



DELAWARE HEALTH AND SOCIAL SERVICES
Division of Public Health
Office of Radiation Control

Authority on Radiation Protection

Radiation Technologists/Technicians Certification Manual

BASED ON THE

“REGULATION FOR THE CERTIFICATION OF RADIATION
TECHNOLOGISTS/TECHNICIANS”

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**STATE OF DELAWARE
RADIATION TECHNOLOGIST/TECHNICIAN CERTIFICATION MANUAL**

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MESSAGE TO DELAWARE RADIATION TECHNOLOGISTS/ TECHNICIANS

Radiation safety is the business--and the responsibility--of every person taking part in the use of radiation for diagnostic, therapeutic, or research purposes.

There is no doubt that determining the amount of radiation to be applied to a person, and the way it is applied, is the prerogative and responsibility of the licensed practitioner, for instance, a physician or a dentist. However, applying radiation in a way that is safe for the patient, the staff, and the general public is the personal responsibility of each individual involved in the process. To exercise that responsibility, each person who applies ionizing radiation in Delaware must have a basic understanding of how the equipment works, of safety principles and practices, and of the Delaware regulations about ionizing radiation.

To assure that proper safety standards are met, Delaware's Authority on Radiation Protection requires that all Radiation Technologists/Technicians be certified as competent in the knowledge and principles of radiation protection. This manual contains necessary safety information, and guidance explaining how non-state-licensed health care professionals can become certified as Radiation Technologists/Technicians by the State of Delaware.

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DEFINITIONS

AGENCY	The administrative agent of the Authority on Radiation Protection; i.e., the Office of Radiation Control, Division of Public Health, Delaware Department of Health and Social Services.
AMPERE	The unit of measure of the amount of current flowing in an electric circuit. The unit milliamperere (mA) is 1/1000 of an ampere, and is the usual unit used to measure the current supplied to the x-ray tube. The milliamperere is used to determine the amount of radiation emitted from the x-ray tube.
ANODE	The positively-charged side of the x-ray tube. It contains the target.
AUTHORITY	Delaware's Authority on Radiation Protection as specified by 16 <u>Del. Code</u> 7404.
BARRIER	A radiation-absorbing material such as lead, concrete, or plaster, used to protect an individual or an area by reducing exposure.
BITEWING RADIOGRAPHS	Intra-oral films that show the crown portions of opposing teeth in the biting position.
CASSETTES	A holder for x-ray film that protects the film from exposure to visible light but permits penetration of x-rays. Cassettes may be plastic, cardboard or metal.
CATHODE	The negatively-charged side of the x-ray tube. It contains the filament and the focusing device.
CENTRAL RAY	The x-ray that is located in the center of the x-ray beam as it leaves the tube head.
CERTIFICATE	A document issued by the Agency recognizing the successful completion of an Authority-approved Certification Examination. Unless otherwise specified, a "certificate" allows practice of Radiation Technology to the level of examination passed. A "temporary certificate" may be issued under certain circumstances.

COLLIMATION	The process of restricting the diameter of the x-ray beam which restricts the area of exposure to the patient. Collimation can be by an extension tube or blades that limit the size of exposure to the affected area.
DENSITY	The mass of an object through which the x-ray beam passes, which makes it appear either radiopaque or radiolucent.
DENTAL TECHNICIAN	An individual who is certified to perform Dental Radiography.
DENTAL HYGIENIST	An individual with formal training in dental hygiene, including application of dental x-rays, licensed by the Delaware Board of Dental Examiners.
DENTAL RADIOGRAPHER	An individual who applies radiation to humans for diagnostic purposes in dentistry. This category includes both Dental Assistants and Dental Hygienists.
DEVELOPER	The solution used in the processing of exposed x-ray film that turns it into a visible image.
ELECTRON	A subatomic particle with a small mass carrying a negative charge. The electrons are converted into x-ray photons upon striking the target of the anode.
EXPOSURE TIME	The time interval, usually expressed in fraction of a second during which x-rays are generated.
FILM BADGE or DOSIMETER	A recording device worn to record an individual's cumulative exposure to ionizing radiation.
FILM SPEED/ SENSITIVITY	An expression of how much radiation (milliampere-seconds) will be necessary to produce a diagnostic image on the film. Films are produced by the manufacturer with designated speeds by number (i.e., 100 speed, 400 speed, etc.) or letter (i.e. D, E, etc.).
FIXER	The chemical solution used in the processing of exposed x-ray film that preserves the developed image by removing the unexposed silver halide crystals. The proper "fixing" of a film allows for extended archival quality.

FOCAL-FILM DISTANCE (FFD) or SOURCE IMAGE DISTANCE (SID)	The distance from the focal spot (target) at the anode of the x-ray tube to the film. It is usually expressed in inches, for example 8-inch FFD. More recently called the source image distance or SID.
FULL MOUTH SURVEY	A series of intra-oral radiographs that gives diagnostic information for all teeth and desired bony areas. It is usually composed of peri-apical and bite-wing films.
IMAGE	Any likeness of an object reproduced on photographic film or other viewing device. The image is the entire radiograph.
ION	An electrically charged (+ or -) particle.
IONIZATION	Process whereby electrically neutral atoms or molecules are converted to positively or negatively charged fragments on exposure to x-rays.
IONIZING RADIATION	The kind of radiation that produces ions when interacting with matter. Dental equipment and medical equipment produce this type of radiation.
KILOVOLT (kVp)	One thousand (1000) volts. Used in radiology to describe the kilovoltage setting used to expose a particular body part. The thicker (denser) the part, the higher the kVp setting required to penetrate the part to produce a diagnostic image. kVp determines the quality of the x-ray beam
LICENSED PRACTITIONER	An individual licensed to practice medicine, dentistry, podiatry, chiropractic, or osteopathy in Delaware. In other words, any individual licensed to prescribe therapeutic or diagnostic radiation for human patients. In addition, this category includes dental hygienists who cannot prescribe radiation.
MILLIAMPERE (mA)	One one-thousandth (1/1000) of an ampere. This unit of measurement predetermines the amount of radiation delivered over a prescribed time (workload). The workload when coupled with kilovoltage determines the quality and quantity of radiation a patient is exposed to and needed to produce the desired diagnostic image.
OBJECT	The structure being radiographed, i.e., mandible, tooth, leg.
OBJECT FILM DISTANCE	The distance between the object (area of patient exposed to x-rays) and the x-ray film. Increased OFD, increases magnification of the part and reduces detail.

PANORAMIC RADIOGRAPH	A dental radiograph that shows both the mandible and the maxilla.
PENETRATION	The ability of x-rays to pass through an object and reach the film. Penetration of the beam is determined by the kVp.
PERIAPICAL RADIOGRAPH	An intra-oral film that shows the tooth location and surrounding bony structures.
PRIMARY RADIATION (PRIMARY BEAM)	The original radiation that comes directly from the target of the x-ray tube.
RADIATION	Used for medical and dental imaging. Ionizing radiation can cause cells to mutate and must be used carefully.
RADIATION ABSORBED DOSE	A measurement of the unit of absorbed radiation also known as "Gray". The older unit is the rad (100 Gray = 1 Rad). In radiation protection, a rad or rem is approximately equal to a roentgen.
RADIATION EXPOSURE	The process of being struck by radiation, either primary or secondary.
RADIATION TECHNICIAN	Section IV, M, of the Radiation Technologist/Technician Certification Regulation – means any individual who has not graduated from a JRCERT -approved or CODA program in radiation technology, but has passed a Delaware-approved examination.
RADIATION TECHNOLOGIST	Any individual who is a dental hygienist, a medical radiographer, a nuclear medicine technologist, or a Radiation Therapy Technologist who has completed an approved program and is nationally credentialed.
RADIOGRAPH	The finished visual image of the part produced by exposing an object to radiation and recording that exposure on x-ray film and then chemically processing the film
ROENTGEN	The basic unit for measuring x-rays (ionizing radiation) exposure in air. It is the amount of radiation needed to produce one electrostatic charge in one cubic centimeter of air. The milliroentgen (mR) is 1/1000 of a roentgen (R).

SCATTERED RADIATION	Radiation that changes direction during its passage through matter. It may also be changed in its energy, by attenuation, i.e., become "softer." It is one form of secondary radiation. Scattered radiation can present a serious danger to the operator if appropriate protective measures (time, distance, shielding) are not used.
SECONDARY RADIATION	Radiation that comes from any matter being struck by primary radiation. Secondary x-rays are less penetrating ("softer") than primary x-rays.
SHIELDING	Preventing or hindering the passage of radiation, by use of one or more barriers that attenuate the x-rays. Lead aprons, leaded walls, collimation are all forms of shielding. Patients should have gonadal shielding applied before any radiation that may expose the gonadal region.
TARGET	That part of the anode that the high-speed electrons strike, and that produces x-rays and heat. It is usually made of tungsten.
TECHNIQUE	Term used to define the exposure to the patient based on mA, time, and kVp used to make the radiograph.
TISSUE SENSITIVITY	A measure of the tendency of a given tissue type to mutate when exposed to ionizing radiation. Some tissues (for example, epithelium) are very radiosensitive, while others (for example, bone) are relatively radio-resistant.
TOTAL BODY EXPOSURE	The radiation dosage that describes the effect of an exposure on the entire body of the person.
TUBE	X-ray tube containing the cathode and anode where x-rays are produced.
USEFUL BEAM	The part of the primary radiation that goes where it is aimed and exposes the patient.
WORKLOAD	A measure of the amount of use (high or low) of an x-ray tube in one week and is used to determine appropriate shielding when building a new room. The amount of time that an x-ray tube is used during a week based on the type of exposures performed in a room. Product of x-ray tube "ON" time in a week; milliamperes x seconds, i.e., milliamp seconds per week (mAsec/wk).
X-RAYS	Penetrating electromagnetic radiation. X-rays travel in a straight line from the source and are invisible.

I. CERTIFICATION

A. *The Certificate*

The Delaware Radiation Technologist/Technician Certificate is a permit/license to practice Radiation Technology in Delaware, as required by Delaware Radiation Control Regulations. It is issued to qualified individuals who meet the requirements of the Radiation Technologist/Technician Certification Regulation, as amended, by the Office of Radiation Control (ORC) in the Division of Public Health, the Administrative Agent of the Authority on Radiation Protection.

- ▶ The certificate is valid only when signed by the Radiation Technologist/Technician to whom it has been issued.
- ▶ Under the provision of the Delaware Radiation Technologist/Technician Certification Regulation, "holders of a certificate under these regulations shall display the official certificate or a verified copy in each place of regular employment."
- ▶ The certificate is valid for four (4) years from date of issue.
- ▶ The certificate is renewable by application to the Office of Radiation Control, accompanied by payment of the prescribed renewal fee.

B. *Who Must be Certified?*

Each Radiation Technologist/Technician in Delaware must be certified in order to practice, according to the "Radiation Technologist/Technician Certification Regulation", as established by Delaware's Authority on Radiation Protection on February 27, 1989. **THIS IS A LEGAL REQUIREMENT.** Individuals administering radiation to patients who do not hold a current Radiation Technologist/Technician Certificate in good standing can subject their employer (registered radiation facility) to citation under the Delaware Radiation Control Regulations, as amended.

Students, who administer radiation under the direct supervision of a Licensed Practitioner or certified Radiation Technologist as part of their training, will not be certified. This applies to a student enrolled in and attending a school or college of medicine, osteopathy, chiropractic, podiatry, dentistry, radiation technology or dental hygiene.

C. *Requirements for Certification*

1. Application

Radiation Technologists:

Each Radiation Technologist who is nationally credentialed or has confirmation for national testing must submit the completed, signed, official application form (ORC-R16N) to:

Delaware Division of Public Health
Office of Radiation Control
417 Federal Street
Dover, Delaware 19901

The application must consist of:

- ▶ A request that the Certificate be granted by filing the appropriate, official application form (ORC-R16N).
- ▶ Applicant's full name, home address, date of birth, social security number and daytime/evening phone number as required on the application form. Applicants should retain a copy of the completed application.
- ▶ The nonrefundable/nontransferable application fee in the form of check or money order made payable to the Delaware Office of Radiation Control (*cash will not be accepted*). Please allow a minimum of three (3) weeks for processing, and incomplete applications will be returned.
- ▶ A copy of the National Credential, or a copy of seat reservation for national credential examination (see Appendix IX for list of National Credentials recognized by Delaware).

Application/Request for State Exam - Medical Radiation Technician or Bone Densitometry Radiation Technician:

- ◆ Contact the Office of Radiation Control at the above address to obtain application form ORC-R16S.
- ◆ Complete the Delaware application with full name, home address, social security number, date of birth and daytime telephone number.
- ◆ Submit the nonrefundable/nontransferable application and examination fee (see application for specific fee amounts) by check or money order payable to the Delaware Office of Radiation Control (*cash will not be accepted*). Please allow a minimum of three (3) weeks for processing. Incomplete applications will be returned.

Application/Request for State Exam - Dental Radiation Technician:

- ◆ Contact the Office of Radiation Control at the above address to request application form ORC-16-S.
- ◆ Submit completed Delaware application with payment of nonrefundable/nontransferable application fee (see application for

specific fee amounts) in the form of check or money order made payable to the Delaware Office of Radiation Control, (*cash will not be accepted*). Please allow a minimum of three (3) weeks for processing. Incomplete applications will be returned.

- ◆ Upon receipt of completed application and fee, the Office of Radiation Control will mail applicant the State Radiation Technologist/Technician Manual and Test Administration Firm Candidate Guide.
- ◆ Applicant submits the completed Exam Registration form and examination fee directly to the Test Administration Firm.
- ◆ The Test Administration Firm will forward a test admission notice to each applicant directly.

Certificates will be sent to the home address of the applicant given on form ORC-R16S or ORC-R16N. **Certificate holders are required to notify the Office of Radiation Control in writing with any change of name, address or other contact information** to ensure that Agency records remain accurate throughout the four-year certification cycle. **If requesting name change, you are required to submit supporting documentation with your change of address/name form, e.g. copy of marriage license, judgment of divorce or other court papers.**

Failure to provide change of name information in a timely manner may jeopardize your certification standing.

The application remains valid for a period of (6) months.

A copy of this Delaware Radiation Technologist/Technician Manual is routinely forwarded to the applicant's address for the first time applicant.

2. Certification

Certification will be granted if any one of the following criteria is satisfied:

- a. The applicant presents evidence of possessing a current credential granted by a recognized national voluntary credentialing body (see Appendix IX), issued on the basis of an examination satisfactory to the Authority. **Note that the Authority will not accept any certification, registration, or license/permit issued by another state.**
- b. The applicant presents evidence of completing an appropriate course of study, approved by the Joint Review Committee on Education in Radiologic Technology/Therapy, the Joint Review Committee on Education in Cardiovascular Imaging or the Commission on Dental Accreditation (CODA), or an equivalent course of study acceptable to the Authority, and has a seat reservation to take the appropriate national credentialing examination for which a temporary state certificate will be granted.
- c. The applicant passes the Authority approved state examination, and is at least 18 years of age.

3. Examination

The Authority has authorized the use of examinations specified below:

- a. The American Registry of Radiologic Technologists Limited Scope State Licensing Examination: This test consists of 6 parts: 100 “CORE” questions that every medical radiation technician takes about general radiation safety and patient care. Five additional parts are provided for specific body part (anatomical) areas. An examinee may choose from Chest, Ankle and Feet, Skull/Sinuses, Extremities, and/or Spine. This computer-based, Limited Scope exam is administered by the American Registry of Radiologic Technologists (ARRT), through local computer test centers, specifically for State licensing requirements. It is non-transferable to other states. Prior to taking medical x-rays, the applicant must successfully pass the 100-question core part and at least one other body part exam before a certificate will be issued. Technicians will only be certified to x-ray body parts based on the test parts passed.
- b. The American Registry of Radiologic Technologists Bone Densitometry Operator’s Examination: This test consists of 60 questions, in 8 parts: Basic Concepts, Equipment Operation & Quality Control, Radiation Safety, and DXA Scanning of Finger, Heel (Os Calcis), Forearm, Lumbar Spine and Proximal Femur. This computer-based exam is administered by the American Registry of Radiologic Technologists (ARRT), through local computer test centers, specifically for State licensing requirements. It is non-transferable to other states. Prior to taking bone densitometry x-rays, the applicant must successfully pass the exam, before a certificate will be issued.
- c. The Delaware Dental Radiation Technician (DDRT) Examination, is administered by the Dental Assisting National Board (DANB) through local computer test centers, specifically for State Licensing Requirements. It is intended for dental examinees and covers aspects of radiation technology and practice pertaining to radiation safety of the dental patient. The Authority intends that passage of this examination will assure that the applicant has sufficient knowledge of radiation principles, with regard to basic theory and equipment operation, to responsibly and safely administer radiation to patients. The Delaware Radiation Technologist (DDRT) exam is equivalent to the DANB Radiation Health & Safety Examination (DANB RHS) exam, and this examination may be recognized by other states, for licensure (eg. New Jersey and Maryland).

D. Taking the Examination

1. The examination process is administered by the Division of Public Health, Office of Radiation Control. Tests are provided based on arrangements made with each test administration organization under contract. The Test

administration organization will provide specific information to each applicant on scheduling, and sites for testing.

Applicants are responsible for registering with the test administration organization to schedule to sit for an exam on a given date.

If you do not hear from the test administration organization regarding your exam within three weeks of registering with the test administration organization to sit for an exam, you are responsible for contacting them directly to determine the status of your registration. Contact the Office of Radiation Control at (302) 744-4546 immediately if you experience any customer service issues with a test administration organization.

2. The initial examination must be taken within six (6) months of the date the application form is signed. After the six-month period has expired, applicants must submit a new application with application fee, as described in Section C.1 above. See application for specific fee amounts.

3. **DENTAL APPLICANTS**
 - Stage 1: Applicant contacts the Office of Radiation Control at the above number and submits application form ORC-R16S and the nonrefundable/nontransferable application fee. See application for specific fee amounts. ORC mails the first-time applicant the State Radiation Technologist/Technician Manual and Candidate Information packet from the test administration firm. Please allow a minimum of three (3) weeks for processing. Incomplete applications will be returned.
 - Stage 2: Applicant completes Candidate Registration form and submits the required information and examination fee directly to the test administration firm per their guidelines.
 - Stage 3: Applicant may choose to buy an additional Exam Study Guide as an option in the Candidate Registration process, and submits the appropriate Study Guide fee directly to the test administration firm.
 - Stage 4: Applicant receives Test Admission Notice from the test administration firm, as described in the Candidate Registration Packet.
 - Stage 5: Applicant takes the examination under the monitoring of the test administration firm. The test administrator (proctor) is responsible for seeing that the applicant completes the examination within the allotted time without any oral or written assistance.
 - Stage 6: The test administration firm notifies the State of the examinee's results.
 - Stage 7: The state (ORC) notifies the examinee of official pass/fail test results. Examinees who have passed the examination and are at least 18 years of age will receive a certificate to practice as a Dental Radiation Technician. Examinees who

pass the examination but are under 18 years of age will receive their examination result letter, but will not receive a certificate to practice until their 18th birthday has elapsed. Unsuccessful examinees will be provided information on how to apply to retest.

NOTE: UNTIL EXAMINEE RECEIVES OFFICIAL WRITTEN NOTIFICATION OF A PASSING GRADE FROM THE STATE OF DELAWARE (ORC), THE EXAMINEE SHALL NOT PERFORM ANY RADIOGRAPHIC PROCEDURES.

4. MEDICAL LIMITED SCOPE AND BONE DENSITOMETRY APPLICANTS
 - Stage 1. Applicant contacts the Office of Radiation Control at the above number and submits application ORC-R16S, the nonrefundable/nontransferable application fee and the exam fee..See application for specific fee amounts. Application and fees are received and processed by the Agency. Please allow a minimum of three (3) weeks for processing. Incomplete applications will be returned.
 - Stage 2. The Agency mails the Radiation Technologists/Technicians Manual to the first time applicant.
 - Stage 3. Applicant's name added to ORC candidate list for the requested ARRT Examination
 - Stage 4. ORC submits list of candidates to ARRT.
 - Stage 5. ARRT sends candidate's admission ticket for examination to examinee.
 - Stage 6. Candidate sits for requested examination, as scheduled.
 - Stage 7. Candidate test scores received by State (ORC).
 - Stage 8. The Office of Radiation Control notifies the examinee of pass/fail results. Examinees who have passed the examination will receive a certificate. Examinees who are unsuccessful will be provided information on how to apply to retest.

NOTE: UNTIL EXAMINEE RECEIVES FINAL WRITTEN NOTIFICATION OF A PASSING GRADE FROM THE STATE OF DELAWARE (ORC), THE EXAMINEE SHALL NOT PERFORM ANY RADIOGRAPHIC PROCEDURES.

E. Scoring the Examination

Test Administration Organizations report test scores to the Office of Radiation Control. Passing rates are determined based on the particular scoring mechanism used by each Test Administration Organization. The Authority on Radiation Protection determines specific passing rates for each examination consistent with scoring mechanism used by each Test Administration Organization. **The Office of Radiation Control issues certificates to examinees who earn a passing score on their requested examination, and are at least 18 years of age.**

F. Retesting Privileges

Examinees may be re-examined twice per 12-month period, following the initial examination.

Examinees who hold a temporary state certificate based on having qualified to sit for their national board exam, and fail to pass their national Credentialing Examination will lose their temporary state privileges, and are not permitted to perform radiographic procedures. Examinees may be re-examined twice per 12-month period, following the initial examination. However, only one temporary state certificate will be issued.

G. Renewal of Certification

1. Permanent Radiation Technologist/Technician Certificates are valid for a period of four years, and must be renewed no later than 30 days following the expiration date printed on the certificate in order for the certificate holder to continue to operate radiation equipment. Radiation Technologist/Technician Certificates are required to be posted in their place of employment.
2. Radiation Technologists/Technicians are responsible for submitting a renewal form, and payment of a nonrefundable/nontransferable renewal fee (see application for specific fee amounts) prior to the expiration date on their certificate, in the form of check or money order made payable to the Delaware Office of Radiation Control (cash will not be accepted). Please allow a minimum of three (3) weeks for processing. Incomplete renewal forms will be returned.
3. Radiation Technologists/Technicians who fail to renew their certificate within the grace period of 30 days following the expiration date, and who continue to operate radiation equipment, will subject their employers (registered radiation facilities) to citation under the Delaware Radiation Control Regulations.
4. Radiation Technologists/Technicians who fail to renew their certificate within 180 days following the expiration date on their certificate must re-apply for certification, qualifying by recognition of an existing national credential, or by passing a state radiation technician examination (see Requirements for Certification Section, 1.C).

H. PENALTIES

Whoever shall:

1. Sell or fraudulently obtain or furnish any radiation technology diploma, certificate, or renewal, or record of the same, or aid or abet therein; or

2. Practice radiation technology and/or hold or claim to be a registered or certified radiation worker under cover of any diploma, certificate, or record illegally or fraudulently obtained, signed, or issued; or
3. Practice radiation technology without certification under this regulation; or
4. Use, in connection with his/her name any designation tending to imply that the person is a registered or certified radiation worker, without certification under this regulation; or
5. Practice radiation technology when his/her certificate is suspended or revoked; or
6. Violate these regulations in any other manner,

Shall be fined not more than \$500, or be imprisoned not more than one year. 16 Del. C. §7416.

II. FUNDAMENTALS OF X-RAYS

Radiation Physics

X-rays are electromagnetic waves, like visible light, microwaves, and radio waves. The difference between these different types of electromagnetic radiation is in their wavelengths, the distance between adjacent peaks of the waves. Our eyes are equipped to see radiation in a certain range of these wavelengths which we call visible light. Radiation at other wavelengths, invisible to the human eye, can only be detected by means of special sensors. Electromagnetic radiation of most wavelengths passes through some materials, for example through air, without either being absorbed or reflected. When visible light passes through such a material we call it transparent. Other materials pass only a fraction of the radiation incident on them and either absorb or reflect the rest (we call such materials translucent or attenuating) and still others absorb or reflect most the radiation incident on them (we call these opaque).

The shorter the wavelength of the radiation is the more energy it carries and the greater is the chance of its passing through various materials without being absorbed or reflected. X-rays have very short wavelengths. They thus carry considerable more energy and are able to pass through many materials without a large fraction of them being absorbed. In fact, the fraction of incident x-rays that is absorbed by a given material depends mostly on the material's density. Thus, dense materials such as lead and gold absorb a much greater fraction of incident x-rays, at a given thickness of the material, than do "light" materials, such as water. Similarly, x-rays, pass mostly unabsorbed through most biological tissues such as muscle and various organs, but they are more strongly absorbed by bone, which has a higher density. X-ray imaging takes advantage of this difference in the x-ray attenuating properties of various tissues in the body.

What we finally see as a finished radiograph is the result of variations in the intensity of the x-ray beam due to differences in attenuation by different tissues. After passing through the body, the x-rays, which have passed through without being attenuated, impinge on fluorescent screens between which a photographic film is sandwiched. The fluorescent screens are made of a dense material designed to absorb most of the incident beam and, on absorbing the x-rays, emitting visible light to which the photographic film is sensitive. They thus expose the film, which is then developed to display the radiograph.

How X-rays Are Made

An x-ray tube is a special case of electronic vacuum tube. It always has a glass envelope with several electrical leads sealed into it, enclosing several electronic elements, with the air removed from it as completely as possible. A schematic diagram of a tube head, which includes the tube itself (glass envelope + contents), is shown as Figure II-1; a typical control panel is shown as Figure II-2.

This section describes how x-rays are generated. Though somewhat oversimplified, the concept is accurate. These steps always occur, though in some modern equipment some of them may happen in a rapid and automatic sequence.

1. The x-ray machine's main power switch is turned ON and the "X-ray Ready" light comes ON. Ordinarily, this is done at the beginning of the workday.
2. The current is adjusted to the value called for by the technique chart, using the current (mA) adjustment control knob. This current heats the filament of the negatively charged cathode, which begins to give off electrons when it gets hot enough. Once the filament gets hot enough to begin emitting electrons (its threshold temperature), it emits them more rapidly, the hotter it gets. A higher current produces a hotter filament which in turn produces a higher rate of electron emission.

At this stage, the electrons have nowhere in particular to go. Generally, they fly a short distance out into the vacuum, stay there awhile, and finally fall back into the surface of the cathode. This makes a sort of "cloud" of free electrons around the hot cathode, just waiting for something to happen.

3. The high-voltage supply is adjusted to the value prescribed by the technique chart (or by the Licensed Practitioner, in case of special radiography), using the kVp control knob. A typical value is 70,000 peak volts (70 kVp), nearly 1000 times the voltage of ordinary "house" voltage. (This voltage is lethally high; the leads are totally enclosed to protect anyone from touching them.)
4. When the operator positions the patient (the object) for the radiograph, he sets the time knob to the appropriate time interval.
5. At this point, the x-ray machine is ready to be used. The electron cloud around the cathode is stabilized according to the mA setting; the high voltage has been set to the desired kVp setting; the time interval is set. **NO X-RAYS ARE GENERATED YET.**
6. When the operator (having taken a safe position behind a protection barrier or 12 feet from the x-ray tube) presses the Remote Activator switch (Deadman Switch/ exposure button), (a) the high voltage is imposed between cathode and anode, (b) the automatic timer starts, and (c) the "X-ray ON" light comes ON.

The anode, now bearing a strong positive charge, attracts the free electrons in the cloud around the cathode. The electrons fly through the vacuum to strike (and stick to) the anode, striking the target with so much energy that it emits x-rays and gets quite hot. The higher the kVp, the faster the electrons move to the anode, the harder they strike the target, and the more energetic the x-rays are--that is, the more penetrating capability they have.

The rate at which the cathode emits electrons is a time function. It controls the rate at which x-rays are generated (x-rays per second) at the target--that is, the intensity of the x-ray beam.

The quantity of x-rays, or radiation exposure, is a function of mA x time interval. (This is often referred to in terms of milliampere-seconds (mAs) per radiograph, and relates proportionately to roentgens or to rem in human tissue.) Penetration is a sole function of kVp. The higher the kVp, the harder the beam, the more penetrating the x-rays.

When the exposure time interval (usually less than a second) has expired, a switch automatically opens to remove the high voltage from the tube electrodes. This instantly stops x-ray generation. (If the automatic timer switch malfunctions, the operator's manual Deadman Switch stops x-ray generation immediately when the operator releases finger pressure on the switch. This protects both patient and operator from overexposure.) Because the high voltage is removed from the tube electrodes,

- a) Electrons stop moving from cathode to anode.
- b) X-ray productions stops.
- c) The "X-Ray ON" light goes out.

Figure II-1 shows the basic parts of the x-ray tube head, and their relation to each other:

1. Cathode: The negatively charged (-) side of the x-ray tube, which also includes the filament. Electrons are emitted from the cathode.
 2. Filament: Wire in the cathode, which is heated to produce free electrons.
 3. Focusing Device (Cup): A negatively charged deflector that directs (focuses) electrons into a beam directed at the target.
 4. Anode: The positively charged (+) side of the x-ray tube. It contains the target.
 5. Target: (See Definition) The part of the anode struck by the electron beam. It is usually made of tungsten, a heavy metallic element with a very high melting point to withstand the heat generated by electron bombardment.
- A. Lead Shielding: Outer layer of lead within the tube head to absorb stray or scattered x-rays not exiting the tube window or port.
 - B. Vacuum: The interior of the tube. It has had all the air removed, and must remain sealed in order to function.
 - C. Beam-Limiting Device: Also known as a "collimator", used to limit the diameter of the useful beam.
 - D. Useful X-ray Beam: The part of the x-ray beam that goes where it is aimed, exposing the patient and the film.
 - E. Glass Envelope: The shell of the x-ray tube, vacuum-tight.

F. Position-Indicating Device: A device used to aim the primary x-ray beam.

Figure II-2 shows controls and meters. The components of this figure perform the following functions:

- A. Remote Activator: Remote switch that activates the x-ray machine. This is preferably a Deadman Switch, i.e., a switch which is made so that it is activated only by the operator's continuous pressure, also known as the exposure button.
- B. kVp Meter: Indicates the peak voltage (kilovolts) between cathode and anode.
- C. mA Meter: Indicates the current (milliamperes) flowing between cathode and anode.
- D. X-ray Ready Light: Indicates that the machine is warmed up and ready to operate.
- E. X-ray ON Light: Lights only during the brief period when the x-ray machine operates.
- F. Timer: Sets the time interval during which the machine generates the x-ray beam. The timer is connected to the TIMER SWITCH. The operator turns the machine ON manually, using the Remote Activator, then the timer switch turns OFF automatically after the preset time interval has elapsed.
- G. mA Adjustment Knob: Allows you to alter the tube current (mA), by controlling the input. The procedures for individual x-ray machines prescribe the normal range of current values.
- H. kVp Adjustment Knob: Allows the operator to select the (operating) voltage across the x-ray tube needed to penetrate the part being x-rayed.
- I. Main Power ON/OFF Switch: Connects/disconnects electrical power to the x-ray machine.

FIGURE 11 - 1

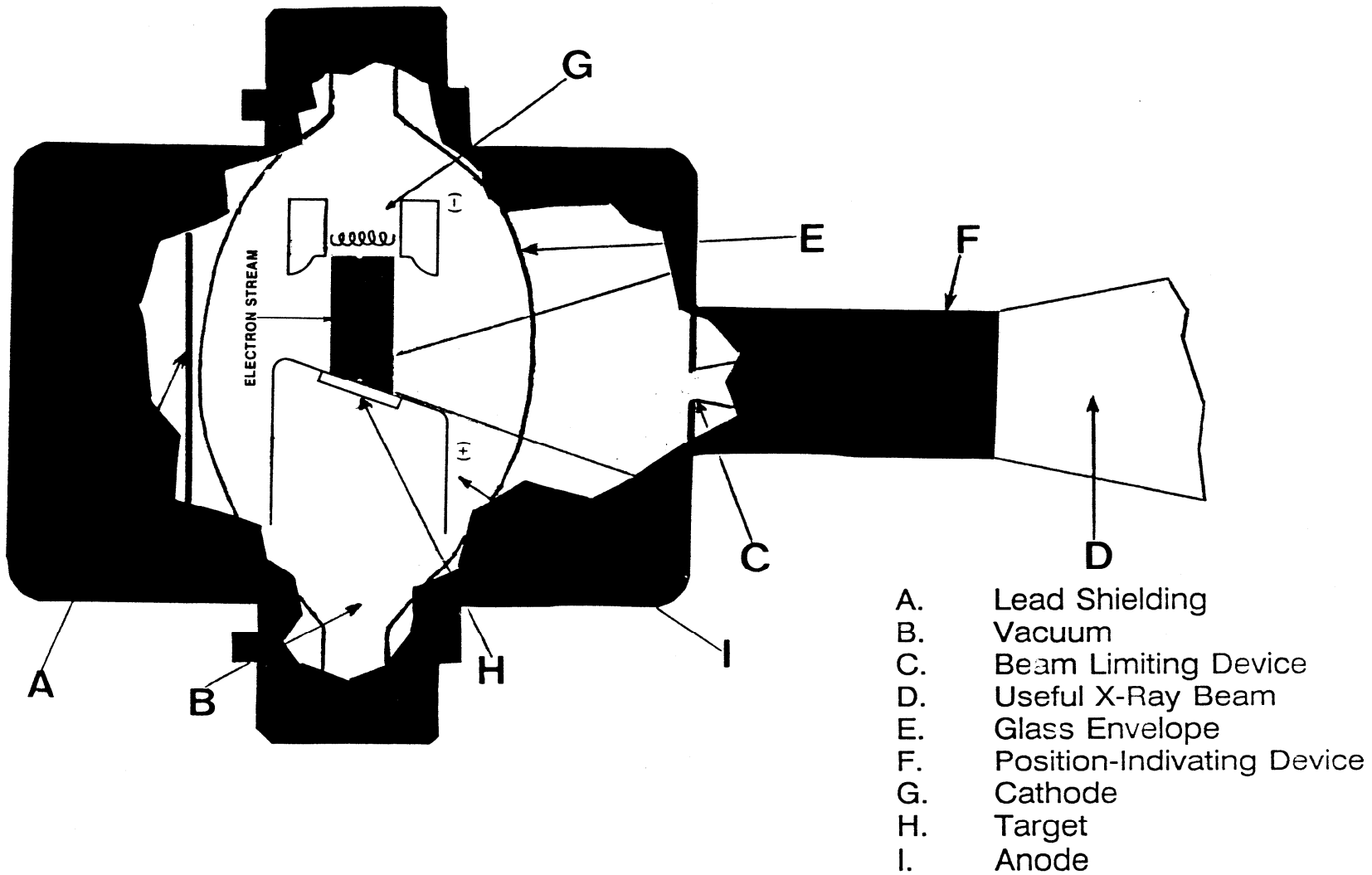


FIGURE 11 - 2

