X-Rays and X-Ray Producing Equipment

General Information

X-rays are electromagnetic energy traveling as waves. They are the same as gamma rays except that gamma rays are emitted from the nucleus of an atom while x-rays originate in the atoms electron cloud. Analytical x-rays are produced by accelerated electrons from a cathode to an anode (target) in an x-ray tube.

X-rays can be very penetrating. The voltage of the system indicates how penetrating the x-rays will be. The higher the voltage of the generator, the more penetrating the radiation. Just like gamma rays, x-rays interact with molecules in the body to produce ion pairs.

To protect personnel from these penetrating rays, thick, dense material (e.g., lead, steel, etc.) is used as shielding. Certain analytical systems, (e.g., x-ray diffraction), have sufficient voltage to produce low energy (e.g., 1 - 50 keV) or "soft" x-rays. The soft x-rays with energies from 1 to 20 keV are absorbed in the first few millimeters of the skin, although for extremities, some of this radiation may also be absorbed to the bone.

Excessive exposure from this type of radiation often produces skin reddening at exposures of approximately 300 rem (300,000 mrem) while severe skin burns can result for exposures above 500 rem. Because some types of analytical x-ray systems can produce exposure rates between 1000 and 1,000,000 mrem/hr, even short exposures to the beam are capable of producing damage. For that reason, the primary radiation beam must always be contained in a shield.

Radiation Protection Techniques

The basic radiation protection principles of time, distance and shielding, apply equally to x-ray and radioisotope sources. Implementation of these principles include:

- TIME: When you need to use an x-ray system, work quickly and efficiently. Experiments should be carefully planned and rehearsed to minimize the exposure time.
- DISTANCE: Because radiation is significantly reduced by distance, remaining at least 6 feet away from an x-ray radiation source provides a great deal of protection. When an x-ray system is being used, if you are not required to be near the system, move away. Note that many analytical systems use narrow x-ray beams. With narrow beams, even being 6 feet away from the system may result in much of the radiation beam being absorbed by your body.
- SHEILDING: On installation, primary consideration should be given to ensure each tube is protected by fixed shielding. Reliance should not be placed on protective aprons and other shielding worn by the person using the system. Emplaced shielding

is the most effective mechanism of protecting workers from unnecessary x-ray exposure. Always operate these systems with all shielding and safety components in place; never tamper with system interlocks.

Analytical X-ray Systems

Analytical x-ray machines (e.g., x-ray diffraction, etc.) are used extensively for microstructure analysis in various research and teaching activities. Tubes for this purpose usually operate about 35 - 40 kV and 10 - 40 mA. In such equipment, the primary x-ray beam is permitted to impinge on the specimen and the scattered radiation is measured by a radiation detector located at various angles with respect to the sample.

The principal hazards with this type of equipment is the possibility of exposure of the hands to the direct beam if a change in specimens is attempted while the tube is still energized. These precautions and operational guidelines, considered the minimum requirements to be followed, help ensure that radiation exposures will be as low as reasonably achievable when working with analytical x-ray systems.

Precautions and Guidelines

- Get proper training/instruction from the person in control before operating x-ray producing machines.
- Never assume the unit was left in a safe working condition by the previous user, check the shielding before turning the unit on.
- Unless a pre-operational check was made, do not trust the warning lights when they are not lit. To check the light's operability, set the unit to its lowest kV and mA setting and check the warning lights and interlocks.
- Do not bypass any safety device or interlock without the approval of the person in control of the machine. In such cases, post a sign stating Safety Device Not Working. Return the system to its unmodified state with all interlocks operational as soon as possible.
- Wear all issued dosimeters at the proper height and facing the radiation source.
- Shielding should always be adequate so other factors need not be required for safety. However, exposure reduction techniques include, increasing your distance from the x-ray source, increasing shielding, and decreasing the time spent near the x-ray source.
- Do not work near the open, unshielded beam. However, if it is necessary to work near the unshielded radiation beam (e.g., for system alignment):
- Reduce the beam current (mA) and the beam energy (kV) to the lowest settings possible to reduce exposure rates.
- Keep hands and body at a safe distance from the beam by using appropriate alignment tools.
- Carry out the manufacturer's alignment procedures.
- Remember, you are in a potentially hazardous situation, think before each step.
- When working with open beam x-ray equipment the unit may not be left unattended and the operator must always be immediately present.
- Secure all unused ports from casual opening.

- In case of a radiation emergency or other situation where something has "gone wrong", notify the Radiation Safety Program immediately (X4275).

Analytical X-ray Equipment Radiation Safety Requirements

X-ray producing devices at UWM are regulated by the State of Wisconsin, Department of Health and Family Services (DHFS), Radiation Protection Section. All applicable regulations and safety requirements should be adhered to whenever working with x-ray producing equipment. Some of the most important safety requirements are:

- A safety device must be provided which prevents entry of any part of an individual's body into the primary x-ray beam path or which causes the beam to be shut off immediately upon such entry.
- Warning devices must be provided near the radiation source housing which indicated the x-ray tube status (ON/OFF) or a shutter status (OPEN/CLOSED) indicator located near each port.
- Unused ports must be securely closed and shielded.
- X-ray equipment must be labeled with a sign bearing the conventional radiation symbol and the works CAUTION - High Intensity X-ray Beam and CAUTION RADIATION - This Equipment Produces Radiation When Energized.
- Equipment installed after 1/1/79 must be equipped (on each port) with a shutter that cannot be opened unless a collimator or coupling has been attached.
- A warning light labeled X-ray On must be located near any switch that energizes the tube and must go on only when the tube is energized.
- The leakage radiation from the x-ray tube housing, with all the shutters closed, must not exceed 2.5 mR/hr at 5 cm from the surface. The x-ray generator must have a protective cabinet which limits leakage radiation from the surface to 0.25 mR/hr or less.
- Each room containing x-ray equipment shall be posted with a sign bearing the conventional radiation symbol and the works CAUTION - X-ray Equipment.
- Written operating procedures must be available to all persons who use the device.
- No safety devices may be bypassed without the approval of the person controlling the installation. In such a case, a conspicuous sign must be posted stating "Safety Device Not Working".
- No one may be permitted to operate an x-ray machine without receiving instruction on the radiation hazards involved, safety devices, operating procedures, symptoms of acute localized exposure and procedures for reporting a suspected overexposure.