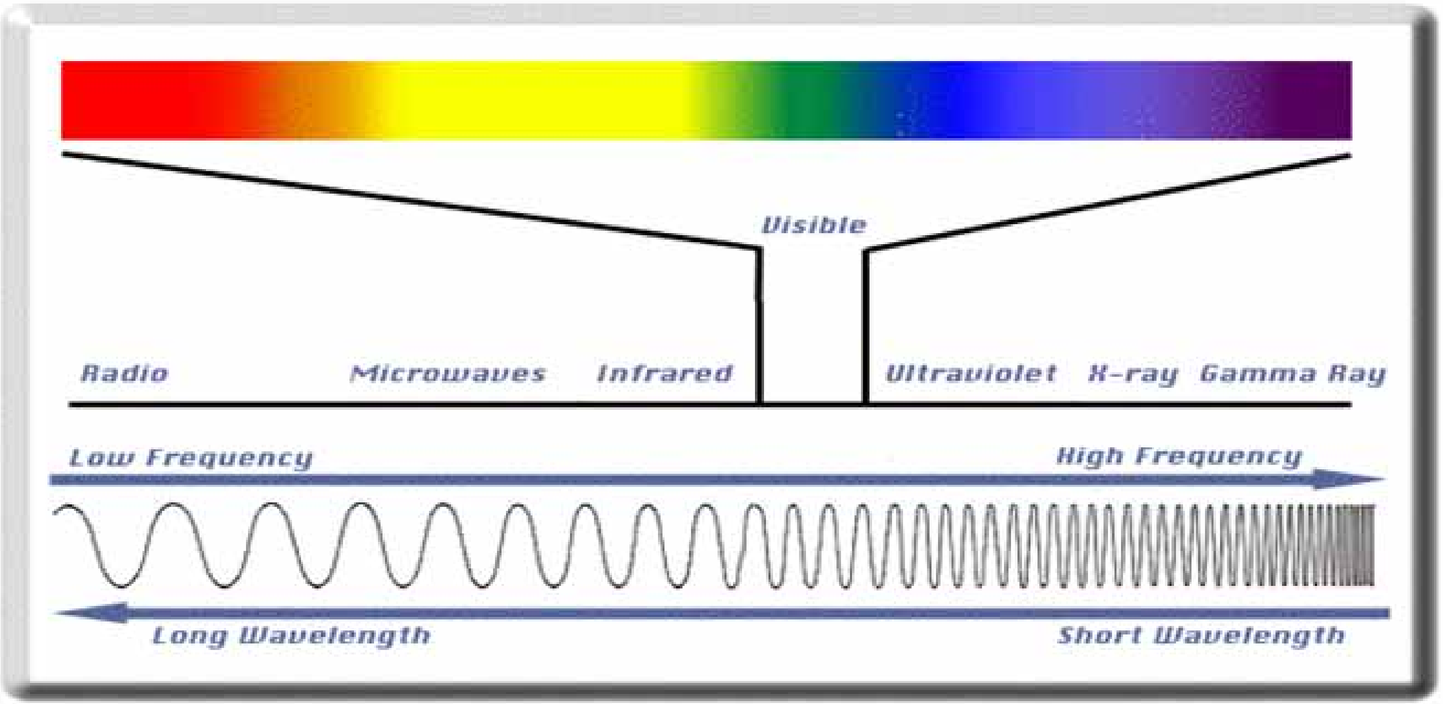
Radiographic Testing (RT) [10]

Definition:

An NDT method that utilizes x-rays or gamma radiation to detect discontinuities in materials, and to present their images on recording medium.

Electromagnetic Radiation

The radiation used in Radiography testing is a higher energy (shorter wavelength) version of the electromagnetic waves that we see every day. Visible light is in the same family as x-rays and gamma rays.



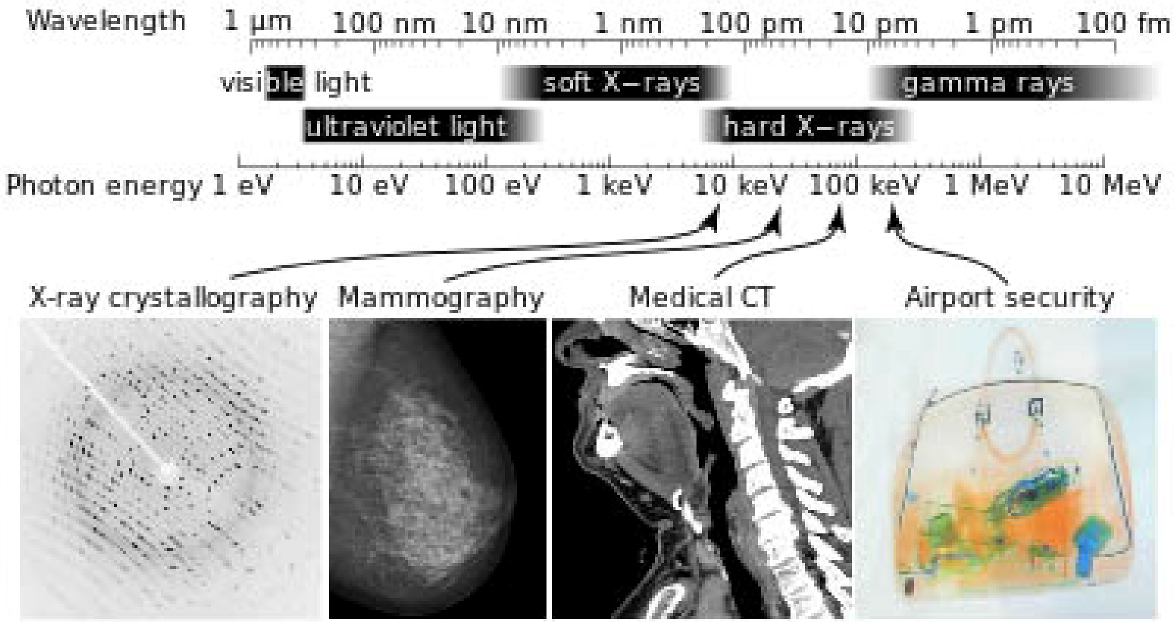
The energy *E* (keV) of the x-rays or gamma radiation is calculated by

$$E = h \cdot \frac{c}{\lambda}$$

Electromagnetic Radiation

X-rays have a wavelength ranging from 0.01 to 10 nanometers, corresponding to frequencies in the range 30 petahertz to 30 exahertz (3×10^{16} Hz to 3×10^{19} Hz) and energies in the range 100 eV to 100 keV.

Gamma rays typically have frequencies above 10 exahertz (or $>10^{19}$ Hz), and therefore have energies above 100 keV and wavelengths less than 10 picometers (10^{-11} m), which is less than the diameter of an atom.



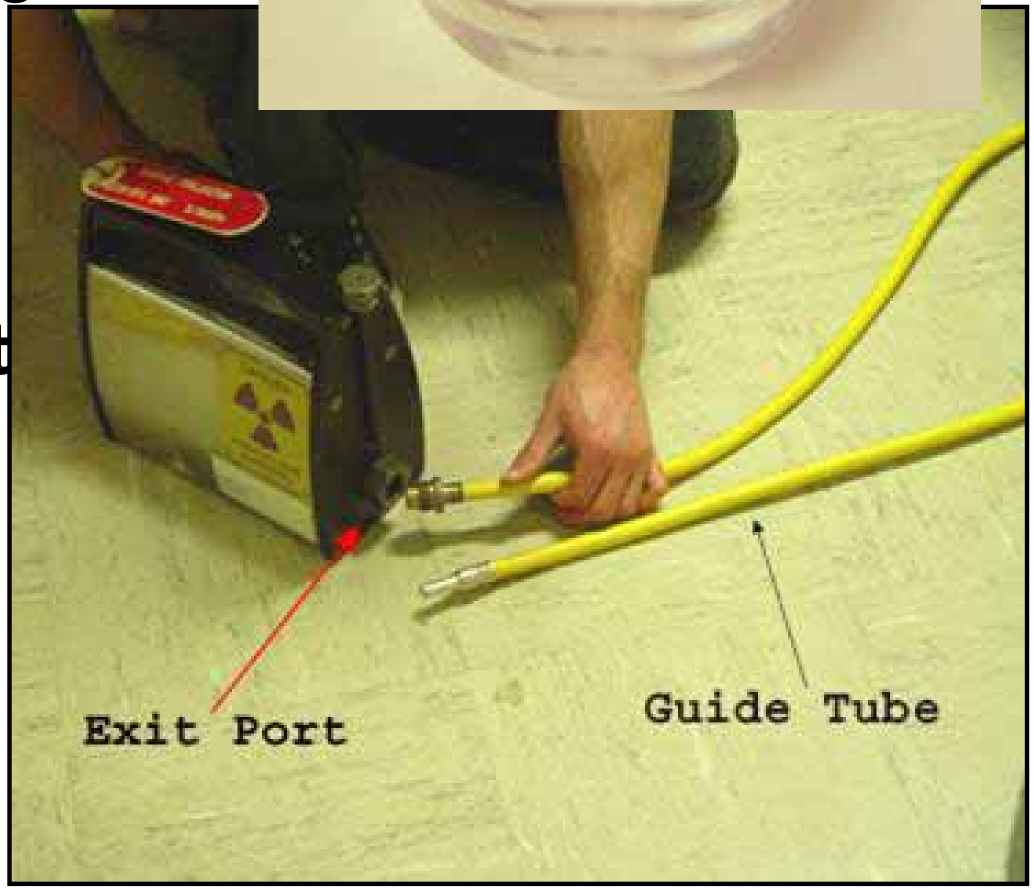
after Wikipedia (2016)

Radiation Sources

Two of the most commonly used sources of radiation in industrial radiography are x-ray generators and gamma ray sources. Industrial radiography is often subdivided into "X-ray Radiography" or "Gamma Radiography", depending on the source of radiation used.

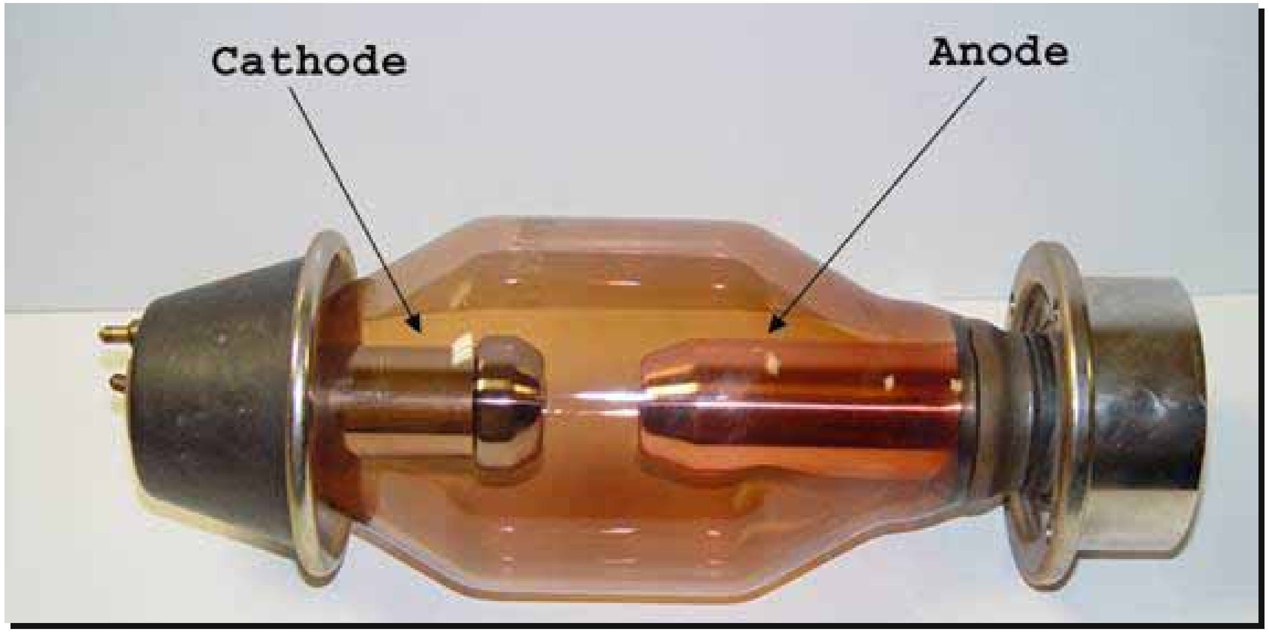
Gamma Radiography Sources

- Gamma rays are roduced by a radioisotope.
- A radioisotope has an unstable nuclei that does not have enough binding energy to hold the nucleus together.
- The spontaneous breakdown of an atomic nucleus resulting in the release of energy and mat is known as radioactive decay.
- Gamma rays cannot be turned off. Radioisotopes for gamma radiography are encapsulated to prevent leakage of the material.



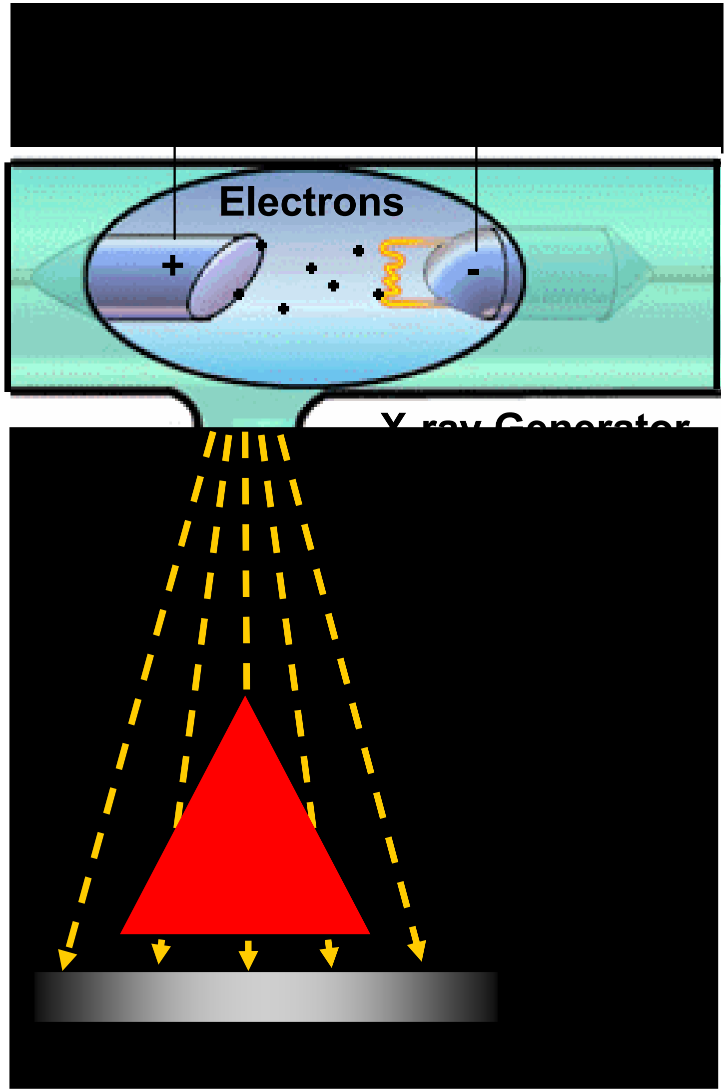
X-rays Radiography Sources

- **X-rays are produced by establishing a very high voltage between two electrodes, called the anode and cathode.**
- **To prevent arcing, the anode and cathode are located inside a vacuum tube, which is protected by a metal housing.**

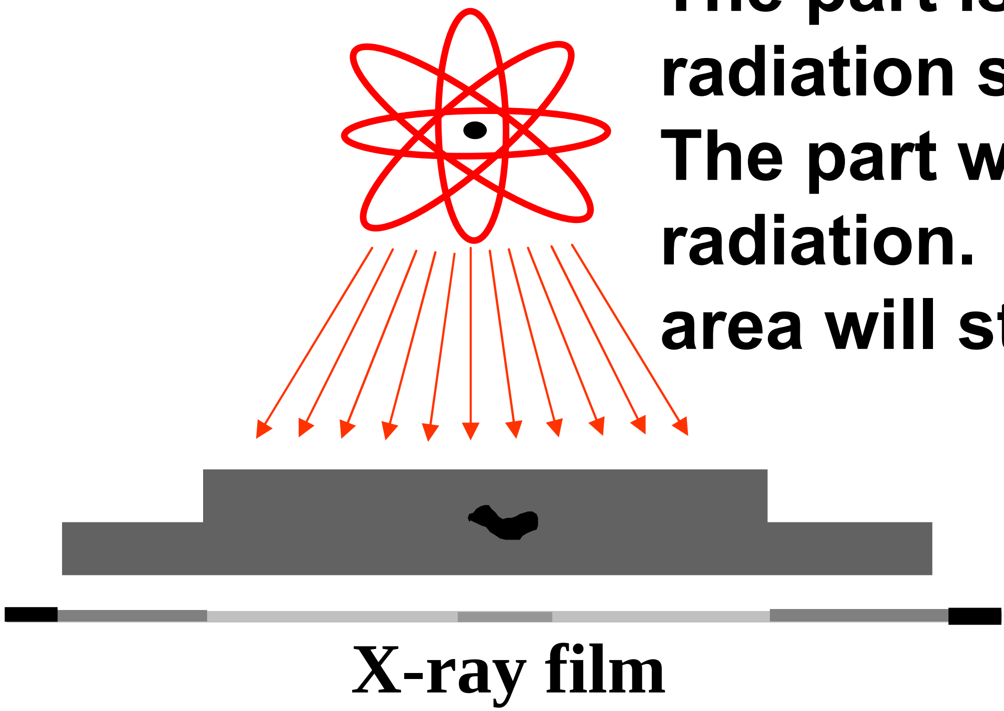


X-rays Radiography Sources

- **The cathode contains a small filament much the same as in a light bulb.**
- **Current is passed through the filament which heats it. The heat causes electrons to be stripped off.**
- **The high voltage causes these "free" electrons to be pulled toward a target material (usually made of tungsten) located in the anode.**
- **The electrons impact against the target. This impact causes an energy exchange which causes x-rays to be created.**



General Principles of Radiography



Top view of developed film

The part is placed between the radiation source and a piece of film. The part will stop some of the radiation. Thicker and more dense area will stop more of the radiation.

The film darkness (density) will vary with the amount of radiation reaching the film through the test object.

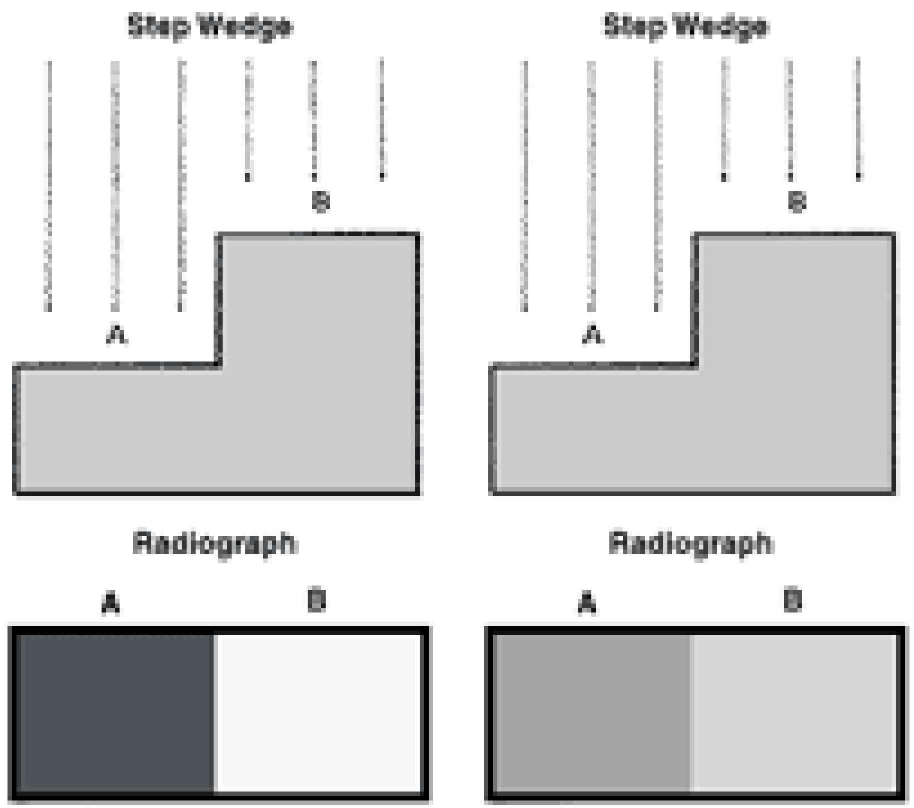
= less exposure

= more exposure

Contrast:

The first subjective criteria for determining radiographic quality is radiographic contrast. Essentially, radiographic contrast is the degree of density difference between adjacent areas on a radiograph.

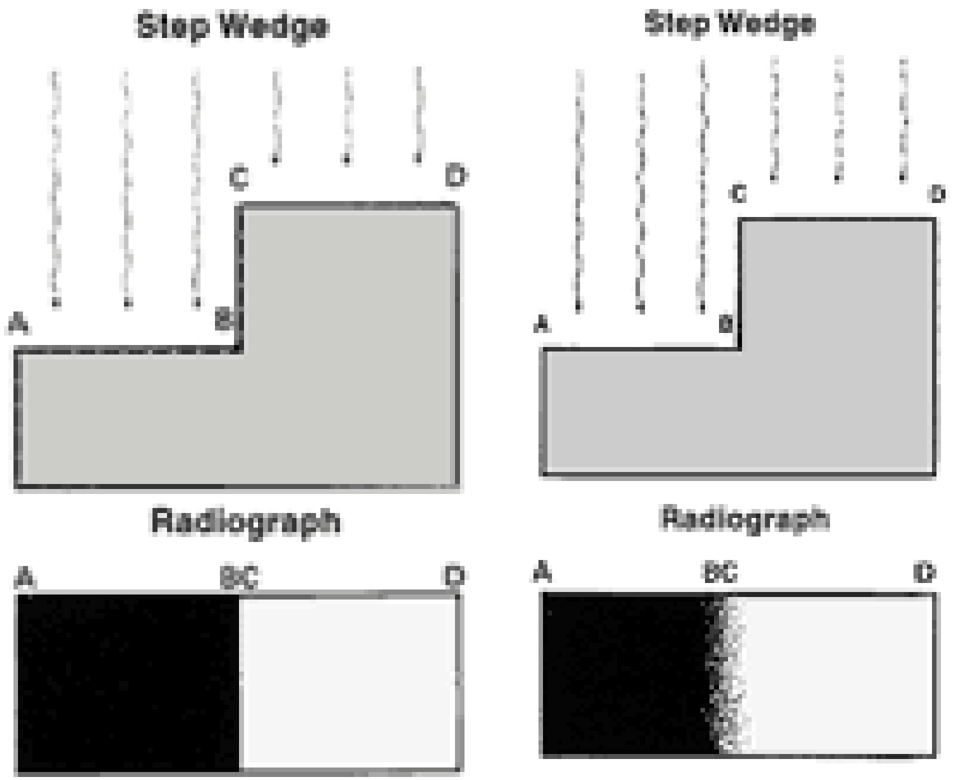
It is essential that sufficient contrast exist between the defect of interest and the surrounding area. There is no viewing technique that can extract information that does not already exist in the original radiograph



low kilovoltage high kilovoltage

General Principles of Radiography

Radiographic definition is the abruptness of change in going from one density to another.

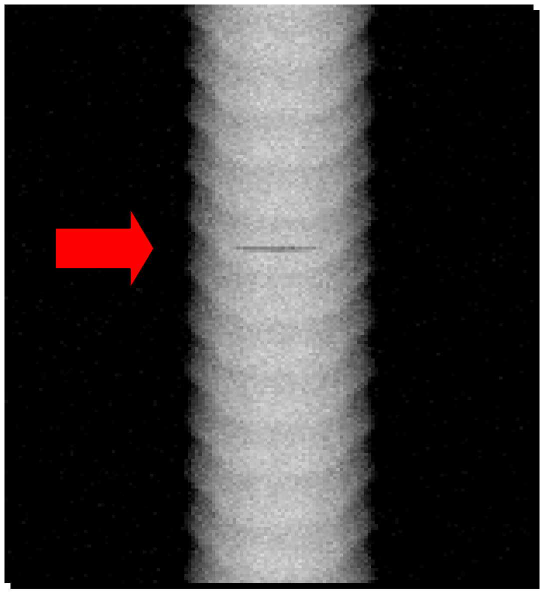


good poor

High definition: the detail portrayed in the radiograph is equivalent to physical change present in the part. Hence, the imaging system produced a faithful visual reproduction.

Flaw Orientation:

Since the angle between the radiation beam and a crack or other linear defect is so critical, the orientation of defect must be well known if radiography is going to be used to perform the inspection.



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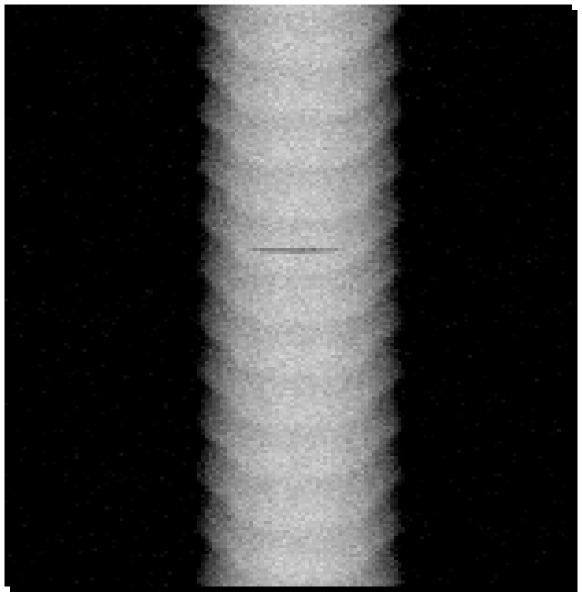

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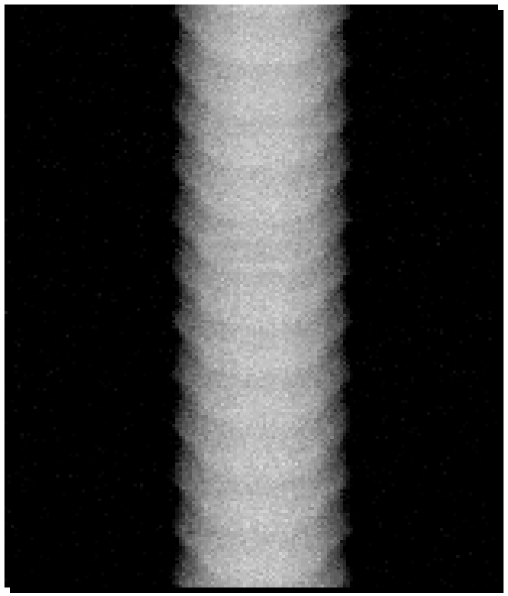

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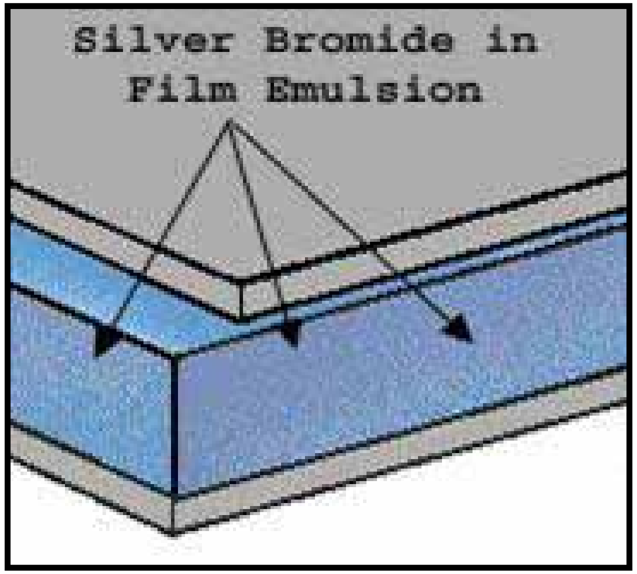
Imaging Modalities

Several different imaging methods are available to display the final image in industrial radiography:

- **Film Radiography**
- **Real Time Radiography**
- **Computed Tomography (CT)**
- **Digital Radiography (DR)**
- **Computed Radiography (CR)**

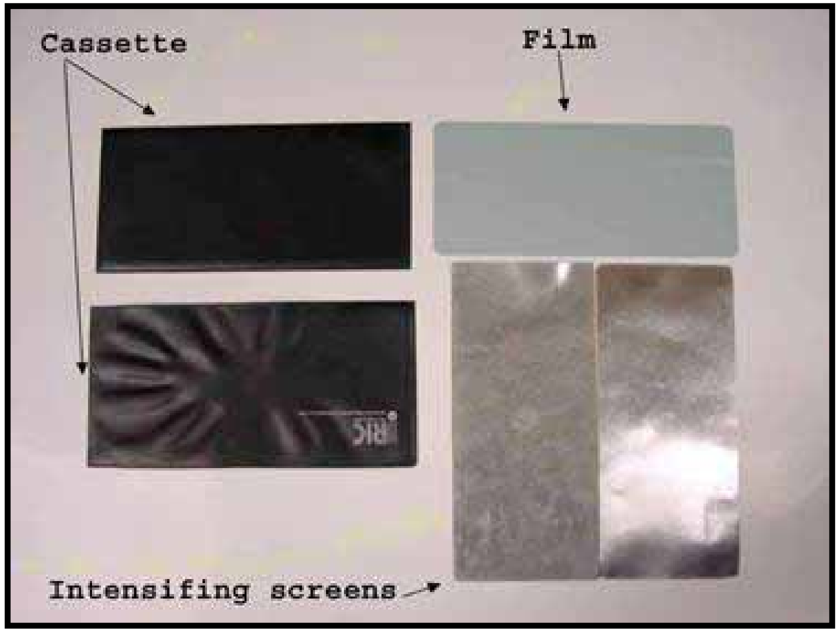
Film Radiography

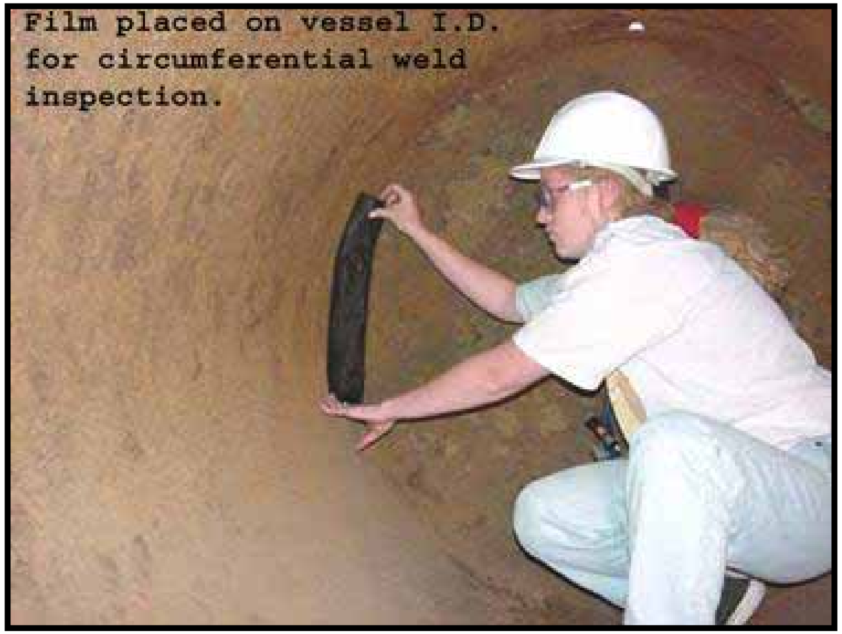


- **One of the most widely used and oldest imaging mediums in industrial radiography is radiographic film.**
- **Film contains microscopic material called silver bromide.**
- **Once exposed to radiation and developed in a darkroom, silver bromide turns to black metallic silver which forms the image.**

Film Radiography

- **Film must be protected from visible light. Light, just like x-rays and gamma rays, can expose film. Film is loaded in a "light proof" cassette in a darkroom.**
- **This cassette is then placed on the specimen opposite the source of radiation. Film is often placed between screens to intensify radiation.**

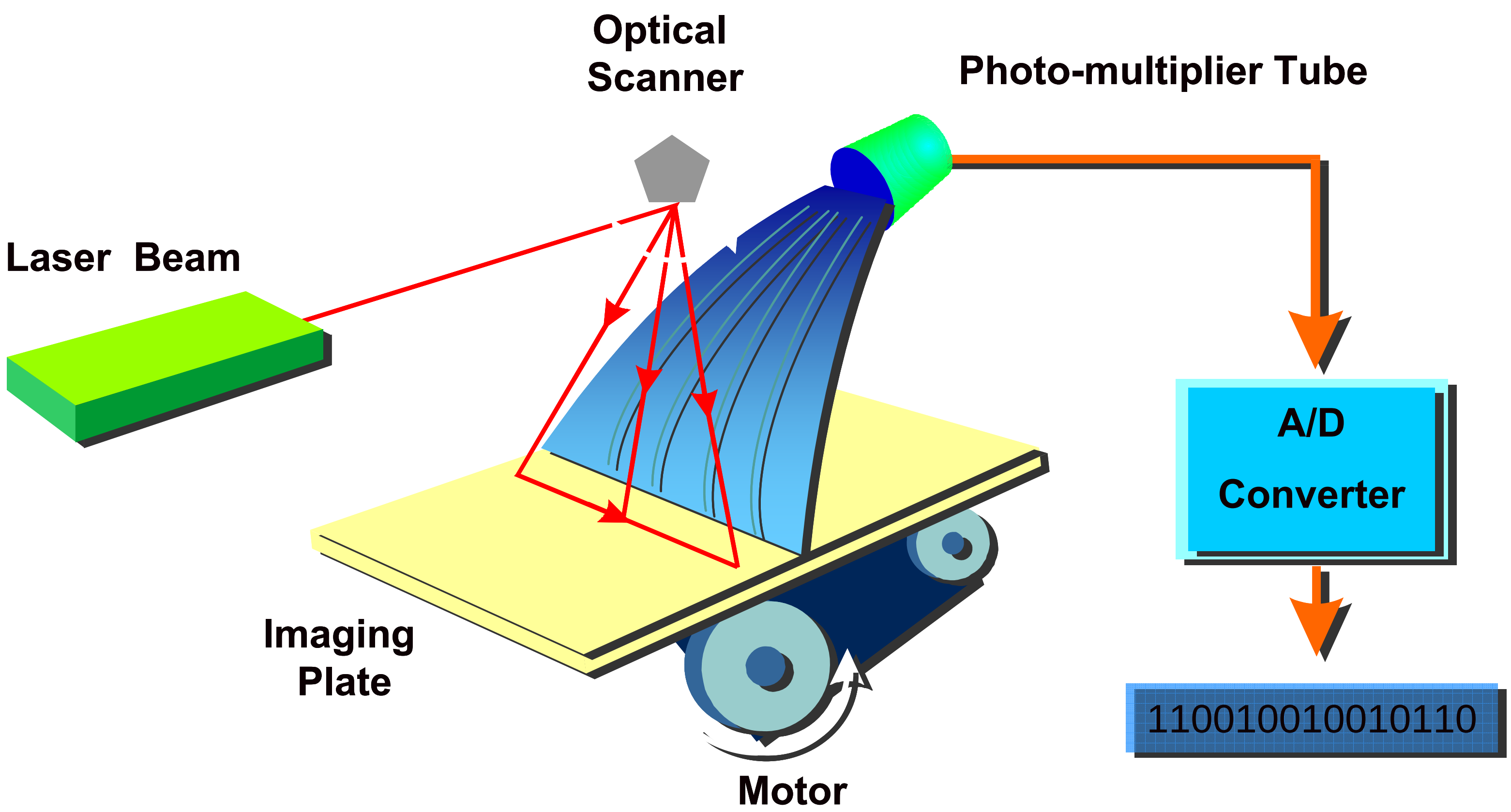




- **In order for the image to be viewed, the film must be "developed" in a darkroom. The process is very similar to photographic film development.**

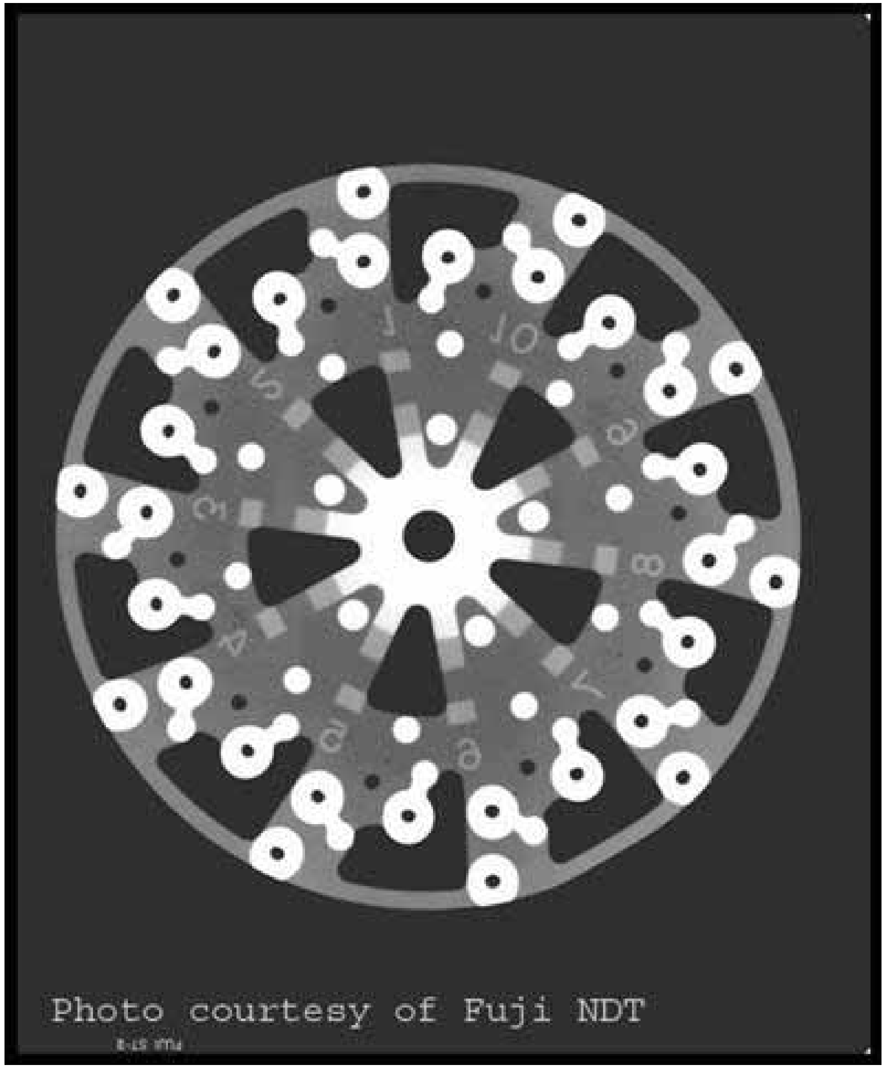
Computed Radiography

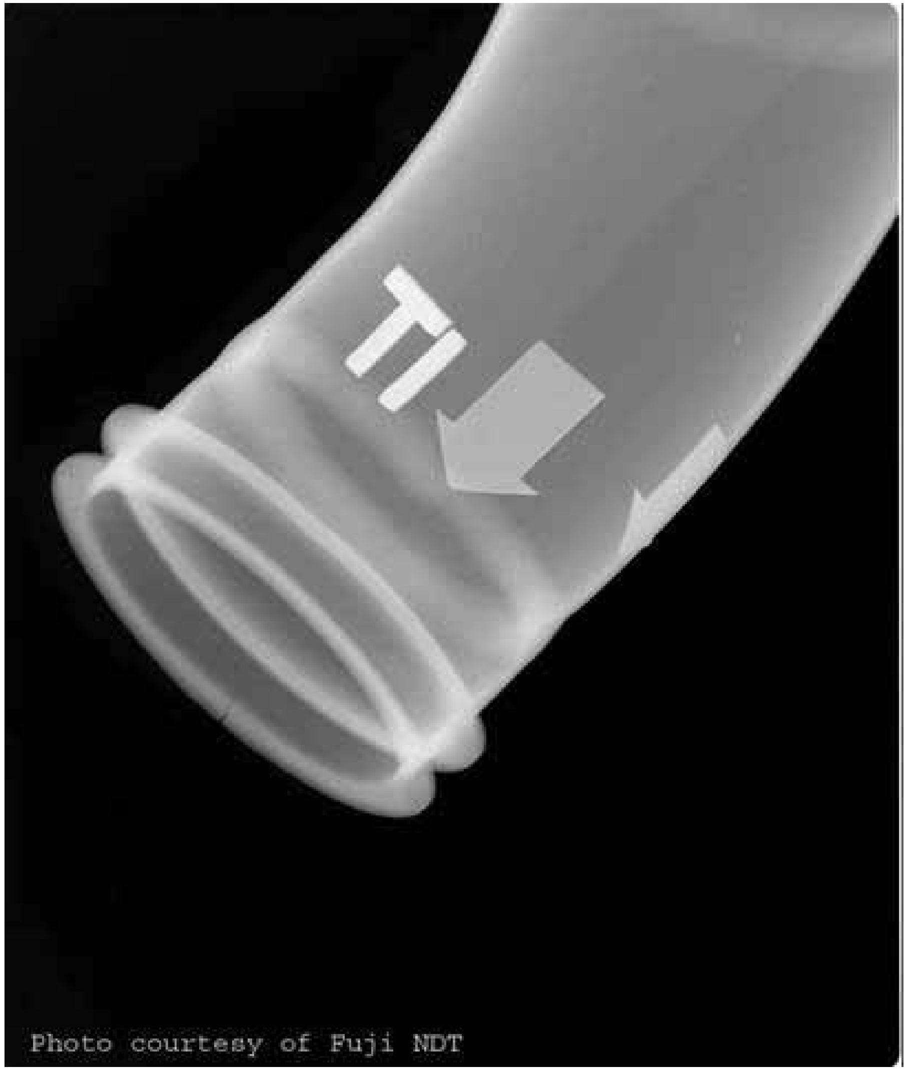
As a laser scans the imaging plate, light is emitted where X-rays stimulated the phosphor during exposure. The light is then converted to a digital value.



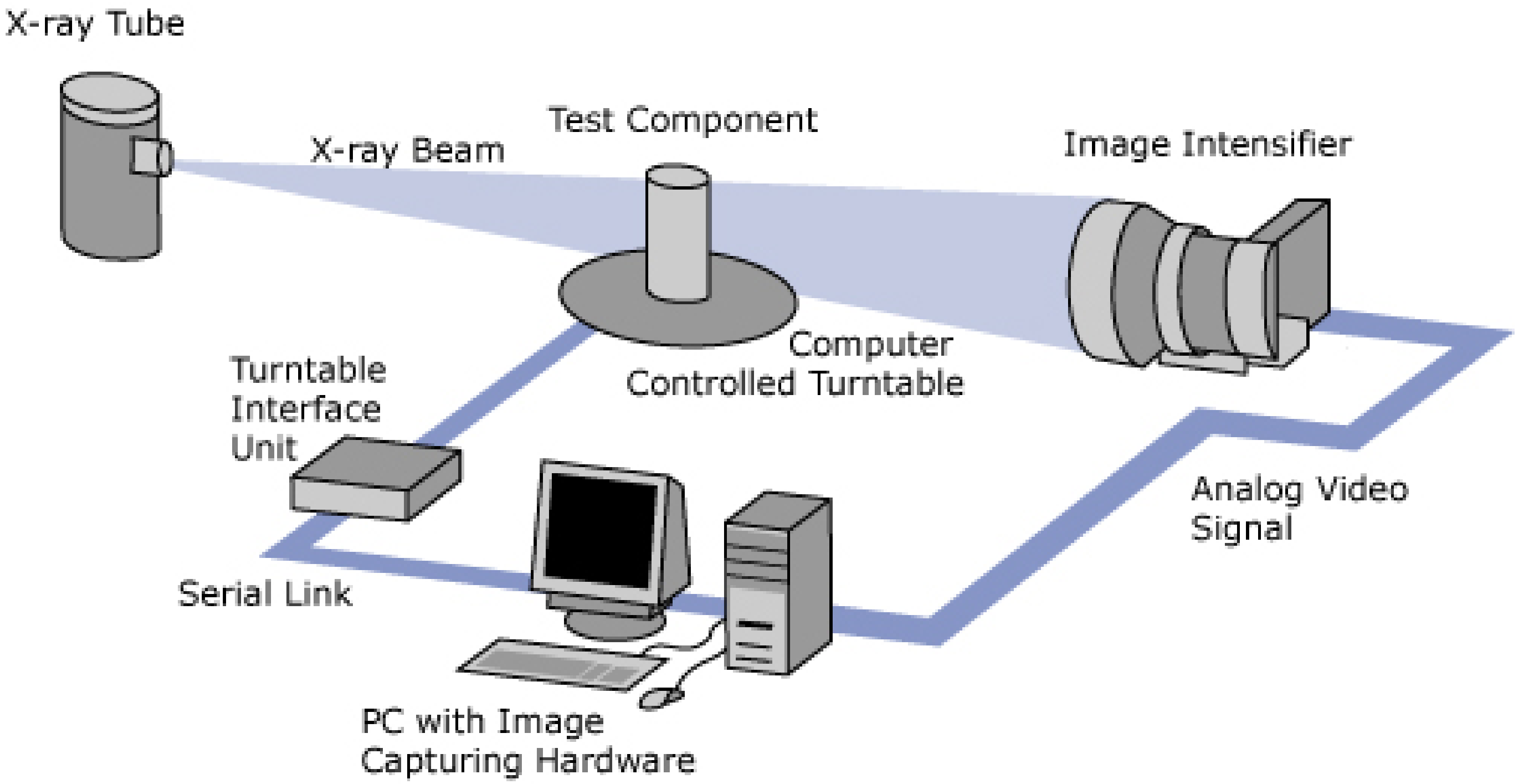
Digital images are typically sent to a computer workstation where specialized software allows manipulation and enhancement.

➢ Examples of computed radiographs:



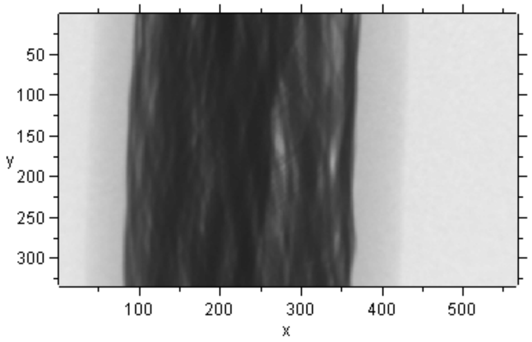


Computed Tomography (CT) uses a real-time inspection system employing a sample positioning system and special software.

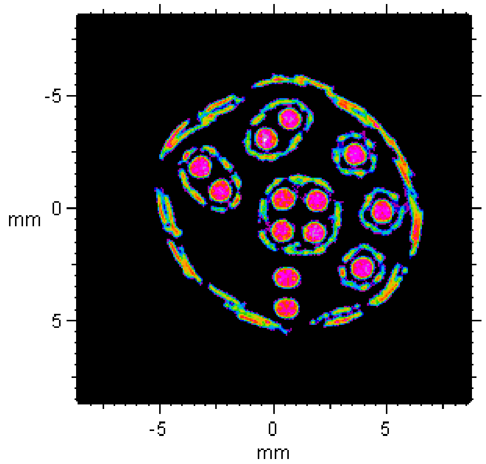


Computed Tomography

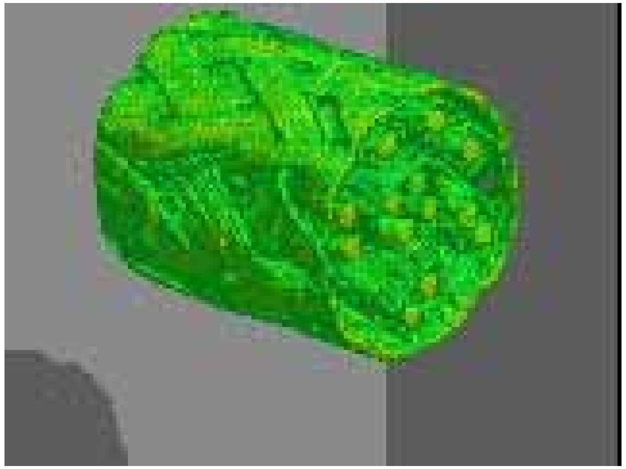
- **Many separate images are saved (grabbed) and complied into 2-dimensional sections as the sample is rotated.**
- **2-D images are them combined into 3-dimensional images.**



Real-Time Captures



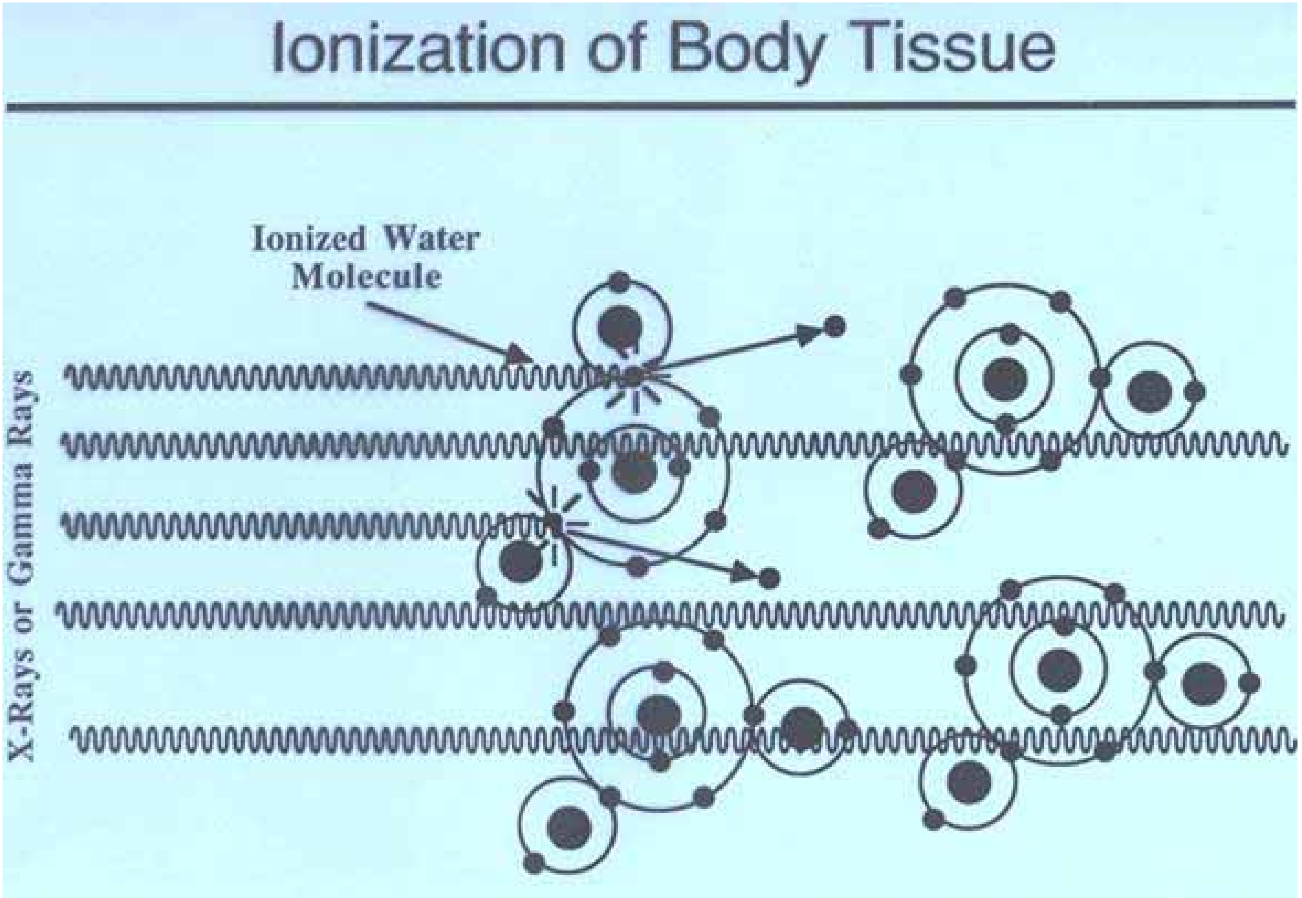
Compiled 2-D Images



Compiled 3-D Structure

Use of radiation sources in industrial radiography is heavily regulated by state and federal organizations due to potential public and personal risks.

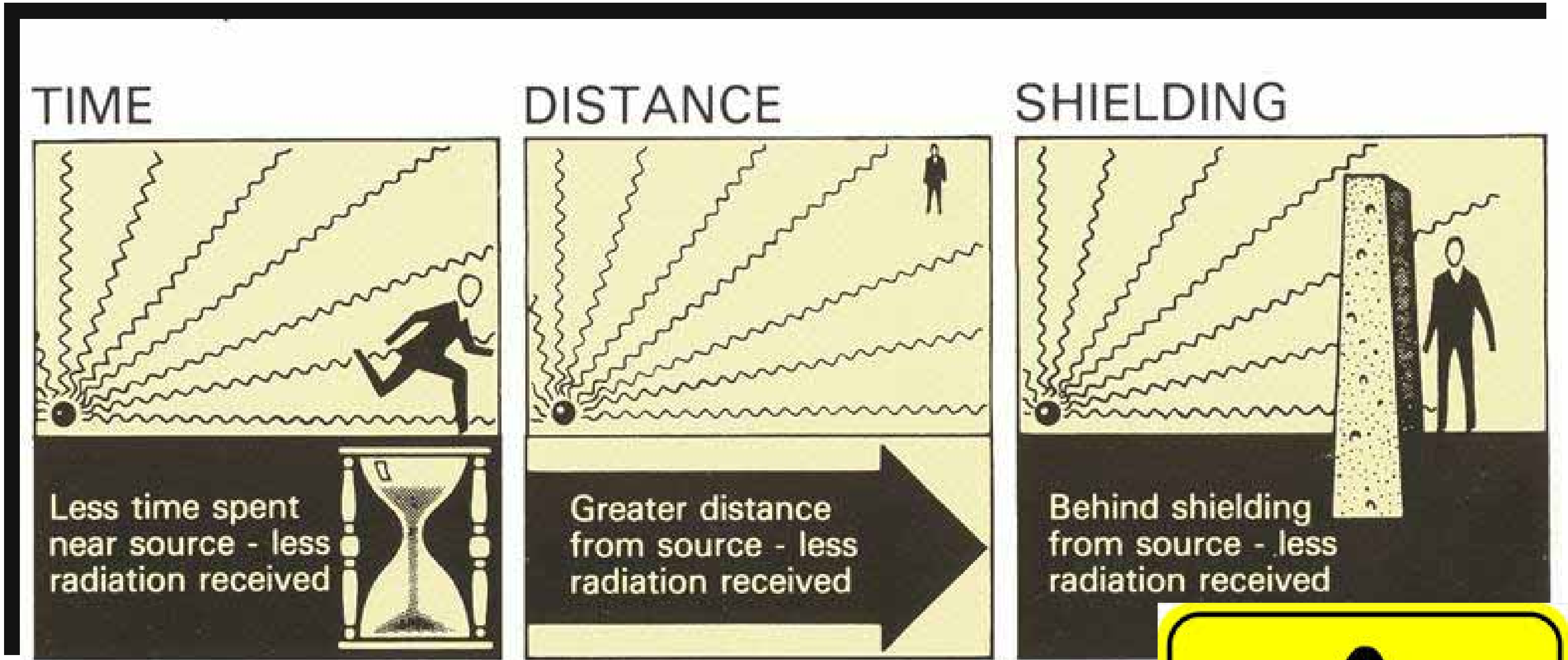
X-rays and gamma rays are forms of ionizing radiation, which means that they have the ability to form ions in the material that is penetrated. All living organisms are sensitive to the effects of ionizing radiation (radiation burns, x-ray food pasteurization, etc.)



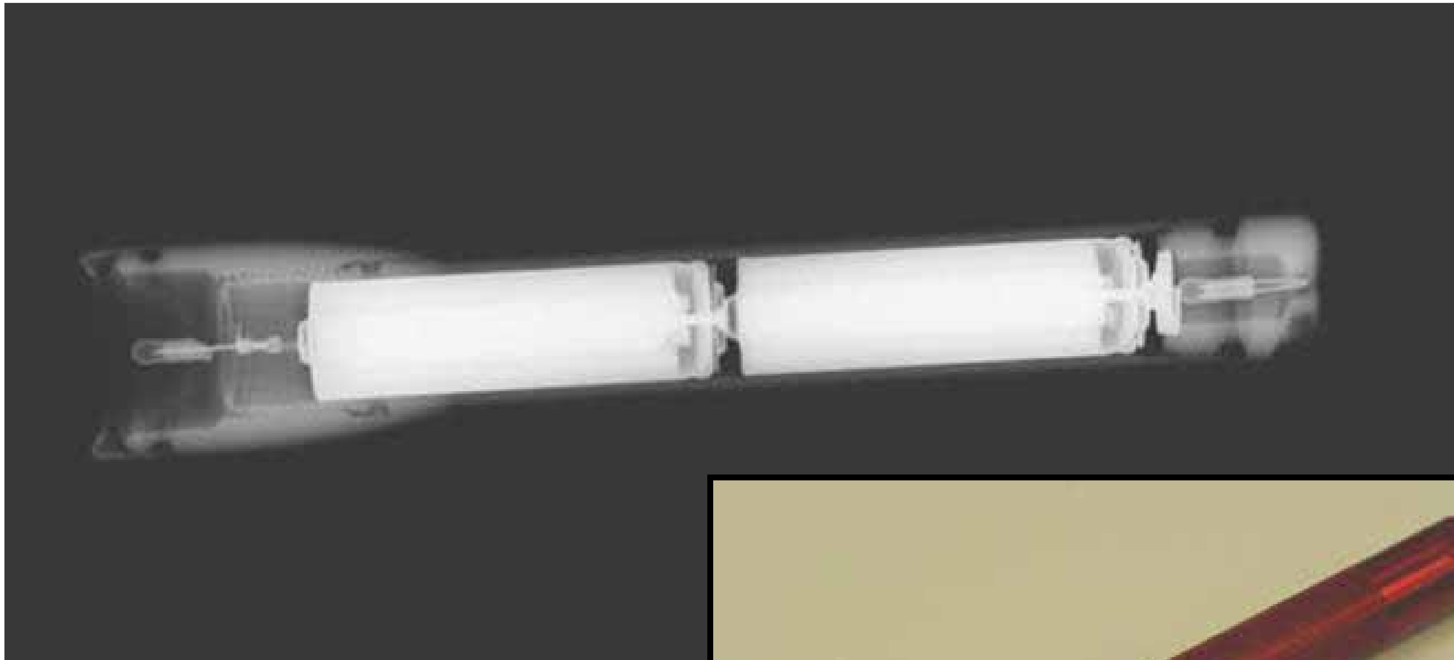
X-rays and gamma rays have enough energy to liberate electrons from atoms and damage the molecular structure of cells.

This can cause radiation burns or cancer.

There are three means of protection to help reduce exposure to radiation:

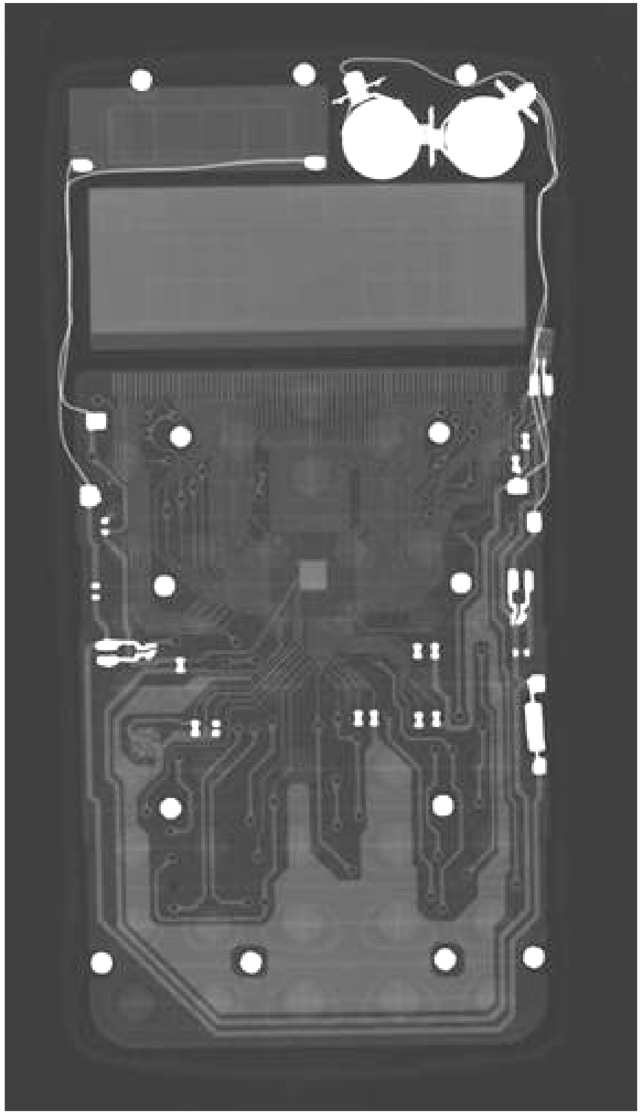


CHALLENGE: Can you determine what object was radiographed in this slide?



Radiographic Images

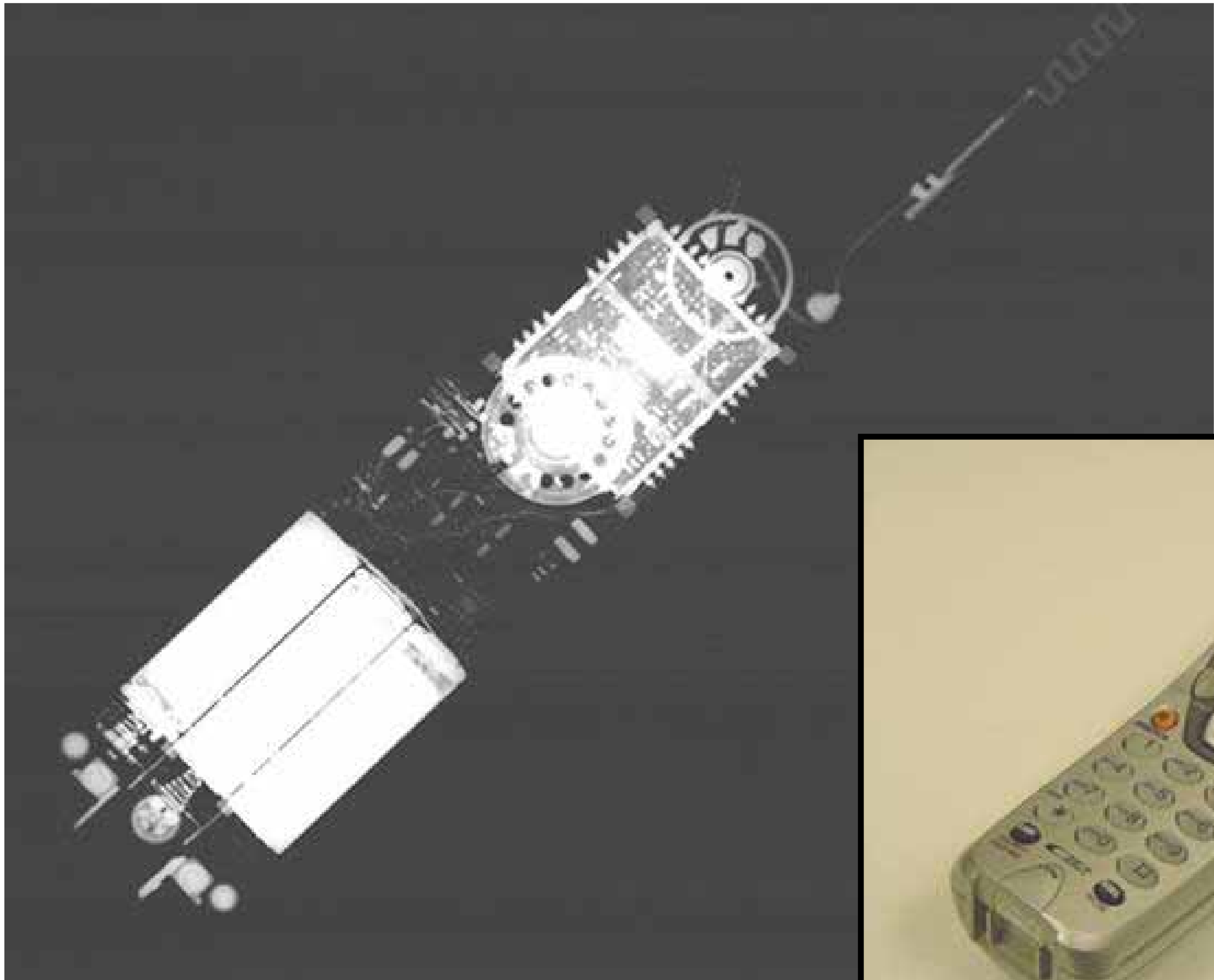
CHALLENGE: Can you determine what object was radiographed in this slide?



CALCULATOR

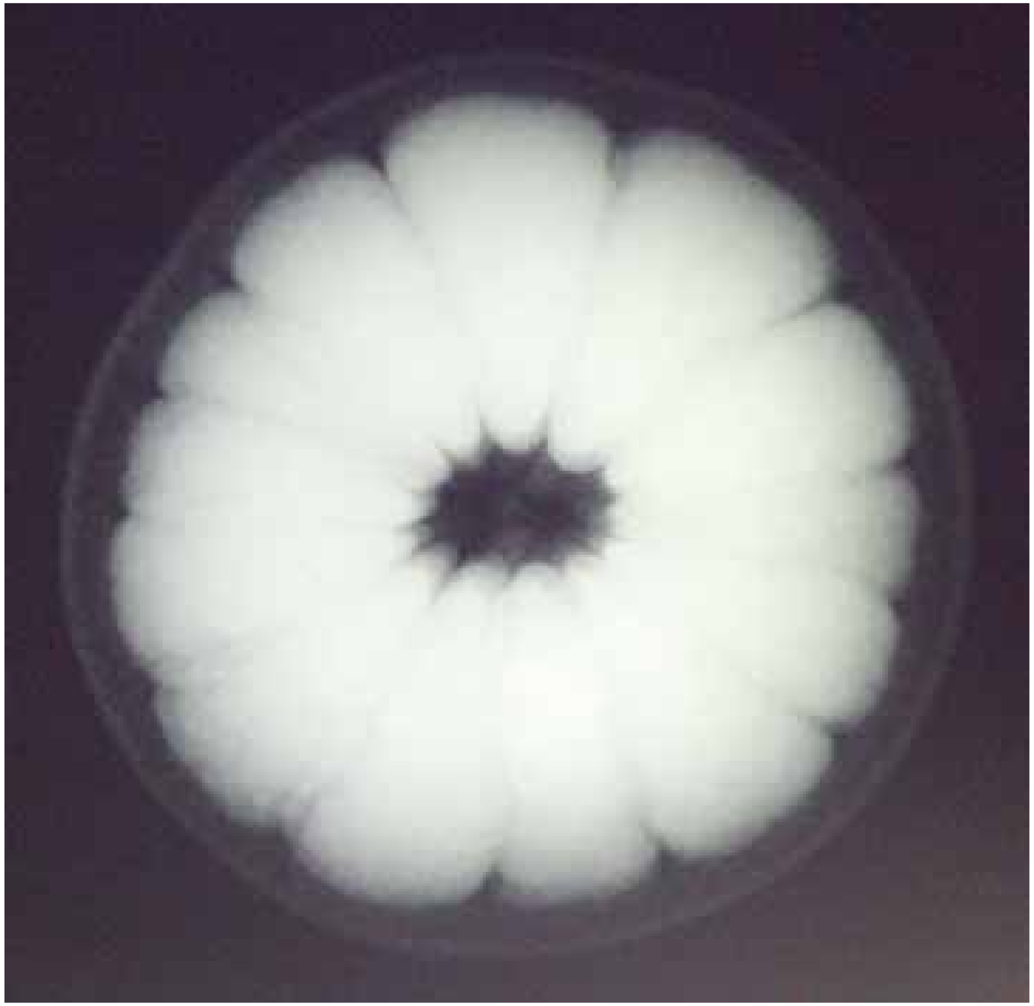
Radiographic Images

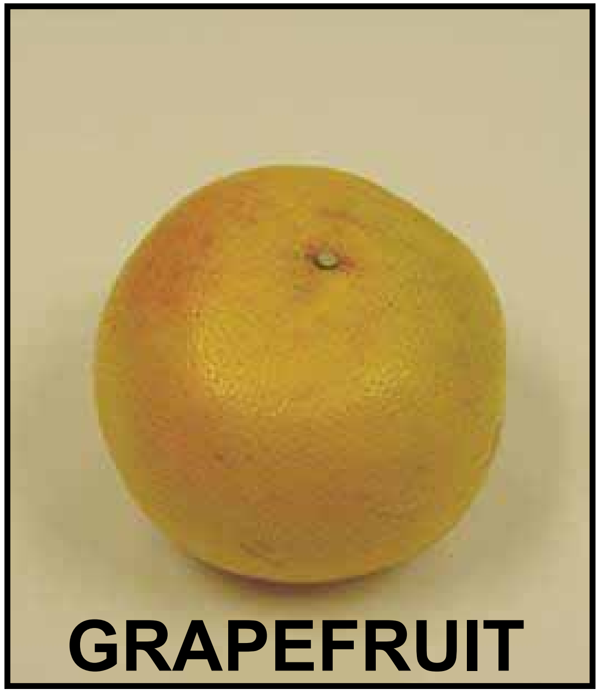
CHALLENGE: Can you determine what object was radiographed in this slide?



Radiographic Images

CHALLENGE: Can you determine what object was radiographed in this slide?





Advantages of Radiography Examination

- **Technique is not limited by material type or density.**
- **Can inspect assembled components.**
- **Minimum surface preparation required.**
- **Sensitive to changes in thickness, corrosion, voids, cracks, and material density changes.**
- **Detects both surface and subsurface defects.**
- **Provides a permanent record of the inspection.**

Disadvantages of Radiography Examination

- **Many safety precautions for the use of high intensity radiation.**
- **Many hours of technician training prior to use.**
- **Access to both sides of sample required.**
- **Orientation of equipment and flaw can be critical.**
- **Determining flaw depth is impossible without additional angled exposures.**
- **Expensive initial equipment cost.**

Some Standards relating to Radiography Examination

➢ **American Society for Testing and Materials (ASTM):**

- **ASTM E94 (2010) - Standard Guide for Radiographic Examination.**
- **ASTM E1030/E1030M (2015) - Standard Practice for Radiographic Examination of Metallic Castings.**
- **ASTM E1032 (2012) - Standard Test Method for Radiographic Examination of Weldments.**
- **ASTM E1742/E1742M (2012) - Standard Practice for Radiographic Examination.**

Radiography Examination Video

https://www.youtube.com/watch?v=IcWjZbXiFkM

References

- https://en.wikipedia.org/wiki/X-ray
- https://en.wikipedia.org/wiki/Gamma_ray
- **NDT Resource Center. https://www.nde-ed.org/index_flash.htm**
- **The American Society for Nondestructive Testing. www.asnt.org**
- **ASTM E94-04 (2010) - Standard Guide for Radiographic Examination. ASTM International, West Conshohocken, 2010. (DOI: 10.1520/E0094-04R10)**
- **ASTM E1030 / E1030M-15 - Standard Practice for Radiographic Examination of Metallic Castings. ASTM International, West Conshohocken, 2015. (DOI: 10.1520/E1030_E1030M-15)**
- **ASTM E1032-12 - Standard Test Method for Radiographic Examination of Weldments. ASTM International, West Conshohocken, 2012. (DOI: 10.1520/E1032-12)**
- **ASTM E1742 / E1742M-12 - Standard Practice for Radiographic Examination. ASTM International, West Conshohocken, 2012,. (DOI: 10.1520/E1742_E1742M-12)**
- **ASM International. ASM Handbook, Volume 17: Nondestructive Evaluation and Quality Control. ASM, 9th edition, 795p., 1989. (ISBN: 978-0-87170-023-0)**