

# NIU Radiation Safety

## Research X-ray Safety Fundamentals



**Early X-Ray Tube (1899):** This tube is a specimen of the first type of gas x-ray tube to incorporate a water-cooled anode. The hollow anode was supplied with water by gravity feed from a supply held in the side bulb. This type of tube was introduced by Mueller about 1899.

### Goals of this training presentation:

1. Explain what are X-rays.
2. Explain the hazards of X-ray devices used in NIU research.
3. Explain NIU requirements and responsibilities for the safe use of X-ray devices.
4. Help you recognize and respond to unsafe conditions.



## What is radiation?

Radiation is energy in the form of waves or particles. Radiation high enough in energy to cause ionization is called **ionizing radiation**. It includes particles and rays given off by radioactive material, stars, and high-voltage equipment. Ionizing radiation includes x-rays, gamma-rays, beta particles, alpha particles, and neutrons.

Without the use of monitoring equipment, humans are not able to "find" ionizing radiation. In contrast to heat, light, food, and noise, humans are not able to see, feel, taste, smell, or hear ionizing radiation.



## What are X-rays?

- X-rays are a form of electromagnetic radiation which arises as electrons are deflected from their original paths or inner orbital electrons change their orbital levels around the atomic nucleus. X-rays, like gamma rays, are capable of traveling long distances through air and most other materials. Like gamma rays, x-rays require more shielding to reduce their intensity than do beta or alpha particles. X and gamma rays differ primarily in their origin: x-rays originate in the electronic shell, gamma rays originate in the nucleus.



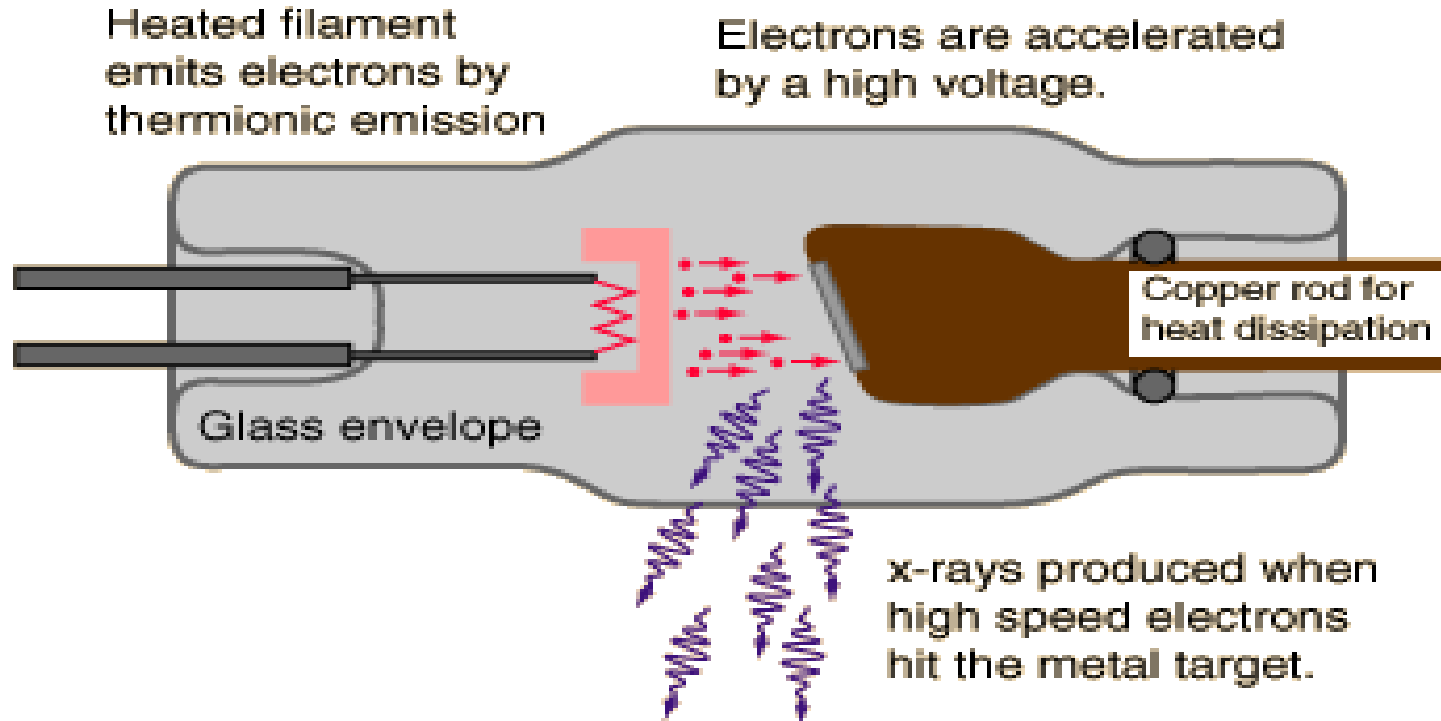
## X-rays

X-rays were discovered in **1895** when **Wilhelm Conrad Roentgen** observed that a screen coated with a barium salt fluoresced when placed near a cathode ray tube. Roentgen concluded that a form of penetrating radiation was being emitted by the cathode ray tube and called the unknown rays, **X-rays**.



# X-ray tube

An x-ray tube requires a source of electrons, a means to accelerate the electrons, and a target to stop the high-speed electrons.





## X-ray interactions

*In passing through matter, energy is transferred from the incident x-ray photon to electrons and nuclei in the target material. An electron can be ejected from the atom with the subsequent creation of an ion. The amount of energy lost to the electron is dependent on the energy of the incident photon and the type of material through which it travels. There are three basic methods in which x-rays interact with matter: photoelectric effect, Compton scattering, and pair production.*



# Analytical X-rays

*This the most common type of research X-ray at NIU*

## Two main uses:

### Diffraction [XRD]

X-ray scattering from crystalline materials.  
“fingerprint” of crystalline atomic structure. Check known library vs. unknown sample.

### Fluorescence [XRF]

Analytical method for determining the elemental composition of a substance.



## HAZARDS OF ANALYTICAL X-RAY EQUIPMENT

- 1. The primary beam:** The primary beam is most hazardous because of the extremely high exposure rates. Exposure rates of  $4 \times 10^5$  R/min at the port have been reported for ordinary diffraction tubes.
- 2. Leakage or scatter of the primary beam through cracks in ill fitting or defective equipment:** The leakage or scatter of the primary beam through apertures in ill fitting or defective equipment can produce very high intensity beams of possibly small and irregular cross section.
- 3. Penetration of the primary beam through the tube housing, shutters or diffraction apparatus:** The hazard resulting from penetration of the useful beam through shutters or the x-ray tube housing is slight in well designed equipment. Adequate shielding is easily attained at the energies commonly used for diffraction and fluorescence analysis.
- 4. Diffracted rays:** Diffracted beams also tend to be small and irregular in shape. They may be directed at almost any angle with respect to the main beam, and occasionally involve exposure rates of the order of 80 R/h for short periods.





## Causes of Exposure Using **ANALYTICAL** X-ray

- Putting fingers in X-ray beam to change sample
- Aligning X-ray beam visually
- Modification of shielding
- Failure to realize X-rays are emitted from several ports
- Failure to read & follow manufacturers X-ray operating instructions

**Any of these actions could cause an unnecessary exposure and a potential very serious negative effect.**



# Diagnostic X-rays

## Two main types of diagnostic X-ray devices:

**Radiograph** – a picture with film or image is sent direct to computer screen

**Fluoroscopic** – a real time “moving” inspection on inside functions

**Diagnostic radiology** is the branch of medicine that has traditionally been known for taking and reading X-rays. Like every other field of medicine, technology has radically changed this specialty forever. Diagnostic radiology is the nucleus of almost every physician’s diagnosis. Being able to detect disease sooner and pinpoint its location more accurately is a huge factor in stopping disease in its tracks.



## Industrial X-rays

X-rays are used for non-destructive testing and has applications in a wide range of industries.

**Non-destructive testing** (NDT) by means of the X-ray beam inspects the integrity of industrial products or processes without damaging the items under observation. The NDT field that's uses radiation is called **Industrial radiography**.

Industrial X-ray machines are used primarily to find defects in castings, structures, and welds. These units help to find foreign material in food products. X-ray machines are used for the inspection of luggage at airports and buildings.



## **X-Ray Effects**

**The effects of x-ray exposure depends upon:**

- **Duration - How fast the dose is delivered.**
- **Energy - How much energy was in the x-ray**
  - **Low Energy (<50 KeV) - damage only to skin or outer part of body**
  - **High Energy - damage to internal organs**
- **Total Dose - The magnitude of the dose**



## Unsafe conditions

Examples of **unsafe conditions**: Access door interlocks do not work, shielding has been damaged, or viewing window is cracked.

### **IF AN UNSAFE CONDITION ARISES WITH YOUR X-RAY DEVICE**

- Stop work!
- Turn power OFF to X-ray (An X-ray requires power to produce radiation)
- Notify your Principal Investigator and NIU Radiation Safety @ 815-753-1093



## **RADIATION PROTECTION – Time**

The dose of radiation a worker receives is directly proportional to the amount of time spent in a radiation field. Thus, reducing the time by one-half will reduce the radiation dose received by one-half. Operators should always work quickly and spend as little time as possible next to X-ray equipment while it is operating.



## Radiation Protection - Distance

Radiation exposure decreases rapidly as the distance between the worker and the X-ray device increases. The decrease in exposure from a point source, such as an X-ray tube, can be calculated by using the inverse square law. This law states that the amount of radiation at a given distance from a point source varies inversely with the square of the distance. For example, doubling the distance from an x-ray tube will reduce the dose to one-fourth of its original value, and increasing the distance by a factor of three will reduce the dose to one-ninth of its original value. Although the inverse square law does not accurately describe scattered radiation, distance will still dramatically reduce the intensity from this source of radiation. Maintaining a safe distance, therefore, represents one the simplest and most effective methods for reducing radiation exposure to workers. Using the principle of distance is especially important when working around open beam analytical x-ray equipment.



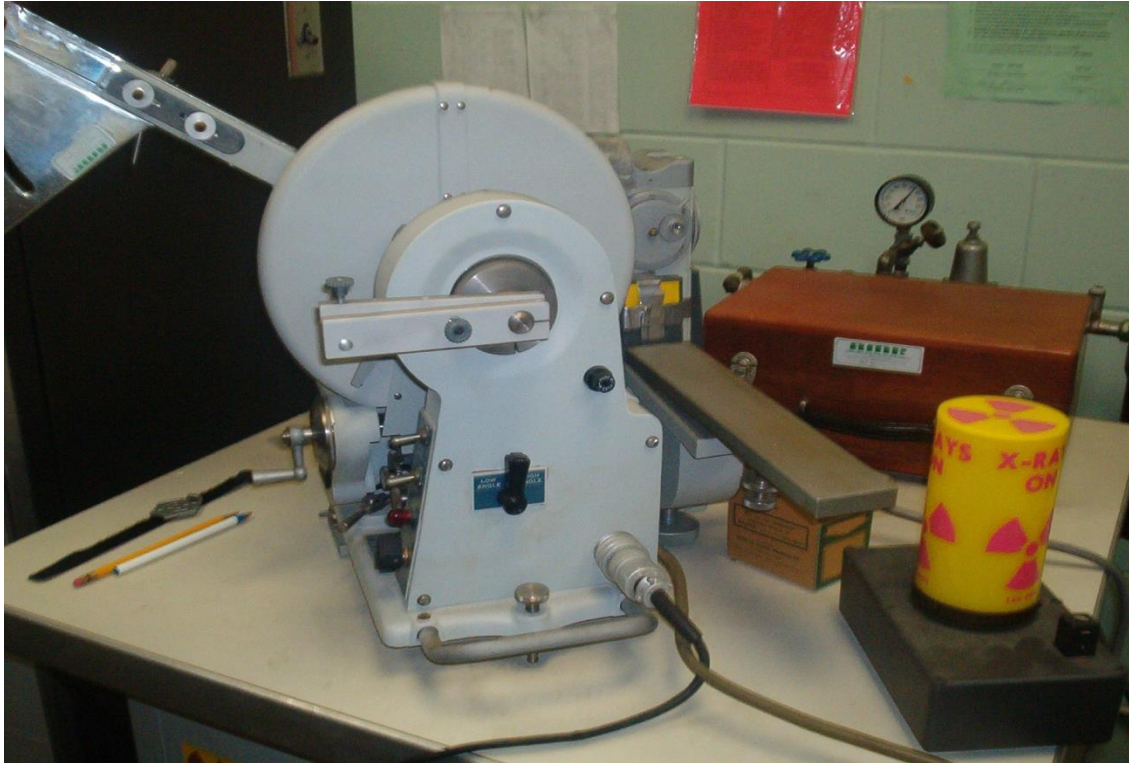
## Radiation Protection - Shielding

Radiation exposure to personnel can also be reduced by placing an attenuating material between a worker and the x-ray tube. The energy of the incident x-ray photon is reduced by Compton and photoelectric interactions in the shielding material. Thus, substances such as **lead**, that are very dense and have a high atomic number, are very practical shielding materials because of the abundance of atoms and electrons that can interact with the x-ray photon. Shielding is often incorporated into the equipment, such as the metal lining surrounding the x-ray tube. It may also consist of permanent barriers such as concrete and lead walls, leaded glass, and plastic movable screens in the case of analytical x-ray equipment.





## X-ray device – Open Diffraction



This an OLD open beam X-ray diffraction device. New diffraction X-ray devices for NIU research **must** be contained in an fully shielded – interlocked cabinet.



## NIU X-ray device – Cabinet Diffraction



The X-ray tube, detector and sample are contained in housing that provides shielding to the user and others in lab. The access doors are interlocked and will shut off X-rays when opened. The large viewing area is made possible by using leaded glass or Plexiglas.



## NIU X-ray device – Cabinet Diffraction



A small compact “totally enclosed” research X-ray device.



# X-ray device – Older type Radiographic Table



This picture X-ray tube in a collimated lead housing. The X-ray beam is pointed down to the table. The table is where the patient is placed and contains a slot for an X-ray film.



This is the mobile shield for operator. It is designed to protect operator from scattered X-rays.



This is the control panel. Operator can select X-ray ON (exposure) time in fraction of minutes, the energy of X-ray (in kVp) and current applied (higher current = more X-rays).

# NIU X-ray device – Radiographic Table, Health Services





## X-ray device – Fluoroscopic C-arm



When this “C-arm” X-ray device is used the operator and support staff **MUST** wear a lead apron, safety glasses and whole body dosimeter badge.



## State of Illinois Regulations

- ❑ X-ray devices must be registered with Illinois Emergency Management Agency, IEMA
- ❑ Each X-ray system **MUST** meet State of Illinois requirements.
- ❑ Each system must have a radiation protection plan (RPP) reviewed yearly by NIU RSO.
- ❑ The State of Illinois (IEMA) routinely inspects X-ray devices, procedures and records



## NIU requirements for X-ray

- ❑ **If you acquire any X-ray devices YOU MUST Notify NIU radiation safety office!**
- ❑ NIU Radiation Safety inspects X-ray devices annually.
- ❑ Each system must have an NIU RSO approved radiation protection plan (RPP)
- ❑ X-ray users must be approved by device Principal Investigator.
- ❑ **X-ray users need to complete X-ray Safety Fundamentals course prior to unsupervised use of an X-ray device.**





## Responsibilities of X-ray owners & users

- Operate x-ray device only as specified in manufacturers operating instructions.
- Notify NIU Radiation Safety Office of any repairs, modifications, disposal, or relocation of X-ray device.
- X-ray owners & users are required to read NIU Radiation Protection Plan (RPP) posted in X-ray area!



## PERSONNEL MONITORING

Most analytical X-ray devices at NIU **do not require** users to be issued personnel monitoring devices.

X-ray users should address any radiation safety concerns to NIU Radiation Safety Officer

Michele Crase 815-753-9251.



## Example of a NIU Radiation Protection Plan (RPP)

**All personnel involved in using a Northern Illinois University X-ray device must review this program and will be held accountable for violations.**

**Any PI that may have a research need to purchase, borrow, or build a radiation generating device (X-ray) shall notify the NIU Radiation Safety Officer (RSO).**

**NIU Radiation Safety will inspect X-ray devices and facilities annually.**

**Any changes to an X-ray device (new tube, design modifications, etc.) MUST be approved by NIU RSO. This X-ray machine will be used as it is currently configured and approved for operation by NIU RSO.**

**This machine will be operated in accordance with the manufacturers operating and safety procedures.**

**A restricted area will be designated as needed by the NIU RSO to protect personnel against undue risks from exposure to radiation.**

**X-ray device users will be persons authorized by the Principal Investigator and/or NIU RSO. Minors (age less than 18) or members of the general public are not allowed to operate X-ray device without prior approval of NIU RSO.**

**Members of the public will be considered to be all persons other than those involved in the authorized use, surveillance, or inspection of this machine.**

**Declared pregnant workers may use X-ray after a dosimeter is obtained from NIU RSO. The dosimeter device shall be worn at all times while using X-ray device.**



*Thanks for taking the time to complete this training*

If you have any questions or comments  
Please contact NIU Radiation Safety  
Officer, Michele Crase

at

815-753-9251 or [mcrase@niu.edu](mailto:mcrase@niu.edu)

