card before you send it to the address indicated.

- After receiving the completed card and verifying training, an RPD staff member will issue the appropriate dosimeters.
• Do not allow person to begin use of radiation source until dosimeter(s) are received and person has received applicable radiation safety and operations training.

Note: Personnel dosimeters do not protect an individual from the effects of radiation, but only record the radiation dose an individual has accumulated.

• Wear the dosimeter(s) in the proper location and orientation.

Body dosimeter. Wear on trunk of body at chest level with name plate facing outward. Ring dosimeter. Wear on finger closest to the radiation source with name label rotated toward the source.
Body dosimeter (white) with lead apron. Wear the body dosimeter at the collar outside of the lead apron.

Dual dosimeters (body & collar for X-ray fluoroscopy). Wear the body dosimeter at belt or chest level under the lead apron, and wear the collar dosimeter (red) at the collar on the outside of the lead apron.

- Wear dosimeter(s) while working with radiation sources.

- Store the dosimeter(s) in a designated work site area away from radiation sources and excessive heat and/or moisture.

V PERSONNEL MONITORING AND DOSIMETRY POLICIES

- Do not take a dosimeter home or wear it during non-job related radiation exposures such as medical or dental X-ray examinations.

- Do not intentionally expose the dosimeter to a radiation source or damage it in any way.

- It is the responsibility of the wearer to change his or her dosimeter during the designated monthly or quarterly change period. Information on the time periods for changing dosimeters will be provided when a dosimeter is issued.

- Failure to change the dosimeter during the designated change period may result in a $50.00 charge. These charges will be assessed against the permit holder’s or registrant’s budget.

- If a dosimeter is lost or damaged (broken clip, lost filter, etc.), call the RPD immediately for a replacement.

- Monthly or quarterly radiation dosimetry reports are sent by the RPD to each monitored group. It is the responsibility of the permit holder or registrant to review these reports with the monitored staff.

- If person is going to leave your facility, have them complete and sign a Radiation Dosimeter Termination Request Form if your group is required to be monitored (see the note in Item B, above). Send this signed form along with the person’s dosimeter(s) to the RPD.
E. Special Considerations

1. Occupationally Exposed Pregnant Women

To assure compliance with Nuclear Regulatory Commission (NRC) and State of Minnesota regulations pertaining to declared pregnant radiation workers, the following policy has been adopted by the All-University Radiation Protection Advisory Committee:

- At the time of employment and on an annual basis thereafter, all personnel who work with sources of ionizing radiation will be informed of the requirements of the NRC and the State of Minnesota relative to the control of radiation exposure received by declared pregnant women (see Appendix S – NRC Regulatory Guide 8.13). The supervisor (permit holder, registrant or designate) will be responsible for conducting this training which should include an explanation of the category of "declared" pregnant radiation worker. In the event that a worker declares pregnancy (in writing to her supervisor), the supervisor or his/her designate shall contact the Radiation Protection Division (RPD) to arrange for the completion of specific training.

2. Minors

It is the policy of the University of Minnesota that minors will not be allowed to be employed in or to occupy an area where ionizing radiation is used. An exception to this policy will be the allowance for minor students to be present or work in such an area as part of an educational program, provided the following conditions are met:

- The permit holder or registrant is responsible for complying with the Guideline on Minors in Laboratories established by the University of Minnesota Committee on Occupational Health and Safety (http://www.dehs.umn.edu/safety/minors.html).

- The minor must satisfactorily complete the required radiation protection training for employees which includes viewing the radiation protection training tapes, and reviewing the relevant sections of the radiation protection manual by the designated trainer for the laboratory or use area to which the minor will be assigned.

- The minor must be assigned a dosimeter prior to working in the laboratory or use area. The permit holder or registrant is responsible for obtaining the dosimeter for the minor. Contact the Radiation Protection Division at 612 626-6940 for a dosimeter request cards or for assistance. The dosimeter must be changed on the required schedule, and the used dosimeter returned to the RPD for processing. Prior to leaving the University, the minor must be instructed to turn in their dosimeter to the permit holder for return to the RPD.

- The minor shall not be allowed to handle any radioactive materials or operate ionizing radiation producing machines. They may handle non-radioactive material and perform only non-radioactive procedures.

- If a radioactive materials spill occurs when a minor is present in a laboratory, the RPD staff must be contacted immediately and arrangements made to perform appropriate bioassay monitoring.
State of Minnesota Rules for Class D X-ray Systems

The State of Minnesota Rules for analytical X-ray users and machines are listed in Chapter 4730, Sections 2510 & 2550 (see Appendix A). The following is a summary of these rules:

Registration requirements (see also U of MN Radiation Protection Division requirements)

- All new or newly acquired analytical X-ray units must be registered and fees paid to the State within 30 days of acquisition. Contact the RPD for assistance with registration.
- The State must be notified within 30 days of the sale, transfer, trade-in, or disposal of any analytical X-ray unit. Contact the RPD for assistance.
- The registration of each unit must be renewed with the State on a biennial basis and the biennial renewal fees paid.

Warning labels and indicators

- A warning label bearing the radiation symbol and stating, “CAUTION RADIATION-THIS EQUIPMENT PRODUCES IONIZING RADIATION WHEN ENERGIZED”, or equivalent words shall be placed on the control console and on the X-ray head.
- A warning label bearing the radiation symbol and stating, “CAUTION - HIGH INTENSITY X-RAY BEAM”, or equivalent words shall be placed on the X-ray source housing.
- An X-ray tube “On-Off” indicator near the radiation source housing, or a shutter “Open-Closed” indicator near each port on the X-ray housing.
- An easily visible warning light labeled with the words, “X-RAY ON”, or other visible warning indicator that clearly shows that the equipment is producing ionizing radiation must be located near the switch that energizes the X-ray tube, and that is illuminated only when the tube is energized.

Equipment requirements

- Unused ports on the tube housing must be closed to prevent opening by an individual other than the operator.
- Equipment with open beam configuration installed after March 1, 1998 shall have each operational port equipped with a shutter that cannot be operated unless either a collimator or coupling has been connected to the port.
- Radiation shielding of the X-ray tube and port covers must ensure that the radiation dose at 5 cm with all shutters closed does not exceed 2.5 millirem in one hour at the maximum specified tube rating.
- The leakage radiation dose from the X-ray generator shall not exceed 0.5 millirem in one hour.

User Requirements

- Written operating and emergency procedures must be provided to each operator. These procedures must include methods of controlling radiation exposure within limits, method and frequency of conducting radiation safety surveys, method of controlling access to unit, method of locking/securing unit, method and condition for personnel monitoring, emergency
procedures/notification requirements in event of accident, methods for maintaining required records, procedures for inspection and maintenance, procedures for calibration and testing of radiation survey instruments.

**State of Minnesota Rules (continued)**

- Initial training of operators (to include operating/emergency procedures, significance of radiation warning signs/devices/interlocks, identification of hazards, recognition of overexposure & symptoms, procedures for reporting actual/suspected overexposure).
- Inspection and maintenance according to manufacturer’s specifications and dates and results recorded (when safety system malfunction, unit is removed from operation until system is repaired and tested).
- Radiation safety survey initially, after change in shielding/operation/equipment, and at intervals not to exceed one year (dates and results recorded).
- Maintain use logs (include date, unit serial #, location, technique factors including voltage/current exposure time/number of exposures).
- Safety devices shall not be by-passed unless written approval is received from the RPD, and a sign is posted on source housing stating, “WARNING: SAFETY DEVICE NOT WORKING”.
- A beam stop that prevents entry of any portion of an individual’s body into the primary beam or shut off the beam must be provided for all open-beam units (does not apply during beam alignment).
- Security systems must be used to assure that no unit is left unattended unless the unit is locked in an inoperable mode or the room is locked to prevent unauthorized access.
- Personnel radiation monitoring in the form of an extremity TLD dosimeter shall be assigned to x-ray diffraction/fluorescence users.

**University of Minnesota Radiation Safety Requirements**

The following radiation safety requirements of the All-University Radiation Protection Committee (AURPAC) apply to analytical X-ray users:

**Registration & State of Minnesota Fees**

- Immediately notify the RPD of all new, donated, transferred analytical X-ray units (612 626-6002).
- Complete the RPD registration form (see Appendix C) and provide a budget number for payment of State fees. Send to the RPD within 15 days of receipt of the unit.
- Contact the RPD prior to the removal of an analytical X-ray unit from service (trade-in, transfer to another user, disassembly or disposal).

**Radiation Safety Survey and Compliance Requirements**

- Arrange for the RPD to conduct an initial radiation safety survey prior to operation of any new, transferred, or donated unit (also required for any unit that has been inactivated/stored).
- Provide initial radiation safety training and operating/emergency procedures training prior to allowing staff to operate unit.
- Arrange with the RPD to conduct annual radiation safety survey at the time of the annual radiation safety audit and refresher.
- Arrange for an RPD survey prior to reinitiating operation if major servicing/maintenance has occurred (X-ray tube replacement, shielding modifications, etc.).
University of Minnesota Radiation Safety Requirements (continued)

- Check for proper operation of warning lights/interlocks/shields as initial step whenever operating the unit (Note: if a safety device is inoperable, post warning sign at controls and on device).
- Assure unit and/or room is secured to prevent unauthorized persons from accessing the unit during operation, and unauthorized persons from turning the unit on.
- Assure authorized operator have personnel radiation dosimeter before allowing them to operate unit.
- Complete and retain required records (training, maintenance, surveys, registration documents).

Notification Requirements

- In the event of a suspected or known radiation overexposure, immediately contact the Radiation Protection Officer, RPD, (work hours - 612/626-6002, after-hours/weekends - dial “911” and give emergency dispatcher your name, phone number, room number and building, and brief description of event).
- If unit will be moved, sold, or removed from service contact the RPD prior to operation or transfer (a radiation safety survey is required at new location before allowing operation by staff).
- If unit undergoes major repairs/servicing (X-ray tube replacement, shielding modifications, etc.) arrange for the RPD to perform a radiation survey prior to allowing operation.