1-1. GENERAL

Radiography is a highly technical field, indispensable to the modern dental practice, but presenting many potential hazards. The dental radiographic specialist must be thoroughly familiar with the procedures necessary to produce radiographs of diagnostic quality. He must also have a thorough knowledge of the hazards associated with the use of radiation and how to protect himself and the patient against those hazards. This lesson deals with the production, characteristics, and effects of radiation and how it may be used safely in dentistry.

1-2. DISCOVERY OF X-RAYS

In 1895, Wilhelm Konrad Roentgen was searching for invisible light by experimenting with a Crookes vacuum discharge tube. This is a glass tube in which the vacuum is nearly complete, having a negative electrode (cathode) and a positive electrode (anode). Many investigators believed that invisible light rays were emitted from the negative electrode when a high voltage current was sent through the tube. With the room darkened and the tube covered with black paper, Roentgen passed a high voltage current through the Crookes tube and was surprised to observe that a fluorescent screen lying on a table at some distance was glowing brightly. He then noted that a shadow was produced when an object was placed between the tube and the screen. Further experimentation revealed that the rays that caused the fluorescent screen to glow also acted upon the emulsion on photographic plates in the same manner as light. Thus it was shown that the rays produced would pass through some substances through which light would not pass. Since Roentgen was unable to determine the exact nature of the rays produced, he referred to them as x-rays (x being commonly used to denote an unknown factor). In later years scientists have referred to them as Roentgen rays.

1-3. RADIOLOGICAL TERMINOLOGY

a. Radiograph. An exposed and processed film (roentgenograph, roentgenogram). Also known as an x-ray negative.

b. Roentgenology. The study and use of x-rays (radiology).

c. Roentgen Ray. Electromagnetic radiation of pure energy and extremely short wavelength (X-ray), sometimes referred to as x-ray photons.

d. X-ray Photon. Electromagnetic rays produced by the x-ray machine. (The x-ray photon will be dealt with in greater detail in Lesson 4 of this text.)

1-4. SOURCES OF RADIATION

a. General. There are two sources of radiation (natural background radiation and man-made) both of which are harmful to man.

b. Natural Background Radiation. There are three sources of natural background radiation: cosmic, earth, and internal. Although natural background radiation may be harmful, man has lived in this environment without significant injurious effects since his appearance on earth.

c. Man-Made Radiation. Man-made radiation has many sources. Some of them are from medical and dental radiographs, occupational exposure, fallout from weapons testing, television sets, and certain radioactive watch dials, clocks, and meters. Man-made radiation, used improperly, can be significantly more harmful to man than natural background.

1-5. TYPES OF RADIATION

a. Particulate. Particulate or corpuscular radiation comes from radioactive decay or disintegration of radioactive materials. Alpha and beta particles are examples of this type radiation.

b. Electromagnetic. Electromagnetic radiation covers a very wide spectrum ranging from electrical power to visible light to x and gamma rays. The portion of the electromagnetic spectrum most important to us in this particular study is the x-ray portion.

Section II. PRODUCTION OF X-RAYS

1-6. PARTS AND COMPONENTS OF THE DENTAL X-RAY MACHINE
a. **General.** The standard structural parts of the dental x-ray machine include a control panel (usually mounted behind a protective shield); a tube head, which houses the dental x-ray tube; and a flexible extension arm from which the tube head is suspended (see figure 1-1).

b. **The Control Panel.** The components of the control panel are switches, dials, gauges, and lights. Basically, each control panel has the same function, the arrangement and location of these components will differ, depending upon the make, model, and year of construction of the dental x-ray unit. An operator’s manual is issued with each unit. The operator should study it until he is familiar with its operational capability.

c. **The Extension Arm.** The tube head is attached to the metal extension arm by means of a yoke that can revolve 360 degrees horizontally where it is connected. The construction of the yoke also provides vertical movement as well.

d. **The Tube Head.** Inside the metal tube housing is the x-ray tube. The diagram in figure 1-2 represents a dental x-ray tube head and a dental x-ray tube. This tube emits radiation in the form of photons (photons will be discussed in Lesson 2) or x-rays. X-ray photons expose the film. In addition to exposing the film, it also exposes the patient to radiation. Unless certain protective measures are taken, the x-ray technician may also be exposed.

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**Figure 1-1.** A representation of a control panel, x-ray tube head, and extension arm.

**Figure 1-2.** Dental x-ray tube head and dental x-ray tube.
1-7. THREE STEP PROCESS OF X-RAY PRODUCTION

a. The First Step. The first step in x-ray production is to turn on the machine. (If there is doubt on the part of the x-ray technician concerning the operation of the unit, reference should be made to the operator's manual.) When the unit is turned on, the filament of the cathode is heated by electrical current, causing it to emit electrons (see figure 1-3).

b. The Second Step. For the second step of this three-step process, high voltage is passed across the x-ray tube. When this is done, the electrons or electron cloud from the filament are drawn across the opening toward the anode. The anode is made of tungsten and is sometimes called the tungsten target. Figure 1-4 depicts the electrons speeding toward the anode (tungsten target).

c. The Third Step. The third and final step in this three-step process is the collision of electrons with the anode (tungsten target). This rapid deceleration of electrons produces x-rays, also referred to as photons. Figure 1-5 represents electrons striking the anode (tungsten target) and producing x-ray photons.

![Figure 1-3. Tube head with the filament of the cathode emitting electrons.](image)
Figure 1-4. Electrons speeding toward the anode (tungsten target).

Figure 1-5. Electrons striking the anode (tungsten target) producing x-ray photons.
1-8. RADIATION HAZARDS

The dental x-ray technician should never receive primary radiation from a dental x-ray unit if safety precautions are observed. However, scattered and/or secondary radiation is more difficult to avoid and is a serious danger to the technician. This type of radiation is produced by a scattering of the primary x-ray beam. The x-ray photons and photo-electrons in the beam undergo a change of direction after interaction with atoms and molecules as they pass through a substance. (Photo-electrons will be discussed in Lesson 2.) Figure 1-6 depicts scattered/secondary radiation. Scattered/secondary radiation from a patient is depicted in figure 1-7.

Figure 1-6. Diagram of scattered/secondary radiation.

Figure 1-7. Scattered/secondary radiation from a patient.

1-9. RADIATION PROTECTION
a. **General.** Filtration and collimation of the x-ray beam are very important safety measures. The filter and collimator (diaphragm) block the majority of the unwanted x-ray photons. As you progress through the next few paragraphs of this text, you will understand their importance. The following diagram will identify the location of these two devices (see figure 1-8).

![Diagram of x-ray tube head assembly](image)

**Figure 1-8.** Tube head assembly: filter, collimator (diaphragm), PID or cone or tube.

b. **Filter.** The aluminum filter or disk is placed in the path of the x-ray beam. It is located at the base of the cone or position indicating device (PID) just inside the metal housing. Figure 1-8 shows the location of the PID. The filter completely covers the opening where the x-ray beam emerges from the x-ray tube. The reason for the aluminum filter is to absorb the low energy, long wavelength x-rays (photons) and allow the high energy, short wavelength x-rays (photons) to pass through the filter. Filters on dental x-ray machines with over 70 kVp have a minimum thickness of 2.5 mm of aluminum. Those machines below 70 kVp have a safety standard minimum of 1.5 mm aluminum.

**NOTE:** The terms cone, PID, or tube are used interchangeably throughout this text.

See figure 1-8.

c. **Collimator.** The lead diaphragm is collocated with the aluminum filter. It restricts the x-ray beam to the desired size. The diaphragm or collimator is constructed of 1/16-inch lead. Without this collimator, x-ray photons would cover a wide area of the patient's head. With the lead diaphragm or collimator in place, only the area necessary for exposure receives the primary beam. This is depicted in figure 1-7. The diagram in figure 1-8 represents an x-ray tube, cone, or PID removed to show the location of the lead diaphragm or collimator and the aluminum filter.

### 1-10. PROTECTIVE MEASURES AND STANDARDS

a. **General.** Every possible safety precaution must be utilized when exposing radiographs. Collimation and filtration are only two of the several measures used to protect the patient and the technician from ionizing radiation. If all safety rules are strictly adhered to, the technician should receive no radiation and the patient exposure will be minimal. Even with the numerous safety precautions, accidental exposure is still possible.

b. **Technician Protection and Standards.**

(1) **Radiation monitoring.** AR 40-14 prescribes monitoring practices for Army personnel. It requires all primary x-ray technicians to wear a dosimeter or film badge. The dosimeter monitors or measures radiation received by the technician. The results are recorded on DD Form 1141. This form is kept permanently and made a part of the individual's health record.
(2) **Radiation standards.** For the technician operating a dental x-ray machine, the level of radiation must not ever exceed an accumulated whole body dose, in rems, of five times the number of years beyond age 18 and a maximum of three rems in any 3-month period.

**NOTE:** The term rem refers to "roentgen equivalent in man," a unit measuring the biological effect of radiation energy. For x-rays, 1 rem is equal to 1 rad, or "radiation absorbed dose" (rad).

(3) **Protective booth and shields.** Standards for dental x-ray booths or rooms require a shielding thickness of 1/16-inch lead or equivalent. The timer switch used to activate the machine for exposures is permanently affixed to the outside wall. The timer switch is mounted outside the protective shielding to prevent the operator from standing inside the booth during exposures. The shield is so designed that the radiation must scatter at least twice before reaching the x-ray technician. Leaded glass on the booth or shield provides a continuous view of the patient during the exposure. Consequently, any holding of the film or tube head by the x-ray technician is strictly prohibited.

c. **Patient Protection.** It is the responsibility of the x-ray technician to use all available protective measures to reduce exposure to the patient. Only those radiographs requested by the dental officer will be taken. Be sure that a good quality x-ray is produced each time a request is made. Wrong exposures, improper exposures, and faulty processing techniques must be avoided. These mistakes result in retakes and unnecessary patient exposure. Also, the lead apron must be used for every exposure. These safety devices significantly reduce patient exposure.

**1-11. X-RAY BEAM QUANTITY AND QUALITY**

The quality of the x-ray beam is controlled by the voltage, while the milliamperes control the quantity. An increase in the voltage and milliamperes reduces exposure time for the patient.

a. **X-ray Beam Quality.** The quality of the x-ray beam is controlled by the amount of voltage. Voltage provides contrast to the film. The desired contrast appears as various shades of gray, black and white in the x-ray negative (radiograph). Increased voltage provides less contrast (or more shades of gray). However, the beam has more penetrating power. Decreased voltage, on the other hand, provides more contrast (fewer shades of gray and more black and white shades). However, there is less penetrating power in the low voltage exposure. The technique most commonly used to expose periapical and bite-wing X-rays is a 90 kilovolt peak and 15 milliamperes.

b. **X-ray Beam Quantity.** The x-ray beam quantity is controlled by the milliamperes. The more x-rays (photons) in the x-ray beam, the more dense (dark) the x-ray negative (radiograph) becomes. By increasing the milliamperes, we increase the number of available electrons at the cathode filament. When electrical current (voltage) is applied to the x-ray tube, the electrons cross the gap. When they impact on the anode (tungsten target), a greater number of x-rays (photons) are also produced. The more x-rays that are available to penetrate an object, the more dense (dark) is the x-ray negative (radiograph).