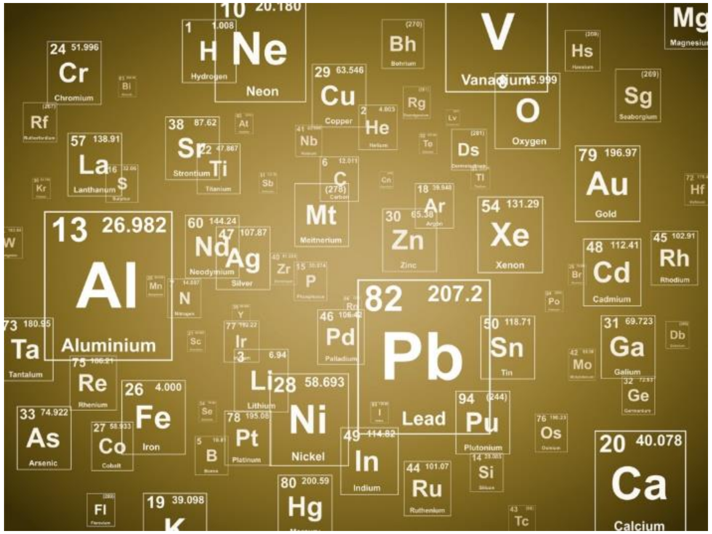
Safety Training for Tube Based and Sealed Source XRF Instruments

Welcome!

This is a training course on radiation safety for the use of tube based and sealed source X-Ray fluorescence analyzers, also known as XRF analyzers.



Geotech Environmental Equipment, Inc.

800-833-7958 www.geotechenv.com

Your complete source for performance-driven environmental equipment and supplies.

Safety Training for Tube Based and Sealed Source XRF Instruments

Learning Objectives

- Radiation Exposure (Dose)
- Measuring Dose Exposure
- Exposure Reduction (ALARA)
- XRF Basics
- Safety and Responsibility

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Radiation Exposure (Dose)

The term radiation is used with all forms of energy—light, X-rays, radar, microwaves, and more. For the purpose of this training, radiation refers to invisible waves or particles of energy from radioactive sources or X-ray tubes.

High levels of radiation may pose a danger to living tissue because it has the potential to damage or alter the chemical structure of cells. This could result in various levels of illness. The user of a tube based XRF analyzer must understand the nature of radiation and how to safely use XRF analyzers.

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Radiation Exposure (Dose) Section Definitions:

Radiation: the emission of energy as electromagnetic waves or as moving subatomic particles, especially high-energy particles which
cause ionization.

Ionization: is a process by which an atom or a molecule acquires a negative or positive charge by gaining or losing electrons.

X-Ray: an electromagnetic wave of high energy and very short wavelength, which is able to pass through many materials opaque to light.

XRF: is the emission of characteristic "secondary" (or fluorescent) X-rays from a material that has been excited by being bombarded with high-energy X-rays or gamma rays.

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Radiation Exposure (Dose) Section Definitions:

Dose: is the concentration of energy deposited in tissue as a result of an exposure to ionizing radiation.

RAD: is a unit of absorbed radiation dose, defined as 1 rad.

REM: one of two standard units used to measure dose equivalent, which combines the amount of energy and medical effects of the given type of radiation. The related international system unit is the Sievert (Sv) unit.

100 Rem = 1 Sv

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Radiation Exposure (Dose)

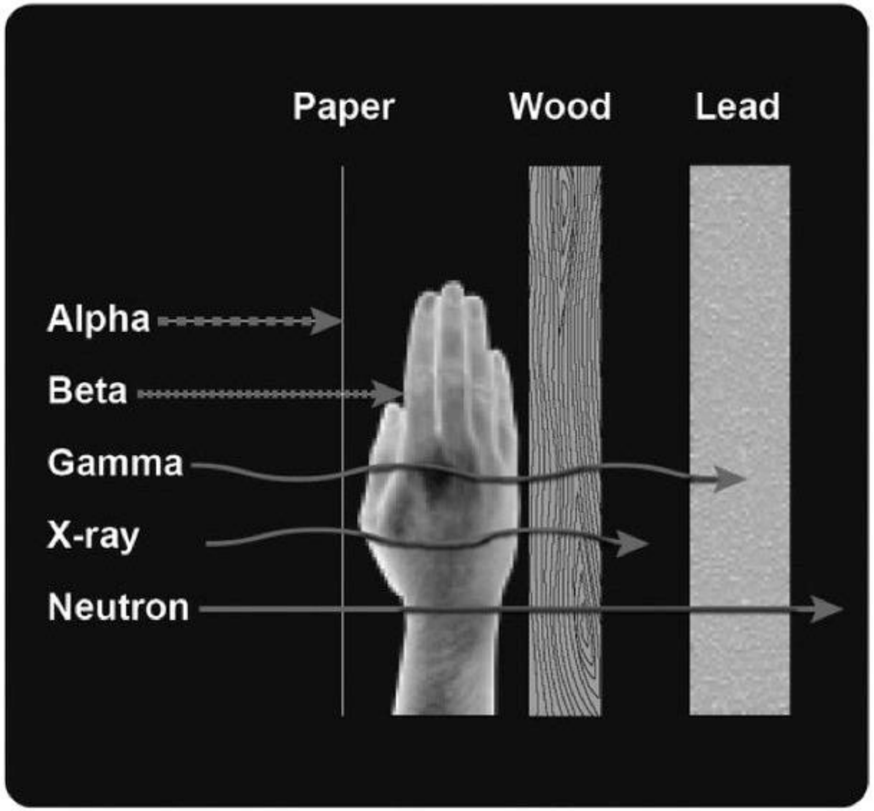
Alpha:

Beta:

Gamma Rays and X-rays:

Neutron Particles:

Penetration:



U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

As of July 2018

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Radiation Exposure (Dose)

Alpha: Has low penetrating power and a short range (a few centimeters in air). The most energetic alpha particle will generally fail to penetrate the dead layers of cells covering the skin, and can be easily stopped by a sheet of paper

Beta: Is emitted from the nucleus of a radioactive element during radioactive decay of an unstable atom. Large amounts of beta radiation may cause skin burns, and beta emitters are harmful if they enter the body. Beta particles may be stopped by thin sheets of metal or plastic

Gamma Rays and X-rays: Gamma radiation frequently accompanies emissions of alpha particles and beta particles. Gamma rays are similar to x-rays, but are very penetrating and are best stopped or shielded by dense materials.

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Radiation Exposure (Dose)

X-rays: These rays are usually produced by excitation of the electron field around certain nuclei. In nuclear reactions, it is customary to refer to photons originating in the nucleus as x-rays. XRF analyzer that Geotech supports produce X-rays and Gamma rays.

Neutron Particles: are ejected from the nucleus of an atom during the normal operation of a nuclear reactor or particle accelerator, as well as the natural decay process of some radioactive elements. They are best shielded by materials with a high hydrogen content (water, concrete or plastic).

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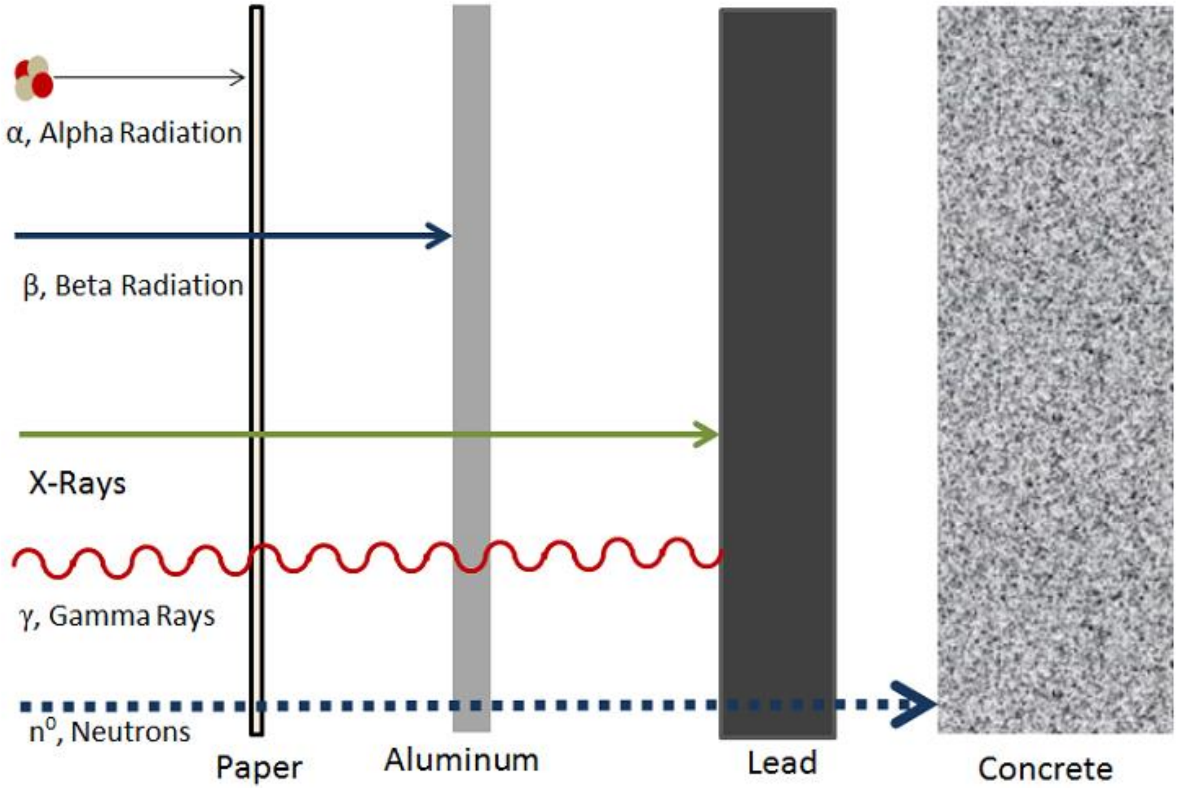
Penetration: the power for each of the four basic radiations vary significantly, as shown here.



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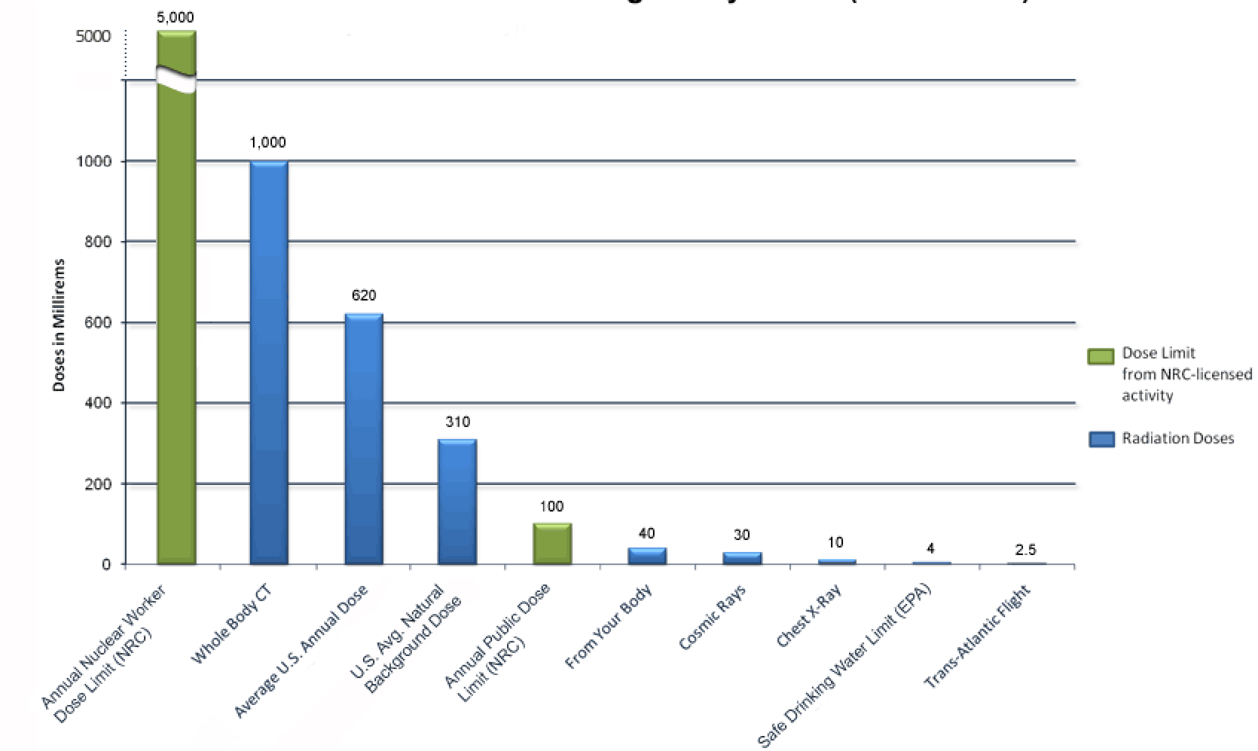
Radiation Exposure (Dose) Perspective

To help put dose radiation exposure into perspective: On average, Americans receive an average radiation dose of about 0.62 rem (620 millirem) each year.

Radiation Doses and Regulatory Limits (in Millirems)



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Radiation Exposure (Dose) in Perspective

Half of this dose comes from natural background radiation.

Most of this background exposure comes from radon in the air, with smaller amounts from cosmic rays and the Earth itself.

The other half (0.31 rem or 310 mrem) comes from man-made sources of radiation, including medical, commercial, and industrial sources. In general, a yearly dose of ~620 millirem from all radiation sources has not been shown to cause humans any harm.

Typical Radiation Doses from Selected Sources (Annual)*	
Exposure Source	**mrem per year**
Background (50%)	311
Medical (48%)	300
Consumer (2%)	13
Occupational (0.1%)	0.5
Round trip US by air	5
Building materials	3.6
Worldwide fallout	<1
Natural gas range	0.2
Smoke detectors	0.0001
** Based on 2006 U.S. data only*	

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Radiation Exposure (Dose) in Perspective

You will also note that a coast-to-coast roundtrip commercial airplane flight will result in a 5 mrem exposure. This extra dose is from the increase in natural cosmic radiation at higher altitudes.

This dose is more than double the maximum estimated dose to an XRF operator under proper use conditions

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- **XRF Operator (2000 hours of operation) = 200 mrems or .2 rems**

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Radiation Exposure (Dose) in Perspective

An occupational dose is a dose received by an individual in the course of employment in which the individual assigned duties involve exposure to radiation. The effective dose (sometimes referred to as the whole body dose) limit is concerned with carcinogenic risk, whereas the equivalent dose limits are designed to ensure that individual doses are kept below the dose thresholds for deterministic effects. The dose limit for the skin applies to the dose averaged over an area of 1 cm^2

[Bruker S1 Titan
Broad Metals XRF Analyzer]

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Radiation Exposure (Dose) in Perspective

You'll also note the combined whole body limits are defined as from top of head to just below the knee. This is where most of the blood-producing and vital organs are located. Since the whole body contains most radiation-sensitive organs, it has the lowest limit for occupational workers. The whole body dose limit is 5 rem or 5000 millirem. Whole body dose is difficult to measure accurately. It is based on the deposited energy averaged over a large area. Localized dose to the skin, tissue or bone of the hand is a more likely result of improper use of an XRF analyzer. For this type of exposure, the skin dose limit is 50 rem.

Viken Pb200i
Lead paint XRF analyzer.

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Maximum Permissible Dose Equivalent for Occupational Exposure

Combined whole body occupational exposure	
Prospective annual limit	5 rems in any 1 yr
Retrospective annual limit	10-15 rems in any 1 yr
Long-term accumulation	(N-18) x5 rems. where N is age in yr
Skin	15 rems in any 1 yr
Hands	75 rems in any 1 yr (25/qtr)
Forearms	30 rems in any 1 yr (10/qtr)
Other organs, tissues and organ systems	
Fertile women (with respect to fetus)	0.5 rem in gestation period
Population dose limits	0.17 rem average per yr
(Reprinted from NCRP Publication No. 43, Review of the Current State of Radiation Protection Philosophy, 1975)	

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Biological Effects of Radiation

When humans are exposed to low levels of ionizing radiation, the risk of a health effect is either non-existent or too small to be observed in scientific and medial studies. Regulatory authorities make every attempt to see occupational dose limits so that workers are not exposed at radiation levels that known to be hazardous.

All radiation, if received in sufficient quantities, can damage living tissue. The key lies in how much and how quickly a radiation dose is received. Doses of radiation fall into one of two categories: Acute or Chronic.

Biological Effects of Radiation

Acute Dose
A large dose of radiation received in a short period of time.

Chronic Dose
Small doses over an extended period of time

Improper use, i.e. exposure to the primary beam of an analyzer can result in the following.

Dose (rem)	Effect (at exposure site)
50-500	Blurred vision (eye cataracts)
200-1000	Skin redness, inflammation, or burns (Erythema)
1000-1500	Skin peeling, Blister, (Desquamation)
1800-2000	Permanent tissue death (Dermal Radionecrosis)

You should notify your RSO or safety manager and seek medical evaluation immediately if you observe any sign of overexposure.

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Measuring Radiation Exposure

Dosimeters:

Because we cannot detect radiation through our senses, Dosimeters may be required in some jurisdictions for personnel operating an XRF Analyzer to monitor and record the operator's exposure.

Remember: a dosimeter <u>does not</u> protect you against radiation exposure; it is simply a passive device that measures the amount of radiation exposure received where the dosimeter was worn.

Image curtesy of Bruker.

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Measuring Radiation Exposure

Dosimeters:
While there is variation between dosimeters, and from one type to another, most dosimeters operate in a similar way. Exposure to ionizing radiation is absorbed by a material contained within the dosimeter and, when processed, provides a measured dose.

Regulators require that processing of dosimeters be performed by a company that is NVLAP accredited.

Measuring Radiation Exposure

The following information may apply to personnel using hand-held XRF analyzers in jurisdictions where dosimetry is required:

- Wear a dosimeter
- Wearing a dosimeter for a period of three months – subject to local regulation
- Whole body dosimeter worn on upper body
- Extremity dosimeters worn on fingers or wrist
- Do not expose dosimeter to primary beam
- Do not expose dosimeter to rad sources outside of work
- Do not pack dosimeter in checked or hand carried luggage
- Notify supervisor or RSO is dosimeter is damaged or lost

Geotech recommends that local regulatory requirements in regards to occupational radiation monitoring be determined, understood, and followed.

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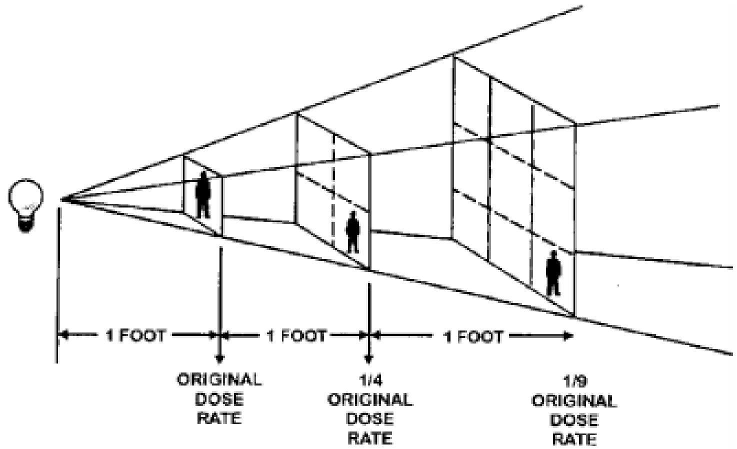
ALARA (As Low As Reasonably Achievable)

While dose limits and administrative control levels already ensure very low radiation doses, it is possible to reduce these exposures even more. The main goal of the ALARA program is to reduce ionizing radiation doses to a level that is As Low As Reasonably Achievable (ALARA).

Time

Distance

Shielding



***WARNING**: To avoid inadvertent exposure to others, the operator should ensure that there is no one on the other side of the wall or barrier when using an XRF analyzer.*

ALARA (As Low As Reasonably Achievable)

Time

The effect of **time** on radiation could be stated as Dose = Dose Rate x Time.

Distance

The second method for reducing exposure is by maintaining the maximum possible distance from the radiation source to the operator or member of the public. The principle of distance is that the exposure rate is reduced as the distance from the source is increased. The greater the distance, the amount of radiation received is reduced.

Shielding

The third, and perhaps most important, method of reducing exposure is shielding. Shielding is generally considered to be the most effective method of reducing radiation exposure, and consists of using a material to absorb or scatter the radiation emitted from a source before it reaches an individual. As stated earlier, different materials are more effective against certain types of radiation than others. The shielding ability of a material also depends on its density, or the weight of a material per unit of volume

ALARA (As Low As Reasonably Achievable)

Shielding

Although shielding may provide the best protection from radiation exposure, there are still several precautions to keep in mind when using handheld XRF devices:

- Persons outside the shadow cast by the shield are not necessarily 100% protected. Note: All persons not directly involved in operating the XRF should be kept at least three feet away.

- A wall or partition may not be a safe shield for persons on the other side.

- Scattered radiation may bounce around corners and reach nearby individuals, whether or not they are directly in line with the test location.

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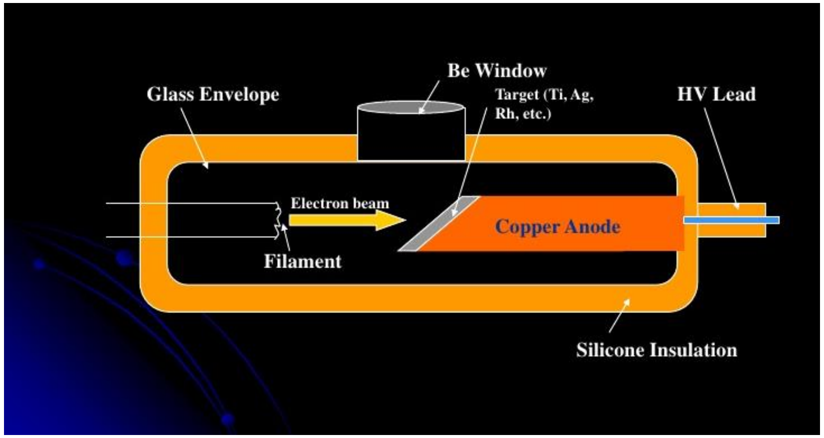
X-Ray Tube Basics

A modern miniature industrial X-ray tube consists of a ceramic container that is under vacuum. The major components of a miniature X-Ray tube is the cathode and anode. High voltage bias is applied between the anode (+) and the cathode (-).



The electrons emitted from the tungsten filament passes through the vacuum of the tube and are accelerated as they are attracted to the positive charge of the anode. The large voltage potential of 40 to 50 keV transfers a large amount of energy to the electrons. Electrons having gained a huge amount of kinetic energy impact the X-ray producing target.

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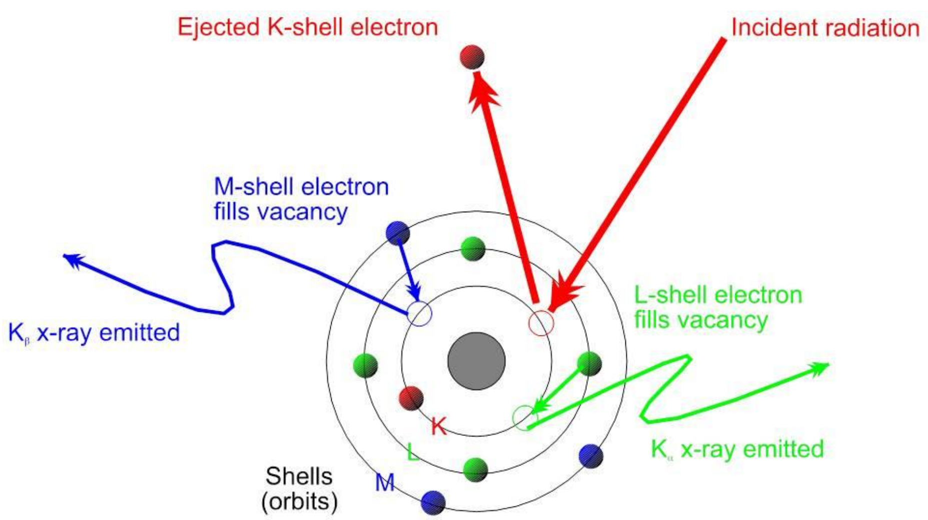
X-Ray Tube Basics

The impaction of electrons on the target anode knocks a lower orbit electron from the target atoms lower shell creating a void. A higher shell electron moves to fill the void, releasing its extra energy in the form of an X-ray photon. This produces the X-rays required to conduct XRF analysis.



1) fluorescence wave process where x-rays are delivered into the sample by the CRF device. These incoming x-rays knock out electrons creating spaces for other electrons to fall into.
2) a falling electron that gives off fluorescence x-rays characteristics – these electrons are measured by the analyzer to identify elements

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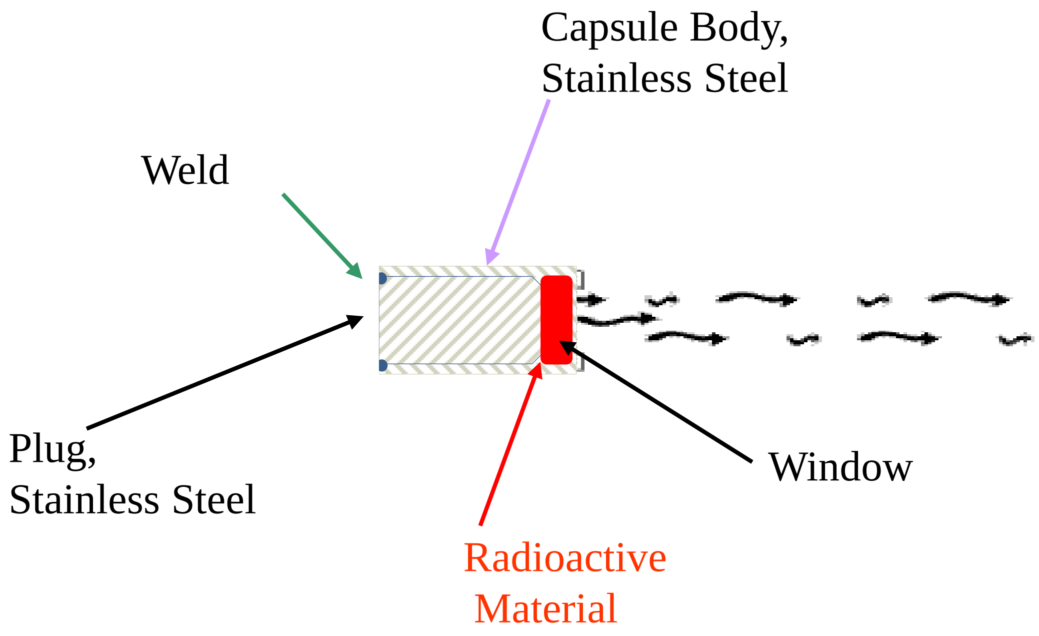
Sealed Source Basics

When radioactive material is used in an XRF analyzer, it is in the form of a sealed source.

The sealed source capsule is located in the instrument's snout.

When the shutter is open, gamma rays and x-rays from the source are emitted in the forward direction. The analysis reaction is the same as a tube based analyzer.



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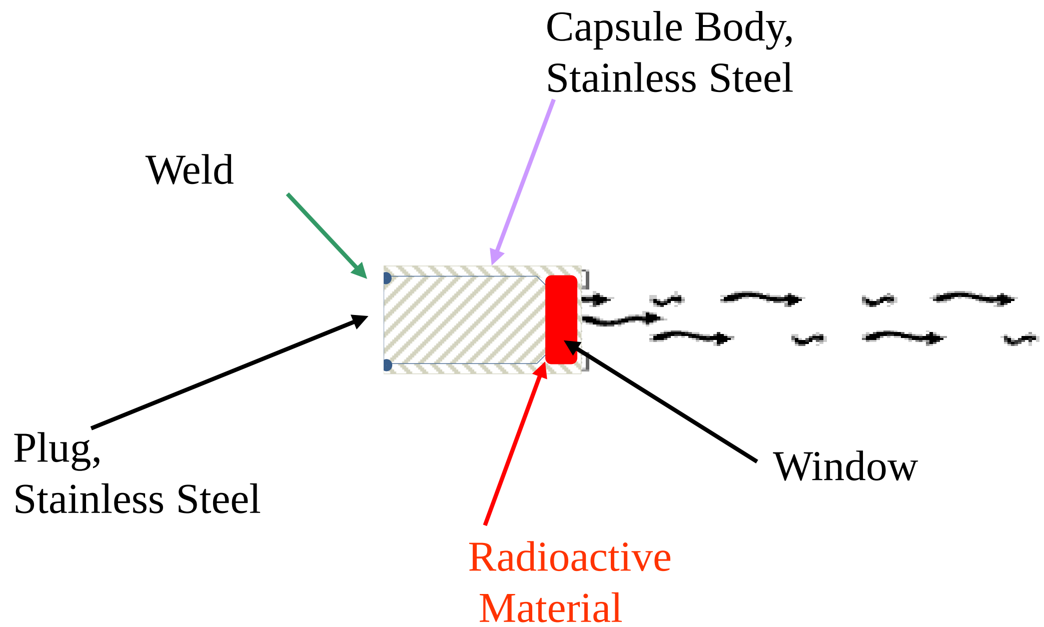
Sealed Source Basics

There are two controls that need to be activated before the shutter will open. First, the proximity sensor at the front of the snout must be depressed. To do this, press the front of the instrument against the surface to be measured. Second, the trigger on the handle must be pressed.

Opening the shutter starts the reading. Releasing the trigger or lifting the snout of the instrument from the sample so that the proximity sensor is not fully depressed will stop a reading in progress.



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Safety Responsibility

As the operator of the handheld XRF analyzer, you are responsible for your safety and the safety of others. Carefully read the instrument's user guide prior to use.

Before pulling the trigger…

- ❑ Be aware of the direction that the X-rays travel
- ❑ Move body parts (legs, hands, eyes) away from the examination area
- ❑ Be aware of others near the examining area
- ❑ Do not hold a sample being analyzed by hand
- ❑ Do not defeat the proximity sensor to bypass safety circuit
- ❑ Use optional safety shield or benchtop stand

Safety Training for Tube Based and Sealed Source XRF Instruments

Safety Responsibility (Con't)

As the operator of the handheld XRF analyzer, you are responsible for your safety and the safety of others. Carefully read the instrument's user guide prior to use.

Before pulling the trigger…

- ❑ Be aware of local dosimeter regulations
- ❑ Be aware of risks operating an XRF if pregnant
- ❑ Operator is responsible for the security of the analyzer
- ❑ Operator(s) must be trained and certified to operate the analyzer
- ❑ Operator must inspect the analyzer for damage
- ❑ Always store the instrument in a secure location when not in use.
- ❑ If you suspect the analyzer is damaged, remove the battery pack and disconnect all power sources and contact Geotech immediately.

Safety Training for Tube Based and Sealed Source XRF Instruments

Safety Responsibility

Carefully read the instrument's user guide prior to use.

Backscatter with Low Density Samples:

- Be aware that when using a handheld XRF analyzer, some radiation is scattered back towards the operator. The amount of scatter is dependent on the density of the sample – with low density samples, such as plastics, scattering is more than high density samples, such as metals – and the shape of the sample – with flat surfaces containing more of the backscatter and curved and irregular surfaces containing less of the backscatter. The operator must keep hands and eyes away from the analyzer nosepiece.

- Further, it should be noted that low-density (LD) materials, such as plastic, wood, soil, paper, or ceramic, will not attenuate higher energy X-rays as efficiently as high-density materials, such as metal alloys. Thus a greater amount of the radiation is transmitted through the sample, which can cause a higher dose rate to the operator. The operator should keep hands and eyes away from the analyzer nosepiece. If LD samples are measured frequently, the use of a bench-top stand is recommended to minimize scattered radiation. If the LD samples are small enough, the Small Sample Safety Shield is adequate.

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Radioactive Materials Licensing Authorities

Nuclear Regulatory Commission (NRC) Agreement State”
(Authorized by Agreement with the NRC)

The Occupational Safety and Health Administration (OSHA) has regulations limiting ionizing radiation dose to occupational workers that are consistent in magnitude to the NRC limits. OSHA does not license radioactive material. It has agreed to allow the NRC to regulate “OSHA workers’” exposure to radioactive materials.

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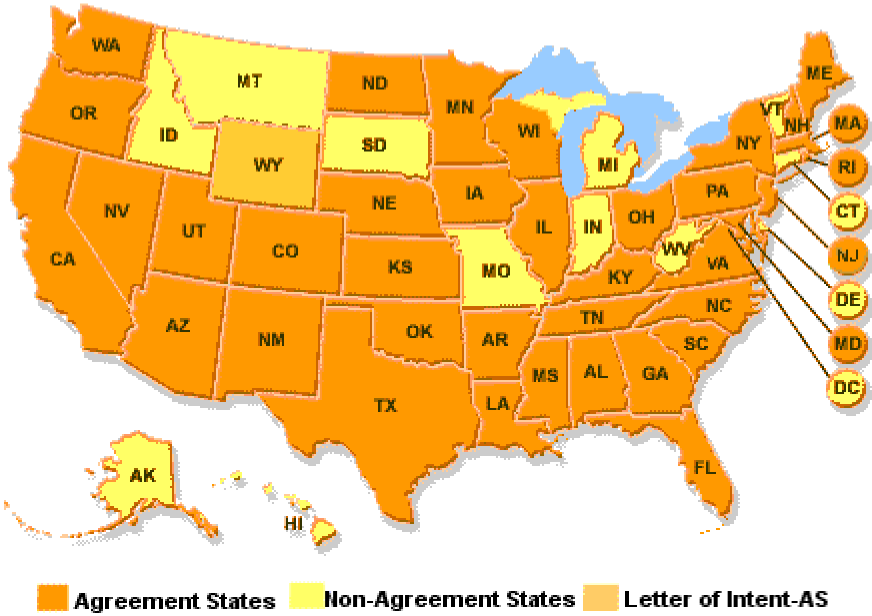
Agreement States and Non-Agreement States



Agreement States, have entered into agreements with NRC that give them the authority to license and inspect byproduct, source, or special nuclear materials used or possessed within their borders.

https://scp.nrc.gov/asdirectory.html

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Licensing – Radioactive Materials

Two License Types

- **Specific License (SL)** – Requires submittal and approval of license application, and issuance of license document, in advance of receipt of radioactive material. Issued by Agreement State or NRC.
  (Check Agency web site for application materials.)

- **General License (GL)** – Where allowed, is granted automatically upon receipt of a properly distributed GL device. No licensing document. Some states require registration by licensee.

Check with your local state authority for additional licensing information.

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You open the XRF Safety Training Test using the QR code or copying the following link into your browser.

https://forms.office.com/Pages/ResponsePage.aspx?id=M9DQHjwJLUqSve1ATuhxAFEbbHsXuRpElOIOhNJImHpUNjNaQUFJOUU1S0JOT01EVlNXUDJXRVFQWS4u