XRF SAFETY MANUAL WITH OPERATING INSTRUCTIONS

Serial Numbers for Units at UMiami Laboratory:
S/N 5429 for Model I-3000C (Green)
S/N 5453 for Model α-2000S (Grav)

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THE MAJORITY OF THE INFORMATION INCLUDED
IN THIS DOCUMENT WAS OBTAINED FROM INNOV-X SYSTEMS

COLLEGE OF ENGINEERING
CIVIL, ARCHITECTURAL & ENVIRONMENTAL DEPARTMENT

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NOTE: OPERATING MANUALS ARE PROVIDED AS A GUIDE. INDIVIDUAL FACILITIES SHOULD MODIFY THE ENCLOSED INFORMATION TO MEET THEIR FACILITY NEEDS.

XRF SAFETY MANUAL WITH OPERATING INSTRUCTIONS

OVERVIEW AND PROPER USE OF HANDHELD XRF

The handheld XRF units emit x-rays in order to analyze test materials. The x-rays are emitted from the lens (sampling window) of the XRF in the form of a focused beam. The standard operating conditions for the tube inside the unit are a voltage of 35 kV, a current of 5 uA, and 2 mm of aluminum filtration. The radiation levels emitted from the beam under the standard operation conditions are as follows: less than 0.05 mrem/hr for the trigger of the unit or any part of the body, 28,160 mrem/hr at the sampling window, 2,080 mrem/hr 4 inches away from the sampling window, 186 mrem/hr 12 inches away from the sampling window, 24 mrem/hr 36 inches from the sampling window, and 14 mrem/hr 48 inches from the sampling window.

The x-rays emitted from the XRF are capable of passing straight through many different materials (such as wood) without loosing strength. Therefore it is very important to be mindful of where the device is aiming whenever performing an analysis. The beam is capable of passing through the sample material and tables upon which the samples are placed. A small amount of the X-rays are scattered back towards the unit. Therefore it is important to keep hands away from the sample window and the metal frontal portion of the unit.

Proper use includes holding the units by the handle and analyzing materials only when they are lying on the floor or a table. The devices should never be used to analyze material that is being held in a person's hand. Always be certain that the beam is not pointed at anyone and assume that the beam may pass through testing material and any table the testing material upon which it is placed.

Radiation badges are recommended for individuals at a facility who will be using the XRF units on a day-to-day basis. According to Innov-X some states require the use of radiation badges. Innov-X also recommends that XRF operators wear badges, at least for the first year of operation, as a general precaution in case of misuse of the instrument.

IMPORTANT SAFETY INFORMATION

THE XRF SHOULD NOT BE POINTED AT ANYONE OR ANY BODY PART, ENERGIZED OR DE-ENERGIZED! The safe and proper operation of the Innov-X XRF instruments is the highest priority. These instruments produce ionizing radiation and should ONLY be operated by individuals, who have been trained by Innov-X Systems, Inc. and received a manufacturer's training certificate. Innov-X recommends that operators and companies implement a written Radiation Safety Program, with safety components specific to the site and application of use of the instrument. The Radiation Safety Program should be reviewed annually and revised appropriately by a competent individual.

Innov-X analyzers must be used by trained operators, according to the instructions presented in this manual. Improper usage may circumvent safety protections and could potentially cause harm to the user. Pay attention to all warning labels and messages.

GENERAL SAFETY PRECAUTIONS AND INFORMATION

Retain and follow all product safety and operating instructions. Observe all warnings on the product and in the operating instructions. To reduce the risk of bodily injury, electric shock, fire and damage to the equipment, observe the following precautions:

Heed service markings. Except as explained in this documentation, do not service any Innov-X product yourself. Opening or removing covers may expose you to electric shock. Service needed on components inside these compartments should be done only by Innov-X Systems, Inc.

DAMAGE REQUIRING SERVICE:

- The power cord, plug or battery contacts for the battery charger are damaged.
- Liquid has been spilled or an object has fallen onto the instrument.
- The instrument has been exposed to rain or water.
- The instrument has been dropped or damaged.
- There are noticeable signs of overheating.
- The instrument does not operate normally when you follow operating instructions.

SAFETY PRECAUTIONS:

Use the correct external power source: Ensure that the voltage is appropriate (100V-240 V/ 50-60 Hz) for charging the battery packs. Do not overload an electrical outlet, power strip, or convenience receptacle. The overall load should not exceed 80% of the branch circuit rating.

USE CABLES AND POWER CORDS PROPERLY:

Plug the battery charger into a grounded electrical outlet that is easily accessible at all times. Do not pull on cords and cables. When unplugging the cord form the electrical outlet, grasp and pull the cord by the plug.

HANDLE BATTERY PACKS PROPERLY:

Do not disassemble, crush, puncture, short external contacts, dispose of in fire or water, or expose a battery pack to temperatures higher than 60^{o}C (140^{o}F). Do not attempt to open or service a battery pack.

INNOV-X SYSTEMS – RECOMMENDED RADIATION SAFETY TRAINING COMPONENTS

Individual Companies and States have specific regulations and guidelines for the use of X-ray tube generated ionizing radiation. The purpose of the recommendations below is to provide generic guidance for an ALARA - best practice - approach to radiation safety. These recommendations do not replace the requirement to understand and comply with the specific policies of any state or organization.

1. **Proper Usage.** Never point the instrument at another person. Never point the instrument into the air and perform a test. Never hold a sample in your hand and test that part of the sample.
2. **Establish Controlled Areas.** The location of storage and use should be of restricted access to limit potential exposure to ionizing radiation. In use, the target should not be hand held and the area at least three paces beyond the target should be unoccupied.
3. **Specific Controls.** The instrument should be stored, in a locked case, or locked cabinets when not in use. When in use, it must remain in the direct control of a factory trained, certified operator.
4. **Time - Distance - Shielding Policies.** Operators should minimize the time around the energized instrument, maximize the distance from the instrument window, and shoot into high density materials whenever possible. Under no circumstances should the operator point the instrument at themselves or others.
5. **Prevent Exposure to Ionizing Radiation.** All reasonable measures, including labeling, operator training and certification, and the concepts of time, distance, & shielding, should be implemented to limit radiation exposure to as low as reasonably achievable (ALARA).
6. **Personal Monitoring.** Radiation control regulations may require implementation of a radiation monitoring program, where each instrument operator wears a film badge or TLD detector for an initial period of 1 year to establish a baseline exposure record. Continuing radiation monitoring after this period is recommended, but may be discontinued if accepted by radiation control regulators.

WARNING: Danger of explosion if battery is incorrectly substituted. Replace only with Innov-X specified batteries. Used batteries may be returned to Innov-X Systems for disposal.

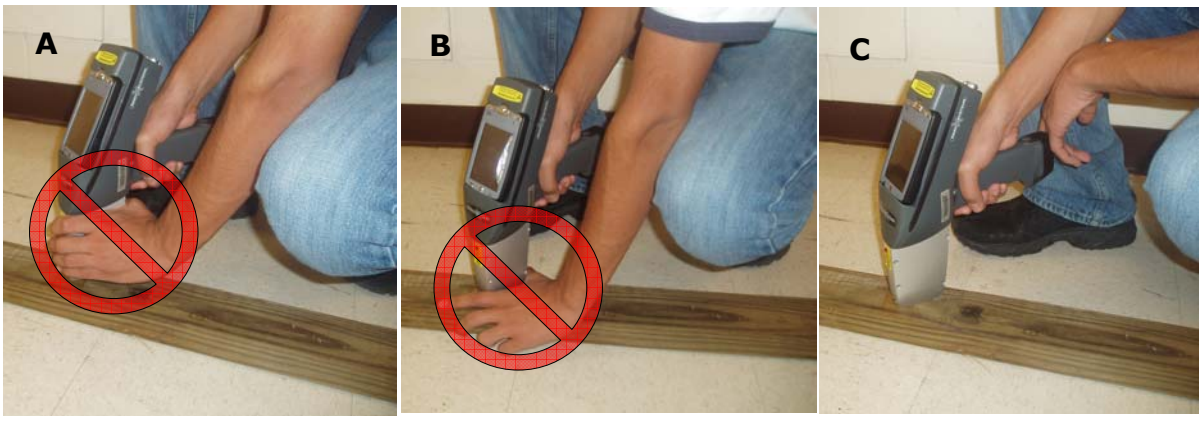
ADDITIONAL SAFETY FEATURES

The XRF units themselves have some built in safety features to protect against accidental exposure. The Innov-X analyzer is very safe when used correctly, however the analyzer does emit radiation through the analyzer window, and all precautions must be taken to reduce exposure to this radiation. In order to minimize the possibility of accidental exposure, the following safety features are standard in all Innov-X analyzers.

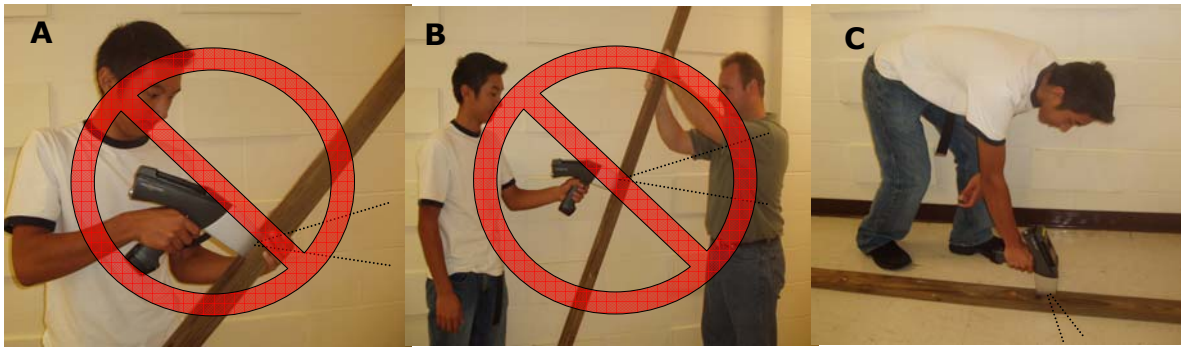
1. **"Deadman" Trigger.** The trigger must be held for the duration of the test. This requires that the user consciously depress the trigger whenever x-rays are emitted, and ensures that the analyzer is attended at all times while x-rays are emitted.
   Upon completion of safety training, an INNOV-X certified trainer may deactivate this feature upon request. The deactivation of the trigger is recommended only if long tests are required (such as for soil mode) and if the unit is used primarily by only 1 or 2 users who utilize it frequently, in a very controlled environment. In situations where multiple users are sharing the unit, it is recommended that the deadman trigger remain active.

2. **Software Trigger Lock.** Before using the trigger, the user must tap on a lock icon located in the lower right hand corner of the iPAQ screen. The user must then confirm that they wish to unlock the trigger. If the instrument is used continuously, the software trigger lock will remain off. If five minutes elapse between tests, the trigger will lock automatically.

3. **Software Proximity Sensor.** The software requires that a sample be present in front of the analyzing window. This prevents the accidental exposure of bystanders to an open beam. If the analyzer detects that a sample is not present, it will abort the test and shut off x-rays two seconds after the test is started.



Incorrect Ways to Hold the Hand-Held XRF Unit (Photos A and B) and Correct Way to Hold XRF Unit (Photo C)



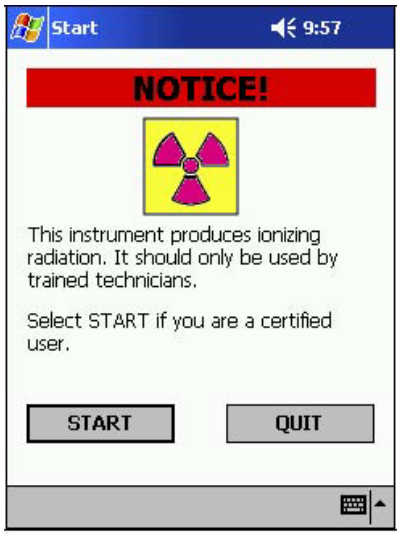
Incorrect Ways to Position the Hand-Held XRF Unit (Photos A and B) and Correct Position the XRF Unit (Photo C). Lines in the figures show the predominant direction of the X-Rays.

PERFORMING A TEST FOLLOWING APPROPRIATE RADIATION SAFETY PROCEDURES

STARTING THE ANALYZER:

When an operator opens the Innov-X software on the iPAQ, he or she will be presented with one of the displays shown below. Provided an operator has received training from an authorized Innov-X trainer, he/she should tap the START button to begin using the analyzer.

From this point the operator is presented with the main menu of the analyzer to choose an operating mode and begin testing. The remainder of this section is dedicated to operational and safety aspects that pertain to safe use and storage of the analyzer.



STARTING A TEST USING THE TRIGGER.

When the trigger is depressed, the analyzer supplies power to the x-ray tube and opens the shutter to emit x-rays.

If deadman trigger is enabled, the trigger must be depressed for the duration of the test. Releasing the trigger will close the shutter and immediately end the test. If deadman trigger is disabled, pulling the trigger once will start a test, pulling it again will stop it.

Handle of Analyzer Trigger is
Located at Top of Handle

STARTING A TEST USING THE "START" ICON ON THE IPAQ SCREEN

This feature is disabled in all units shipped. It will become active only if the "deadman" trigger is disabled.

An operator may also begin a test by pressing the **Start** button on the touch screen, as shown below. The **Start** button, rather than the trigger, is generally used when the analyzer is docked into the testing stand.

CORRECT AND INCORRECT INSTRUMENT USAGE

The Innov-X XRF analyzer can be used in several different testing configurations. Safety guidelines are described for each configuration.

CONFIGURATION 1: USAGE AS A HANDHELD ALLOY ANALYZER:

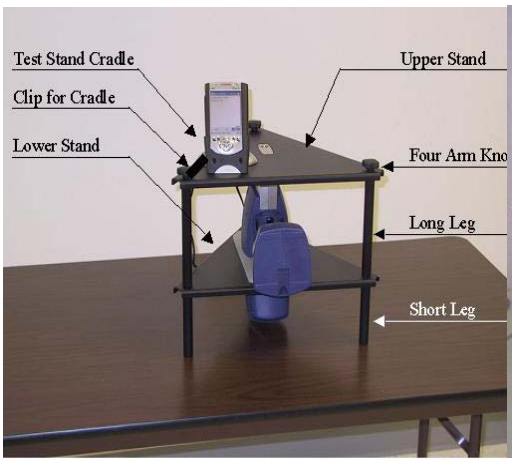
In this configuration the analyzer is held in the hand, placed on various types of samples and a test is performed. Samples include pipes, valves, large pieces of scrap metal, basically any sample large enough to be tested in place, rather than held in the operator's hand. Point the instrument at a metal sample such that no part of your body including hands and/or fingers is near the aperture of the analyzer where x-rays are emitted.

Using the analyzer in this manner assures that the operator will not obtain a radiation dose to any body part or extremity in excess of naturally occurring background radiation. The radiation at any surface of the analyzer is < 0.1 mR/hr except at the exit port and the immediate area around the exit port.

The user should take care that personnel are not located within 3' (1 m) of the front end of the analyzer during testing, in the direction of the x-ray beam. Provided the analysis window is completely covered, there is virtually no radiation being emitted around the area of the sample. However, if a small component or curved surface is being analyzed, some radiation will be detectable.

CONFIGURATION 2: USAGE IN THE TESTING STAND

Innov-X strongly recommends that testing small pieces or small samples (rod, fasteners, turnings, XRF sample cups, bagged samples, etc.) be analyzed using the Innov-X Testing Stand. This allows the sample to be placed onto the analysis window of the analyzer without requiring the sample to be held by the operator. See figure below:



Warning: Innov-X strongly recommends that operators do NOT hold samples in their hand for testing. Never hold a small sample in your hand, and test that sample, such that your hand is exposed to the x-ray beam being emitted from the analyzer. This type of testing produces a small but non-negligible radiation dose to the operator's hand.

TESTING OF SMALL COMPONENTS

Operators often are required to test small components, particularly in the field of alloy analysis. Examples of small samples include turnings, weld rod, wires, fasteners, nuts and/or bolts.

There are specific procedures to test small components. These procedures should be followed at all times. **Never hold a small part with your fingers or in the palm of your hand and perform a test. Doing so may deliver a significant dose of radiation to your fingers or hand.**

TESTING A SAMPLE LYING ON A FLAT SURFACE.

Performing a testing for a sample lying on the surface of a table. This is a good way to test small samples, rather than holding them in your hand.

To analyze small sample:

1. Place the sample onto a flat surface.
2. Place the window of the analyzer onto the sample and begin the test.

Safety Precautions:
Do not test samples in this manner at a desk or table where the operator is sitting. If the desk is made of wood or another non-metallic material, some radiation will penetrate the desk and may provide exposure to legs or feet if the operator is sitting at the desk or table.

Analytical Precautions:
If the sample does not completely cover the window, be sure the surface used does not contain metals or even trace levels of metals, as this may affect the accuracy of the XRF result. The XRF may report the presence of additional metals in the surface material. For this type of testing, it is good to place the sample onto a piece of 1100 series aluminum alloy and perform the analysis. The operator should disable the aluminum analysis capability.

RADIATION WARNING LIGHTS AND LABELING

MAIN POWER SWITCH AND INDICATOR LIGHT:

The main power switch is found on the rear of the unit and is shown in the figure. Pressing the switch for several seconds will turn on the main power. A green LED indicates the main power is on. The main power must be turned on in order to operate the unit however; this switch DOES NOT turn on the x-ray tube. No power will be supplied to the x-ray tube unit the Innov-X software is started.

PROBE LIGHT AND PROBE LABEL:

The Innov-X analyzer is equipped with warning lights that alert the operator when the tube is receiving power, and when x-rays are being emitted from the analyzer.

When the red light on the front nose of the analyzer is ON continuously (not blinking), this indicates the x-ray tube is receiving a low level of electrical power and the shutter is closed. The system is producing a low level of x-rays internally in this condition, but the shutter is providing adequate shielding to keep x-ray levels below levels of detection. The instrument is safe to be carried around or set down in this configuration.

When the red light is blinking, this indicates the tube is powered, the shutter is open and the analyzer is emitting x-ray radiation out of the analysis window. The analyzer should only be pointed at a sample, or be in the testing stand with a sample resting on the window, in this configuration.

DISPLAY ON BACK OF ANALYZER:

The display on the back of the analyzer, shown in the figure below, provides a "testing" message to indicate that the x-ray tube is energized and the shutter is open. This display is for testing conditions (i.e. overhead) where the operator cannot see the Probe Light or the iPAQ display.

LABEL BEHIND IPAQ:

The analyzer also has a label just below the iPAQ indicating:

CAUTION RADIATION
This Equipment Produces
Radiation When Energized

This label is required by most regulatory agencies. The term "When Energized" refers to the condition where the tube is fully energized and the shutter is open. This condition is also indicated by the red blinking light on the probe.

Probe light and labeling. When the light is on continuously, the x-ray tube is receiving minimal power and it is producing a minimum level of x-rays. The shutter is also closed so there is no radiation exposure to the operator or bystanders.

Back Light on Analyzer

RADIATION LEVELS FROM ANALYZER

Two pictures of the analyzer are shown below. In the first picture, all the relevant components referenced in this radiation safety section are displayed and labeled. The second picture shows a close-up of the front end of the window. The four sides A, B, C and D are indicated on this picture because they are referenced in terms of radiation levels output by the analyzer. The measured radiation levels for standard operating conditions are shown in the figures and tables below. Standard operating conditions are tube voltage operating at 35 kV, tube current of 5 uA, and 2 mm aluminum filtration.

Innov-X Analyzer, Side View

Innov-X Analyzer, Front View

RADIATION DOSES FOR SEVERAL SCENARIOS

In this section we provide data, concrete examples of use and misuse of the analyzer and common questions and answers we encounter when training personnel on the safe use of the Innov-X analyzer. The goal is to explain scenarios of safe versus improper usage of the analyzer.

The table below presents radiation doses for normal operating conditions and also for examples of misuse of the analyzer and even extreme misuse.

Example of Instrument Usage	Radiation Exposure and Comments
Normal Operation - Dose to Hand: User analyzes samples according to standard operating procedures described in this manual. Assumption: Operator using system with x-ray tube ON for 8 hours/day, 5 days/week, 50 weeks/year. (Practically constant usage).	Maximum exposure is to operator's hand, at the trigger. Exposure is < 0.1 mrem/hr. Annual exposure to hand is then < 200 mrem (2mSv). US: Maximum exposure under OSHA regulations is 50,000 mrem annually. Thus continuous operation provides a dose that is at least 250 times lower than maximum allowed by OSHA. Canada: Maximum exposure under ICRP regulations is 500 mSv for radiation workers and 50 mSv for the general public. Thus continuous operation provides a dosage 250 times lower for a radiation worker and and 25 times lower for the general public.
Normal Operation – Dose to Torso: Analyzer is used under the same operating conditions described above.	Exposure to Torso is so low it cannot be measured. To be conservative we use the same figure as the trigger, <0.1 mrem hr. Annual exposure using operating conditions above is < 40 mrem. (0.4 mSv). Maximum allowed is 5,000 mrem under OSHA and 20 mSv under ICRP for radiation workers (1 mSv for general public).
For the x-ray energy emitted by portable XRF analyzers (10-60 keV region), the bone in the fingers will absorb radiation about 3-5 times more than soft tissue, so the bone would be at an elevated radiation risk compared to soft tissue. For this reason no person shall hold a test specimen in front of the window with the fingers in the direct beam, or direct the beam at any part of the human body. Reference: Health Physics 66(4):463-471;1994.	
Misuse Example 1: Operator holds samples in front of window with fingers, such that fingers are directly in the primary beam. Do not do this!.	For fingers at the port, in the primary beam, the maximum dose to the fingers is 28,160 mrem/hr. Assume an operator performs a 10 sec test (typical). The dose to the operator's fingers or hand is 28,160 x (10/3600) = 78 mrem. If the operator did this 641 times/year they would exceed the allowable annual dose of 50,000 mrem to an extremity. In Canada, the maximum allowed dose is 500 mSv/year (Canada ICRP radiation worker) or 50 mSv/year (Canada ICRP general public). If the test time was 30 seconds instead of 10 seconds, the operator would receive a dose of 234 mrem for each exposure, and thus would exceed the annual safe limit of 50,000 mrem after 213 tests. Even though it is unlikely to make this mistake so many times in a year, do not even do it once. Take the extra time to test a sample on a surface or use a testing stand. **Note: If the operator takes an average of only two shortcuts per week and places his/her fingers within the primary x-ray beam at the window, they will exceed the annual dose rate.**

Misuse Example 2: Operator places analyzer against body and pulls the trigger to start a test. Analyzer tests to preset testing time (usually 10 seconds) unless operator pulls trigger again to stop test. This applies to analyzer being in contact with operator or with bystander.	Dose at exit of sampling window is 28,160 mrem/hr. Dose for a 10 second exposure with analyzer in contact with Torso: 78 mrem (.78 mSv). US: If an operator did this act 64 times in a year, the operator would exceed the annual safe dosage to the torso of 5,000 mrem/year. The maximum dose of 5,000 mrem/year is a whole body limit, which does not truly apply in this case because the x-ray beam size is small (about 2 cm^2 area – 1.5 cm x 1 .3 cm – at the port). Applying correction factors for the beam size is complex and beyond the scope of this manual. The important point is that for proper operation there is no reason to ever exposure any part of the human body directly to the x-ray source. This example serves to provide estimated exposure in the event this occurs. If the testing time was 30 seconds instead of 10 seconds, thus the operator placed the port against his body or that of a bystander and performed a 30 second test, the dose would be 234 mrem. This is about the same as a mammogram. Repeating this gross mis-use 22 times would exceed the annual allowable limits. Canada: Radiation worker would have to repeat this example (234 mrem exposure) of gross misuse 8 times to achieve the ICRP level of 20 mSv. (general public 1.3 times to achieve limit of 1mSv)
Misuse Example 3: Operator manages to initiate a test for 10 seconds and exposes a bystander that is standing 12" away from analyzer port. What is exposure to bystander? Note: The proximity sensor would automatically shut down the x-ray tube after 2 seconds, so this is an extremely improbable occurrence. Note 2: Equations to scale these to other scenarios involving longer or shorter tests, and bystander being at distances other than 12" are provided at right.	Dose to bystander at 1 foot is 350 mrem/hr. For a 10 second exposure dose is 1 mrem. This is 5,000 times lower than the allowable dose to a worker in a year. This would have to happen 5,000 times to for that worker or bystander to obtain the maximum allowable dose. Formula for calculating other scenarios: $Dose = 1\,mrem\left(\frac{13.25}{D+1.25}\right)^2 x\left(\frac{t}{10}\right)$ D = distance from port in inches T = testing time Example: Bystander is 3' away from port for a 30 second test. In this case the dose is calculated as: $Dose = 1\,mr\left(\frac{13.25}{36+1.25}\right)^2 x\left(\frac{30}{10}\right) = 0.38\,mrem$ US OSHA: Maximum allowable level is 5,000 mrem assuming bystander's torso is exposed. Thus, this misuse would have to occur 12,500 times in a year to the same bystander before that bystander achieved his maximum allowed dose. ICRP: 5000 times for rad worker, 250 for general public

COMPARATIVE: RADIATION DOSES FROM TYPICAL EXPOSURES TO IONIZING RADIATION

Common medical and/or dental x-rays:	20-30 mrem each.
Mammogram:	100-200 mrem
Flying in a commercial jet coast to coast (6 hrs.):	1-2 mrem.
Daily exposure from background radiation:*depends on geographic location	0.3 to 0.5 mrem/day

From the above table, a single case of analyzer misuse, thus producing a one-time exposure of 70-250 mrem, is comparable with single-event common medical x-ray procedures such as an annual chest x-ray or mammogram, or 25-50 airline flights in a year, and thus is not considered harmful. Regular misuse, such as taking safety shortcuts twice weekly, produces radiation exposure that greatly exceeds these typical levels and should be avoided entirely.

SAFE GUARDS AND EMERGENCY RESPONSE

The main safeguards to use as an owner of an Innov-X portable XRF are really intended to restrict access to properly trained operators:

1. Keep the system in a controlled location, where only authorized users are likely to have access to the analyzer at any given time.
2. Make a simple sign that is kept with the analyzer indicating that an operator must have completed a training class provided by your company or must have attended an Innov-X training course in order to use the analyzer. Note that when the Innov-X system is turned on, the screen displays a message indicating that the system should only be used by authorized personnel.

EMERGENCY RESPONSE:

Because the Innov-X system is a battery operated, x-ray tube based analyzer; the emergency response plan is very simple. If the operator believes the analyzer is locked up in an "OPEN" position, they should do two things:

1. Press the On/Off switch on the base to power the analyzer off. The green LED indicator will turn off, indicating system power is off. At this point it is not possible for the analyzer to be producing x-rays.
2. As an additional precaution, the operator may remove the battery trap door at the bottom of the analyzer (have the nose pointing away from personnel), and pull out the battery. Even if the operator has failed to properly power the system off in Step #1, removing the battery guarantees that no x-rays can be produced. There is no electrical power being provided to the x-ray tube.

Note: It would be highly unusual for an operator to somehow lock up the analyzer with the x-ray tube powered on. This would require the operator to crash the iPAQ during an analysis. If this happens the analyzer will shut off the x-ray tube 10 seconds after the last communication with the iPAQ. However, if at any time the operator believes the x-ray tube is on and no test is in progress, powering off the analyzer and restarting will automatically shut down the x-ray tube and close the shutter. It will no longer be possible to produce x-rays at this point.

DOSIMETER BADGES

Dosimeter badges are provided as a monthly service by several companies, listed below. The badges are generally provided monthly, and the operator returns the previous month badges to the company for analysis. The operator receives a monthly report showing any personnel with readings higher than typical background radiation.

Dosimeter badges are required by some states, and optional by other states. Innov-X recommends that operators wear badges, at least for the first year of operation, as a general precaution to flag any misuse of the analyzer. Dosimeter badges are available for the torso (generally worn on the belt loop or shirt pocket) and are available as "ring" badges. The best single badge to obtain is a ring badge that is worn on a finger, on the opposite hand used to hold the analyzer. This will record accidental exposure for the most likely case – an operator grabbing a small sample and holding it in one hand while analyzing it. Note: these badges generally have a threshold of 10 mrem, and are renewed monthly. So it will take several cases of misuse even to obtain a reading on a typical badge. When purchasing a badge, obtain the type used for x-ray and low energy gamma ray radiation.

Dosimeter Companies:
Here are two companies that provide badges as a regular service. There are certainly many more.

- **Landauer Inc**. Glenwood, IL
  Ph: 708-755-7000
- **AEIL.** Houston, TX
  Ph: 713-790-9719

COMMON QUESTIONS AND ANSWERS REGARDING RADIATION SAFETY

Question: When I'm shooting a piece of pipe or valve on a rack or on a table top, is there any exposure to people standing in other locations, or standing several feet away from the analyzer?

> *Answer:* Even a thin amount of metal sample (1-2 mm thickness) is enough to completely attenuate the x-ray beam emitted from the Innov-X analyzer. Shooting a piece of material that covers the sampling window on the analyzer will completely shield any bystanders from radiation exposure. However, good practice recommends that the area for at least 4-5 feet in front of the analyzer is clear of people. ***"Note: the XRF beam penetrates wood and the operator should not assume that wood will stop the beam. The XRF beam should be pointed down and away from people when analyzing wood samples."***

Question: If I forgot to switch the safety on the trigger to "ON", I pick up the analyzer and accidentally pull the trigger, is that dangerous to nearby personnel?

> *Answer:* No, this example of misuse is not dangerous, but it may produce a non-negligible radiation exposure to nearby personnel. For an exposure to occur, the following things must happen. First, you must be holding the analyzer so that a bystander is actually standing in the x-ray beam being emitted. Just being near the analyzer is totally safe otherwise. Second, the bystander must be within 1-3 feet from the nose of the analyzer in addition to being in the beam path, to receive any appreciable dose. If all of these

conditions are true, the dose received by a bystander is still extremely low. It ranges between 0.1 to 0.5 mrem depending on the exact location of the bystander. This dose is 10,000 to 50,000 times less than the allowed dose.

Question: Do I need to create restricted areas where I am using the analyzer?

Answer: No, provided you are following normal operating procedures there is no reason to restrict access to an area where the analyzer is in use. The operator should take precautions to keep any personnel more than 3 feet away from the sampling window of the analyzer in the event of accidental misuse as detailed above. Should the operator also elect to test small components like weld rod as shown in Figure 3.3, the operator should also be sure that no personnel are standing within about 4-5 feet of the sampling window.

Question: How does the x-ray tube in the Innov-X system compare to a radiography system used for taking images of metal parts.

Answer: The x-ray tube used in the Innov-X system produces between 1,000 and 10,000 times lower power than most radiography systems (0.5-1 watt for Innov-X versus kW for radiography systems). This is because a portable XRF is designed to perform surface analysis of alloys and other samples, whereas radiography systems are designed to shoot x-rays entirely through metal components in order to obtain an image on the other side of the object being bombarded with x-rays. For example, many tube-based radiography systems use a 300-400 kV tube and currents in the tens or hundreds of milliamps (mA). The Innov-X analyzer uses a tube operating at 35 kV and 5-30 micro-amps. The radiation levels produced are therefore thousands or tens of thousands times lower with the Innov-X system.

Question: Should we use dosimeter badges with the Innov-X analyzer.

Answer: Dosimeter badges are required by some states, and optional by other states. Innov-X recommends that operators wear badges, at least for the first year of operation, as a general precaution to flag any misuse of the analyzer. Dosimeter badges are available for the torso (generally worn on the belt loop or shirt pocket) and are available as "ring" badges. The best single badge to obtain is a ring badge that is worn on a finger, on the opposite hand used to hold the analyzer. This will record accidental exposure for the most likely case – an operator grabbing a small sample and holding it in one hand while analyzing it. Note: these badges generally have a threshold of 10 mrem, and are renewed monthly. So it will take several cases of misuse even to obtain a reading on a typical badge. When purchasing a badge, obtain the type used for x-ray and low energy gamma ray radiation.

TYPICAL REGISTRATION REQUIREMENTS

Innov-X maintains a database of the registration requirements for every state, including sample registration forms. Most states require some form of registration, and generally they require the registration to be received within 30 days of receipt of the instrument. Some states require no registration, while a few require notification in advance. Please contact Innov-X for specific questions regarding the state where the instrument will be used, or for copies of registration forms.

In general a company will have to provide the following information regarding the device:

1. Purpose of device. Generally this is "Analytical" or "Industrial." Be sure to inform the state registration office that the device will NOT be used for radiography or for medical uses.

2. Radiation Safety Officer – Monitors training, safe use, and controls access to the instrument.

3. Authorized Users – Trained by Innov-X Factory Authorized Representatives in the safe and proper use of the XRF

4. Operating parameters of the analyzer – 35 kV, 5-30 micro-amps.

5. Type of system, either fixed, mobile or portable. Generally the correct choice is "Portable."

6. User Training Specified – Indicate that only individuals receiving manufacturer training, documented by a manufacturer's training certificate will operate the instrument.

7. Personal Monitoring. This may be required by radiation control authorities. Many registration forms will ask that you indicate whether or not you intend to perform dosimeter monitoring.

8. Copy of Registration & Manual at the Job Site

If you have any questions regarding the type of registration form or filling out the form, please contact Innov-X Systems. Many states may confuse a portable XRF system that uses a tube with medical or industrial radiography systems. This is because of the relative newness of portable tube-based systems. In all likelihood, Innov-X personnel have experience providing the necessary documentation to the state in question, and can readily assist the customer in this process.

USE OF XRF ANALYZER: SUMMARY

BASIC INSTRUCTIONS FOR MAKING A MEASUREMENT USING THE INNOV-X XRF ANALYZER

1. Make sure that the standardization clip is attached to the front of the unit. Turn on power to the XRF (power button located at the rear of the device) and the power to the iPAQ (silver button on top right of iPAQ).

2. Next start the Innov-X software. Tap start (top left of iPAQ screen) and then tap Innov-X when the start menu opens (this is a square blue icon with a large white "X"). Tap "start" when the notice screen appears.

3. The Innov-X software will now load. The screen that appears will have two choices. Tap on "Soil".

4. The XRF will now begin to initialize itself. This may take a minute.

5. Once the XRF has initialized it must standardize. To do this tap the gray box on the iPAQ screen. The standardization takes about a minute. Once the standardization is complete a message will appear on the screen of the iPAQ indicating that it was successful. Tap the 'ok" on the top right of this message window to remove it. Remove clip if standardization was successful.

    a. If the standardization is not completed successfully try the following:
        i. Make sure that the standardization clip is attached properly. It should click into place.
        ii. Make sure the battery has a good charge. It may need to be changed. It pulls right out of the handle very easily and the charged battery only fits in one way so it can't be placed in wrong.
        iii. If battery is charged and the clip is placed on correctly and it will not standardize try restarting the system (Steps 9 – 11).
        iv. If it will still not standardize then it is broken.

6. Now the XRF is ready to perform the analysis. Press the unit against the sample and hold down the trigger. Once the trigger is released the XRF will stop performing the analysis. If the trigger is released in less than two seconds the analysis will be cancelled. After five seconds the analysis will automatically stop. (Refer to XRF Safety Manual for Proper Configurations for Use).

7. The results page will now appear. This will show what and how much the XRF has detected in the analysis. The results page can be closed by tapping the "X" on the top right of the iPAQ screen. You can either compress the trigger to perform another analysis from the results window or close it, either way the data is saved.

8. Once the analysis is complete the program must be turned off before turning off the power. Since the results are saved automatically, close the results window if it is open.

9. Next tap "File" at the bottom left of the iPAQ screen then choose "Exit".

10. Now the original Innov-X screen will appear. Tap "File" and "Exit" again.

11. The regular iPAQ screen will now appear. Turn off the iPAQ and XRF unit.

Please refer to Innov-X XRF Operations Manual to download data from the IPAQ and for instructions for regular maintenance items (e.g. charging of batteries).

FIELD SAFETY INFORMATION

Below is general safety information which can be used as a guide to supplement a facilities general operating safety manual.

General Safety Instructions

- Researchers are to report to the office immediately upon arrival to the facility in order to let the employees know of their presence at the facility. This will enable those who operate heavy equipment to know of their presence.
- Researchers should limit their activities to the area designated by the facility.
- Researchers should try to stay as a group while on the site.

Safety Apparel

- All researchers will be given the following, which should be worn at all times while on the site:
  - Bright Vest with Convenient Pockets
- Other Clothing Guidelines
  - While on site all researchers should wear long pants such as denim jeans.
  - There should be no loose clothing or jewelry dangling from the body. This could cause body parts to be pulled into machines such as the conveyer.
  - Hair should also be pulled back.
  - Any safety equipment that is not working properly or malfunctioning should be reported at once.

Equipment Safety

- XRF units
  - These devices should never be pointed at people. While in use they should only be pointed at samples being tested. Refer to XRF safety document in prior appendix and to radiation safety information provided by instrument manufacturer.
  - The XRF devices are somewhat fragile. While using them caution is required to insure that they are not dropped or bumped into other things.
  - Once the XRF devices are no longer being used for the day they should be locked up in the office.

- Equipment in general
  - Most of the equipment is valuable and possibly fragile.
  - All of the equipment must be safely locked up in the office on site or brought back to the lab and locked up safely.
  - Equipment is not to be left in vehicles or left outside without supervision.
  - If any equipment appears to not be working correctly or malfunctioning supervisor should be alerted at once.