



UNIVERSITY OF TORONTO

X-RAY SAFETY MANUAL

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Glossary

ALARA

An acronym for **A**s **L**ow **A**s **R**easonably **A**chievable. This takes into account the regulatory dose limits, social and economic factors being taken into consideration.

Absorbed Dose

The quantity of radiation energy absorbed in a unit of mass of material. SI unit: Gray (Gy). Old unit: rad. $1\text{Gy} = 100\text{ rad}$

Air Kerma

The sum of the initial kinetic energies per unit mass of all the charged particles liberated by uncharged ionizing radiation in air.

Background Radiation

Radiation external to occupational exposure. This includes sources from medical uses, consumer products and natural radiation resulting from cosmic and terrestrial sources.

Bremsstrahlung Effect

The effect of slowing down of an electron (or any other charged particle) moving in the strong electric nucleus field of an atom; results in the decreasing of the kinetic energy of the incoming charged particle to varying degrees. In this process the electrons give up their energy in the form of X-rays. This process of X-ray production is also called **bremsstrahlung** from the German phrase for “braking radiation”.

Characteristic X-rays

X-rays can be created when electrons undergo a change in the amount of energy that they possess. When a vacancy is created in the inner orbital shell of an atom, the electrons from the higher energy outer shell drop to fill the inner vacancy. This results in a loss of energy by the atom in the form of X-rays. The emission of X-rays is “characteristic” of the target atom and whose energy corresponds to the difference between the initial and final electron energy state.

Dose (Absorbed) see Absorbed Dose

Dose (Equivalent) see Equivalent dose

Dose (Effective) see Effective Dose

Dose Rate

Dependent on time and is expressed as a function of dose per unit time, i.e. gray per hour (Gy/h) or Sievert per hour (Sv/h)

Dosimeter

Personal dosimeters are worn to record cumulative dose received from occupational exposures to ionizing radiation including X-ray producing machines. The badges are worn at chest or waist levels to record whole body exposure. Thermoluminescent dosimeters (TLD) are composed of thermoluminescent material chips (i.e. lithium

fluoride [LiF]), which record the exposure to ionizing radiation.

Electron Volt (eV)

The unit of energy for radiation is usually given as electron volt(s). One eV is defined as the energy of an electron that has been accelerated through an electron potential of one volt. One electron volt is $1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$. Typically the radiation energies associated with the emission from radioactive materials is in order of magnitude of thousands (keV) or even millions (MeV) of electron volts. The energy for X-rays is greater than 5 keV but typically range from 40-100 keV.

Equivalent Dose

A measurement of the biological effects on a specific tissue or organ exposed to a specific type of radiation. It is a function of the absorbed dose and is dependent on the type of radiation absorbed. The radiation-weighting factor for X-ray is 1. SI unit: Sievert (Sv). Old unit: rem (roentgen equivalent man). $1 \text{ Sv} = 100 \text{ rem}$

Effective Dose

A measurement of the whole body dose based on the summation of the equivalent dose received by all organs. Each organ contributes with a tissue-weighting factor. The effective dose has the same units of measure as the equivalent dose.

Exposure

A measure of X-ray intensity in terms of its ionizing effect in air. SI unit: C/kg. Old unit Roentgen. $1 \text{ C/kg} = 3876 \text{ R}$ and $1 \text{ R} = 2.58 \times 10^{-4} \text{ C/kg}$.

Failsafe Design

A design in which any failure of safety indicators or components that can reasonably be anticipated causes the production or emission of X-ray to cease.

Filtration

A process using filters made from metal used to “harden” the X-ray beam from low, medium and high energy X-ray machines to make the X-rays more penetrating.

Genetic Effects

Biological effects from ionizing radiation exposure that are inherited by children from their parents at the time of conception.

Gray

SI unit of absorbed dose is called Gray (Gy).

Ionizing Radiation

Radiation with sufficient energy to physically remove electrons from neutral atoms to create ions.

Principal Investigator

An appointed U of T professor who is in charge of an X-ray source situated on U of T controlled areas.

Photoelectric Effect

An incident photon (X-ray or gamma ray) interacts with one orbital electron. The electron absorbs all the energy of the photon and the photon completely disappears. The ejected electron can cause ionization and in the process reduces its energy. This effect is preponderant at low photon energy.

Radiation weighting factor (Quality factor)

Takes into account the biological effect of each type of radiation on human body. Can vary between 1 (for beta, gamma and X-ray) to 20 for alpha or high-energy neutrons

Redundant

When used in reference to a light sign, means a light sign with two or more separate and equivalent bulbs so designated that the failure of one will not affect the operation of other bulb or bulbs.

Scattered Radiation

A photon interacts with an electron in the atomic orbit. Part of the energy of the incident photon is absorbed by the electron and as a result the electron is ejected from its orbit. The remaining energy of the photon is carried by the scattered photon. The scattered photon may undergo another scattering process, resulting in another reduction of energy. The likelihood of scattering increases with the decrease of photon energy. This effect is also called Compton effect.

Sievert

SI unit for equivalent and effective dose (Sv).

Shield or Shielding

Radiation absorbing material or materials used to reduce the absorbed dose or absorbed dose rate imparted to an object or tissue.

Sky shine

X-rays that scatter over and around shielding walls.

Somatic Effects

Biological effects from ionizing radiation exposure in our lifetime are called somatic effects. Somatic effects may result from acute or chronic doses of radiation.

Tissue Weighing Factor

Takes into account the biological effect of radiation on different organs or tissues of the human body. It is used to calculate the effective dose when the equivalent doses received by human organs are known.

X-ray machine

An electrically powered analytical device with a primary purpose of producing X-rays to analyze materials or structures.

X-ray source

Any part of a device, in whole or in part that emits X-rays, whether or not the device is an

X-ray machine. The primary use of the device may not be the production of X-rays. Examples include electron microscopes.

X-ray worker

Any person who in the course of his work, business or occupation, is likely to receive a dose of ionizing radiation in excess of the annual dose allowed to the general public.

X-ray source supervisor

An X-ray worker who due to his knowledge, experience and training is designated by the principal investigator to supervise the safe use of an X-ray source.

X-ray

Is a type of ionizing radiation (maximum energy greater than 5 KeV) that is generally produced from machines rather than emitted from radioactive materials. X-ray as the name implies is not comprised of physical particles like alpha or beta radiation but is made up of individual packets of energy called photons.

1 INTRODUCTION

This X-ray safety manual is intended to provide information to persons using X-ray sources in an U of T controlled area so that:

- The use of all X-ray sources under U of T control is done in such a way that health and safety of all staff, students and visitors, and the environment, are protected
- Governmental regulatory requirements shall be met, and
- To ensure compliance with the University's own local code of practice in the safe use of X-ray machines or sources, and other radiation-emitting devices.

At the University of Toronto, there are two types of X-ray equipment, namely the medical machine and the non-medical X-ray source. The medical X-ray machines are used for patient diagnostic purposes, and the non-medical X-ray sources are used for teaching or experimental research purposes, not for the irradiation of human beings.

The **University of Toronto Radiation Protection Authority (UTRPA) as the philosophy governing the use of all ionizing radiations has adopted the ALARA (As Low As Reasonably Achievable) concept.** The ALARA principle seeks to keep all doses of ionizing radiation as low as reasonably achievable, social and economic factors being taken into consideration. No practice involving the exposure of patients or X-ray workers to ionizing radiation may take place if there is no benefit to them as a result of carrying out the practice. Radiation exposures must be kept below the statutory limit regardless of the practice. Persons using X-ray equipment should endeavour to keep all radiation exposures as low as possible.

In the Province of Ontario, the Ministries of Health and Labour, under the Healing Arts Radiation Protection (HARP) Act and the Occupational Health and Safety Act and regulations, regulate the use of medical X-ray machines. The Ministry of Labour under the Occupational Health and Safety Act regulates the use of non-medical X-ray sources. However, X-ray sources which produce X-rays of high energy capable of inducing radioactivity in materials exposed to them are regulated and licensable by the federal government, under the Nuclear Safety and Control Act (NSCA), enforced by the Canadian Nuclear Safety Commission (CNSC).

As with other radiation work, all unnecessary exposure to radiation should be avoided. The Principal Investigators, X-ray supervisors and X-ray workers should bear in mind that they have a responsibility to protect themselves and all other persons from hazards arising from their use of X-ray equipment. All radiation exposure must be kept as low as reasonably achievable, in accordance with the ALARA principle, and consistent with all applicable standards of good radiation hygiene and safety.

2 GENERAL NOTIONS

2.1 Generation of X-rays

X-rays are a type of ionizing radiation (maximum energy greater than 5 KeV) that is generally produced from machines rather than emitted from radioactive materials.

Gamma and X-rays as the name implies are not comprised of physical particles like alpha or beta radiation but are made up of individual packets of energy called photons.

Unlike gamma rays, which are emitted from the nucleus of a radioactive atom, X-rays are emitted when:

- high speed electrons (or any charged particles) are slowed down or change direction in a strong electric field like the one created by the nuclei (see **Bremsstrahlung Effect**) of the target materials. These type of X-rays are called continuous because they have a continuous spectra
- electrons move from a higher to a lower level of energy inside of an atom. These types of X-rays are called characteristic X-rays and have a line type spectrum. Therefore, characteristic X-rays are emitted from the electron shell of an atom.

Wilhelm Röntgen (1845-1923) discovered X-rays in 1894. He built the first X-ray tube. An X-ray tube emits in general continuous spectra on which are superposed the characteristic spectra of the cathode material. The X-ray tubes have many practical applications in medicine, geology, crystallography, chemical analysis, physics, etc.

X-rays can also be emitted as a secondary effect in instruments that use high voltages (on the order of tens of kV) as power sources for other applications.

2.2 X-ray interaction with matter

After X-rays hit matter they interact with the atoms of the matter through various mechanisms by either being absorbed or scattered. The most common interaction of X-rays with matter include:

2.2.1 Photoelectric Effect

An incident photon (X-ray) interacts with the orbital electron. The electron absorbs all the energy of the photon and the photon completely disappears. The ejected electron can cause ionization and in the process reduces its energy. This effect is more probable to appear in heavy materials with low incident photon energy.

2.2.2 Compton Scattering

A photon interacts with an electron in the atomic orbit. The electron absorbs part of the energy of the incident photon and as a result the electron is ejected from its orbit. The remaining energy of the photon is carried by the scattered photon. The scattered photon may undergo another scattering process, resulting in another reduction of energy. The likelihood of scattering increases with the decrease of photon energy. When X-rays pass through any material, some will be transmitted, some will be absorbed and some will scatter. The

proportions depend on the photon energy and the type of material.

2.2.3 Filtration

High and low energy photons are sometimes referred to as *hard* and *soft* X-rays, respectively. Hard X-rays are more penetrating and not absorbed near surfaces like soft X-rays. Hard X-rays are more desirable for such work as radiography because of their penetrating properties. Filters made from aluminum, copper or lead are used to “harden” the X-ray beam from X-ray machines.

2.3 Units for measuring X-ray energy absorbed in matter

2.3.1 Exposure

X-rays can produce air ionisation. The exposure measures the electric charge (positive or negative) produced by electromagnetic radiation in a unit mass of air, at standard atmospheric conditions (STP means 0 degrees Celsius and 760 mm Hg of pressure =1 atm).

In the SI system of units, exposure is measured in X unit:

$$1 \text{ X unit} = 1 \text{ C/kg air}$$

where C stands for coulomb, the SI unit for electric charge.

The average energy dissipated to produce a single ion pair in air is 34 eV. Since the charge of an electron is equal to 1.6×10^{-19} C, an association can be established between an X unit and the energy measured in joules, dissipated in 1kg of air. Hence, one X unit is equivalent to 34 J/kg.

Formerly, before the SI system was adopted, the unit of X-ray exposure was called the roentgen (R). R was defined as the quantity of gamma or X-radiation that can produce ions carrying one statCoulomb (sC) of charge (of either sign), per cubic centimetre of air at 0 degrees Celsius and 760 mm Hg of pressure (1 atm) (STP).

$$1 \text{ R} = 1 \text{ sC/cm}^3$$

The statCoulomb is the old unit of measure for electric charge. The relation between SI unit (C) and sC is $1 \text{ C} = 3 \times 10^9 \text{ sC}$. The mass of one cubic centimetre of standard air is $0.001293 \text{ g} = 1.293 \times 10^{-6} \text{ kg}$

With the above associations we can now establish the correspondence between X unit and R:

$$1 \text{ X unit} = 3881 \text{ R} \text{ or } 1 \text{ R} = 2.58 \times 10^{-4} \text{ C/kg}$$

Exposure refers to the effect of X-rays in air. However it is often used to characterize the intensity of an X-ray source or an X-ray beam.

2.3.2 Air kerma

Ions (free electrons and positive ions) produced by X-rays in air have each a kinetic energy equal with the difference between the energy lost by the X-rays and the electron bound energy in the atom. Air kerma is the sum of all initial kinetic energies of ions produced by X-rays in a unit of mass of air. The SI unit for air kerma is the same as for the absorbed dose (see below).

Even though the air kerma and absorbed dose have the same units they are quite different. When some of the ions escape from the volume of air (if the air volume is small) air kerma is bigger than the absorbed dose. When all the ions produced are absorbed in the air volume, air kerma is smaller than the absorbed dose.

2.3.3 Absorbed Dose (D)

Total X-ray energy absorbed per unit of mass of material is measured in Gy. In this case the definition is not restricted to air but refers to any type of material.

$$1\text{Gy} = 1\text{J/kg}$$

The old unit is rad, and the connection between them is:

$$1\text{Gy} = 100\text{ rad}$$

As mentioned above, to produce an ion in air (electric charge of 1.6×10^{-19} C), an average energy of $34\text{ eV} = 34 \times 1.6 \times 10^{-19}\text{ J}$ is required. Since the mass of one cubic centimetre of standard air is 0.001293 g , an exposure of 1 R corresponds to an absorbing energy of 0.00877 Gy (0.877 rad) in **dry air**.

$$D(\text{rads})/\text{Exposure}(\text{R}) = 0.877 \quad \text{or} \quad D(\text{Gy})/\text{Exposure}(\text{X unit}) = 34$$

Because most instruments used air filled detectors to measure the radiation intensity, a relation between dose absorbed in **any material** and exposure in air was obtained:

$$D(\text{rads})/\text{Exposure}(\text{R}) = 0.877 \times (\mu_m/\rho_m) / (\mu_a/\rho_a) \quad \text{or} \quad D(\text{Gy})/\text{Exposure}(\text{X unit}) = 34 \times (\mu_m/\rho_m) / (\mu_a/\rho_a)$$

Where $\mu_a = 3.46 \times 10^{-5}\text{ cm}^{-1}$ is the energy absorption coefficient in air at standard temperature and pressure (STP), $\rho_a = 1.293 \times 10^{-6}\text{ kg/cm}^{-3}$ is the dry air density at STP, and μ_m and ρ_m are the same for the material.

This ratio depends on the energy of the X-ray and on the composition of the material. For muscle ($\mu_m = 0.03\text{ cm}^{-1}$ and $\rho_m = 10^{-3}\text{ kg/cm}^3$) this ratio is approximately constant in the X-ray energy interval (few tens of keV to few hundreds of keV). With these considerations we can **approximate** the above ratio for **muscle tissue**:

$$D(\text{rads})/\text{Exposure}(\text{R}) = 1 \quad \text{or} \quad D(\text{Gy})/\text{Exposure}(\text{X unit}) = 37$$

For this reason, an exposure of 1 R is frequently considered approximately equivalent to an absorbed dose of 1 rad , and the unit "roentgen" is loosely (but incorrectly) used to mean "rad".

2.3.4 Equivalent Dose (H)

The equivalent dose (H) is the unit used to measure the biologic effects on a specific tissue or organ of a specific type of radiation. H is a function of the absorbed dose and is dependent on the type of radiation absorbed. If more than one type of radiation is absorbed in a tissue, H is:

$$H = \sum w_R \times D_R$$

The radiation-weighting factor (w_R) for X-ray is 1, but can vary between 1 to 20 for other types of radiation.

The SI unit is Sievert (Sv); and the old unit is rem (roentgen equivalent man)

$$1\text{Sv} = 100 \text{ rem}$$

When **X-ray** is the only type of radiation absorbed in a **muscle tissue**, 1 rem is equivalent to one rad, and with the considerations explained at 2.3.3, it is also equivalent to one roentgen.

2.3.5 Effective Dose (E)

The effective dose, also called whole body dose, is the summation of the equivalent doses received by all organs. Each organ that was irradiated contributes with a tissue-weighting factor (w_T).

$$E = \sum_T w_T \sum_r w_R \times D_{T,R}$$

E has the same units of measure as equivalent dose (Sv).

2.4 Radiation measurements

2.4.1 Particle counting instruments

To measure the intensity of an X-ray source or an X-ray beam a particle-counting instrument can be used. In general the instruments used to measure X-ray intensity are gas filled type detectors. This type of detector uses the ionisation effect of the X-rays. The most common detectors are Geiger-Muller (GM) or ionisation chambers. The meter indication of this type of instrument is in counts per minute (cpm) or in counts per second (cps). The reading depends on the type of the detector, detector's window and dimensions, as well as on the geometry of the measurement process.

2.4.2 Dose measuring instruments

If a gas filled detector is built with wall material whose radiation absorption property is similar to that of a tissue, an instrument can be built to measure tissue dose directly. The meter will indicate R (X units), rad (Gy), or rem (Sv). The connection between all these units is made as explained in section 2.3. The most used instrument to measure the exposure or the dose generated by an X-ray source has an ionisation chamber detector.

2.4.3 Personal dosimeters

The dose received by a person working with or near an X-ray source can be measured by a personal dosimeter. There are basically two different types of personal dosimeters: one that indicates the dose received immediately and one that stores the information inside the dosimeter. In the last case the stored dose is read later.

A personal electronic dosimeter (PED) is an example of the first type. This instrument can indicate the shallow dose (dose received by the surface of the skin up to the depth of 0.007cm) and the deep dose (dose received by a person up to one cm depth inside the tissue). It can also be set-up to alert, through an alarm system, when a certain dose or dose rate is reached.

A few examples of the second type of personal dosimeters are: film, a thermo-luminescent dosimeter (TLD), and optically stimulated luminescence (OSL) dosimeter. The X-ray energy is deposited inside the dosimeter's material and can be read later by a method specific to each type of dosimeter.

2.5 Biological effects

Biological effects of X-rays can be classified as direct or indirect, acute or delayed, and as deterministic or stochastic.

When radiation is absorbed inside the cells the action is called direct action. The critical target is the DNA molecule. X-rays can break this molecule and the cell can be damaged resulting in cell death or in cell function alteration. The altered cells can be repaired or can be transformed. Depending on the level of radiation the cell death or alterations can be dangerous.

When radiation is absorbed in atoms or molecules other than biological material (for example with water molecule) the interaction with the body is called indirect action. Ions and free radicals can result from these interactions. Depending on the chemical reactions these ions and free radicals can be dangerous for human body.

Among acute effects of skin overexposure to X-rays are erythema (skin reddening), changes in pigmentation, epilation, blistering, necrosis, and ulceration. If an overexposure of the whole body occurs above 2000 mSv, depending on the level, acute radiation syndromes (hemopoietic, gastro-intestinal, and central nervous system) can result. Blood changes, nausea, vomiting, malaise and fatigue, or increased temperature of the body can accompany these syndromes.

Delayed effects of radiation may be due either to a single large overexposure or continuing low-level overexposures to X-rays. Among the delayed consequences of overexposure to X-rays that are of concern are cancer, genetic effects, mental retardation of children who have been irradiated in utero, shortening of life span, and cataracts.

Deterministic effects are effects in which a clear connection between the person that suffered the overexposure to radiation and the effect can be made. In these cases there is a causal relationship between dose and effect on a particular individual. To cause a deterministic effect a certain minimum dose must be exceeded, and the severity of the effect increases with the dose. Deterministic effects can be acute or delayed.

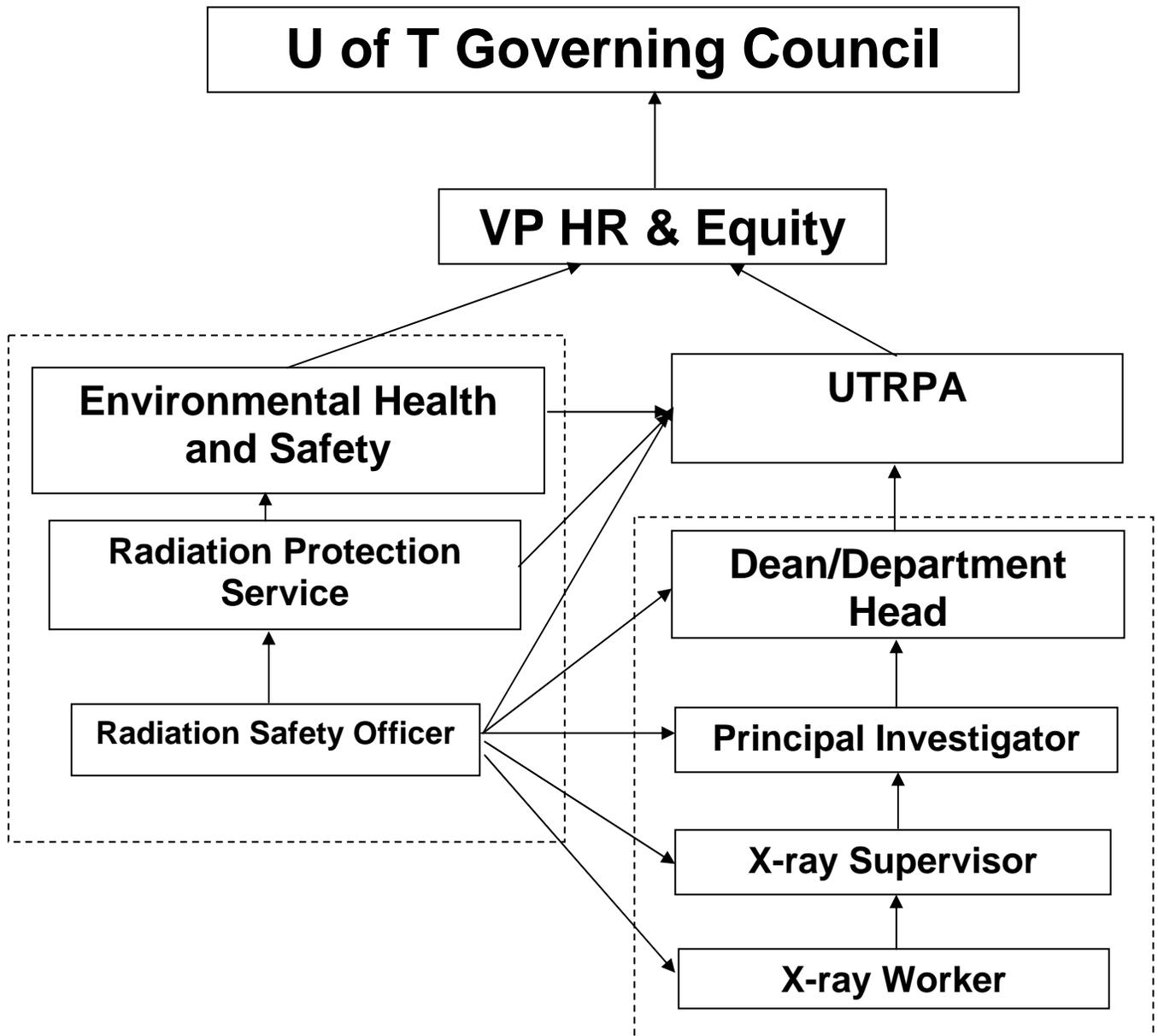
Stochastic effects can occur with no threshold dose, and their probability of occurrence increases with an increase in dose received by an overexposed exposed population. The

stochastic effects are delayed.

2.6 Radiation Protection at U of T

At the University of Toronto, the UTRPA has the overall authority over the use of radioactive materials and radiation-producing devices (including X-ray sources) in all U of T controlled areas. For X-ray sources the responsibility scheme is presented in Figure 1.

Figure 1 - Responsibility for X-ray safety in U of T



An U of T X-ray Safety Program and an X-ray Safety Policy were developed by the RPS and approved by the UTRPA. The RPS is responsible for updating and implementing the U of T X-ray Safety Program.

The detailed role of the Radiation Protection Service and of the Radiation Safety Officer in implementing the U of T X-ray safety program is outlined in section 7 of this manual.

The responsibility of a principal investigator (PI) that has in his/her laboratory one or more X-ray sources is outlined in sections 3, 4 and 5 of this manual.

The main elements of the X-ray Safety Program are:

2.6.1 Registration of X-ray sources

It is the responsibility of all PI's to register all X-ray sources existing within U of T controlled areas. The details of the registration process are outlined in sections 4 & 5 of this manual.

2.6.2 Training of X-ray workers

It is the responsibility of each PI that all persons working with an X-ray source receive the appropriate training for the safe use of that X-ray source. The training will consist of a general X-ray safety training session organized by the RPS and a work specific safety training session organized by the PI.

Each X-ray worker should participate in the X-ray safety program organized by the RPS before starting working with an X-ray source. The content of this program is approved the UTRPA. A refresher training course is required every 3 years.

Before starting work with an X-ray source, each X-ray worker should receive a work specific training for the particular X-ray source that he/she will be using. The responsibility of this training stays with the PI but the X-ray supervisor can deliver it.

2.6.3 Personal dosimetry

Each X-ray worker should wear a personal dosimeter (TLD) during work near an X-ray source. The procedures and responsibilities are outlined in section 6 of this manual

2.6.4 Engineering controls

Engineering controls are physical barriers designated to keep the risks of using X-ray sources under control. When, due to the nature of the device these engineering controls are not applicable, the PI has the obligation to ensure that equivalent controls are in place. These controls should offer equal or greater protection than the ones described here.

To reduce the dose received by X-ray workers according to ALARA and under the permissible limits:

- Structural or other shielding shall be installed as is necessary,
- Diaphragms, cones and adjustable collimators or other suitable devices shall be provided

and used as are necessary to limit the dimensions of the useful X-ray beam

- Each port shall be designed in such a way that the X-ray beam can emerge only when a camera or other recording device is in its proper position, wherever applicable
- All unused ports shall be secured in such a way as to prevent inadvertent opening

When the air kerma in an area may exceed 100 μGy in one hour, access to the area should be controlled by:

- Locks or interlocks if the X-ray source is installed in a permanent location, and
- Barriers and X-ray warning signs if the X-ray source is portable or mobile and is being so used
- A guard or interlock which prevents entry of any part of the body into the primary beam path shall be used, wherever applicable
- When an interlock terminates an exposure, it shall only be possible to restart the exposure from the control panel.

A shutter is a mechanical device installed near the exit of the X-ray tube capable of blocking the beam when is necessary.

2.6.5 Administrative controls and X-ray signs

Engineering controls are the preferable way of keeping the risks of using the X-ray sources under control. Administrative controls are rules and procedures intended to supplement the engineering controls or to replace them when they are inapplicable. Examples of administrative controls are:

- The work with X-ray sources is restricted to authorize personal. Authorization is given by the PI and is verified by the RSO
- All X-ray workers shall be adequately trained before they start working with an X-ray source
- All persons working with an X-ray source on U of T controlled areas shall wear personal dosimeters
- A standard operating procedure (SOP) for the use of the X-ray source should be written by the X-ray supervisor, verified by the RSO and approved the PI.

Every room that hosts an X-ray source shall have posted on the door or doors the sign indicating X-ray room (see Appendix 3).

Every X-ray source shall have on the control panel, in close proximity to the "ON/OFF" switch one of the signs "X-ray source # 1, 2, or 3 from Appendix 3.

Equipment capable of generating X-rays shall have the sign "X-ray source # 4 from Appendix 3.

A warning light shall be mounted near each X-ray tube in such a way as to be clearly visible from any direction from which the tube can be approached indicating when X-rays are being produced.

The condition of each shutter, open or closed, shall be clearly indicated at or near the X-ray tube.

2.6.6 X-ray sources inspections

Each new X-ray machine should be inspected by the RSO before the start of operations. All X-ray machines on U of T controlled areas shall be inspected yearly by the designated RSO.

2.6.7 Program audit

The manager RPS will audit the U of T X-ray Safety Program every year and the results of this audit will be communicated to the UTRPA. This audit will cover all main aspects of the X-ray safety (hazards control, X-ray workers training, personal dosimetry, X-ray locations inspections).

3 UNIVERSITY X-RAY SAFETY CODE OF PRACTICE

3.1 X-ray Machines in General

The following are guidelines for the safe use of all X-ray equipment in general:

- 3.1.1 The equipment shall be used under the guidance and supervision of a qualified person who is also responsible for the safe use of the equipment.
- 3.1.2 X-ray warning signs shall be posted on the doors of all X-ray rooms, and X-ray warning labels shall be affixed to all X-ray equipment.
- 3.1.3 All work should be well planned in advance before carrying out an experiment or making an exposure.
- 3.1.4 Persons who are classified as X-ray workers shall all wear personal dosimeters, as provided by their respective departments.
- 3.1.5 Persons wearing lead aprons should wear their personal dosimeter under lead aprons to avoid false high readings.
- 3.1.6 All equipment capable of producing X-rays shall be lead shielded or installed in protective lead enclosure. The area in which this equipment is used shall be marked with warning signs to indicate that x-radiation may be present.
- 3.1.7 Energized equipment shall not be left unattended in a location with unrestricted access.
- 3.1.8 High voltage power supplies using rectifier tubes should be housed in protective lead enclosures.
- 3.1.9 A radiation survey of a new or modified X-ray installation and its vicinity shall be carried out before it is put into operation, to ensure compliance with regulatory requirements.
- 3.1.10 Protection of staff or students working in areas surrounding an X-ray machine should be achieved by means of lead barriers, which absorb the scattered, leakage, or transmitted radiation. The barriers shall be positioned as close as possible to the equipment.
- 3.1.11 The primary beam shall be directed towards an unoccupied area (i.e. an area to which access is not permitted) or towards a wall containing adequate shielding. The beam should be well collimated so that it covers only the minimum area necessary for the nature of work being undertaken.
- 3.1.12 Protective lead aprons and gloves shall be inspected annually to ensure that they remain in good condition.
- 3.1.13 A mobile X-ray machine used routinely in one location should be considered as a permanent installation and be lead or lead equivalent shielded accordingly.
- 3.1.14 A mobile X-ray machine should be used only in an unoccupied area with restricted access. If the equipment must be used in an area with unrestricted access, a lead shield shall be provided to prevent persons present in the surrounding areas from being exposed to radiation. The operator shall remain behind the protective lead screen during all exposures.
- 3.1.15 Prior to any major change/modification of the approved X-ray installation, or the use of the X-ray machine, which may result in an increase in the exposure of the machine user, an application shall be prepared and submitted to the appropriate Ministry through the Radiation Protection for Ministerial re-approval.
- 3.1.16 Early submission to the Radiation Protection Service for any new project using an X-ray tube for proposed research or experiment would ensure that any problems could be considered and discussed in advance. A radiation survey shall be carried out prior to the X-ray work.

- 3.1.17 The Radiation Protection Service shall be provided with written notice in advance of any purchase of new X-ray equipment, or the sale, relocation or disposal of an existing X-ray machine or source.
- 3.1.18 The X-ray tube shall not be energized during adjustments or repairs or when any protective safety cover is removed.
- 3.1.19 No interlock or other safety device shall be deliberately defeated or by passed.
- 3.1.20 Any defect in a piece of X-ray equipment shall be reported immediately to the authority responsible for the radiation safety of the particular equipment and to the Radiation Protection Service.
- 3.1.21 Service specialists, such as the manufacturer's agents will, normally carry out repairs, etc. When internal University personnel are used, their competence to control any radiation hazard incidental to the repair procedure, and to the use of the repaired equipment, shall be established prior to initiating the repairs.

3.2 Radiographic X-ray Machines

In addition to the relevant precautions in Section 3.2, the following rules shall be observed in using radiographic equipment:

- 3.2.1 No person shall operate an X-ray machine for the irradiation of a human being unless the operator meets the qualifications and requirements as outlined in the Healing Arts Radiation Protection Act (HARP), and authorized by the individual in charge of the X-ray facility.
- 3.2.2 The entrance door to the X-ray room should be kept locked during all exposures.
- 3.2.3 X-ray exposure shall be controlled only from the lead shielded control booth.
- 3.2.4 X-radiation warning signs forbidding unauthorized use shall be affixed to the control panel of the equipment.
- 3.2.5 The beam exposure switch should be of the fail-safe type in which the power is turned off immediately upon release of the switch.
- 3.2.6 The total filtration should be permanently installed in the X-ray machine.
- 3.2.7 The X-ray tube shall be mounted in lead shielded type housing.
- 3.2.8 The equipment shall be provided with collimating devices to keep the size of the primary beam to equal to or less than the area of the X-ray film selected for each exposure.
- 3.2.9 Quality assurance testing for the medical X-ray machine used for patient diagnostic purposes, must be carried out in accordance with the regulatory requirements set out by the legislation.

3.3 Fluoroscopic X-ray Machines

In addition to the relevant precautions set out in Section 3.1 and 3.2, the following rules shall be observed in using fluoroscopic equipment:

- 3.3.1 In order to keep to a minimum the dose received by the patient, the operator should allow at least 10 minutes for his/her eyes to become sufficiently dark-adapted before making a direct fluoroscopic exposure.
- 3.3.2 The equipment shall be provided with a re-settable cumulative time device, which indicates the total time of exposure or terminates the exposure after a preset time has been reached.
- 3.3.3 An image intensifier system should be used for all fluoroscopic equipment with which

- patients are irradiated.
- 3.3.4 For the image intensifier system, it is essential that the vertical and horizontal shutters be properly aligned with the axis of the direct beam, and that the size of the useful beam be directed to within the area of the input of the image intensifier system. In addition, the tube assembly and the image intensifier system shall be arranged in such a way that the exposure will automatically terminate if the image intensifier system is moved out of the useful beam.
 - 3.3.5 A lead-rubber curtain consisting of several over-lapping parts should be provided for covering the gap between the image intensifier system and the tabletop. The operators shall not consider the curtain provided as a sufficient substitute for wearing the protective lead apron.
 - 3.3.6 When making an exposure, particular attention should be paid to any possible scattered radiation, which may be present at the operator position. Necessary lead shielding shall be provided.
 - 3.3.7 The hands of the operator shall not be placed in the direct beam unless protective lead gloves are worn. In this mode of operation, the work shall be conducted as rapidly as possible.

3.4 Dental X-ray Machines

In addition to the relevant precautions set out in Section 3.1 and 3.2, the following rules shall be observed in using X-ray emitting devices for dental diagnosis:

- 3.4.1 In operating an X-ray machine for diagnosis, students or persons in training shall work under the direct supervision of an experienced operator authorized by the person in charge of the department. They shall not be allowed to irradiate patients until they have received sufficient instruction in the precautions necessary for the safe operation of the equipment.
- 3.4.2 The X-ray exposure should be controlled only from a lead shielded control booth where the patient can be observed through a viewing window having lead-equivalent thickness conforming to the rest of the shielding.
- 3.4.3 Control knobs for adjusting kilovoltage, milliamperage, power-on, or X-ray-on switches shall have their functions clearly and durably labelled.
- 3.4.4 All pilot lights, which indicate that the control panel is ready to be energized, shall be functioning properly at all times.
- 3.4.5 The X-ray tube shall be rigidly fixed and correctly aligned within its tube housing. The tube head shall maintain its exposure position without drift or vibration during the examination.
- 3.4.6 Lead-lined localizing collimators or cones shall be used with all dental equipment. Such collimators or cones shall provide the maximum practical field size in conformity with the requirement set by government, or other regulatory agencies.
- 3.4.7 Open-ended cones shall be used for intraoral examinations.
- 3.4.8 The equipment shall be provided with an automatic timer, which will terminate the exposure after a preset time or earlier at the discretion of the operator.
- 3.4.9 The X-ray tube housing or cone shall not be held by hand during exposure.
- 3.4.10 No person other than the intended patient may place any part of his or her body within the direct beam.
- 3.4.11 Dental films shall be placed in a fixed position. If the patient is a child or in a weak condition, the film can be held by an accompanying adult who is suitably protected.

Under no circumstances may the film be held by a person occupationally exposed to x-radiation.

- 3.4.12 Gonadal lead shielding and, when appropriate, thyroid lead shielding shall be provided for all X-ray exposures on children and persons of reproductive age.
- 3.4.13 The exposure of the patient during an X-ray examination shall be kept to a minimum necessary to produce satisfactorily diagnostic results.
- 3.4.14 An X-ray room in which more than one X-ray machine is installed shall not be used for more than one X-ray investigation at any one time unless a lead barrier has been installed to ensure adequate separation and protection.
- 3.4.15 Where more than one tube is controlled by one control panel, dental X-ray equipment shall be designed to facilitate the inclusion of an interlock system such that it is not possible to energize more than one tube at a time and an indicating light will show which tube is connected and is ready to be energized.
- 3.4.16 In order to avoid an excessive number of duplicated exposures, processing of exposed films should be as specified by the X-ray manufacturer. As well, the design of the darkroom should conform to the standard facility recommended by government or other regulatory agencies.

3.5 Requirements for Compliance Inspection&Test Procedures (R.R.O. 1990, Reg. 543)

In order to comply with the Healing Arts Radiation Protection (**HARP**) Act and regulations applicable to the dental profession, a **Quality Assurance (QA)** program relative to X-ray safety, which is a key component required by the Act, **must** be instituted in every dental facility. The radiation protection officer shall establish and maintain procedures and tests for the X-ray machine and X-ray equipment in the facility for which he or she is a radiation protection officer to ensure compliance with the regulations.

3.5.1 Ontario Ministry of Health Quality Assurance Procedures

The **HARP** sets out specific requirements for quality assurance procedures and tests for dental facilities. The radiation protection officer shall ensure that at the facility where the officer acts, the following procedures and tests set out in Column 1 of Table 3 are conducted at the frequencies set out opposite thereto in Column 2 of Table 3 (R.R.O. 1990, Reg. 543):

TEST	FREQUENCY
Photographic Quality Control	Daily (each operational day).
Patient Entrance Exposure Measurements	Every 12 months, and upon alteration or servicing of the machine
Collimation	Every 12 months, and upon alteration or servicing of the machine.
Half-Value Layer	Every 12 months, and upon alteration or servicing of the machine

The radiation protection officer shall ensure that the records of the above quality assurance tests results including the action taken to correct each deficiency identified by the test are maintained for at least six years from the time of their being entered in the log kept in the X-ray facility housing the X-ray machines to which they refer (R.R.O. 1990, Reg. 543, s. 8). These records must be readily available to the inspector.

4 MEDICAL X-RAY MACHINE PROCEDURES

All medical X-ray machines are regulated by the **Healing Arts Radiation Protection Act (R.S.O. 1990, c. H.2)** administered by the Ministry of Health. These machines include medical radiographic or fluoroscopic X-ray machines, intraoral, panoramic, and cephalometric dental X-ray machines that are used for irradiating human beings for diagnostic or treatment purposes.

4.1 Healing Arts Radiation Protection (HARP) Act X-ray Safety Regulations (R.S.O. 1990, C. H.2, S. 3 -9)

Regulations made under the Healing Arts Radiation Protection Act require that all medical X-ray machines be registered with the Director of X-ray Safety, Ministry of Health, before their use. The University is the nominal owner of all X-ray equipment on all U of T Campuses and legally responsible for the safe use of this equipment; it is registered with the Director under the registration number 1.1.

A Principal Investigator who intends to purchase or install a medical X-ray machine at a permanent location on the properties of the University must notify the Radiation Protection Service at the Office of Environmental Health and Safety before the machine is put into use, and, in addition, shall comply with the following requirements outlined in the Act and regulations for the X-ray installation:

- 4.1.1 Submit an application and the plan location drawings to the Ministry through the Radiation Protection Service for Ministerial approval.
- 4.1.2 Upon approval of the submitted plan, carry out the required acceptance tests prior to clinical use of the X-ray machine, and forward the test results to the Ministry through the Radiation Protection Service.
- 4.1.3 Re-submit another application to the Ministry, through the Radiation Protection Service, if any change to the structure of the approved X-ray facility, or orientation/location of X-ray machine, or change in the emission, may take place.
- 4.1.4 Shall not permit any person to operate a dental X-ray machine for the irradiation of a human being unless:
 - that person meets the qualifications and requirements prescribed by the Healing Arts Radiation Protection (**HARP**) Act;
 - the irradiation has been prescribed by a member of the Royal College of Dental Surgeons of Ontario;
 - the performance of the machine meets the standards prescribed by the regulations.

In addition:

- 4.1.5 For every dental X-ray facility, a Radiation Protection Officer who is a member of the Royal College of Dental Surgeons of Ontario shall be appointed as required by the HARP Act. A dental radiation protection officer for a facility is responsible for:
 - ensuring that every X-ray machine operated in the facility is maintained in safe operating condition; and
 - such other matters related to the safe operation of each X-ray machine in the facility as are prescribed by the regulations (R.S.O. 1990, c. H.2, s. 9).

Currently, Dr. M.J. Pharoah, Head, Radiology Department, Faculty of Dentistry, is the Dental

Radiation Protection Officer for the facility. Ms. J. Davis, Radiology Clinic Supervisor assists him in the task to ensure compliance with the regulations, but he is ultimately responsible for the HARP Act and regulations compliance.

- 4.1.6 At all reasonable times, an inspector appointed by the Ministry may enter premise where any X-ray machine is operated for the purpose of inspection, to ensure compliance with the HARP Act and the regulations.
- 4.1.7 An inspector is entitled to make tests and examinations to determine whether or not X-ray machines are installed and used in compliance with the regulations.
- 4.1.8 Upon an inspection under this Act, an inspector may issue an order for matters that require compliance or modifications to the X-ray facility or to the X-ray machine. The order must be complied with within the time frame given by the inspector.

4.2 Ontario Ministry Of Health Dental X-ray Machine Requirements (R.R.O. 1990, Reg. 543)

The following are the Healing Arts and Radiation Protection (HARP) requirements for the dental X-ray machines:

- 4.2.1 X-ray caution signs must be posted on the doors of the X-ray room.
- 4.2.2 A label, with the X-ray warning symbol and the words prohibiting unauthorized use, must be affixed to the control panel of the machine.
- 4.2.3 No person, other than the patient, is allowed in the X-ray room during any exposure.
- 4.2.4 The X-ray exposure should be controlled only from a lead shielded control booth.
- 4.2.5 All control knobs, i.e. kilovoltage, milliamperage, power-on, or X-ray-on, must have their functions clearly labeled.
- 4.2.6 All control panel pilot lights must be functioning properly at all times.
- 4.2.7 An automatic timer must be provided to terminate the exposure after the preset time interval.
- 4.2.8 Lead shielding, such as a lead apron and collar, must be provided for all exposures on patients, especially on children and persons of reproductive age.
- 4.2.9 The X-ray tube must be radio graphically checked to ensure that it is rigidly fixed and correctly aligned within its tube housing. Before making an exposure, the tube housing must be visually checked so that it shall maintain its required exposure position without drift or vibration.
- 4.2.10 Lead lined localizing cones or collimators shall be used with all dental machines.
- 4.2.11 The beam-limiting device shall provide the maximum field size in conformity with the requirements set by the regulatory agencies. The centre of the X-ray field must be properly aligned with the centre of the direct beam.
- 4.2.12 Open-ended cones shall be used for intraoral examinations.
- 4.2.13 Total filtration should be permanently installed in the X-ray machine.
- 4.2.14 The location of the focal spot must be clearly marked on the tube housing.
- 4.2.15 An X-ray room in which more than one X-ray unit is installed shall not be used for more than one procedure at any one time unless lead barriers have been installed to ensure adequate separation and protection.
- 4.2.16 A dental X-ray machine, having more than one tube connected to one control panel, shall be designed to facilitate the inclusion of an interlock system such that it is not possible to energize more than one tube at a time and an indicating light will show which tube is connected and is ready to be energized.

- 4.2.17 Mobile machines should be used only in an unoccupied area, i.e. an area from which persons are excluded. All exposures must be made behind the protective screen (lead or lead equivalent).
- 4.2.18 It is not advisable to use the mobile machine in an area with unrestricted access. However, if the machine must be used, all necessary precautions must be taken to prevent persons present in the surrounding areas from being exposed to any unnecessary x-radiation. The person operating the machine must remain behind the protective screen during all exposures.
- 4.2.19 A mobile machine used routinely in one location should be considered as a permanent installation and be lead or lead equivalent shielded accordingly.
- 4.2.20 A Quality Assurance program relative to X-ray safety must be instituted in every dental facility. The minimum requirements of the acceptable Quality Assurance tests are:

TEST	FREQUENCY
Half Value Layer	Yearly
Patient Entrance Exposure Measurements	Yearly
Collimation	Yearly
Photographic Quality Control	Every Operational Day

5 X-RAY MACHINE ADMINISTRATION

5.1 Ontario Ministry of Labour X-ray Safety (R.R.O. 1990, Regulation 861)

The Ministry of Labour X-ray safety R.R.O. 1990, Reg. 861 applies to all X-ray machines and all X-ray sources capable of producing an air kerma rate greater than 1 $\mu\text{Gy/hr}$ at any accessible point outside its surface, except for:

- X-ray sources that are licensable under the Canadian Nuclear Safety Act, and
- Sections 5, 6, 7 and 8 of the R.R.O. 1990, Reg. 861 do not apply in respect of an X-ray machine installation, registration or operation of which is subject to the Healing Arts Radiation Protection Act.

5.1.1 Registration

All X-ray sources, for which R.R.O. 1990, Regulation 861 applies, will be registered with the Ministry of Labour through the U of T Radiation Protection Service. For the registration the PI responsible for the X-ray source will send to the RPS application form 2 and a copy of the drawing completed according to the R.R.O. 1990, Regulation 861.

5.1.2 Installation

Before the first use of an X-ray machine or before the first use in a new location the PI responsible should inform the RPS. A RSO will inspect the location and the X-ray machine, and inform the Ontario Ministry of Labour, as necessary.

5.1.3 Operation

Only personnel authorized by the PI will be permitted to operate an X-ray machine. The PI shall send the list of authorized personnel (Appendix 4) to the RPS.

5.2 Internal Licensing Procedure

The University of Toronto Radiation Protection Authority has established an **Internal Licensing** system governing the installation of X-ray machines/sources on all properties owned or controlled by the University. An **X-ray Permit** must be obtained before installation of all X-ray machines/sources - either purchased or donated. To obtain an **X-ray Permit**, a completed application form should be submitted to the University of Toronto Radiation Protection Authority. The application form, shown in Appendix 1, is available from the Radiation Protection Service.

An **X-ray Permit** will be issued only to a PI having knowledge and experience in the field of X-radiation, in order to ensure the responsible and safe use of the X-ray equipment for the facility.

An approved **X-ray Permit** requires the signatures of at least two UTRPA members. The Manager Radiation Protection Service will be the final signatory of the X-ray Permit.

When applying for an X-ray Permit, **an application form and the drawings of the planned location in duplicate**, for the intended use of a permanent X-ray facility should be prepared by

U of T Radiation Protection Service
the applicant for Ministerial approval, and forwarded, together with **the X-ray Permit application**, to the Radiation Protection Service.

The Radiation Protection Service will inform the applicant when relevant Ministerial approval for a permanent X-ray installation has been granted. Copy of the approved **X-ray Permit** will be sent to the applicant.

An application form for obtaining approval of a permanent X-ray installation from the appropriate Ministry is available from the Radiation Protection Service, Office of Environmental Health & Safety.

The Radiation Protection Officer (X-ray) will provide, upon request, consultation and assistance on the completion of an application form and the design of the required structural shielding in compliance with the legislated standards of the Acts.

5.3 X-ray Permit Termination and Disposal of X-ray Machines

Radiation Protection Service must be informed in writing when the installation is no longer to be used for X-ray work.

The following procedure must be followed for the disposal of X-ray equipment.

For the disposal of an X-ray machine, the RSO shall observe the instructions provided by the manufacturer in the product manual or contact the manufacturer for information and guidance. In a case where a manufacturer is no longer in the business of manufacturing, selling or servicing industrial X-ray equipment, the following procedures shall be followed:

- the vacuum in the X-ray tube must be breached;
- the X-ray tube window should be investigated to determine whether or not it contains beryllium, and if it does, special disposal procedures must apply since beryllium presents a toxic ingestion or inhalation hazard;
- the transformer oil, if this exists, must be disposed of in accordance with pertinent environmental legislation; and
- the lead must be recycled accordingly

If no other X-ray source remains under the supervision of the PI, the X-ray permit will be archived by the RPS.

6 DOSIMETRY

6.1 ALARA Principle

Observance of the **ALARA** principle implies that all reasonable measures are being taken to reduce risk exposure to the minimum. All possible measures may not, however, prove feasible where the cost would be prohibitive. Dose exposure must therefore be carefully assessed to ensure consistency with the ALARA concept, which has been adopted by the University of Toronto Radiation Protection Authority (UTRPA) as the basic philosophy governing the use of all sources of ionizing radiation at the University.

6.2 X-ray Dose Limits

6.2.1 X-ray Workers

A worker who may be exposed to x-radiation as a necessary part of his/her employment and could receive a dose equivalent in excess of the annual dose limit recommended by the ICRP (Jan 1977) for a member of the general public, is classified as an **X-ray Worker**.

Both the annual dose limit recommended by the ICRP, stipulated in their publication 26, 1977 and "**ALARA**" principle, have been adopted for use in the Province of Ontario by the Ministry of Labour and the Ministry of Health.

Note:

These annual dose limits do not include doses received as a result of exposure to background radiation, or doses received by an X-ray worker who undergoes medical diagnostic or therapeutic procedures or radiation therapy as a patient. They **do** include any dose received by a worker from all occupational sources of ionizing radiation. If a worker is exposed, for example, to gamma radiation other than X-ray as a part of his/her work, the dose from this gamma radiation must be added to any dose from X-rays, for comparison with the limits. The employer must ensure that the sum of the total doses received from all occupational sources of ionizing radiation from the start of the year do not exceed the annual dose limit (20 millisieverts).

The above annual whole body dose limits are not considered to be absolutely "safe" limits because there is an assumed risk of health effects associated with doses down to zero. In 1990, the ICRP, in its publication 60, has recommended new limits, which are lower. In Canada, the Canadian Nuclear Safety Commission (CNSC) is responsible for establishing radiation dose limits for Atomic Radiation Workers and the general public based on international standards. The new limits have, therefore, been adopted by the UTRPA for occupational use of radioactive materials at the University. The annual limits of radiation exposure for X-ray Workers (shown in Table 1) will be the same as those for Atomic Radiation Workers.

TABLE 1

Annual Limits of Radiation Exposure for U of T X-ray Workers and Members of the Public

	Whole Body	Skin	Hand/Feet	Lens of Eye
X-ray Workers	20 mSv (2 rem)	500 mSv (50 rem)	500 mSv (50 rem)	150 mSv (15 rem)
General Public	1 mSv (100 mrem)	50 mSv (5 rem)	50 mSv (5 rem)	15 mSv (1.5 rem)

The above maximum permissible values represent the sum of all radiation dose values incurred by **occupational** exposures. Nevertheless, **all** measures should be taken to avoid unnecessary exposures.

If when using an X-ray machine for the diagnostic examination of animals, the animals are required to be held by hand, a protective apron and gloves providing shielding equivalent to at least 0.5 mm of lead shall be worn by the person providing the restraint or support. The person shall wear an extremity dosimeter (ring) under the gloves during the procedure.

6.2.2 Pregnant X-ray Workers

A specific dose limit has been set for female X-ray workers. As soon as a pregnancy is confirmed, the pregnant X-ray worker must be limited to an external radiation exposure dose for the balance of the pregnancy of 4 millisieverts (4mSv) received through external exposure, measured at the surface of the abdomen. A personal dosimeter provided by her Department must be worn in order to monitor the dose to the abdomen every two weeks. The personal dosimeter or badge should be worn at the waist level as close as possible to the surface of the abdomen. This limit, 4 mSv dose to the abdomen, is intended to prevent developmental defects incurred by X-ray exposure of the embryo or foetus, and to reduce the potential risk of childhood cancer.

A female X-ray worker must notify in writing her immediate supervisor as soon as she knows she is pregnant so that necessary recommendations can be made and precautions taken to provide the appropriate degree of radiation protection to the foetus during the term of pregnancy.

After analysing the specific work place procedures followed by a pregnant X-ray worker, she will receive a personal electronic dosimeter (PED) for the remainder of pregnancy. Weekly the pregnant worker that has a PED will inform the designated RSO of the readings. If the limit of 0.4 mSv (on top of natural background) is reached the RSO will investigate the work place and will recommend measures to reduce the dose. Under no circumstances the X-ray pregnant worker will be allowed to continue work with/near X-ray sources if the dose received is above 4 mSv during pregnancy.

In addition, the pregnant X-ray worker must continue to ensure that all X-ray exposure doses received in the workplace are in accordance with the ALARA principle, and must also avoid all unnecessary exposures to other sources of radiation inside and outside the workplace.

6.2.3 Non-Classified X-ray Workers

Workers who are not exposed to X-rays as a necessary part of their work are referred to as **Non-Classified Workers**. No special dose limit is required for non-classified X-ray workers during the term of pregnancy. The exposure limits set for non-classified workers (1 mSv as shown in Table 1 above) are equal to the limits recommended by the ICRP for individual members of the general public. This annual dose limit is one-quarter of the limit for pregnant X-ray workers. Therefore, the dose limits for pregnancy will not be exceeded.

6.3 Implementation of the ALARA Principle for X-ray Imaging

The main objective of the ALARA principle is that radiation exposure of X-ray workers and patients be kept to the minimum. A certain amount of radiation exposure to patients is, however, necessary to achieve effective image quality. Thus the attainment of a sufficiently high quality image must be balanced against the desirability of keeping radiation exposure within acceptable limits. This balance must be observed in order to avoid unnecessary repetition of exposure arising from failure of earlier attempts to achieve acceptable image quality.

To implement the ALARA principle for diagnostic imaging, the following strategy is recommended in the Healing Arts Radiation Protection Requirements (June 1987):

- The person in charge of the X-ray unit shall ensure that the entrance exposures for standard projections are below the legal maximum values as specified in the X-ray Safety Code. For most cases where the present values are too high, the necessary reductions can be achieved through improved techniques. However, updating of the equipment will be required by the UTRPA where acceptable exposure quality cannot be obtained with exposures below the present limits.
- Persons in charge of X-ray units, which are already at or below the legal maximum values, should further attempt to reduce exposures with either improved techniques or minor changes in equipment. Image quality, as determined by peer review, shall be maintained or improved.

6.4 Information for All Persons Using X-ray Equipment

All persons using or operating X-ray equipment have certain responsibilities. These are:

- 6.4.1 Work is to be carried out in compliance with all regulatory requirements, and local policies and rules for X-ray safety observed.
- 6.4.2 Before the start of X-ray work, users are to receive sufficient instruction, from the person in charge of the X-ray facility on the safe operation of the machine and the hazards associated with x-radiation and the precautions to be taken.
- 6.4.3 All users should acquire thorough knowledge of contents of the procedural manual before the machine is operated.
- 6.4.4 All users must, when required, wear personal monitors, e.g., pocket dosimeters or thermoluminescent dosimeters provided by users' departments.
- 6.4.5 If necessary, use protective shielding, such as lead aprons, lead screens, to prevent exposure to any possible scattered or leakage radiation which may be present in the vicinity of X-ray equipment.
- 6.4.6 Users must not expose themselves, their co-workers or patients to x-radiation to a

greater extent than is necessary in the pursuit of their work.

- 6.4.7 For the fluoroscopy mode of operation, the hand of the operator must not be placed in the direct beam unless protective gloves (lead or lead equivalent) are worn, and the work must be conducted as rapidly as possible.
- 6.4.8 All protective aprons, gloves, and screens (lead or lead equivalent) are to be checked annually to ensure that they are in good condition.
- 6.4.9 The person operating a medical X-ray machine for the irradiation of a human being must meet the qualifications and requirements prescribed by the HARP regulations (HARP examination must have been successfully completed).

In addition:

- the number of exposures of the patient during X-ray examination must be kept to the minimum necessary to produce satisfactory diagnostic results,
 - protective lead shielding must be provided for all X-ray exposures on patients, particularly for X-ray exposures on children and persons of reproductive age.
- 6.4.10 Any malfunction of a machine must be reported immediately to the person in charge, and use of the equipment discontinued without delay. Resumption of use of equipment should occur only after repair has been satisfactorily completed.

7 RADIATION PROTECTION SERVICE

The principal goal of the Radiation Protection Service is to assist in the safe use and operation of all X-ray emitting devices located on the properties of the University.

7.1 General

- 7.1.2 Provision of technical advice and consultation in the preliminary planning and design of new permanent X-ray installation and relocation of existing equipment, as required by the legislation.
- 7.1.3 Assistance in the preparation of application and of floor plan drawings for submission to the appropriate Ministries for approval.
- 7.1.4 Advice on the modification of an already-approved X-ray facility and assistance in the preparation of application for obtaining re-approval.
- 7.1.5 Liaison with the government agencies regarding X-ray regulatory requirements.
- 7.1.6 Provision of hazards evaluation for X-ray installation.
- 7.1.7 Provision of information on X-ray safety.
- 7.1.8 Assistance in the design of protective enclosure required for any proposed special research project, which utilizes x-radiation.
- 7.1.9 Provision of environmental as well as specific surveys on any sources capable of X-ray emissions, to ensure that the radiation levels are within safe limits.
- 7.1.10 Evaluation of safe performance of other x-radiation emitting devices.
- 7.1.11 Provision of X-ray safety training.

7.2 Compliance Inspection

In compliance with the **Occupational Health and Safety** and **Healing Arts and Radiation Protection Acts**, the Radiation Protection Service carries out the following services in order to fulfil all requirements set out by the regulatory agencies:

7.2.1 Medical X-ray Machine

Inspection is carried out on an annual basis. In addition to visual and leakage checks, a series of quality control measures are conducted to ensure that the machine meets a high standard of performance, i.e. to produce good quality image with minimal exposure to the patient. Detail of inspection is outlined in Section 4.2 of this manual.

7.2.2 Non-Medical X-ray Machine

All new X-ray sources will be inspected to assess the radiation hazards before first time use or before moving to a new location.

Inspection of all other X-ray sources in U of T will be carried out on an annual basis, to include visual inspection and leakage measurements.

8 OTHER MACHINES OR EQUIPMENT

8.1 General

This refers to equipment, which produces X-radiation in a totally enclosed protective housing. Nevertheless, there is the possibility of emission of leakage radiation while the unit is in operation. Leakage measurements should be implemented annually, and after any major machine modifications to ensure that no leakage of radiation exists.

8.2 Indirectly Generated X-ray Units

This category of equipment includes the electron microscope, a high voltage power supply using rectifier tubes.

There have been concerns about the possible emission of low energy X-radiation from the video display terminals (VDTs). A standardized and properly designed Video Display Terminal does not present any hazard from this radiation.

The Radiation Protection Service has conducted surveys for any possible emission of low energy x-radiation from over one thousand VDTs on the University campus since 1980. No evidence of this radiation was found. Nevertheless, if there is still any cause for concern for staff and students using these units on a regular basis, a testing service for individual VDTs will be provided, but only upon request. A booklet, which identifies Key Ergonomic and Environmental Principles, provides useful information on planning your VDT workstations, and is available from the Occupational Hygiene and Safety Service, Office of Environmental Health and Safety of the University of Toronto.

APPENDIX 1 - APPLICATION FOR INTERNAL X-RAY PERMIT

APPLICATION FOR INTERNAL X-RAY PERMIT
UNIVERSITY OF TORONTO RADIATION PROTECTION AUTHORITY

Licence No.: _____

(Please print or type)

Name: _____
Department: _____
Office Room No.: _____
Building: _____

University Status: _____
Office Telephone No.: _____

1. The X-ray machine/source will be located at:

Room No.: _____
Department: _____
Building: _____

Date expected to commence use/operation:

2. The X-ray machine/source will be used for:

- Medical or Dental Diagnosis
- Diffraction or Crystallography
- Radiography (non-medical)
- Fluoroscopy (non-medical)

3. The general nature of work:

- Diagnosis
- Veterinarian
- Research
- Teaching
- Training
- Other (Please specify) _____

X-RAY WORK EXPERIENCE:

ADDITIONAL INFORMATION:

Applicant's Signature: _____

Date: _____

Chair of the Department

Name (Please Print) _____

Signature _____

Date: _____

RETURNING THE X-RAY PERMIT

Please be advised that the above location is no longer used for X-ray work. This licence is returned to your office for your records.

Signature _____

Date _____

Permit No. _____

Please return to:

**Radiation Protection Service
Office of Environmental Health & Safety
215 Huron Street, 7th Floor
University of Toronto
Toronto, Ontario, M5S 1A2**

***** FOR OFFICE USE ONLY *****

COMMITTEE APPROVALS (UTRPA)

UNIVERSITY OF TORONTO RADIATION PROTECTION AUTHORITY

<u>APPROVED</u>	<u>SIGNATURE</u>	<u>DATE</u>
UTRPA Member	_____	_____
UTRPA Member	_____	_____
UTRPA Member	_____	_____

COMMITTEE COMMENTS:

APPENDIX 2 - ACKNOWLEDGEMENT OF X-RAY WORKER STATUS FORM

**X-RAY SAFETY PROGRAM
Acknowledgement of X-ray Worker Status**

In accordance with the Occupational Health and Safety Act and Ontario Regulation 861 (X-ray Safety), this is to inform you that you have been designate an X-ray Worker. An X-ray Worker is defined by the Ontario Regulation 861 as **a worker who, as a necessary part of the worker's employment, may be exposed to X-rays and may receive a dose equivalent in excess of the annual limits (1 mSv per year for the whole body)**. The designation facilitates tracking by the National Dose Registry maintained by the Radiation Protection Bureau of Health Canada of each workers lifetime exposure to X-rays and radioactive material.

You must be familiar with the following documents that are provided to you:

1. Dose limits as outlined in Ontario Regulation 861;
2. Dose limits for Pregnant X-ray Workers as outlined in Ontario Regulation 861
3. Radiation Risk in Perspective, a position statement of Health Physics Society
4. Risk Assessment, a position statement of the Health Physics Society

A pregnant X-ray Worker must inform, in writing, her Permit Holder and the Radiation Safety Officer as soon as she is aware of her condition.

I have been informed in writing of:

- a) the risks associated with radiation to which I may be exposed during the course of my work, including the risk associated with the exposure of an embryo and foetus;
- b) the applicable dose limit as specified in the Ontario Regulation 861;
- c) typical occupational dose levels of 0.2-1.0 mSv/year;
- d) dose equivalent limit (whole body) of 50 mSv/year

I understand the risk, my obligations and the radiation dose limits and levels that are associated with being designated an X-ray Worker.

Date: _____

Signature: _____
(X-ray Worker)

Date: _____

Signature: _____
(Radiation Safety Officer)

WORKER INFORMATION (print)

Last Name: _____ First Name: _____

Social Insurance Number (SIN): _____

Date of Birth (Year, Month, Day): _____

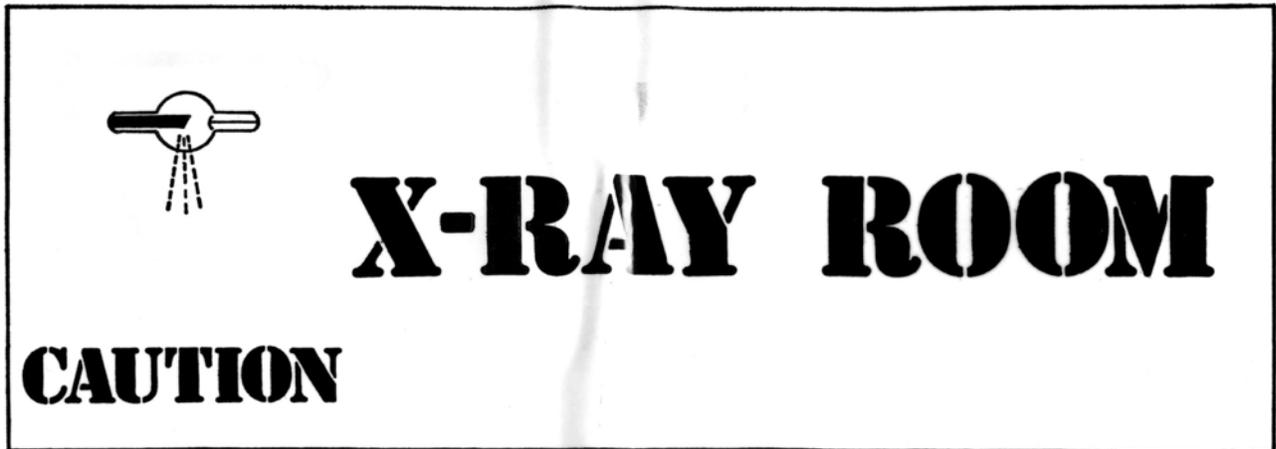
Place of Birth (Country, or Province if born in Canada): _____

Sex: **Female** **Male**

Have you worn a TLD in the past 5 years? **No** **Yes, where:** _____

All information will be kept confidential

APPENDIX 3 - X-RAY SIGNS



X-ray Room sign

CAUTION X-RAYS

WARNING

X-rays are emitted when the control panel is energized and the exposure switch is activated. Unauthorized use is prohibited.



ATTENTION RAYONS X

MISE EN GARDE

Des rayons X sont émis lorsque le tableau de commande est allumé et que l'interrupteur d'exposition est activé. L'Utilisation sans autorisation est interdite.

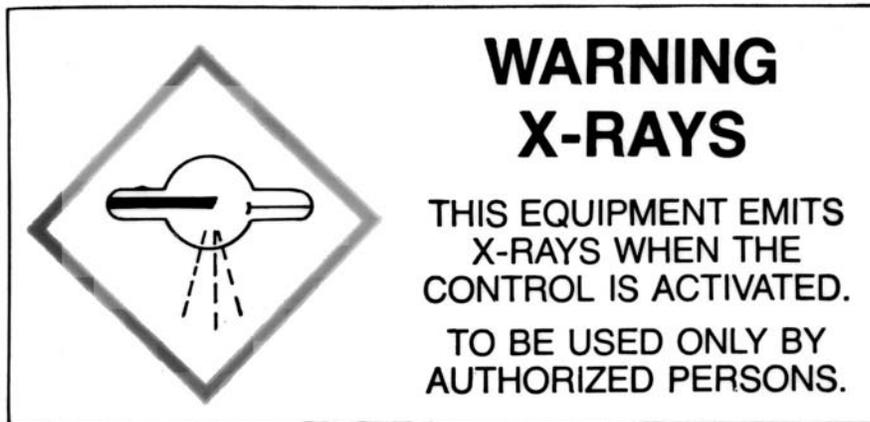
X-ray source sign #1

**ATTENTION
RAYONS X**



CAUTION X-RAYS

X-ray source sign # 2



X-ray source sign # 3



X-ray source sign # 4

APPENDIX 4 – LIST OF AUTHORIZED PERSONNEL

List of Authorized Personnel for X-ray Machine Use

Principal Investigator		Department	
Building		Rm #	
X-ray machine model		Serial #	
Max kV		Max mA	

List of authorized X-ray machine users

Please supply the following details regarding persons who will be using the x-ray machine under the supervision of the Principal Investigator.

#	Name of Authorized User	Date of X-ray Training	Signature
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

Name of Principal Investigator

Signature of Principal Investigator