REGION I
RADIATION SAFETY FOR USE OF PACKAGE INSPECTION X-RAY UNITS

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REGION I

Radiation Safety for Use of Package Inspection X-Ray Units

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DEFINITIONS AND ACRONYMS

Unless otherwise specified, the definitions and acronyms in this section are consistent with those provided in Management Directive 10.131

RADIATION SAFETY OFFICER (RSO)

The Radiation Safety Officer (RSO) or the Alternate RSO are designated to act on all radiation safety matters related to the x-ray unit and to conduct all activities specified in the following sections.

AUTHORIZED OPERATORS

Notwithstanding other training requirements, the Package X-Ray Inspection Unit shall only be operated by individuals who have completed all associated x-ray radiation safety training.

RADIATION SAFETY TRAINING

Radiation safety training is not required for individuals likely to receive less than 100 mrem in any calendar year (January 1 to December 31). However, to encourage authorized operators to maintain their doses As Low As Reasonably Achievable (ALARA), the Attachment A, "Radiation Safety for Use of Package Inspection X-Ray Units", is provided with more details to assist operators' understanding of radiation safety for operating x-ray units. This training also includes references to the following documents (current revision):

- USNRC Regulatory Guide 8.29, "Instruction Concerning Risks from Occupational Radiation Exposure"
- USNRC Regulatory Guide 8.13, "Instruction Concerning Pre-Natal Radiation Exposure"
- Management Directive 10.131, "Protection of NRC Employees Against Ionizing Radiation"

If an authorized operator receives radiation safety training from another source, the RSO or Alternate RSO shall determine if that training satisfies the training requirement specified above. DRM shall maintain a record of all personnel who have completed the approved radiation safety training for x-ray machine use.

OCCUPATIONALLY EXPOSED INDIVIDUALS

All authorized operators of the Package X-Ray Inspection Unit are designated Occupationally Exposed Individuals.

PERSONNEL DOSIMETRY

Due to the minimal radiation levels in normally occupied areas during routine operation of the x-ray unit, personnel dosimeters will not be issued. The RSO has determined that occupationally exposed individuals will not receive in excess of 500 mrem in one calendar year (January 1 to December 31).

DECLARED PREGNANT FEMALES

Any female, classified as an occupationally exposed individual, who is pregnant or believes that she may be pregnant may voluntarily declare her pregnancy in writing to her immediate supervisor. If this is done, she will also provide a copy of the declaration to the RSO or Alternate RSO. Normally, this would initiate actions to reduce the level of exposure to the embryo/fetus to less than 500 mrem during the entire gestation period. However, since no occupationally exposed individual at the x-ray unit is expected to receive more than 500 mrem in one calendar year under any circumstances, no specific actions need be taken upon receipt of the declaration.

AREA MONITORING

Area dosimeter monitoring is performed in the vicinity of the x-ray unit. The area dosimeter results are documented at least once each calendar quarter.

SURVEYS

The RSO or Alternate RSO, using an appropriate calibrated instrument, shall conduct an initial radiation survey, an annual survey, and confirmatory surveys (after maintenance or movement of the x-ray unit) in the immediate vicinity of the x-ray unit and document the results. The area dosimeter results may be used in lieu of the annual radiation surveys.

ACTIVITIES IN THE VICINITY OF THE X-RAY UNIT

No one, except authorized operators, shall be permitted to assist in the loading or unloading of articles onto or off of the conveyor belt unless the x-ray unit is de-energized. While the x-ray unit is energized, individuals may be permitted to conduct routine activities in the room. However, personnel who are not authorized operators and anyone who is not directly involved with the immediate operation of the x-ray unit shall not linger near the unit when it is energized. The authorized operator who has control of the x-ray unit shall be responsible for ensuring that all individuals in the vicinity comply with these restrictions.

X-RAY UNIT OPERATIONS

The x-ray unit is designed for the inspection of incoming packages, mail, and articles carried by visitors. At no time should any other objects be processed through the x-ray unit without the express permission of the RSO or Alternate RSO. Under no circumstances should anyone place any portion of their bodies beyond the drapes with the x-ray unit energized.

If a package placed on the conveyor belt fails to pass through the lead drapes at the entrance, the package shall not be pushed through by hand. A weighted object may be placed behind the package to provide enough resistance to ensure that the package will proceed through the system unassisted. If the package becomes stuck inside the cabinet or is unable to pass through the exit drapes, the unit will be de-energized before any attempt is made to extract the package.

REPORTING OF HAZARDS

All personnel are advised that, if, in your opinion, a radiation safety hazard exists or could exist, you must cease operations and advise the RSO or Alternate RSO immediately.

EMERGENCY TERMINATION OF OPERATION

If, in the judgment of the RSO or Alternate RSO, a radiation safety hazard exists or could exist, the RSO or Alternate RSO is authorized to terminate operation of the x-ray unit and take whatever actions are deemed necessary to adequately protect public health and safety. The RSO or Alternate RSO shall provide a brief written report of the event (e-mail acceptable) to the Radiation Safety Committee. If this should occur, the x-ray unit shall not be returned to operation until the RSO or Alternate RSO has informed the Radiation Safety Committee in writing (e-mail acceptable) that it is safe to do so. The RSO's or Alternate RSO's actions and reports shall address only radiation safety issues. Any other hazards (electrical, mechanical, physical etc) shall be evaluated by competent individuals designated by DRM management.

ATTACHMENTS:

A. "Radiation Safety Training for Users of Package Inspection X-ray Units"
B. USNRC Regulatory Guide 8.29, "Instruction Concerning Risks from Occupational Radiation Exposure"
C. USNRC Regulatory Guide 8.13, "Instruction Concerning Pre-Natal Radiation Exposure"
D. Management Directive 10.131, "Protection of NRC Employees Against Ionizing Radiation"

ATTACHMENT A

"Radiation Safety Training for Users of Package Inspection X-ray Units"

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NRC RADIATION SAFETY TRAINING FOR USERS OF PACKAGE INSPECTION X-RAY UNITS

SUMMARY:
This document describes:
A. Radiation safety
B. The nature of x-rays
C. The operation of the x-ray unit
D. What you need to know to protect yourself

A. RADIATION SAFETY

Who is responsible for radiation safety?
The one who is most responsible for radiation safety is **YOU**. By understanding the operation of the unit, the hazards of radiation and the procedures described in this document, you can protect yourself from unnecessary radiation exposure. However, you are not alone. There are many people available if you need help. Don't hesitate to ask. Health and safety is everyone's responsibility. If you feel you need help, contact someone listed in Appendix C. Start with your RSO or someone in your own organization, but, if you feel you need additional information, or just want to talk to someone else about radiation safety, you may contact anyone on the list.

What is an RSO?
RSO stands for Radiation Safety Officer. He/she is that person who is specifically tasked with developing a program to ensure adequate protection of your health and safety. The RSO is usually designated by senior management and usually reports to senior management through a channel separate from his/her normal supervisory chain. This ensures that radiation safety issues are given a high priority.

What is an RSC?
RSC stands for Radiation Safety Committee. This is a group of individuals who establish and review radiation safety for large organizations. It typically consists of a Chairperson, the RSO, a management representative and representatives from groups whose people may be exposed to radiation. The RSC will meet periodically (usually annually) to review the status of the radiation safety program and recommend improvements. If you have any concerns, you may want to have them discussed at the RSC meeting.

Where can I find the rules concerning the NRCs radiation safety program?
The rules that govern radiation safety for NRC employees are contained in Management Directive (MD) 10.131 which is titled, "Protection of NRC Employees Against Ionizing Radiation". MD 10.131 is based on 10 CFR Part 20 which contains the regulations governing radiation safety for NRC licensees. Your organization may also have an internal set of rules specific to where you work. Check with your RSO.

Does anyone else regulate the radiation safety of x-ray units?
Each state has regulations which govern radiation safety and x-ray unit performance. OSHA (the Occupational Safety and Health Administration) also has regulations (29 CFR 1910.96) covering radiation exposure from x-ray sources. These regulations are similar to NRC's regulations. In addition, the manufacturer of the unit has to comply with requirements for cabinet x-ray systems (21 CFR 1020.40) written by the National Center for Devices and Radiological Health (NCDRH), an organization which is part of the Food and Drug Administration (FDA). This organization sets limits on how much radiation can leak out of the cabinet surrounding the x-ray unit. Companies which manufacture and sell package inspection x-ray units must also comply with regulations written by the Federal Aviation Administration (FAA) (14 CFR 108.17 and 129.26) since many of these units are used to check baggage at airports. Basically, all of these regulations require that cabinet x-ray units (like the one you'll be using) must not emit more than 0.0005 rem (½ mrem) of radiation per hour (0.5 mrem/hr) at any surface of the unit where someone could have access. The radiation level would be even lower as you backed away from the surface. This is the same standard that applies to virtually all commercially available electronic devices designed for public use such as the TV sets which we have in our homes.

Am I a radiation worker?
You will be classified as a radiation worker (more correctly, an occupationally exposed individual). That's because your duties require you to operate an x-ray machine which is a source of radiation. Although it is not likely that you will receive any more radiation than a member of the public, a member of the public would not normally be expected to operate an x-ray unit.

What is my exposure limit?
Your official radiation dose limit will be 5 rem per year. However, at no time would you be expected to receive more than the 0.1 rem per year which is the limit for members of the public. This is 50 times lower than the occupational limit.

What is the difference between exposure and dose?
For our purposes there is no difference. The word "exposure" is typically used when referring to the radiation levels in the air around you so that we can say "he is being exposed to a certain amount of radiation". The word "dose" is typically used to identify how much radiation is actually received by an individual so that we can say "he has received a small radiation dose".

Will I be given a radiation badge to wear? If not, why not?
No! The regulations do not require that you wear a badge unless you are **likely** to receive 0.5 rem in one year (that's 5 times more radiation than a member of the public). Given the type of x-ray machine you'll be using, that is **not likely to happen** so you won't be given a radiation badge. However, to measure "worst case" possibilities, radiation badges may be installed near accessible locations most likely to be exposed to x-rays. These **area monitors** will be checked periodically. The exposure you receive would be no greater than what the area monitor is exposed to and will probably be a lot less. Your RSO will decide on whether area monitoring is needed and, if so, what type of monitor to use, how many, where to post them and how often to check them.

Why am I being given this training?
MD 10.131 states that anyone who might be exposed to radiation sources while performing their duties or who may work in areas where radiation is present needs to be given information about the radiation exposure and how to protect themselves. However, it will likely be revised soon to coincide with 10 CFR 19.12 which states that radiation safety training is not required if you are likely to receive less than 0.1 rem in a year. Even when MD 10.131 is revised and training is no longer required, it would still be prudent to receive radiation safety training initially and refresher training every two years to ensure that all authorized users are aware of the potential hazard of working with radiation sources. Specific training requirements are contained in MD10.131 as well as 10 CFR Part 19 and other federal and state rules and regulations.

B. THE NATURE OF RADIATION AND X-RAYS

What is radiation?
Radiation is everywhere. In most cases we can't see, hear, taste, smell or feel it. There are many different types of radiation. Some types are non-ionizing while others are ionizing radiation.

What is non-ionizing radiation?
Examples of non-ionizing radiation are visible light, heat (thermal radiation), microwaves, lasers, radio waves, ultraviolet (UV) light etc. These types of radiation can be harmful in large amounts. For example, ultraviolet light can burn you (sunburn), microwaves can cook food (and you), lasers can cause burns and eye damage etc. It usually takes a lot and most people are comfortable living with these types of radiation. Store checkout counters use laser scanners to verify prices; homes and offices have microwave ovens; we go outside in the sun but we avoid sunburn by using sunscreens. If we are exposed to too much non-ionizing radiation, it can cause physical injury (mostly burns).

What is ionizing radiation?
The other type of radiation is ionizing. This radiation tends to scare people more than non-ionizing radiation but it is also very common. There are two types of ionizing radiation, natural and manmade. We are exposed to both types all the time as a part of background radiation.

What is background radiation?
Background radiation is what we have to live with. It's all around us, we can't avoid it. When you think about it, can you avoid being exposed to non-ionizing radiation (transmissions from TV and radio stations, cellular phones etc)? Obviously not. These waves are everywhere. They penetrate and bounce off your body all the time. Background ionizing radiation is no different. Nature emits ionizing radiation all the time. We are bombarded by cosmic rays from space, radiation from elements like uranium in the ground and we breathe radon emitted from the earth. We even have radioactive potassium inside of us, naturally, all the time. We can't avoid this radiation. We've always been exposed to it and always will be. This is natural background and varies due to your location. Average background radiation in the U.S. is approximately 300 mrem/yr.

What is man-made radiation?
In addition to natural sources of radiation, we are also exposed from man-made sources. Smoke detectors emit ionizing radiation as do many consumer products like TV sets. Of course the amount of radiation is extremely small. Sometimes, we unintentionally make things worse. We said that radon is part of nature, but by using certain types of materials for building houses or by making houses very energy efficient, we can actually make the natural, low background level of radon exposure worse. Nuclear power plants and what's left of fallout from nuclear tests also contribute some radiation to the man-made background. On the average, all of these man-made sources are very small compared to natural background radiation. However, there is one area where large numbers of people are deliberately exposed to high levels of radiation (high compared to background). What we're talking about is medical x-rays. On the average (that is if we spread all of the radiation exposure out among all the people in the country), medical radiation exposure represents a big chunk of all the radiation the public receives (approximately 320 mrem/yr). Of course, this varies as some people might never have a medical x-ray procedure and some might have a lot.

How do you detect radiation if you can't see or feel it?
YOU can't detect it but your **RSO can** using a radiation detector. He/she can determine where it's coming from and how much is there. If you are an x-ray operator, your RSO might give you a radiation monitor that makes noise when it "sees" radiation. Instead of giving it to you, the RSO might install one near the x-ray unit to monitor how much radiation is coming out. This can help you to avoid problems that might occur unexpectedly. We'll discuss this type of monitoring later.

What are x-rays?
We're all familiar with medical x-rays. Everyone of us has probably had at least a chest x-ray sometime in our lives and you may have had other medical x-ray procedures done, perhaps for a broken bone or some other problem. If by some miracle you've never had a medical x-ray, you've probably had dental x-rays taken. The x-rays produced by medical and dental x-ray machines are all the same. They're produced by a machine similar to the package inspection unit you'll be using. The only difference between a medical x-ray unit, a dental x-ray unit and the package inspection x-ray unit that you'll be using is the type of machine and how much radiation it emits.

How are x-rays generated?
The way an x-ray machine works is very similar to the way an old cathode ray tube TV works. Electrons are produced at one end of a "tube". The other end of the tube is a "target" made positive by a voltage (either by being plugged into a wall outlet or in some cases by a large battery). The "beam" of negative electrons slams into the target. If the target is a TV screen, it glows and you see a picture. If the target is a chunk of metal in an x-ray tube, the electrons stop dead and their energy is converted to either heat or x-rays (mostly heat). The x-rays that are produced are emitted from the target in all directions. But the tube is shielded everywhere except for a small "window" so that the x-rays only exits the tube in one direction (towards the object being x-rayed).

Are x-rays like other types of radiation?
X-rays are identical to gamma rays that are emitted by radioactive material. The only difference is where the rays come from. If they come from the center of the atom (the nucleus), they are called gamma rays. If they come from the electrons that surround the atom they are called x-rays. Some people think that gamma rays are more powerful than x-rays. This may not always be the case. X-ray machines can be built which can produce x-rays much more powerful than gamma rays. An example is a "linear accelerator" which is used to treat cancer. The package inspection unit which you'll be using doesn't produce x-rays that powerful. It produces x-rays with about the same energy as a standard medical x-ray unit.

C. THE OPERATION OF THE X-RAY UNIT

How does the package inspection x-ray unit work?
The NRC has two types of package inspection x-ray units. The machine used by the mail room personnel is an American Science and Engineering, model GEMINI 6040. The machine used by security personnel is a Smith Heimann, model HS 6040i. They are essentially identical as far as the x-ray operation is concerned. The x-ray tube produces x-rays inside a lead lined chamber. When you plug the unit in and turn the key switch on, the unit is energized but does not produce any radiation (except briefly during the self test mode). To use the unit, a package is placed on the conveyor belt and the belt is activated. As the package enters the cabinet an x-ray beam shoots straight through from the x-ray tube. The x-rays travel through the conveyor belt and the package and hit a set of detectors which convert the x-rays into a picture which is sent by video cable to the TV monitor on top of the cabinet.

The number of x-rays produced by an x-ray machine depends on the "current" at which the machine operates. This is similar to the amount of radioactivity present. The x-ray units in Region 1 typically operate at a current of 1 mA (milliampere). That's a lot less than a medical x-ray unit which may be operated up to as much as 1,000 mA. So the package inspection units produce far fewer x-rays than a medical unit.

Wait a minute! Didn't we say a little while ago that the package x-ray unit was about the same as a standard medical unit. Actually, no. We said that the energy of the x-rays (that's the ability of the x-rays to penetrate objects) was about the same. But the number of x-rays produced is very different. In any case, a medical x-ray unit is typically pulsed for a short time (maybe one tenth of a second or less). That's because people can't hold perfectly still, they tend to move around so the technician wants to make sure the patient doesn't move while they're taking the picture. The same rule applies when you take a photograph. You might set a camera for 1/60 second or less to avoid blurry pictures (with a point and shoot camera, the camera automatically sets the shortest time depending on the amount of light available). Since packages don't usually move, and since we don't have to worry about any biological effects on the package, the package inspection x-ray tube can stay on longer. In fact it has a "100% duty cycle" which means the x-rays can stay "ON" all the time without damaging the tube. That's the same principle as a special medical unit called a "fluoroscopic" unit. If you've ever had a GI series for stomach problems you know that the doctor keeps the x-rays going while you drink some barium. The doctor watches it go through your system real-time. These medical fluoro x-ray units are

operated at low current settings just like the package inspection x-ray system. With such a low current it's essentially impossible to burn up these units by leaving them on too long. However, even though the x-ray unit can be operated for a long time, the system takes advantage of image storage technology so that the x-rays are actually "ON" for only a fraction of a second, the picture is stored and displays on the TV monitor. So you can look at the inside of the package as long as you want without having to be concerned about radiation.

How can I be exposed to x-rays while operating this unit?
X-rays, like the light from a flashlight, travel in a straight line spreading out as they get farther from their source. What happens if the light hits a shiny object? It reflects so that the light is now going in a different direction. Something similar happens to x-rays. Even though the x-rays start out going straight up, when they hit an object (like the package on the conveyor belt) some of the x-rays are scattered in different directions. Some go along the conveyor belt and some are scattered back towards where you're standing. Before you panic, remember that the cabinet is shielded.

What stops the x-rays from coming out?
The cabinet is made of lead which stops most of the x-rays. Drapes which look like vertical blinds hang down in front of the openings at either end where the packages enter and exit the cabinet on the conveyor belt. The cabinet is solid so that it will shield very well unless the manufacturer messed up and made a hole in the lead. Don't worry, the RSO will check the shielding to be sure it hasn't happened. The drapes also have lead but it's flexible lead so that the package can push them aside as it moves into the cabinet and moves out the other side. You've probably seen this type of system at airports. They're used for carry-on baggage inspection. Because they are flexible and just hang down from the top, the drapes don't provide the same type of shielding as the cabinet which is solid with no gaps. However, the unit has several sets of overlapping drapes to eliminate any direct path for radiation to escape from the cabinet while they're hanging down in their normal position. And don't forget that the x-rays only turn on when a package enters the cabinet. Unfortunately, the drapes are pretty heavy and stiff so that a very light package may have a difficult time pushing them aside as the conveyor belt tries to carry it into the cabinet. This might prove frustrating so that you may be tempted to use your hand (or ask someone else) to push the package into the cabinet. **Don't do that!** Although the x-rays are not being produced all the time (they start when the package trips a sensor after it passes the drapes) your hand (or someone else's) shouldn't be in there with the package. Since you don't know exactly when the sensor will be tripped, your hand should never be in there when the power is on. Remember, if it needs a push to get in, the package might also need a pull to get out the other side. If a package gets stuck inside, POWER (not just the x-rays) must be OFF before you can retrieve it.

Is the x-ray unit dangerous?
An x-ray machine is not dangerous (from a radiation standpoint) if it is used properly. A good rule of thumb is to recognize that radiation should be respected for what it can do to you, but you shouldn't be afraid of it since it can be useful. That's not very original since the same rule applies to just about everything including things we use every day like a table knife. Radiation aside, keep in mind that an x-ray unit is an electrical device that uses AC power and generates

about 160,000 volts. It should be treated like any other device that could pose an electrical hazard. Only authorized people should open the cabinet and mess with the power unit.
It would be ironic if you were very cautious about getting exposed to the radiation and then ended up getting electrocuted, or hurt because you got your hand stuck in the conveyor belt, or even more likely you hurt your back lifting a heavy package onto the belt. Sometimes things that we live with every day turn out to be the most dangerous and things that we fear like x-rays tend to be no big deal at all. The chances of being killed outright by the x-rays is zero. That's not the case if we consider the electrical power. In some respects, the x-ray unit is safer than working with radioactive material. If a radioactive source was exposing you, your only option might be to run away or hide behind some heavy object made of concrete, steel or lead. After all, the radioactive source never stops producing radiation. It would be difficult to "fix" the source without going back into the room and being exposed to some of the radiation. However, if the same thing happened to an x-ray unit (it didn't turn off after the package passed through) you could just turn the key to shut off the power or if that didn't work you could pull the plug. No power, no x-rays! Or, you could walk away and find a main power circuit breaker somewhere and shut it off from there. You wouldn't have to go into the room with the x-ray unit on.

Are the packages safe to pick up after they've been through the unit?
X-rays do not make anything radioactive. That's good to know if you've ever had medical x-rays. They didn't make you radioactive and they won't make a package radioactive. The package is safe to pick up immediately as long as you don't stick any part of your body beyond the drapes. Keep in mind that the packages are safe from a radiation safety point of view. The reason for using this x-ray unit is to evaluate bomb threats. The package may not be safe from an explosives point of view.

Will the x-rays harm anything inside the package?
Nope! Unless there's some very sensitive photographic film or electronic component or something alive inside and even then one pass through won't make any difference. Some people worry that film will be fogged by the x-rays. The x-ray unit manufacturer claims it is safe even for photographic film with an ASA speed of 1600 which is a lot more sensitive than what most people use (about ASA 400). To cause a problem you'd have to keep the film in the x-ray beam for a long time.

Who is responsible for fixing the unit if it doesn't work?
The NRC has a maintenance agreement with the installer to correct any equipment issues. The RSO should be notified whenever someone is called to work on the unit.

How often is the unit checked for radiation?
At least once each year a survey is performed and more frequently depending on maintenance and repairs. If you feel that something might be wrong, don't hesitate to ask for help. "When in doubt, ask the RSO to check it out!" Your RSO will decide whether it needs to be resurveyed or not.

D. WHAT YOU NEED TO KNOW TO PROTECT YOURSELF

What do I do if the unit malfunctions?
If you know or think that the unit is producing x-rays when it shouldn't be, think **TPESC!** If you're wondering what the heck that means, it means:
TURN the key to "OFF"
PULL the plug if the key didn't work
EXIT the room
STOP anyone else from entering
CALL the RSO

This is probably overkill since the unit is shielded, however, whenever something appears to be wrong, the RSO should be notified.

Will there be any signs posted and what do they mean?
Since the unit does not emit very much radiation you won't see a "Caution, Radiation Area" sign posted on the door to the room or inside the room like you might have seen in some other places. What you might see near the unit is a sign which reads:

CAUTION
X-RAYS WHEN ENERGIZED

This sign tells you what's really going on. It says that x-rays are produced when the machine is given power (turned "ON"). Otherwise, no x-rays and no hazard.

Is everything hazardous labeled?
The only way to actually get exposed to the beam of x-rays is by sticking your arm (or some other part of your body) through the drapes at either end or by opening up the cabinet and messing around with the x-ray tube itself. There are labels at each end of the unit above the drapes telling you not to do that. The words are:

CAUTION
Do not insert any part of the body when system is energized
X-RAY HAZARD

In case you aren't certain when the x-rays are actually being generated, there is a red light at either end of the cabinet above the lead drapes. In front of each light is a sign which states:

X-RAY ON

Also, the panel over the x-ray tube is interlocked so if someone tries to take it off (unauthorized access) the machine should shut down. There are labels on the panel doors warning:

CAUTION

Do not open - Factory adjustments only

Inside, there are labels warning of an electrical hazard (high voltage).
Finally, there is a danger of getting ones fingers pinched by the rollers so there are warning signs near the conveyor belt which state:

CAUTION

Do not touch rollers

How does the RSO know that I'm not being exposed to more radiation than a member of the public?
The RSO can use area monitors to verify this. An area monitor is a radiation detector that stays in one place. Even though you might only operate the unit occasionally, perhaps sharing the workload with someone else, the area monitor would be there all the time. If it records less than 0.1 rem in a year, then the RSO can safely say that you also received less than that amount. In addition to the area monitor the RSO will survey the unit for radiation leakage at least once per year.

Will the area monitor tell me what's happening right away?
If it is a TLD or OSD badge, it will have to be sent away for processing so that it will not tell you or the RSO what is happening while it is happening. The RSO will get the results once a month or once a quarter. If an audible alarming device is posted or issued, it will give you immediate feedback. Depending on what kind is used it will either beep every so often as it detects radiation (the more radiation the faster the beeps) or it might just alarm if it exceeds some limit set by the RSO. Or, it could do both. If an alarm is set, it will be set way below your dose limit so that if the alarm goes off, it just means that radiation was detected but nowhere near your annual limit. The only beeps you're likely to hear from an alarming dosimeter will probably be caused by background radiation.

What can happen to me if I'm exposed to x-rays?
The effects of being exposed to x-rays from a package inspection x-ray unit would be the same as being exposed to a medical x-ray unit operating under similar conditions. Appendix A-1 gives a detailed discussion of the possible biological effects of exposure to radiation.

What should I do if I think the unit is not working right?
When in doubt call the RSO. You might need to call the repairman also but notify the RSO so he/she can keep track of problems and verify proper maintenance. The RSO may also want to perform a radiation survey before and/or after the unit is repaired.

How will I know if the x-ray unit is leaking x-rays?
Since the unit will have been surveyed by the RSO to check for any radiation leakage before it is used, there is very little possibility that it will suddenly start leaking x-rays without warning. The unit is very simple, it is shielded and there is very little that can go wrong from a radiation safety standpoint. When a unit gets a lot of use (more than your unit is likely to get), the lead drapes can sometimes become damaged from being bent back and forth a lot. If any of the individual panels of the lead drapes breaks off, report it to the RSO.

APPENDIX A-1
BIOLOGICAL EFFECTS

REFERENCES
USNRC Regulatory Guide 8.29, "Instruction Concerning Risks from Occupational Radiation Exposure"
USNRC Regulatory Guide 8.13, "Instruction Concerning Pre-Natal Radiation Exposure"

INTRODUCTION
To understand what radiation can do, you must first understand how radiation interacts with matter and how the body is constructed. Very simply, the body is made up of organs such as the skin, lungs, liver, bones etc and these organs are made up of tissues (i.e., lung tissue, bone marrow etc). The tissues are made up of cells which are in turn composed of molecules and atoms. Ionizing radiation interacts with atoms causing ionization which is the process of knocking out electrons. It's a physical process, a transfer of energy, which is no different from how radiation interacts with any substance (wood, concrete, glass etc). The only difference is that cells are more important to us than concrete or glass.

Biological effects of ionizing radiation are typically divided into two categories:

- High Dose (Acute) Effects (injury) and
- Low Dose (Chronic) Effects (mutations)

Radiation dose limits are set low enough so that high dose effects don't occur and the probability of a low dose effect is very small. Both of these effects result from radiation hitting cells. High doses of radiation tend to kill cells while low doses tend to damage or change them. High doses can kill so many cells that organs are damaged which can result in the Acute Radiation Syndrome (ARS). This is a different effect from the changes produced in cells by low doses of radiation which don't cause any immediate problems. However, these cell changes can develop into cancer many years later.

SENSITIVITY
Not all cells in the body have the same sensitivity to radiation. Some are more sensitive because they reproduce very quickly and cells are always more sensitive when they divide to form 2 new cells. The cells in the bone marrow that make blood are the most sensitive. Reproductive cells (eggs and sperm) are also very sensitive. The skin is also pretty sensitive but the muscles in your body and your brain are not very sensitive at all. Since the developing embryo of a pregnant woman is composed of rapidly dividing cells, it is very sensitive to radiation injury.

HIGH DOSES
Very high doses of radiation can kill cells which can lead to injury such as skin burns, cataracts, sterility or even death. However, radiation accidents that hurt people only happen where there is a lot of radiation.

SKIN

Skin effects include reddening (like a sunburn), peeling, blistering and hair loss. Skin effects are more likely with very low energy x-rays. Such low energy radiation can't penetrate very far into the body so it is mostly deposited in the skin surface. The package x-ray unit that you'll be operating can produce that type of radiation. However, the manufacturer of the unit has placed a filter (probably aluminum) in the path of the x-rays to get rid of much of the low energy radiation that could cause skin effects. Besides, the dose required to cause even the lowest level skin effect (reddening) is relatively high, about 300 rad and up. You'd have to put your body in the direct path of the x-rays (such as by lying on the conveyor belt) for a long time (maybe 20 hours). Not likely!

CATARACTS

Another effect is cataracts (clouding over the lens of the eye). You would have to get about 200 rad to the eye to form cataracts. It would require your head to be in the direct path of the x-rays for many hours. Again, not likely!

STERILITY

Sterility (inability to produce children) can be caused by radiation in both males and females. In either case it requires high doses (on the order of hundreds of rad) to the reproductive organs (the testicles or ovaries) to produce sterility. There's no way to accumulate the high doses needed to produce sterility during normal operation of this package inspection x-ray unit.

HIGH DOSE CONCLUSION

Since the package x-ray unit you'll be working with doesn't produce that much radiation, we won't spend any more time discussing the biological effects of exposure to high doses of radiation. If you want more information about high dose biological effects talk to your RSO.

LOW DOSES

Radiation workers as well as members of the public are far more likely to receive low doses of radiation spread out over a long period of time. The principle effect of low doses of radiation is cell mutations with the greatest concern being cancer. Given the inherent safety designed into package inspection x-ray units, even low doses are hard to come by during normal operation. However, it is always possible that given a worst case scenario the unit could malfunction or leak radiation. So we'll cover the low dose radiation effects in a little more detail.

There are three basic effects that can result from exposure to low doses of radiation. These are:

a) Somatic - the individual exposed suffers the effect (cancer is the primary result)
b) In-Utero - the developing embryo/fetus is exposed while in the mother's womb. Since the embryo/fetus is growing very quickly, it is very sensitive to radiation. For more information about protecting the embryo/fetus see Appendix A-2.
c) Genetic - the children of the individual exposed suffers the effect (whatever it is)

SOMATIC (CARCINOGENIC) EFFECT

This effect is the one which usually causes the most concern. The individual exposed suffers the consequences (typically cancer). Some examples of cancer causing agents are:

a) Radiation
b) Cigarettes
c) Viruses

Radiation induced cancer is well known. Many studies have been done which directly link cancer with exposure to radiation. Some of the groups studied and the cancers they developed are:

a) Lung Cancer - uranium miners
b) Bone Cancer- radium dial painters
c) Thyroid Cancer - therapy patients, Chernobyl victims
d) Breast Cancer - therapy patients
e) Skin Cancer – radiologists
f) Leukemia - atom bomb survivors, in-utero exposures, radiologists, therapy patients

IN-UTERO EFFECTS

Radiation can cause malformations in developing embryos. This is called a "teratogenic" effect. Some examples of teratogenic agents are:

a) Radiation
b) Chemicals (e.g. Thalidomide)
c) Viruses (e.g. German measles)

The malformation is not a genetic effect since it was the embryo itself that was exposed, not the sperm or egg cells of the parents.

The possible effects of exposure in the womb are:

a) Death
b) stunted growth
c) developmental abnormalities
d) childhood cancers

Although the amount of radiation exposure is important, the time during the pregnancy when the exposure occurs is also important. If we look at the time during pregnancy when the embryo/fetus was exposed we might see the following possible effects:

Weeks After Conception Effect
0-1 (before it gets to the uterus) death (spontaneous abortion)
2-7 (organs developing) developmental abnormalities/growth retardation/cancer
8-40 (organs functioning) same as for 2-7 weeks but with less risk plus some possible functional abnormalities

The risk of childhood cancer due to exposure in the womb is about the same as for an adult getting exposed to the same amount of radiation, however, the risk of all possible effects from exposure while in the womb is about 10 times greater. By far, medical procedures are the biggest source of radiation exposure during pregnancy. However, "normal" risks of fetal abnormalities (problems not due to radiation exposure) are pretty high anyway, up to 3 times higher than the risk from exposure to one rem of exposure.

GENETIC EFFECT

This effect involves the mutation of sperm and egg cells. Mutations in these cells are passed to the children of the individuals exposed. Some examples of things which can cause genetic mutations are:

a) Radiation
b) Chemicals
c) Viruses

One very important fact to remember is that even without radiation exposure there is a "normal" possibility of some mutation. Exposure to radiation might increase the "normal" mutation rate. It doesn't produce any new mutations. Despite all of the hideous creatures purportedly produced by radiation in science fiction books and movies, no such mutations have ever been observed in humans. In fact, genetic effects from low dose radiation exposure have not been observed in any human studies.

RISK

The risk of cancer is determined from studying real people exposed to radiation. Since people can get cancer even without being exposed to radiation it's difficult to know if the cancers people get are caused by the radiation exposure or some other factor. We can never really be sure that someone who has cancer got it from radiation. All we can say is that given a large number of people exposed to some level of radiation, some of them might get cancer. Since the probability of getting cancer is related to the amount of radiation dose, the additional cancers caused by higher doses are easier to see since there are more of them. We still can't say for sure if anyone's specific cancer is radiation related. The information obtained from looking at cancer levels in large groups exposed to high doses is used to "estimate" the risk from low doses where there is little hope of being able to distinguish the "normal" cancers from the radiation induced cancers. No one knows if these estimates are valid. The NRC has adopted what they call the "linear no-threshold dose response model" which means that there is no dose of radiation that is "safe". No matter how small, every dose of radiation produces some risk. The smaller the dose, the smaller the risk. That leads directly to the principle of ALARA (As Low As Reasonably Achievable). If we assume that a worker has to be exposed to some radiation (it can't be prevented) then the risk is kept small by keeping the dose small. The RSO has some responsibility to try to do this but the person with the greatest responsibility for keeping doses low is **YOU**. You can control your dose by following the rules and knowing what to do in an unusual situation. The risk estimate is about 2 to 10 radiation induced cancers for every 10,000 people exposed to one rem. The "normal" risk is about 1 in 4 chances of developing any type of cancer. This means that even without any radiation exposure, about 2,500 people out of 10,000 are likely to get some type of cancer. If we exposed that same group of 10,000 people to one rem of radiation we might see 2,510 people get cancer. If we lined up those 2,510 people could we pick out the 10 who got cancer because of the radiation? Not likely. All the cancers would look "normal". Radiation doesn't produce some unique type of cancer. That's why it's so difficult to determine the risk of cancer from radiation exposure. Remember, exposure to radiation doesn't mean you'll get cancer. However, because the risk is related to the dose, more exposure means more risk. There is no dose of radiation so small that it will not have some effect. Remember too that not all cancers are fatal.

APPENDIX A-2

INSTRUCTION FOR PREGNANT OR POTENTIALLY PREGNANT FEMALES

The responsibility for protecting the embryo/fetus while it is developing in-utero rests with the pregnant woman. If you are pregnant (or think you might be) you may voluntarily declare that you are pregnant. You don't have to declare your pregnancy. If you don't, you will be treated no different from any other worker even if it is obvious that you are pregnant and your embryo/fetus will receive no special protection. You can declare your pregnancy by giving your supervisor and the RSO a written statement indicating that you are (or might be) pregnant. Your declaration must be in writing. This classifies you as a Declared Pregnant Woman (DPW). Normally that would prompt the RSO to take special precautions to reduce the radiation exposure to your embryo/fetus. Although a worker is allowed to get 5 rem in a year, the embryo/fetus of a DPW is limited to one tenth of this amount or 0.5 rem during the gestation period (9 months of pregnancy). However, since you will likely receive less than 0.1 rem per year anyway while using the x-ray unit, your embryo/fetus would receive much less than the 0.5 rem permitted even without special precautions.

APPENDIX A-3
PEOPLE WHO CAN PROVIDE RADIATION SAFETY INFORMATION

For questions about radiation safety, contact your regional RSO or ARSO. Information for the current Region I RSO/ARSO can be found using the following link:

http://r12k3web.nrc.gov/radsafety/index.aspx

ATTACHMENT B

USNRC Regulatory Guide 8.29

"Instruction Concerning Risks from Occupational Radiation Exposure"

See most current version on-line at:



02-1996.url

ATTACHMENT C

USNRC Regulatory Guide 8.13

"Instruction Concerning Pre-Natal Radiation Exposure"

See most current version on-line at:



06-1999.url

ATTACHMENT D

Management Directive 10.131

"Protection of NRC Employees Against Ionizing Radiation"

See most current version on-line at:
http://www.internal.nrc.gov/ADM/DAS/cag/Management_Directives/md10.131.pdf