SYLLABUS ON FLUOROSCOPY

RADIATION PROTECTION

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DEAR READER:

This document is the sixth revision of the Syllabus on Fluoroscopy Radiation Protection. Your review and comments of this revision would be sincerely appreciated. Please mail your comments to:

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6th revision

STATUTES REGARDING X-RADIATION

A. **Laws Relating to Radiologic Technology.**

Laws that govern the use or supervision of use of X-radiation on human beings are found in sections 106965 to 107110, inclusive, and sections 114705 to 114895, inclusive, (old sections 25660 to 25699.3, inclusive) of the California Health and Safety Code.

B. **Radiation Control Laws.**

Applicable provisions for X-ray equipment safety are:

Sections 114960 - 11500, inclusive, (old sections 25800 - 25811, inclusive), sections 115060 - 115110, inclusive, (old sections 25815 - 25826, inclusive), sections 115130 - 115170, inclusive, (old sections 25835 - 25856, inclusive) of the California Health and Safety Code.

C. **Regulations Relating to Radiologic Technology.**

Regulations relating to radiologic technology are found in sections 30400 to 30468, inclusive, of the California Code of Regulations (CCR), title 17.

D. **California Radiation Control Regulations, including 10 CFR 20 (the Nuclear Regulatory CommissionRegulations), incorporated in section 30253, California Code of Regulations (CCR), title 17.**

Regulations relating to radiation control are found in sections 30100 - 30146, inclusive, and sections 30250 - 30313, inclusive, of the California Code of Regulations (CCR), title 17.

In this syllabus applicable provisions of the radiation laws and regulations will be either reworded or quoted verbatim. There is no need for you - the radiologic technologist - to purchase a complete set of statutes because your X-ray supervisor/doctor must make the laws and regulations readily available to you. If your X-ray supervisor/doctor does not have these statutes, please advise him/her to obtain a complete set of statutes by contacting BARCLAY LAW PUBLISHERS either by telephone (415) 244-6611or 1-800-888-3600, or by writing to:

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South San Francisco, CA 94083-3066

Barclay's Code Number for Title 17 is 17 01 542; for complete package including (1) 10 CFR 20, (2) CCR, Title 17, and (3) amendments Barclay's Code Number is 17 01 552. Price: Inquire.

Please be reminded that regulations do not repeat provisions that are clearly stated in the law. Thus, neither law alone nor regulations alone will provide adequate answers to many questions that you may have regarding the "provisions of the radiation laws and regulations."

NOTE: The Health and Safety Code has been recodified pursuant to the SB 1360 (Chapter 415, Statutes of 1995). The legislation reorganized, renumbered, and made technical changes to the public health portion of the Health and Safety Code (H&SC).

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- Mosby Year Book, Inc., 11830 Westline Industrial Drive, St. Louis, Missouri 63146. Publications:

  (1) Stewart C. Bushong, Sc.D., **Radiologic Science for Technologists**, 5th edition, 1993; and **Workbook and Laboratory Manual**, 5th edition.

  (2) Mary Alice Statkiewicz-Sherer, et al, **Radiation Protection in Medical Radiography**, 2nd edition, 1993.

- W.B. Saunders Company, The Curtis Center, Independence Square West, Philadelphia, PA 19106. Publications:

  (1) Steven B. Dowd, **Practical Radiation Protection and Applied Radiobiology**, 1st edition, 1994.

  (2) Michael A. Thompson, et al, **Principles of Imaging Science and Protection**, 1st edition, 1994.

- Charles C. Thomas, Publisher, 2600 South First Street, Springfield, IL 62717. Publications:

  (1) Joseph Selman, M.D., **The Fundamentals of X-Ray and Radium Physics**, 7th edition, 1985.

  (2) Joseph Selman, M.D., **Elements of Radiobiology**, 1st edition, 1988.

- Williams & Wilkins, 428 East Preston Street, Baltimore, MD 21202. Publications:

  (1) Bushberg, Jerrold T., Ph.D., James A. Seibert, Ph.D, et al, **The Essential Physics of Medical Imaging**, 1st edition, 1994.

  (2) Thomas S. Curry, III, M.D. et al, **Christensen's Physics of Diagnostic Radiology**, 4th edition, 1990.

Study Guides:

- **Workbook on Syllabus on Fluoroscopy** by K. Judy Ciuba. Available from: T.J. Enterprises, 2842 Oleander Avenue, Merced, CA 95340, telephone: (209) 384-7119.

- **Principles of Fluoroscopic Image Intensification and Television Systems: Workbook and Laboratory Manual,** by Robert J. Parelli, M.A., available from St. Lucie Press 100E Linton Blvd., Suite 403B, Delray Beach, FL 33483, telephone: (407 or 561) 274-9906.**

** Formerly titled: **Self-Paced Fluoroscopy Course (programmed instruction)** by Robert J. Parelli, M.A., Printed by :Par Rad Publishing Company, and is now out of print.

PREFACE

This syllabus is not a textbook but rather a guide to good practice in fluoroscopic radiation protection and includes information how to protect the patient, the operator and others during the use of fluoroscopic and ancillary equipment.

The syllabus will also provide information for the preparation to take the State fluoroscopic radiation protection examinations:

- Licentiates of the Healing Arts who wish to obtain a Supervisor and Operator Radiology Certificate or a Supervisor and Operator Fluoroscopy Permit are responsible for knowing **all** of the provisions of the syllabus.

- Radiologic technologists who wish to obtain a Technologist Fluoroscopy Permit should know all of the provisions noted in the syllabus.

Elimination of unnecessary exposure to ionizing radiation requires doctors who hold Supervisor and Operator Radiology Certificates or Supervisor and Operator Fluoroscopy Permits to use qualified judgement in deciding whether fluoroscoping (X-raying) a patient is essential, knowing the yield of fluoroscopic examinations, and adhering strictly to good practice during fluoroscopic examinations, as explained in the syllabus.

Supervisors must exercise proper supervision over technologists who hold Technologist Fluoroscopy Permits and ensure that they follow standing orders, do not practice medicine, and perform their assigned tasks conscientiously and correctly. Supervisors are also responsible for ensuring that the fluoroscopic and ancillary equipment is in safe operating condition at all times. Also, the use of fluoroscopic equipment places high demands on the proper training and performance of both the supervisors and the holders of Technologist Fluoroscopy Permits.

It is unfortunate that terminology regarding fluoroscopy technology and radiation protection is not uniform. For example: terms such as "collimate," "restrict," "area exposed" are used interchangeably. In the syllabus such terms often will be presented in this form: "collimate/restrict." **The reader is advised to ascertain the terminology by consulting the glossary.**

The mention of commercial products, their sources, or their use is not to be construed as either actual or implied endorsement of such products by the California State Department of Health Services.

NOTE: This syllabus contains over 62,000 words, 9,500 sentences, and 4,700 paragraphs. The word length is 5 letters and the average sentence length is 7 words. The estimated readability is 12 - 14 grade level. Estimated time required to prepare for the examination is 6 - 8 hours.

INTRODUCTION

X-rays were discovered because of their ability to cause fluorescence, and the first X-ray image of a human body part was observed fluoroscopically.

The first case of human injury from X-ray exposure was reported in the scientific literature just a few months following Roentgen's original paper in 1895, announcing the discovery of X-rays. As early as 1902, the first case of X-ray induced cancer was reported.

Evidence that harmful effects can result from a large exposure of ionizing radiation existed in the 1920s and 30s, based upon the experience of the early radiologists and persons working in the radium industry. The potential long-term biological significance of smaller, chronic exposures of radiation, however, was not widely appreciated until much later, and most of our current knowledge of the biological effects of radiation has been accumulated since World War II.

We know that over 90 percent of the average populations exposure from man-made radiation sources comes from medical uses of radiation. The largest contribution to this total radiation dose results from diagnostic X-ray examinations. The obvious and immediate benefits of medical X-ray examinations for the patient justify incurring biological and genetic risks. However, estimates indicate that over 50 percent of the exposure from diagnostic X-ray examinations could be eliminated without decreasing patient benefits. Consequently, each holder of a Radiology Certificate or Fluoroscopy Permit (often referred to as Fluoroscopy Supervisors and Operators)[1/] should endeavor to eliminate the unproductive exposure of patients to X-radiation.

Basically, a radiologic service involves three distinct phases:

1. Determining whether or not the patient should have an X-ray examination -- a licentiate (physician) responsibility,not discussed in this syllabus.

2. Performing the examination -- the Fluoroscopy Supervisor and Operator[2/] who have responsibility for performing fluoroscopic examinations and for supervising radiologic technology personnel that includes assigning specific tasks to technologists, who must hold Technologist Fluoroscopy Permits, to perform.

3. Interpreting the findings – a qualified licentiate responsibility, not discussed in this syllabus.

1/ See sections 30460 to 30468, inclusive.
2/ See sections 30462, 30463 and 30464.

Note: Unless otherwise specifically indicated, the above and subsequent section citations refer to California Code of Regulations, title 17; sections 30100 to 30397, inclusive, are California Radiation Control Regulations; sections 30400 to 30468, inclusive, are California Regulations Relating to Radiologic Technology.

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CHAPTER I

FLUOROSCOPY UTILIZATION

Studies of X-ray utilization provide data on the volume and distribution of diagnostic X-ray examinations. These studies also indicate why examinations are performed.

Approximately 5 percent of the population of the United States are fluoroscoped each year. On the average, the number of fluoroscopic examinations per person is 1.3. The number of spot films taken per fluoroscopic examination was 4.6.

Fluoroscopic examinations by body area showed the following distribution: gastrointestinal tract - 53 percent; barium enema - 28 percent, and other examinations - 19 percent.

Exposure to such a large part of the population, even at the low levels of diagnostic radiation used, is cause for concern. Based on currently accepted nonthreshold linear dose-effect hypothesis (see Chapter IV - Biological Effects and Significance of Radiation Dose, page 61), it is assumed that any X-ray exposure carries the possibility of producing adverse somatic and/or genetic effects.

Nevertheless, the available data confirm that the prudent course of action is to obtain necessary diagnostic information from fluoroscopic examinations, accepting a small statistical increase of risk. At the same time, however, it is vital to minimize patient and X-ray operator radiation exposure by adhering to established principles of radiation protection. If radiologic technologists are required to use fluoroscopic equipment they must possess Technologist Fluoroscopy Permits, be competent in the performance of their duties and be under proper supervision at all times.

Fluoroscopic examinations should be performed only after careful consideration, because these examinations could expose the patient to much larger quantities of radiation than radiographic examinations. For example, an upper GI tract fluoroscopic study utilizing 120 seconds actual fluoroscopic exposure time could deliver a skin entrance exposure to the patient of as much as 5 - 15 rads, as compared to an AP abdominal film where the skin entrance exposure range, according to the California Entrance Skin Radiation Dose Averages data, is 100 to 500 millirads to the patient.

Fluoroscopy is defined as a radiological examination utilizing fluorescence for observation of the transient image (section 30400). Fluoroscopy is utilized first as a means of studying dynamic procedures (visualization of motion of internal structures and fluids) and secondly as a means of post-fluoroscopic patient positioning, if necessary, for optimum results for image recording (spot filming). However, **using fluoroscopy to position patients prior to taking routine radiographic films is prohibited.**

Fluoroscopic procedures may be performed by licentiates of the healing arts who hold either Supervisor and Operator Radiology Certificates or Supervisor and Operator Fluoroscopy Permits, and **who have been properly trained in the use of a fluoroscope and its techniques. The regulation specifies [section 30305 (b) (1)] that only persons who have been adequately instructed in safe operating procedures and who are competent in the safe use of the equipment may operate it. In addition, these individuals must demonstrate competency before they may operate fluoroscopic and ancillary equipment.**

CHAPTER II

FACTORS INFLUENCING PATIENT FLUOROSCOPY RADIATION DOSE

After deciding that a fluoroscopic examination is necessary, the condition of fluoroscopic and ancillary equipment, accessories, and the manner in which that examination is conducted will influence the radiation dose to the patient, the operator and others who are required to remain in the fluoroscopic room during the procedure. Knowledge and understanding of the basic factors influencing patient exposure is necessary in order to carry out the fluoroscopic procedure effectively with a minimum amount of exposure to the patient, self and others.

The factors influencing patient fluoroscopic exposure are:

A. X-ray tube, X-ray equipment, and use of equipment

1. X-ray tube and X-ray equipment

   a. Milliamperage (mA)

   b. Kilovoltage (kVp)

   c. Collimation or X-ray beam restriction

   d. Filtration

   e. Source-to-image distance (SID) or target-to-tabletop or panel distance (TPD) (over-the-table and under-the-table X-ray tube)

   f. Patient-to-image intensifier distance

   g. Low absorption tabletop

   h. Exposure switch

   i. Primary protective barrier

   j. Bucky slot cover

   k. Protective curtains or drapes

2. Allowable exposure rates

3. Exposure time

4. Cumulative manual-reset timer

5. Light in the fluoroscopy room (illumination)

B. Image intensifier and image quality considerations

1. Image intensifier

2. Image quality considerations

a. Quantum mottle

b. Image and detector contrast

c. Resolution

d. Distortion

e. Lag

f. Vignetting

g. Magnification (geometric and electronic)

C. Ancillary equipment

1. Closed-Circuit Television Systems

a. Camera

b. Camera control unit

c. Monitor

2. Cinefluorography

a. Synchronization

b. Framing frequency

c. F-number of the optical system

d. Framing and patient radiation dose

3. Video disc recording/video tape recording

4. Pulsed fluoroscopy

5 High level control fluoroscopy

6. Spot films with conventional cassettes

7. Photospot (film) cameras/digital photospot cameras

8 Digital subtraction angiography

D. Contrast media

E. Accessories

1. Gonad shields and gonad shielding

2. Grids

3. Cassettes

a. Cassette fronts

b. Intensifying screens

F. Radiographic or X-ray film and film processing

1. Radiographic or X-ray film

2. Cine film

3. Optimum processing techniques

G. Patient and patient positioning

1. Patient

2. Absorption and scatter

H. Ancillary factors

1. X-ray generator design

2. Automatic Brightness control (ABC)

Many of the factors mentioned (such as the X-ray tube, filtration, or tabletop) cannot be influenced by fluoroscopist during the procedure. Other factors that influence patient and operator exposure can be changed or modified periodically.

The factors that directly influence the exposure rate at the panel or tabletop and the patient and the operator's radiation dose are:

1. Milliamperage (mA)

2. Kilovoltage (kVp)

3. Collimation

4. Filtration

5. Exposure time

6. Target-to-panel (tabletop) distance (TPD)

7. Patient-to-image intensifier distance for over-the-table and under-the-table image intensifier systems

8. Sensitivity of the image receptor

All of the following will reduce patient exposure:

- **Collimating to the area of clinical interest only (required by regulations)**
- **Using "last-frame-hold" or "last-image-hold" fluoroscopy**
- **Keeping the patient-to-detector distance or patient-to-image intensifier distance as short as practicable**
- **Using the highest kilovoltage (kVp) and lowest milliamperage (mA) practicable**
- **Pulsed fluoroscopy, particularly with lower frame rates**
- **Using the largest image intensifier mode (non-magnification) with strict collimation**

The factors which indirectly influence the exposure rate by impacting the use of technical factors are:

1. **Illumination or lighting in the fluoroscopy room**

2. **Image receptor quality; image monitor adjustments (brightness/contrast)**

3. **Absorption of tabletop**

Patient and operator shielding are also important considerations in reducing patient/operator exposure:

1. **Gonad shields**

2. **Bucky slot cover**

3. **Scatter from the patient (isoexposure curves)**

A. X-Ray Tube, X-Ray Equipment, and Use of Equipment.

1. X-Ray Tube.

Fluoroscopic X-ray tubes are similar to X-ray tubes used for radiography except that fluoroscopic tubes are often designed with a smaller focal spot and operate for a longer period of time at much lower mA (usually 1 to 3 mA). Radiographic and fluoroscopic tubes are used interchangeably.

X-rays are produced by energy conversion when a fast moving stream of electrons is suddenly decelerated in the "target" (anode) of the X-ray tubes (see pages 16).

a. Milliamperage (mA).

X-ray tube current is measured in milliamperes (mA). During image intensified fluoroscopy, tube currents of 0.5 to 5 mA (usually 1 to 3 mA) are used continuously with time as long as the fluoroscopy pedal is depressed. With spot films, the mA is typically over 100 but used with a short exposure time (usually 100 msec or less). **In fluoroscopy the X-ray output (and the patient radiation dose) is directly proportional to the mA used.**

b. Kilovoltage (kVp).

The X-ray tube voltage (kilovoltage - kVp) used determines the maximum photon energy or the peak value in kilo-electron volts (keV) of the X-ray beam produced (see page 38). Producing high-quality fluoroscopic examinations largely depends upon proper selection of peak kilovoltage, so that the adequate X-ray energy will result in maximum differential absorption by the tissue.

c. Collimation (X-Ray Beam Restriction, Area Exposed or Field Size).

Collimating the useful or primary X-ray beam to the area of clinical interest is required by law. It is one of the most important actions a fluoroscopist can take in order to avoid unnecessary radiation dose to the patient. The fluoroscopic image will not be brighter with a larger beam size. Image quality is improved as the size of the X-ray beam is reduced (well collimated). For automatic collimating devices, an unexposed border must be visible at all heights above the tabletop. Most fluoroscopic tubes are equipped with electronically controlled shutters that permit maintenance of close collimation from the fluoroscopy carriage during both fluoroscopy and spot filming.

d. Filtration.

X-ray tubes used in fluoroscopy are capable of operating at 125 - 150 kVp, therefore, the filtration must be at least 3 millimeters (mm) aluminum equivalent at these energies. Filters, usually made of aluminum, are located in the useful (primary) X-ray beam's path to preferentially absorb/eliminate the less penetrating X-rays before they reach a patient. Filtration is necessary to protect the patient's skin from receiving unnecessary radiation dose (see page 39). Total filtration includes also tabletop, patient cradle, or other material positioned between the X-ray tube and the tabletop.

e. Source-to-Tabletop Distance (STD) or Target-to-Panel Distance (TPD).

X-rays are produced when a fast moving stream of electrons hits a "target," generally made of tungsten. The target is the origin of the X-ray beam. Source-to-tabletop distance is of concern for both the under-the-table and over-the-table or C-arm (portable) units.

It has been established that a 18-inch target-to-panel distance is optimal for most fluoroscopic examinations; however, target-to-tabletop distance shall not be less than 12 inches and should be at least 18 inches. This is because patient dose decreases with increasing distance due to loss of low energy X-rays and energy intensity as determined by the inverse square law (see page 80).

f. Patient-to-Image Intensifier Distance.

For a fluoroscopic system equipped with an automatic brightness control (ABC) mechanism and where the X-ray tube is fixed **below** the table, moving the image intensifier away from the patient **increases** patient radiation dose, because fewer X-rays are intercepted at the image intensifier due to inverse square law losses (see page 80).

g. Low Absorption Tabletop.

Tabletops are made of material such as aluminum, Bakelite or carbon fiber that do not appreciably attenuate the passage of X-rays. Carbon fiber tabletops significantly reduce patient radiation dose where the X-ray tube is located under-the-table.

h. Exposure Switch.

The fluoroscopic exposure switch must be of the dead-man type (terminates exposure when pressure is released). **The conventional foot pedal is a dead-man type exposure switch.** Care must be taken not to accidentally activate the foot switch before or after examination when in operating mode.

i. Primary Protective Barrier.

The image intensifier assembly serves as a primary protective barrier and must be at least 2 millimeter of lead equivalent for equipment capable of operating above 125 kVp. The image intensifier must be coupled with the X-ray tube and interlocked so that the fluoroscopic tube cannot be energized when in the parked position.

j. **Bucky Slot Cover.**

During fluoroscopy, the Bucky tray is moved to the end of the examination table, leaving an opening in the side of the table approximately two inches wide at the fluoroscopist's gonad level. This opening must be automatically covered with at least 0.25 millimeters lead equivalent material [section 30307 (a) (11)].

k. **Protective Curtains (Drapes or Sliding Panel).**

Protective curtains or drapes of at least 0.25 millimeters lead equivalent shall be positioned between the fluoroscopist and the patient to intercept the scatter radiation coming from the patient for over-table tower image intensifier designs. The primary purpose of the protective curtains or drapes on a fluoroscopic table is to reduce radiation coming primarily from the patient because **scatter radiation from the patient at one foot from the patient could be as high as 500 millirads per hour.** (Note: Protective curtains or drapes are not required on C-arm systems.)

2. Allowable Exposure Rates (X-Ray Intensity).

For routine fluoroscopy, the exposure rate measured at the panel or tabletop shall be as low as practicable and **may not exceed five rads per minute**. This limit does not apply when using automatic brightness control (on large patients), during magnification procedures, or the recording of fluoroscopic images where higher exposure rates are allowed [section 30307 (a)(7)(A)].

3. Exposure Time.

The radiation dose to the patient and the operator is directly related to the duration (time) of exposure. Therefore, **you should restrict the X-ray beam "on" time to a minimum by using "on-off" rather than continuous "on" time. Doubling the exposure time also doubles the radiation dose to the patient and the operator.**

4. Cumulative Manual-Reset Timer.

A cumulative manual-reset timer, activated by the exposure switch that produces an audible signal or interrupts the X-ray beam when the fluoroscopy time has exceeded a predetermined time, must be provided. The timer records the amount of X-ray beam "on" time. **The predetermined time limit may not exceed five minutes** [section 30307 (a) (6)]. The cumulative timer is intended to serve as reminder to the fluoroscopist of how much total exposure time has been used. The **primary purpose** of the device that is used to indicate total fluoroscopy time is to assist in the protection of the patient from prolonged and unnecessary exposure to radiation.

5. Illumination (Lighting in the Fluoroscopy Room).

Since fluoroscopy is a dynamic imaging process, the fluoroscopist's eyes must adapt to perceiving images that may be dim. Fluoroscopists must therefore have a knowledge and understanding of image illumination and visual physiology (see Appendix No. 1, Visual Physiology, page 77).

For image intensified fluoroscopy, the room lighting should be dim to enhance visualization of the black and white television images. Excessive light decreases the ability of the eye to resolve detail on the television screen and thus may indirectly cause the fluoroscopist to change technical factors to produce a brighter image. Increasing the technical factors (mA, kVp) will increase patient radiation dose. The luminance (brightness and contrast of the TV screen) must also be adjusted properly.

B. Image Intensifier and Image Quality Considerations.

1. Image Intensifier.

a. Function.

In fluoroscopy, those X-rays which penetrate and exit the patient (remnant radiation) strike the image intensifier's **input phosphor**. The input phosphor is a layer of fluorescent material that absorbs X-rays and converts their energy into light photons. The light photons are immediately absorbed by the **photocathode** causing **electrons** to be given off in direct proportion to the intensity of the fluorescent light. The electrons are sped up by the **accelerating anode** and focused with little geometric distortion by **electrostatic lenses** onto a second and smaller fluorescent layer of material called the **output phosphor**. The output phosphor (screen) absorbs electrons and emits light photons, which then are available for viewing or further electronic processing by a video system.

b. Brightness Gain.

Brightness gain in the image intensifier is achieved by acceleration of the electrons (electronic gain) and by minification of the output image (minification gain). The product of these two factors results in the total gain of the image intensifier.

2. Image Quality Considerations.

a. Quantum Mottle.

The number of X-ray photons which reach the input phosphor of the image intensifier determine the statistical quality of an imaging system. **Statistical fluctuation occurs when the number of absorbed photons is low and manifests itself in the fluoroscopic image as quantum mottle, a sort of grainy or blotchy appearance.**

The visibility of mottle is determined by the resolution, sensitivity, and contrast level of the system in use. The mottle level can be adjusted by changing exposure factors (kVp and mA). Increasing exposure increases the number of available X-ray photons, which decreases statistical fluctuations. Most fluoroscopists use 2 to 5 mA in the manual mode for adult abdominal fluoroscopy to maintain adequate X-ray photon stability in the final image.

b. Contrast.

There are two components of contrast. One is "subject" contrast, which is chiefly determined by the kVp (energy of the X-ray beam). In general, subject contrast is reduced with high kVp X-ray beams. The other is "detector" contrast, which is determined by the characteristics of the image intensifier, the type of TV camera target (e.g., vidicon, plumbicon), the amplitude of the output image brightness/ video signal, and the brightness/contrast settings of the monitor to optimize the signal-to-noise ratio.

c. Resolution.

The primary limitation of resolution is the 525-line raster pattern of the video monitor in common fluoroscopic systems. Higher resolution video (e.g., 1000-line systems) provide better resolution.

Resolution is the ability of the imaging system to differentiate small objects as separate images when they are close together. **Resolution is measured in line pairs per millimeter (lp/mm).** The overall resolution of an imaging system is expressed in terms of its modulation transfer function (MTF).

d. Distortion.

Size distortion is caused by the same factors that affect static radiographic magnification, primarily object-to-image distance (OID). **Shape distortion** is caused primarily by geometric problems in the shape of the image intensification tube. Although the input screen is convex, it does not completely eliminate edge distortion at the output screen. The effect is called **pincushion distortion** and may comprise 8-10 percent of the image area, mainly at the periphery of the image.

e. Lag.

Another image quality problem that occurs with fluoroscopic systems which utilize vidicon television cameras is the blurring of the image as the camera is moved rapidly during an imaging procedure. This blurring or "lag" occurs because it takes a certain amount of time for the image to build up and decay on the vidicon target.

f. Vignetting.

The peripheral image is displayed over a larger area of the output screen, and thus its brightness gain is less than that in the center. **A fall-off in brightness at the periphery of an image or image brightness loss at the edges of the image is called vignetting.** Vignetting causes image intensity to be greater at the center of the image and less at the edges.

g. Multi-Mode Intensifier Tubes (Magnification Tubes).

Image intensification tubes can be designed to magnify the image electronically by changing the voltage on the electrostatic lenses. In other words, the component in the image intensifier that changes the field of view from the standard to magnification mode is the electrostatic lens. Proportional increase of voltage to the electrostatic lenses (focusing lenses) further compresses the electron beam. This results in a smaller input surface and image magnification, which is due to the fact that the crossover point now if further away from the output phosphor (see Figure 8, page 19). There are dual-field, triple-field and quad-field intensifiers available. Image intensifier resolution can be increased from about 4 line pairs per millimeter (lp/mm) to about 6 lp/mm when the magnification mode is used.

C. Ancillary Equipment.

1. Closed-Circuit Television Systems.

Fluoroscopic television systems are closed-circuit systems; that is, the video signal is transmitted from one component to the next through cables rather than through the air, as in broadcast television.

a. Camera.

The vidicon camera is the type usually employed in diagnostic fluoroscopy. The vidicon camera has a vidicon tube, a small electronic vacuum tube which contains the vidicon (photoconductive) target and the electron gun. The electron gun produces the scanning electron beam that is focused onto the vidicon target. Light intensity makes the target conductive, allowing a proportional electron charge to be generated for that particular position. This charge is converted into a proportional voltage which is sent to the camera control unit where synchronization timing pulses are attached to produce the "video signal." The video signal is then connected to the television monitor, whereby the video signal is decoded into an image, typically consisting of 525 horizontal lines of dots. These 525 lines represent the total number of lines in the entire picture, regardless of the size of the television screen.

b. Camera Control Unit.

The second component of a closed-circuit television system is the camera control unit. It contains the power supply and all the controls that regulate the camera. It amplifies the video signal, regulates the focusing, and synchronizes the video signal between the camera and monitor. This is to retrace the exact image on the television monitor as seen from the output phosphor through the vidicon.

c. Monitor/Television Tube.

The final link in the closed-circuit television system is the monitor. It contains the picture tube called Cathode-Ray-Tube (CRT) and the controls for regulating brightness and contrast. The television image is stored as an electrical image on the target of the vidicon tube, and it is scanned along 525 lines by a narrow electron beam 30 times per second. Each scan of the entire target is called a frame. It is necessary to synchronize or coordinate the video signal between the camera and the monitor to avoid unnecessary flicker in the television picture. The dots are arranged in horizontal scan lines. In the United States, most fluoroscopy and all commercial television systems use 525 scan lines per image. These 525 lines represent the total number in the entire image, regardless of the size of the television screen. Newer systems are available with 1000 scan lines per image.

2. Cinefluorography.

a. Synchronization.

Synchronization is the operation of camera shutters at the same frequency as X-ray pulses. X-ray production is synchronized so that there is no exposure made while the cine film is being transported from frame to frame.

b. Framing Frequency.

Framing frequency, or the number of frames of film per second (f/s), in cinefluorography is usually a division of 60 (7.5, 15, 30, 60, 90, 120). This framing sequence provides the motion aspect as the operator later views the examination on the cine projector. However, the higher the frame rate sequence, the higher dose will be applied to the patient during the examination.

c. F-Number.

The speed of any given camera system depends on the ability of its lens to concentrate light on a given area of the cine film and is denoted by the lens' "f-number." The higher "f-number" means that less light is available to form the image on the cine film.

d. Framing and Patient Radiation Dose.

Patient radiation dose increases as the framing frequency (frame rate) increases.

3. Video Disc Recording.

Video disc recording, when properly interfaced to the fluoroscope by a technique referred to as **electronic radiography**, combines some of the advantages of both fluoroscopy and radiography, namely, the instantaneous image associated with fluoroscopy coupled with the short exposure time associated with a radiograph. In this technique, the use of the electronic radiography function permits fluoroscopic radiation to continue only long enough to build up a useful image on the display monitor and television camera tube. The image is stored as a single television frame on the video disc recorder. Immediately after storage of the image, the exposure is terminated automatically by the equipment even though the operator continues to stand on the foot switch. Newer systems use a solid-state frame buffer and computer memory instead of a video disk. **Manufacturers report up to 95 percent dose reduction when utilizing video disc recording during fluoroscopy.**

4. Video Tape Recording.

Video tape recorders have two advantages over cinefluorography: (1) the image is available for instant replay without any intermediate processing system, and (2) the patient's exposure to radiation is not increased. Video tape also has disadvantages, the most important being relatively poor image quality. Another disadvantage of video tape is its fixed frame speed (30/sec in the United States).

5. Spot Films with Conventional Cassettes.

Most fluoroscopic examinations are accompanied by "spot filming" when permanent images are necessary to make medical diagnosis. The cassette is positioned between the patient and the image intensifier. These images have the best resolution because they are made using higher mA (100 or more) with short exposure time to reduce patient motion, and are acquired with very high resolution screen-film cassette detectors.

6. Spot Film Cameras – "Photospot" Cameras.

Spot film cameras photograph the image coming from the output phosphor of the image intensifier on small format film. Utilization of the spot film camera requires about 1/2 to 1/3 the dose of film cassette spot films. These systems use a higher mA (not as high as the cassette spot film) and short exposure time. Thus, spot films taken with spot film cameras can result in substantial dose reduction to the patient when compared to the spot films using conventional radiographic cassettes. However, the image quality is inferior to the one made on conventional cassettes.

D. Contrast Media.

Contrast media are composed of relatively low toxicity materials such as barium or iodine which also possess high atomic numbers and thus decrease the transmission of X-rays. Use of optimal kVp is necessary for proper differential attenuation of the X-ray photons to achieve good image contrast.

E. Accessories.

1. Gonad Shields and Gonad Shielding.

Suitable protective devices must be used to shield/protect gonads in potentially procreative patients when gonads cannot be excluded from the useful X-ray beam and the shielding of gonads does not interfere with the diagnosis.

2. Grids.

The function of a radiographic grid is to reduce the scattered radiation produced in the patient (part being X-rayed) before it reaches the image intensifier or the X-ray film. In fluoroscopy, low ratio grids (e.g., 8:1 ratio) are typically used and are positioned prior to the input layer of the image intensifier.

3. Cassettes.

A cassette is a thin, light-tight X-ray film holder containing intensifying screens mounted within front and spring-loaded back structures (covers) which are hinged together.

a. Cassette Fronts.

The front surface of the cassette must be made of material that has a low atomic number such as carbon fiber, cardboard, Bakelite, or aluminum.

b. Intensifying Screens.

Today X-ray films are exposed in a cassette with intensifying screens. The intensifying screens convert the energy of the X-ray beam into visible light which then exposes the X-ray film.

3. Radiographic or X-Ray Film and Film Processing.

a. Radiographic or X-Ray Film.

Spot filming with conventional cassettes is performed on so-called screen films in cassettes using intensifying screens. X-rays that strike the intensifying screens are converted into light (fluorescence). The fluorescence from the screen exposes the film, and forms an invisible "latent image." Subsequent film processing produces the optical density patterns of the film image.

b. Cine Film.

Two film sizes of either 16 or 35 mm are available. The 35 mm film size involves more patient exposure than 16 mm but produces images of higher quality. Nearly all cinefluorography is done on 35 mm film and involve studies of the heart. Due to high framing frequencies patient radiation dose in cinefluorography are significantly greater than with other types of image recording systems. On a per frame basis, cine radiography delivers approximately 10 times more dose than fluoroscopy for the same kVp used for the examination.

c. Optimum Processing Techniques.

In order to produce satisfactory cine films or spot films taken with conventional cassettes, the darkroom, the processor, and the processing techniques must be of optimum quality. Film processing must be done according to the film manufacturer's recommendations. Also, processor quality control checks must be accomplished on a daily basis prior to acquisition and processing of patient images.

F. Patient and Patient Positioning.

1. Patient - Human Body.

The human body is made of muscle, fat, bone, air passages and compartments of fluid. The different thicknesses of these components and different combinations of them will result in a differential absorption across the exposure field. Thus, the patient's physique, the type of pathological process and the type of tissue exposed will determine a patient's radiation dose.

Tissue density is an important factor affecting attenuation and absorption. The image contrast is largely dependent upon differences in tissue density. Thus, high contrast between air and soft tissues is created entirely because of density differences. Disease processes alter tissue densities. Skin pigmentation does not influence exposure factors.

Elemental composition (the atomic number) of the tissues is also an important factor affecting attenuation and absorption. Higher atomic number materials (e.g., calcium in bones, iodine and barium in contrast agents) will absorb considerably more X-rays than the surrounding tissues.

In passing through the patient, most of the photons will interact, and only about 5 percent of the incident photons will emerge from the patient unaffected. These remaining photons or remnant X-rays form the resulting image.

The following chart shows comparison of physical characteristics of air, fat, water, muscle, bone, aluminum, and lead:

Material	Effective atomic number	Density (g/cm^3)	Abundance in human body (in percent)
Air	7.64	0.00129	
Fat	5.92	0.91	14.0
Water	7.42	1.00	
Blood	7.42	1.00	7.7
Bone marrow	7.42	1.00	4.2
Muscle	7.42	1.00	43.0
Organs	7.42	1.00	12.4
Subcutaneous tissue	7.42	1.00	5.8
Skin	7.42	1.00	2.9
Bone	13.80	1.85	10.0
Aluminum	13.00	2.70	
Lead	82.00	11.00	

Our discussion of attenuation has only dealt with primary radiation, which either passes through the patient unchanged or is completely removed from the useful X-ray beam. The primary radiation that exits the human body, called **remnant radiation**, consists of non-interacting and small-angle scattered photons, and carries the X-ray image.

The entrance skin dose for the patient is the surface closest to the X-ray source. With an undertable unit the entrance skin dose is measured from the surface next to the tabletop. With an over-table unit it is measured from the surface toward the fluoroscopy carriage. The minimum source-to-skin distance is 12 inches (30 centimeters) for mobile fluoroscopic equipment and **should be** at least 18 inches (45 centimeters) of stationary fluoroscopic equipment.

2. Absorption and Scatter.

When an X-ray photon interacts with matter, it is either absorbed and removed from the beam or scattered. **In fluoroscopy the patient (body part being fluoroscoped) is the main source of scattered radiation.** Scattered radiation is produced primarily by Compton interactions.

Factors affecting an increase in scattered radiation are:

- o High kilovoltage (kVp) used
- o Large field size (area exposed)
- o Thick body part (volume exposed)

F. Ancillary Factors.

1. X-Ray Generator Design.

Generators available for X-ray systems include single-phase, three-phase, medium/high frequency, and constant potential designs. There are certain technical advantages of three-phase generators and medium/high frequency generators over one- or two-phase generators such as:

- o Relatively high mA available
- o High effective kilovoltage
- o Near constant potential

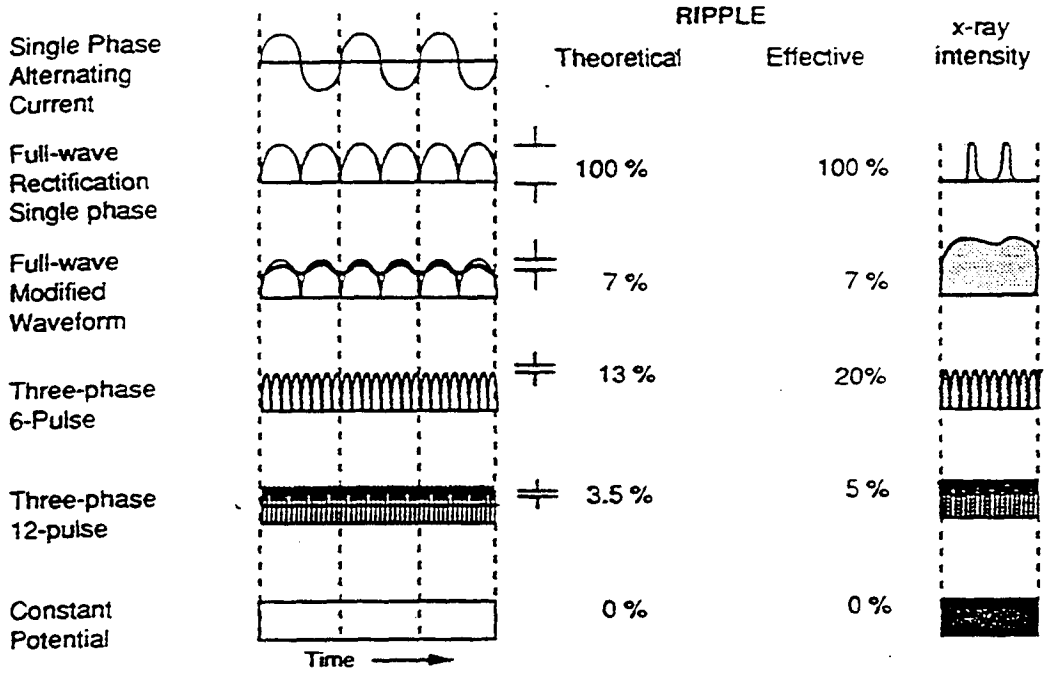

Figure 1. Tube current and X-ray intensity diagrams.

Alternating voltage output from the X-ray transformer is converted into direct current by means of full-wave rectification. Short pulses of X-ray intensity are produced by the single-phase generator, whereas steady X-ray intensity results from the constant potential system.

CHAPTER III

FLUOROSCOPY AND ANCILLARY EQUIPMENT - TECHNICAL CONSIDERATIONS

A. Fluoroscopic Image Production.

Today all modern fluoroscopes utilize image intensifiers, which make the fluoroscopic images brighter, and the image is viewed usually on a television (TV) monitor (see Figures 2 and 3).

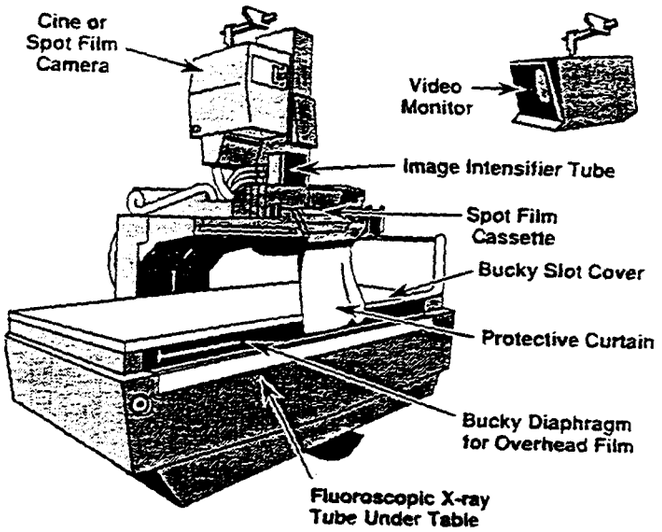

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Figure 2. Fluoroscope and associated parts.

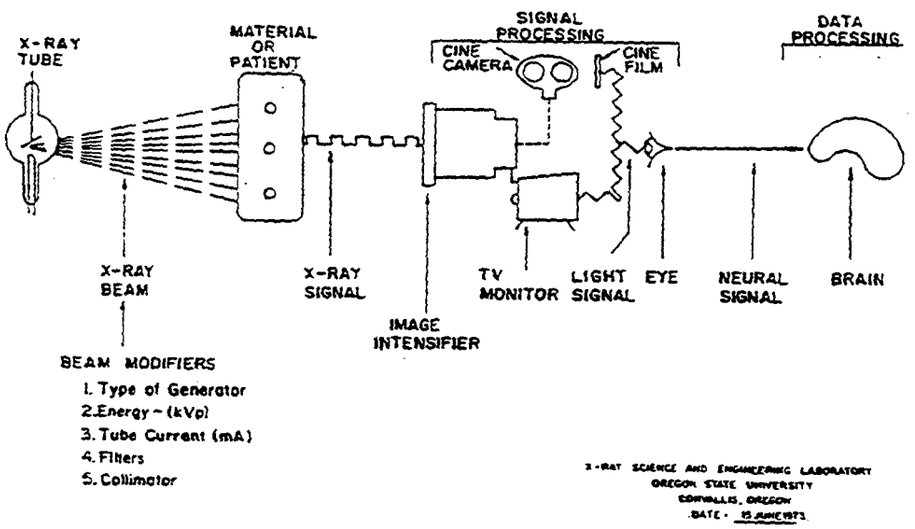

Figure 3. Cine radiography with television (TV) monitoring.

In image intensified fluoroscopy, the fluoroscopic unit has two basic components:

1. X-ray tube, and
2. Image intensifier.

1. X-Ray Tube.

The X-ray tube is a standard rotating anode tube (see Figure 4), identical to those X-ray tubes used for radiography, except that for fluoroscopic purposes it is operated at a much lower tube current of up to 5 mA, but preferably below 3 mA, as compared to 100 to 500 mA or even higher for radiography. The X-ray tube is operated with the small focal spot during fluoroscopy to obtain detailed diagnostic information. Tube heating and loading is not a problem with these low mA values.

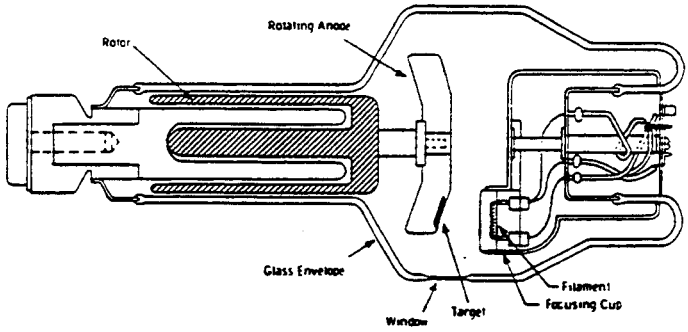

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Figure 4. The major components of a rotating anode X-ray tube.

The X-ray tube contains two important parts, a **cathode**, which serves as the source of the electrons, and a rotating **anode**, which is the **target** that produces the X-rays. In an X-ray tube, a stream of electrons (from the cathode filament usually made of tungsten) is accelerated under a high potential difference (from ~50 to 150 kilovolts) against a target (the anode). The high velocity electrons possess kinetic energy, and are stopped when they hit the target. Although most of their energy is transformed into heat, a small amount of incident energy is transformed into X-rays.

The cathode consists of a tungsten filament wound in a coil, and is set about an inch from the anode. When the filament is heated and a very high potential (measured in kilovolts or kV) is applied between the cathode and anode, electrons are emitted from the cathode and are accelerated toward the anode.

The anode in the X-ray tube is a rotating tungsten disc designed to distribute intense heat efficiently over a large area. Tungsten has a high melting point and a high atomic number and thus is a more efficient producer of X-rays than other metals. When the accelerated electrons strike the tungsten target some of their kinetic energy is converted into X-rays.

2. Image Intensifier.

The function of the X-ray image intensifier tube is to convert an X-ray flux into a minified light image, or, in other words, to electronically amplify the brightness of an image.

There are four principal components of an image intensifier (see Figure 5, page 17):

- A vacuum bottle/glass envelope to keep the air out and to provide airtight environment
- An input layer that converts the X-ray photons (signal) to electrons
- Electronic lenses that focus the electrons
- An output phosphor that converts the energy of the electrons bombarding it into visible light

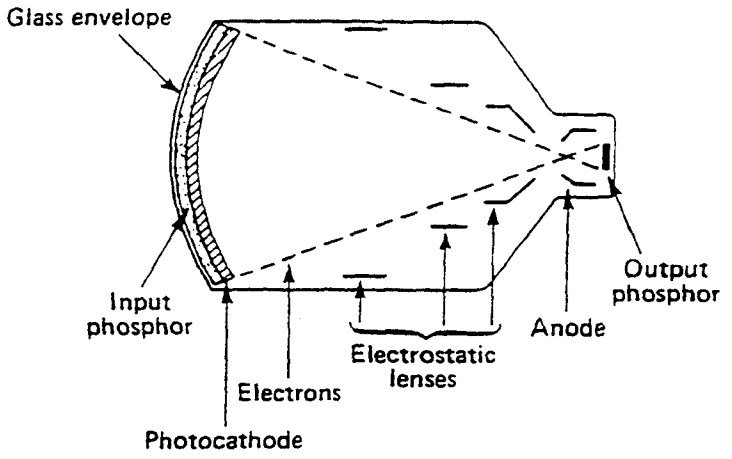

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Figure 5. Image-Intensifier Tube.

When X-rays are directed onto a patient, most are absorbed by the patient (especially by dense structures, such as bone) while some pass through the patient. In fluoroscopy, those X-rays which penetrate the patient and exit the patient (remnant rays) then strike the image intensifier's **input phosphor**, which is a layer of fluorescent material (see Figure 5). This layer of fluorescent material absorbs X-rays and converts their energy into light photons proportional to the intensity of the X-ray beam. The light photons impact on the **photocathode** causing **electrons** to be given off by photoemission or photoelectric emission in direct proportion to the intensity of the fluorescent light. The electrons are speeded up by the accelerating anode, maintained at a very high potential difference (about 25,000 volts) and focused without geometric distortion by **electrostatic lenses** onto a second and smaller fluorescent layer of material called the **output phosphor**.

When the speeded up electrons strike the output phosphor their energy is converted back into light photons. The output phosphor is thousand of times brighter than the input phosphor because of its smaller size and the additional energy given to the electrons when they are accelerated through the image intensifier. The ability of the image intensifier tube to increase the illumination level of the image is called its **brightness gain** which is the product of:

a. the minification gain, and
b. the flux gain.

a. Minification Gain.

Minification gain occurs as a result of the same number of electrons that were produced at the large input phosphor (screen) being compressed into the area of the small output phosphor (screen). The minification gain is calculated as the ratio between the area of the input and output screens:

$$\text{minification gain} = \frac{(\text{input screen diameter})^2}{(\text{output screen diameter})^2}$$

Minification gain is simply an increase in brightness or intensity, not an improvement in the quality or number of X-ray photons making up the image.

Example: The minification gain achieved by an image intensifier with a 12-inch input phosphor and a 1-inch output phosphor is approximately 144.

Note: Most modern image intensifiers are constructed with 1 inch output phosphor.

b. Flux Gain.

Flux gain is a measurement of the increase in light photons due to the conversion efficiency of the output screen. (Flux gain does not take into account the conversion efficiency of the input screen.) The flux gain deals only with the gain accomplished by the electron to light conversion at the output screen. Flux gain varies from 50 to 150, depending on manufacturer's specifications.

c. Total Brightness Gain.

Total brightness gain can be calculated as a function of minification gain and flux gain:

brightness gain (B.G.) = minification gain x flux gain

Example: What is the brightness gain of an image intensifier that has 9-inch input phosphor, 1-inch output phosphor, and has 50 gain flux?

B.G. = 81 x 50 = 4050

Brightness gain can deteriorate or degrade as much as 10 percent per year due to the "aging" of the input and output screen phosphors. Because of this degradation, a periodic check of brightness can be made by measuring the conversion factor.

The measure of the brightness gain is a **conversion factor** that is the ratio of the intensity of the output phosphor to the input exposure rate to the input phosphor:

$$\text{conversion factor} = \frac{\text{intensity of output phosphor (measured in candelas or cd)}}{\text{millirads/second}}$$

d. Beam Splitter Mirror.

The beam splitter mirror typically allows 10 percent of the output phosphor light image to be scanned by the vidicon, and 90 percent the output phosphor light to be projected towards the cine camera, photospot camera, or direct viewing through the mirror that is found outside the older generation image intensifiers.

The light photons from the output phosphor are viewed through a variety of suitable optical systems (usually a television camera), or photographed (see Figure 6). The best image resolution and brightness is found at the center of the image intensifier (see Figure 7, page 19).

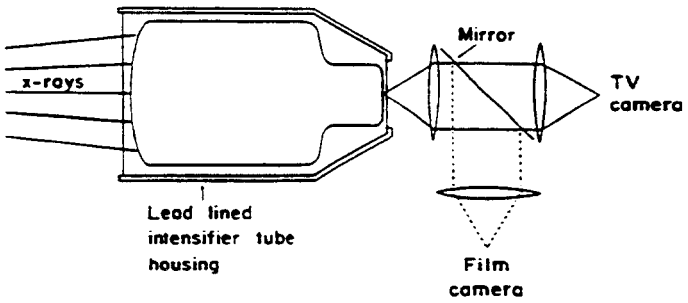

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Figure 6. Optical coupling between an image intensifier, viewing and recording systems.

The component in the optical coupling distributor that controls the exposure incident at the input phosphor for cine or photospot film imaging is the aperture, which is similar to that found in a regular 35 mm camera. The size of the aperture is defined by the lens' f-number - the greater the f-number, the smaller the size of the aperture.

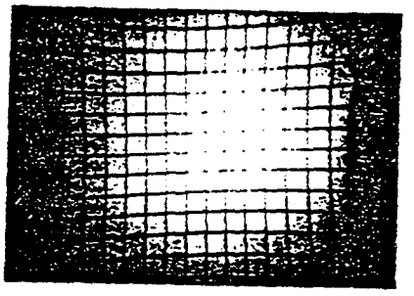

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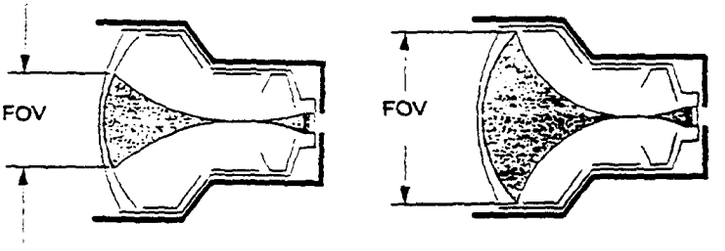
Figure 7. Test film of a wire screen from a 9-inch image intensifier illustrating that the center of the output screen is brighter and the resolution better at the center of the screen.

The X-ray tube and the image intensifier must maintain constant alignment during imaging procedures. The fluoroscopic unit must be so constructed that the image intensifier intercepts the entire useful beam [section 30307 (a)(4)]. This may be accomplished either electronically with alignment sensor switches or by the use of a "C-arm" or "U-arm" which physically maintains constant alignment between the X-ray tube and the image intensifier.

A fluoroscope is often operated for a period of time up to several minutes per examination, as opposed to a fraction of a second for routine radiography. Also, fluoroscopic image quality is poor compared to radiographs, and, unless recorded on video tape, cine film or video disc, or conventional cassette, the image is not permanent. For these reasons, fluoroscopy should be reserved to study dynamic procedures and should **never be used when lower exposure radiography can provide the needed information**.

B. *Multifield (Dual-focus and Trifocus) Image Intensifier Tubes.*

Field size on the input phosphor is changed by applying a simple electronic principle: the higher the voltage on the electrostatic focusing lens, the more the electron beam is focused (see Figure 8), while the output phosphor size remains constant (1 inch).



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FOV - Field of view.

Figure 8. Normal operation and magnification mode.

Magnification with an image intensifier is achieved by applying different voltages to the electronic lens site. In magnification mode, only the electrons emitted from a small diameter circle are focused on the output phosphor. Because a smaller portion of the image is enlarged to the full output window, this results in a magnified image of the object.

If the center of the image intensifier has better resolution and less geometric distortion it follows that a small image intensifier, that encompasses only the central, more accurately focused electrons, produces a better-quality image than a large unit. Dual-field image intensifiers utilize this concept to resolve the conflict between image size and quality. They can be operated in either a 6- or 9-inch input phosphor mode.

The 9-inch mode is used when it is necessary to view large anatomic areas. When size is unimportant, the 6-inch mode is used because of better resultant image quality. The physical size of the output phosphor is the same in both modes. In the 6-inch or magnification mode, the useful area of the input phosphor is decreased while the output phosphor remains the same size, thus increasing the effective magnification of the resultant image. Concurrently, the collimator must automatically reduce the X-ray field to the useable input phosphor area. The 6-inch mode has a reduced minification gain with fewer photoelectrons incident on the output phosphor. A dimmer image is the result. With automatic brightness control (ABC) the mA is automatically increased when the unit is used in the 6-inch mode to compensate for the decreased brightness. Thus, patient dose also increases. In general, a single-mode unit can outperform a dual-mode intensifier of any given size. The advantage of the dual mode is versatility. Triple mode and quadruple mode image intensifier's are also common.

The 6- and 9-inch modes have different magnification gains. Exposure factors are automatically increased when the unit is used in the magnification mode to compensate for the decreased brightness.

The ratio of patient radiation dose is calculated using the following formula:

$$\frac{(\text{Normal mode size})^2}{(\text{Magnification mode size})^2} = \text{Increase in patient radiation dose}$$

Example: When operating the image intensifier in the magnified 6-inch mode from the normal 9-inch mode, the patient will receive how many times more radiation dose?

Answer: $\frac{(9)^2}{(6)^2} = \frac{81}{36} = 2.25$

C. Image Quality Considerations.

The number of absorbed X-ray photons (by the system components) determines the statistical quality of an imaging system. Image quality of the image intensifier system is affected by:

1. Quantum mottle (sometimes called quantum noise or scintillation).
2. Contrast.
3. Resolution.
4. Distortion.

1. Quantum Mottle.

Quantum mottle is a grainy appearance in an image caused by statistical fluctuation of absorbed X-ray photons. Mottle is more visible in a high resolution, high contrast system.

The number of photons in an X-ray image cannot be decreased indefinitely even though patient radiation doses would also be decreased. A large decrease in the number of X-ray photons would cause a serious deterioration of image quality (see Figure 9).

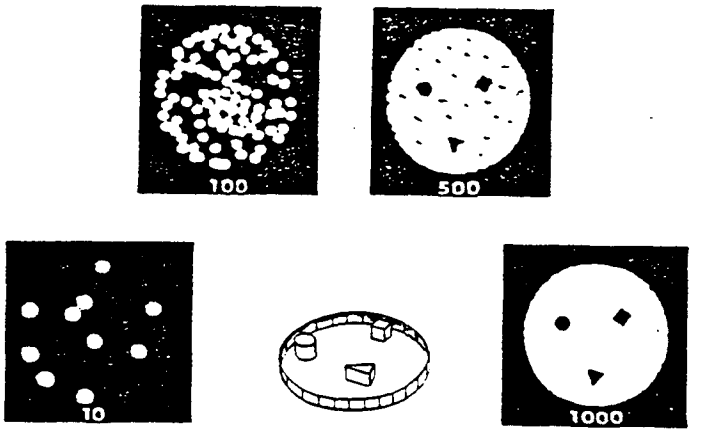

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Figure 9. The "pennies-in-the-hat" model illustrating the concept of quantum mottle.

Eventually a point is reached at which there are not enough photons to produce an image. The fluoroscopic X-ray image is usually close to that point. The mottle level can be adjusted by changing exposure factors (kVp and mA). Increasing exposure increases the number of absorbed and remnant beam photons, which decreases statistical fluctuation. Most fluoroscopists use 2 to 3 mA in the manual mode for adult abdominal fluoroscopy to maintain adequate statistics.

2. Contrast.

Overall contrast in the image is dependent upon subject contrast (determined by the relative attenuation of the tissues dependent upon kVp) and detector contrast of the image intensifier and the TV camera. The ratio of brightness between two adjacent areas of a fluoroscopy image is called intensifier contrast. One method of determining detector (intensifier) contrast is to take the ratio of the brightness in the open field at a given exposure to the brightness underneath a lead disk covering 10 percent of the useful central imaging area in a second exposure. Contrast ratios for modern image intensifiers exceed 15:1. Contrast is definitely better with cesium iodide tubes than with older zinc-cadmium sulfide tubes.

These factors tend to diminish contrast in image intensifiers:

- The input phosphor does not absorb all the photons in the X-ray beam. Some are transmitted through the intensifier tube and are eventually absorbed by the output phosphor. These transmitted photons contribute to the illumination of the output phosphor but not to image formation. They produce a background of fog that reduces image contrast in the same way that scattered X-ray photons produce fog and reduce contrast in a radiographic image.

- Retrograde light flow from the output phosphor can also diminish contrast. This retrograde light activates the photocathode that emits photoelectrons bearing no relationship to the principal image.

- Similarly, the output phosphor is transparent to light photons that spread within the structure before visualization or detection. These electrons and light photons produce "fog" and further reduce image contrast. **Contrast tends to deteriorate as an image intensifier ages.**

3. Resolution.

Resolution is the ability of the imaging system to differentiate small objects as separate images as they are positioned close together. Resolution can be measured in object size visible, or in "line pairs per millimeter." The relationship between object size and line pairs per millimeter is inversely related: as the object size becomes smaller (better resolution), the spatial frequency becomes higher. The overall resolution of an imaging system is usually expressed in terms of its **modulation transfer function (MTF) as a function of spatial frequency.** A "perfect" system would have an MTF of 1 at all frequencies; however, at any given frequency (number of line pairs/mm), the MTF of a "real" system is a specific number that is less than one at higher spatial frequencies (smaller object sizes). The overall MTF of a system is the product of the MTF of each of the component parts that comprise the imaging system, for example the image intensifier and the TV camera. Limiting resolution of a system is defined as the value in line pairs per millimeter at an MTF value of about 0.05. The limiting resolution of zinc-cadmium image tubes is approximately 1 to 2 line pairs per millimeter (lp/mm), which is a little less than the resolution of a conventional fluoroscopic screen. The apparent improvement that the fluoroscopist observes is entirely from the increased visual acuity of photopic vision. The resolution of cesium iodide image tubes is approximately 4 lp/mm, a dramatic improvement over zinc cadmium sulfide. The individual cesium iodide crystals are somewhat aligned, channeling the produced light down the crystal "pipe," minimizing light spread and allowing a thicker phosphor layer, both contributing to improved resolution as well as improved detection efficiency. The central portion of the image intensifier possesses the greatest resolution.

4. Distortion.

In the present state of development, electron focusing is not uniform across the entire field of an image intensifier. Electrons at the center of the unit are more accurately focused than those at the periphery. Peripheral electrons tend to flare out from an ideal course. The result is unequal magnification, which produces peripheral distortion. The amount of distortion is greater with large intensifiers because, the further an electron is from the center, the more difficult it is to focus.

Pincushion distortion is a form of spatial distortion that warps the appearance of the image. It is a consequence of projecting the image formed on a curved input phosphor to a flat output phosphor. Pincushion distortion results in slightly higher magnification of the input image toward the edge of the image. The amount of pincushion distortion is usually determined by imaging grid or screen with regular rectangular spacing. This is illustrated in Figure 10.

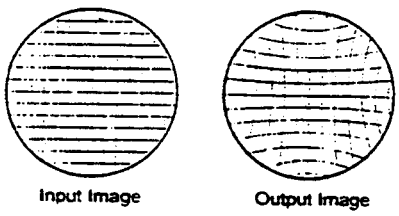

Figure 10. Pincushion distortion.

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Pincushion distortion results because the input phosphor is curved but the output phosphor is flat. This results in a warped image, which bends straight lines inward. The pincushion distortion is exaggerated in the Figure 10. Pincushion distortion is reduced when magnification modes are used. Another image quality problem that occurs with fluoroscopic systems that utilize vidicon television cameras is the blurring of the image as the camera is moved rapidly during an imaging procedure.

The blurring or "lag" occurs because it takes a certain amount of time for the image to build up and decay on the vidicon target. In one respect a certain amount of lag is actually advantageous. This is because lag averages out the statistical fluctuations that normally occur with low dose fluoroscopy, thus minimizing the annoying effects of quantum mottle.

5. Vignetting.

Unequal magnification also causes unequal illumination. The center of the output screen is brighter than the periphery. The peripheral image is displayed over a larger area of the output screen, and thus its brightness gain from minification is less than that in the center. A fall-off in brightness at the periphery of an image is called vignetting. Unequal focusing has another effect on image quality; that is, resolution is better in the center of the image intensifier.

The brightness, as measured at the output phosphor, will vary from the center to the periphery of the image, even when a homogeneous X-ray field is incident upon the image intensifier. The brightness will be the greatest toward the center of the image and will fall off at the edges. One source of vignetting is a consequence of pincushion distortion. With pincushion distortion, the image is magnified to a greater extent toward the periphery. Vignetting also occurs in the optical coupling between the image intensifier and recording device, because of scattered light effects. The peripheral image is displayed over a larger area of the output screen, and thus its brightness gain from minification is less than that in the center. Distortion is minimized and contrast is improved at the center of the fluoroscopic image.

6. Veiling Glare.

Veiling glare is mainly the consequence of light scatter in the output window of the image intensifier. The scattered light, just like scattered radiation, adds to the background signal and reduces the contrast in the image. Veiling glare can be reduced by purchasing an image intensifier with advanced output window designs. For a given image intensifier, not much can be done about the presence of veiling glare. The contrast ratio is a good way to quantify the magnitude of the problem.

D. Automatic Brightness Stabilization; Automatic Brightness Control.

The automatic brightness stabilizer (ABS), also known as automatic brightness control (ABC), is the part of the fluoroscopic control system that keeps the light output of the image intensifier constant over variations of patient attenuation (part thickness and density) and system geometry. Portions of the system may be shared with automatic exposure control systems which maintain constant film density of cinefluorographic or fluoroscopic spot films. The ABS circuit interfaces with the X-ray generator to adjust the kVp and the mA in a fast-acting feedback loop.

A properly designed automatic brightness stabilizer (ABS) must accomplish the following objectives:

- Hold the image brightness constant for variation of patient thickness and attenuation
- Ignore information at the image margins
- Operate to preserve image contrast and minimize image noise
- Keep the operation within ratings of the X-ray tube
- Effect a reasonable compromise between patient radiation dose and image quality
- Keep the patient radiation dose within the California Radiation Control Regulations requirements of ten rads/min, except when an override mode or boost mode is selected
- Respond fast enough to track during an examination but slow enough to avoid hunting between bright and dark portions of the image
- Be capable of being disabled or held at a particular setting prior to injection of contrast media
- Be capable of being shut off to permit the manual control of factors
- Display the operating factors and modes of operation to the fluoroscopist

1. Variations With X-Ray Factors.

Operation of the system at higher kVp values will result in increased transmission of the beam through the patient so that less radiation is required. The brightness of the image varies directly with mA and approximately the square of the kVp change. Thus, if the kVp would vary from 80 to 88, a 10 percent change, a 100 percent change (a doubling) of brightness would occur, and the ABS would respond by reducing the mA by approximately a factor of 2 to maintain the output brightness.

It is important to note that image contrast degrades as kVp is increased. Therefore, the automatic brightness stabilization system (ABS) should be operated at higher kVp values for reduced patient radiation dose and at lower kVp values for best image contrast. When viewing low contrast objects in fluoroscopy the system should be operated at the lower kVp values. This is particularly true when using iodine-based contrast media as in cholecystography, arthrography, and arteriography. When examining the gastrointestinal tract, particularly when using barium-based contrast media, operation at high kVp is advisable for reduced patient radiation dose.

2. Brightness Sensing.

Image brightness can be sensed in the following ways:

a. Image Intensifier Photocathode Current.

The photocathode of the image intensifier can be connected to a current amplifier so that the amplifier output is proportional to the radiation input to the intensifying tube.

b. Television Camera Signal Sensing.

Most television cameras have automatic gain control (AGC) circuits for controlling the camera tube target voltage or the gain in video amplifier in order to provide a constant output signal over variations of image brightness. The automatic gain control (AGC) can be used to control the generator as well.

c. Lens-coupled Phototube Sensing.

This method uses a lens often combined with a prism or mirror so that the collimated light from the image intensifier is sampled and the image of the output phosphor is formed over an aperture placed in front of a photomultiplier tube.

The lens-coupled phototube sensing system will compensate for coning effect, field-size changes, and mode changes of the image intensifier tube and will ignore bright flashes at the margin. The gain of the photomultiplier tube can be controlled by adjustment of its power supply voltage so that it may be shared between fluoroscopic ABS circuits and the various filming systems.

3. Types of Automatic Brightness Stabilization (ABS) Circuits.

Brightness stabilizers can be classified in terms of the variables controlled by the brightness sensor:

a. Variable mA, Preset kVp.

In this system the operator presets the kVp and the brightness sensor controls the tube current over a range of about twenty to one. The operator can set this system to the kVp required for the particular examination and the brightness sensor will automatically adjust the mA to yield an image of correct brightness.

b. Variable mA With kVp Following.

This system operates by varying the mA as a function of the brightness sensor but has an additional circuit that senses if an upper or lower bound mA has been exceeded and then adjusts the kVp through a motor-driven variable transformer. Therefore, if the mA rises above a certain preset value, then the motor will drive the kVp value higher.

c. Variable kVp With Selected mA.

In this system the brightness sensor controls the kVp of the system. The operator will have previously selected the value of mA required. If a motor-driven variable transformer is used to select kVp, the system has the additional advantage of remembering the last operating point as the operator energizes the system with the foot switch; thus restabilization of the system is very rapid. The operator can select a lower mA which will force the brightness stabilizer to operate at a higher kVp for gastrointestinal examinations or a high mA that will force the kVp of the system to go down for best contrast when viewing iodine-based contrast media.

d. Variable kVp, Variable mA.

In this system the output of the brightness sensor controls both kVp and mA in order to maintain either constant image signal or constant image contrast. Such systems make it difficult for the operator to select the mode of operation best suited for particular examinations, especially when panning of the fluoroscopic unit is necessary.

E. Closed-Circuit Television Systems.

Fluoroscopic television systems are closed-circuit systems, that is, the video signal is transmitted from one component to the next through the cables rather than through the air, as in broadcast television. The components of a television system are (see Figure 11):

1. Camera.
2. Camera control unit.
3. Monitor.

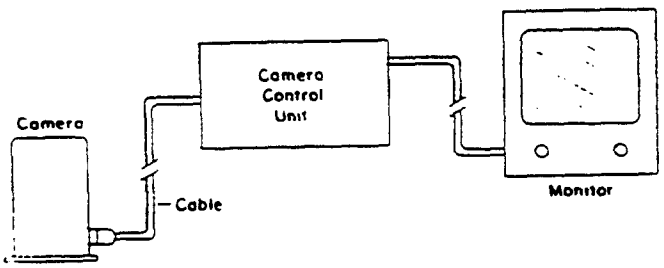

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Figure 11. Components of a television system.

1. Camera Pick-up Tubes or Television Camera Tubes.

The output phosphor of the image intensifier tube is optically coupled to the television (TV) camera. A lens system conveys the fluoroscopic image from the output phosphor of the image intensifier to the TV camera where the image is converted into video signal. This signal is transmitted through the cable to the camera control unit where it is amplified and then forwarded through another cable to the television monitor.

The vidicon camera is the type of pick-up camera usually employed in the fluoroscopic imaging chain. It is a relatively inexpensive, compact unit. The most important part of the vidicon camera is the vidicon tube, a small electronic vacuum tube (see Figure 12), which contains the vidicon target and the electron gun. The electron gun produces the electron beam that is focused onto the vidicon target to produce the television picture consisting of the 525 lines of dots (or more, depending on the TV camera capabilities). One undesirable characteristic of most vidicon tubes is image lag, which causes a "smearing" of moving objects; on the other hand, lag reduces quantum mottle by signal averaging.

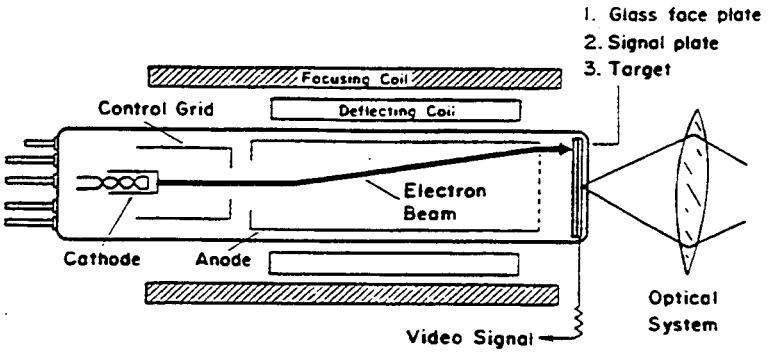

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Figure 12. Vidicon camera.

2. Camera Control Unit.

The second component of a closed-circuit television system is the camera control unit. It contains a power supply and control modules that regulate the camera. It amplifies the video signal, regulates the focusing, and synchronizes the video signal between the camera and monitor.

3. Monitor.

The final link in the closed-circuit television system is the monitor. It contains the picture tube (also called Cathode-Ray-Tube) and the controls for regulating brightness and contrast. The television image is the exact representation of the electrical image coming from the target of the vidicon tube, and is scanned along 525 lines by a narrow electron beam 30 times per second. Each scan of the entire target is called a frame. It is necessary to synchronize or coordinate the video signal between the camera and the monitor to avoid unnecessary flicker in the television picture. This technique is called interlaced scanning whereby only the odd lines are scanned first, then the even lines are rescanned with the same image.

Both the camera and monitor affect the contrast of television image. A vidicon camera reduces contrast by a factor of approximately 0.8, and the monitor enhances contrast by a factor of 2. The net result is a definite improvement in contrast beyond that of the image intensifier alone.

The brightness of the image on the television monitor changes constantly in all fluoroscopic systems as the fluoroscope is moved from one area of the patient to another. Changes in image brightness seriously affect image quality; therefore, the brightness level of the television monitor must be controlled within a rather narrow range. The brightness level of the television monitor can be increased indefinitely, but this does not improve image quality.

At low statistical levels of radiation, image quality is limited by quantum mottle, and at high statistical levels it is limited by the inherent ceiling imposed on resolution by a dot image. Usually brightness and contrast are adjusted in combination to produce a satisfactory image.

F. Television Image Quality.

The television image viewed on the monitor is made up of thousands of tiny dots of differing brightness. Each dot contributes a minute dot to the entire picture. The dots are arranged into **horizontal scan lines**.

In United States, most fluoroscopic and all commercial television systems use 525 scan lines per picture. These 525 lines represent the total number of lines in the entire picture, regardless of the television size. The television camera converts the fluoroscopic image into a series of dots because it can only transmit one dot at a time. Newer systems utilize 1000+ scan lines for the TV camera and the TV monitor, which doubles the spatial resolution achieved by the system. Television image quality is affected by the number of scan lines and the bandpass of the system. More specifically, the television image quality is determined by:

1. Horizontal resolution.
2. Vertical resolution.
3. Contrast.
4. Brightness.
5. Lag.

1. Horizontal Resolution.

Bandwidth, or bandpass, refers to the total number of cycles per second available for display by the television camera and monitor electronics. This number will set an overall limit to the resolving power capability of the television camera. It is the product of scan lines, frame rate, and the frequency rate.

Horizontal resolution is defined as the ability to resolve the image dots on each scan line. Increasing the bandwidth will allow the television camera pick-up tube to turn on and off more times per second. Frequency bandwidth (the maximum number of samples per line per unit time) is a measure of horizontal resolving power of the camera pick-up tube and monitor. Therefore, more information is gained as the bandwidth is increased. Usually, the horizontal resolution is matched to the vertical resolution, which is fixed by the number of horizontal scan lines.

2. Vertical Resolution.

Vertical resolving power is the ability of a television system to resolve objects spaced apart in the vertical direction (e.g., the ability to resolve horizontal lines). One way to improve television resolution is with more and smaller dots, or target globules, which means more scan lines.

Vertical resolution varies with the size of the object, as well as the diameter dimensions of the input phosphor. It is, essentially, the vertical reproduction of the image as seen from the output phosphor by the pick up tube. Vertical resolution can be measured by the following formula (supposing that the object fills the input screen):

$$\text{Vertical resolution (lp/mm)} = \frac{\text{Number of horizontal lines across the object}}{2 \times \text{diameter of object in millimeters}}$$

Kell factor. The Kell factor is a component of vertical resolution. It is defined as the ratio between the vertical resolution and the number of scan lines in the television system. Kell factors are determined experimentally by measuring the maximum number of lines that can be seen with a line pair imaging system, and comparing that value to the theoretical maximum value.

The ratio between the actual vertical resolution of a television monitor as specified in TV lines and the number of horizontal scan lines is called the Kell factor.

The Kell factor can be computed by the following formula:

$$\text{Kell factor} = \frac{\text{Vertical resolution}}{\text{Number of scan lines}}$$

The Kell factor for a 525 scan line system is 0.7.

Example: A 525 line system has actual 525 lines and its vertical resolution is 70% (=367). What is the Kell factor?

$$\text{Kell factor} = \frac{367}{525} = \sim 0.7$$

3. Contrast.

The contrast levels can be adjusted on the television monitor. The contrast should be set so that the darkest object in the scene is just below the black level on the monitor and the bright objects of interest do not completely saturate or "white out" details of the image. It is appropriate when viewing contrast within the patient to adjust the contrast and brightness controls to maximize the visibility of the object even at the expense of increased noise.

4. Brightness.

Changes in image brightness will affect the television image quality. When the fluoroscope is moved from the abdomen to the chest a sudden surge of brightness floods the system, the image becomes chalky and all detail is lost. Therefore, the brightness level of the television monitor must be controlled within narrow limits. Usually the automatic brightness control (ABC) will stabilize the image brightness and the X-ray exposure factors.

It is important to remember that the brightness level of the television monitor can be increased but this does not improve image quality. Usually brightness and contrast are adjusted in combination. Contrast is brought to near maximum level and brightness is adjusted for satisfactory luminance.

5. Lag.

An undesirable property of most vidicon tubes is lag. Lag is blurring of the television image when the fluoroscopic tower is moved rapidly. Lag occurs because it takes a certain amount of time for the image to build up and decay on the vidicon target. Visible lag is not caused by the image intensifier.

G. Plumbicon, Image-Orthicon Cameras, and Charge-Coupled Device (CCD).

Three other types of cameras (besides the vidicon) are in use:

1. Plumbicon cameras are designed for use in the cardiac catheterization laboratories because of the fixed gain and very low lag characteristics of the photoconductive target; thus, better contrast and less motion blurring is achieved. However, quantum mottle is more evident with these cameras because the low lag does not provide signal averaging from previous frames.

2. Image-orthicon cameras are not widely used due to their high expense and other disadvantages.

3. Charge-Coupled Device (CCD) cameras have replaced conventional video camera tubes in many fluoroscopy units. This device is a solid-state semiconductor that has the ability to store the charge produced when light photons strike the photosensitive surface in localized areas. It subsequently transfers this charge by a coupled readout method to produce a video signal which is connected to an appropriate display terminal. The advantage provided by solid state technology is that unit is smaller in size, lower in power consumption, lower in price, and has a longer life. Also, CCDs have a very fast discharge time, which eliminates image lag. This is useful in high speed imaging applications such as cardiac catheterization.

H. Dynamic Image Recording.

There are two typical ways to record dynamic (motion) images with analog devices:

1. Video tape recording.

2. Cinefluorography (cine camera or cine film systems).

1. Video Tape Recorders.

Video tape recorders are a logical addition to a closed-circuit television system. Video tape recorders have two advantages over cinefluorography:

(1) the image is available for instant replay without any intermediate processing system, and
(2) the patient's exposure to radiation is not increased.

Video tape also has disadvantages, the most important being relatively poor image quality. Cine film produces an image of superior quality. Whether or not this difference is significant depends on the importance of image quality for the particular examination. Another disadvantage of video tape is its fixed frame speed (30 frames/seconds in the United States). Cine cameras can be operated at several different speeds, but a frequency of 30 frames/second is adequate for most fluoroscopic needs. Medical needs dictate the preference for one system over another for each particular examination.

VHS (1/2 inch) and U-matic (3/4 inch) recorders are used to record fluoroscopic images. Both video formats are available in cassettes. The best resolution for standard videotape recording systems is obtained by using S-VHS high resolution recorders; however, S-VHS systems require high resolution cameras, recorders, tape and monitor. Videotapes are easy to use, do not require film processing, can provide instant playback and do not add to patient radiation dosage. A disadvantage is that video tapes do not exhibit high resolution.

2. Cinefluorography (Cineradiography).

In cineradiography the television (TV) camera is replaced with a movie camera that records series of static images at high speed on movie (cine) film for later viewing. Cine cameras are commercial movie cameras with several minor modifications. Two film sizes of either 16 or 35 mm are available. The 35 mm film size involves more patient exposure than 16 mm but produces images of higher quality. Nearly all studies are done on 35 mm film and involve heart imaging. **Patient exposure in cinefluorography is significantly greater than with other type of image recording systems.**

In cinefluorography the following are very important:

a. Synchronization.
b. Framing frequency.
c. F-number of the optical system.
d. Framing and patient radiation dose.

a. Synchronization.

Synchronization is the operation of camera shutters at the same frequency as X-ray pulses (radiation production). When cinefluorography was first developed, X-rays were generated continuously during filming. This exposed the patient to X-rays even when the camera shutter was closed and no imaging was taking place. It also shortened the tube life. All modern equipment is now synchronized, meaning the patient is exposed to pulsed X-rays only when the camera shutters are open. This factor is not generally a concern.

b. Framing Frequency.

Framing frequency, or the number of frames of film per second (f/s), in cinefluorography is a division of 60 (7.5, 15, 30, 90, 120). The frequency utilized is determined by the physiological motion of the organ being imaged. Framing frequencies above 30 f/s are typically only necessary for recording pediatric coronary angiography. Patient radiation dose is directly proportional to the framing frequency, where the higher the framing frequency, the higher the radiation dose.

c. F-Number of the Optical System.

The speed of any given camera system depends on the ability of its lens to concentrate light on a given area and is denoted by the lens' "f-number." The concentration will depend on the amount of light made available by the lens and the area upon which it falls. A large diameter lens will allow more light into the camera than a smaller one. The focal length of a given lens will determine the amount of magnification and thus the area over which the light is distributed on the cine film.

A lens with a short focal length will give less magnification (smaller image) resulting in more concentrated light at the image plane. Thus the f-number is dependent on the focal length and diameter of the lens. It is analogous to the f-stop in photography. The lower the f-number, the more light will reach the imaging plane and the faster the lens. The faster the lens (lower f-number), the less exposure to the patient.

Focal length refers to the distance between the lens and the cine film, while diameter represents the dimensions of the lens that intercepts the light coming from the output phosphor. This light ultimately is projected on the cine film.

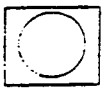
$$\text{f-number} = \frac{\text{focal length}}{\text{lens diameter}}$$

$$\text{Example: f-number} = \frac{100\text{ mm}}{15\text{ mm}} = 6$$

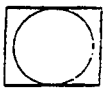
d. Framing and Patient Radiation Dose.

The term framing refers to the use of the available film area to control the image as seen from the output phosphor. The length must be properly framed to match the desired framing mode. Regarding 35 millimeter cine film, the following classification of various degrees of cine framing is used:

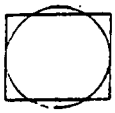
i. Underframing.
ii. Exact framing.
iii. Overframing.
iv. Total overframing.



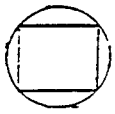
i. **Underframing.** The maximum size of the fluoroscopic image is smaller than the smallest dimension of the frame. Underframing should be avoided.



ii. **Exact framing.** The diameter of the intensifier image at the output phosphor and the smallest dimension of the cine frame (18 millimeters) are the same. No part of the image is lost but only 58 percent of the cine film is used.



iii. **Overframing.** The diameter of the circular image from the optical system is larger than the shortest dimension of the film. Therefore, part of the image is lost.



iv. **Total overframing.** The diameter of the circular image from the optical system is equal to the diagonal measurement of the rectangular aperture (30 millimeters). All of the film is used but 39 percent of the image is wasted.

The X-ray beam must be restricted to match the framing method. If the X-ray beam is not correspondingly restricted, areas of the patient are exposed but the image is never recorded.

The radiation dose at the tabletop for cine fluorography is approximately 10 times greater than the radiation dose for routine fluoroscopy.

l. Static Image Recording.

1. Video disc recording.

2. Spot-film camera.

3. Conventional cassettes.

4. Digital fluorography

1. Video Disc Recording.

Video disc recorders are used to record either single field, single frame, or a short sequence. One application of the video disc recorder is the last image freeze or "sticky fluoroscopy." The machine records the last full frame of information during a fluoroscopy sequence and displays that frame when the fluoroscopic switch is released. During the procedure the fluoroscopist presses the foot switch and real-time information is displayed. At the end of the fluoroscopic sequence the recorded information can be examined one image at a time.

Video disc recording, when properly interfaced to the fluoroscope by a technique referred to as electronic radiography, combines some of the advantages of both fluoroscopy and radiography, namely, the instantaneous image associated with fluoroscopy coupled with the short exposure time associated with radiography. In this technique, the use of the so-called electronic radiography function permits fluoroscopic radiation to continue only long enough to build up a useful image on the output phosphor and television camera, then the image is stored as a single television frame on the video disc recorder.

Immediately after storage of the image, the exposure is terminated automatically by the equipment even though the operator continues to stand on the foot switch. This entire process is completed typically in 1/3 to 1/2 second down to 5 milliseconds, depending on the turn-on and stabilization characteristics of the particular X-ray generator, and repeats each time the foot switch is depressed. Thus, what would ordinarily be a continuous fluoroscopic exposure of up to several minutes duration becomes a series of very brief, consecutive exposures which, in most cases, yield essentially the same information. Manufacturers report up to 95 percent dose reduction when utilizing video disc recording during fluoroscopy. Therefore, video disc recording either by analog or digital means provides an attractive method for lowering patient radiation dose when utilizing fluoroscopy.

Radiography should be performed in lieu of fluoroscopy whenever possible. For example:

An abdominal fluoroscopic study resulting in a 10 rad skin entrance radiation dose may be reduced by 95 percent to 500 millirads if video disc recording is utilized. This 500 millirads radiation dose is approximately the same exposure which would result from an AP abdomen radiograph. It is important to understand that lower exposures achieved utilizing video disc recorded fluoroscopy may equal radiography exposures, however video disc recorded fluoroscopy must not be considered as a lower dose modality than radiography.

Video disc frame rates or speeds vary from a minimum of 1 image per second to a maximum of 30 images per second. The frequency used is determined by the physiological motion of the organ being imaged. With a video disc recorder capable of storing multiple images, an additional benefit is obtained by the fact that each exposure is preserved for later review; these may also be selectively photographed directly off the television screen by an appropriate film camera for recording purposes.

In the absence of such an exposure-limiting device, fluoroscopic equipment operation may result in unnecessary exposure to both the patient and the operator if the latter is not thoroughly familiar with the basic operation of the fluoroscope. Observance of physical principles can reduce both patient and operator exposure significantly and still yield a satisfactory image for the viewing purposes.

Both magnetic and laser video disc equipment are available with digital or analog recording. The magnetic format uses the arrangement of magnetized particles on the moving disc to cause the magnetic field to fluctuate and produce the video signal. The laser format uses a laser light to scan the disc surface, causing the light to be reflected to a photodiode to produce the video signal.

It is important to remember that a significant reduction in patient dose may be achieved in those studies not requiring observation of actual motion by incorporating an image store video disc recorder.

2. Photospot Film Cameras.

Photospot (or spot) film cameras photograph the image on the output phosphor of the image intensifier. Utilization of spot film cameras typically uses a much higher mA with a short exposure time to acquire an image, with a dose that is approximately 20-50 times higher per frame than fluoroscopy.

Photospot films taken with spot film cameras can result in substantial dose reduction to the patient when compared to the exposure to the patient required for spot films using conventional radiographic cassettes. However, most photospot film cameras are really magazines which can take a number of films in quick succession. When this is done, the dose savings to the patient is greatly reduced. If care is taken to avoid this particular problem, the use of spot film cameras is the method of choice.

Photospot film cameras are very close in design to cine cameras. Functionally, they use slower frame rates and larger film sizes than cine cameras. These larger film sizes necessitate their longer focal lengths. Currently, 70 mm roll film, 105 mm roll film, and 100 mm chip film are utilized. The film size used is a matter of personal choice, but the larger the film format, the better the image quality. Unfortunately, as the film size is increased, patient dose is also increased. However, even with 105 mm film size, patient dose for an individual spot film is about 1/2 that for a cassette loaded spot film.

70 millimeter roll film uses a roll of film that has an 70 mm diagonal distance from corner to corner of a square on the active area of the film. Up to 12 frames per second can be acquired with this device. Prior to exposure, the film is positioned in the aperture, a shutter is opened and the X-ray system is energized. The light image generated at the output phosphor of the intensifier is reflected from the beam splitting mirror in the optical junction box to the film. After the exposure, the shutter is closed and the film is advanced to the next position for the process to repeat. The only activity needed prior to exposure is the X-ray beam splitting of the mirror. Like sheet film, the roll film uses a conventional processor to develop the latent image.

105 millimeter roll film uses a roll of film having a square active area with a diagonal distance of 105 mm. Operationally, this system works identically to the 70 mm roll film described above.

100 millimeter sheet film cameras work nearly identically as the roll cameras, with the exception of a mechanical device to handle sheet film instead of roll film. An exposed film receptacle stores the images prior to film processing of the individual sheets.

3. Spot Films with Conventional Cassettes.

Many fluoroscopic examinations are accompanied by "spot filming." The spot film is positioned between the patient and the image intensifier. A second or two is required for the anode to be energized to higher speed to accommodate the spot filming mA of 100 or more. Spot films are images which are taken to document a patient's anatomy at specific moments during the examination. Spot films may be recorded using conventional radiographic cassettes with accompanying radiographic doses or by use of "photospot film cameras" or digital photospot cameras. The tube current applied with spot film cassettes is typically over 100 mA in conjunction with a short exposure time. Patient exposures per image are high when utilizing this method because of the slower speed of the detector. However, the resolution of spot filming is superior to photospot film cameras or digital photospot cameras.

4. Digital Fluoroscopy.

Digital, or computerized, fluoroscopy produce images from the output phosphor of the image intensifier. A video camera and a digital image processor are used to obtain the image. Variations in brightness of the output phosphor are analog in nature, that is, they occur as a range of theoretically infinite brightness levels. This image must be converted by an analog-to-digital converter (ADC). The data is then computer processed and stored in the digital image processor memory. When the data is to be viewed, it is retrieved and converted back to an analog image by a digital-to-analog converter (DAC). A film of the image can be made from the monitor, or the image can be replayed dynamically from the computer. Digital storage or analog storage with videotape recorders is typical.

Three basic types of studies are performed with digital fluoroscopy. The first, mask mode fluoroscopy, is similar to film subtraction angiography with contrast media. The second is called K-edge fluoroscopy. It subtracts X-ray energies just above and just below the K-edge of a contrast medium. The third, time interval difference imaging, changes masks continually, giving information on changes in contrast media content in a structure over time. Most often used is the mask-mode subtraction technique. Non-subtraction digital imaging is also used quite frequently to avoid misregistration artifacts in subtracted images that are caused by patient motion during the acquisition.

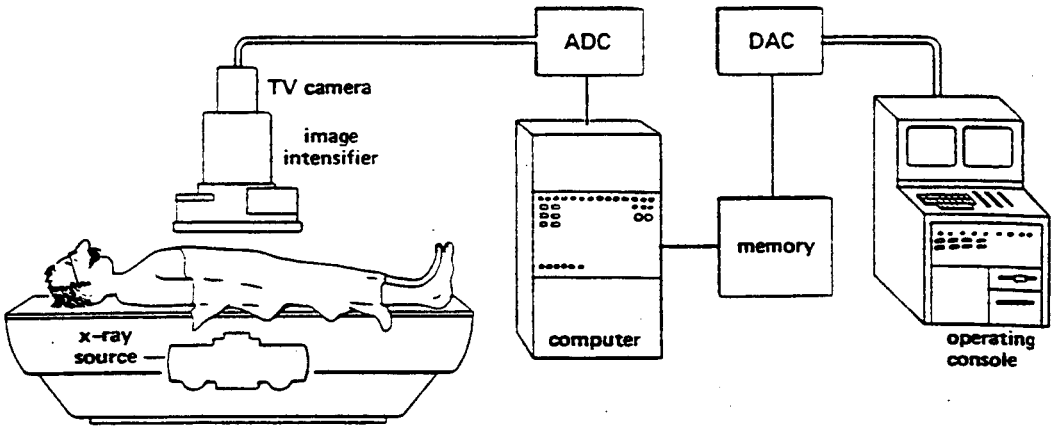


Figure 13. The components of a digital fluoroscopic system.

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5. Digital Photospot Imaging.

Digital photospot imaging uses a high resolution television camera and digital image acquisition/processing in lieu of the film. Advantages of the digital photospot imaging are:

- o Instant playback of images
- o Possible subsequent image enlargement

The only disadvantage is that the resolution of the digital photospot imaging is less than that of film.

6. Pulsed Fluoroscopy.

Pulsed fluoroscopy is a dynamic imaging technique that uses short pulses of X-rays (5 msec or less), synchronized to the video camera readout so that a single image will be acquired and digitized in a digital image buffer memory. Lower frame rates (for example, 15, 7.5, and 3.75 frames/sec) can be obtained by acquiring an image, storing the image data in a digital frame buffer, and continuously displaying an image (frame fill) until the next radiation pulse. With this technique, now commonly used on newer fluoroscopy systems, lower acquisition frame rates will result in a lower dose to the patient for less temporal resolution. In certain cases where there is little patient motion, very slow frame rates can be used in lieu of continuous fluoroscopy, which will substantially reduce patient dose without reducing the information content of the image sequence. The amount of dose reduction is related to the ratio of the frame rate reduction and the dose used per frame. Lower frame rates will not be acceptable when attempting to image moving objects. Nevertheless, pulsed fluoroscopy, when used appropriately, can result in a significant dose reduction to the patient and personnel in the room.

7. High Level (Boost) Fluoroscopy.

High level fluoroscopy refers to a "special activation" capability of a fluoroscopy system to provide significantly higher tube currents, from 10 to 20 mA, and in some instances to even 40 mA. The corresponding entrance dose rate to the patient is 2 to 10 times higher than conventional fluoroscopy, from 10 to 50 rads per minute at the tabletop. These high dose rates are typically used for interventional angiography and cardiography studies, where the need to visualize very small guidewires and catheters requires a high signal to noise ratio and very low amount of quantum mottle in the image. As interventional procedures can be very long and demanding, indiscriminant use of high level fluoroscopy can result in patient doses exceeding several hundred rads that can cause acute skin erythema and possible radiation damage to the underlying tissues. Recent regulations (introduced in 1994) limit the **maximum tabletop dose rate** to **20 rads per minute when acquiring images without recording devices such as videotape.**

Key points regarding high level fluoroscopy include:

- o Special activation at the control panel (key and interlock) is required with additional person
- o Audible signal must be heard in the room while the high level fluoroscopy is energized
- o Tabletop dose rate is limited to 20 rads/minute unless recording devices are used

J. Comparison of Viewing and Recording Systems.

1. Comparison of Various Image Intensification Viewing Systems.

System	Dynamic/Static	Real-time/Delayed	Resolution	Processing time
Optical mirror	dynamic	real-time	highest	none
Video				
Real-time	dynamic	real-time	8th highest	short
Videotape	dynamic or static	delayed	lowest	short
Cine film				
16 mm	dynamic or static	delayed	6th highest	longest
35 mm	dynamic or static	delayed	5th highest	longest
Spot film				
Cassette	static	delayed	2nd highest	high
105 mm roll	static	delayed	3rd highest	high
70 mm roll	static	delayed	4th highest	high
Digital	static	real-time	7th highest	short

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2. Comparison of Recording Systems.

Factor	Spot Film	Photospot/Digital	Cine	Videotape/Disc
Quality	Excellent	Good	Good	Poor
Storage	Sheet	Sheet or digital	Roll	Reel or disc
Patient dose	High	Low	High	Low
Reusable	No	No (yes-digital)	No	Yes (tape) No (disc)
Processor	Radiographic	Radiographic	Cine	None
Framing frequency	1/sec	12/sec	60/sec	60 rpm

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K. Contrast Media.

No discussion of fluoroscopic examinations is complete without mentioning the role of contrast media. These agents are low toxicity materials such as barium or iodine which also possess high atomic numbers and thus decrease the transmission of X-rays to provide contrast in the image of otherwise invisible anatomy Iodine is used as a contrast agent for the blood vessels and vascular anatomy. Barium is used for visualizing internal cavities such as the stomach, intestines, and bowels. The absorption of X-rays in barium and iodine is much greater than that of bone and tissue which have lower effective atomic numbers. When these materials are administered to vessels or organs they allow increased visualization of their structures.

CHAPTER IV

CONDUCTING THE FLUOROSCOPIC EXAMINATION

A. Introduction.

These facts and information should be kept in mind when operating a fluoroscope:

1. Operator radiation dose to scattered radiation is directly proportional to patient radiation dose.

2. Image brightness is directly proportional to the radiation dose rate at the input phosphor.

3. The technical factors utilized in conducting a fluoroscopic examination represent compromises between image quality and patient radiation dose. Each factor, which is selected for a given examination, will never be optimal for both considerations at once.

4. The technical factors which directly influence the radiation dose rate at the panel or tabletop, and hence influence the dose to both the patient and the operator, are:

    a. Milliamperage (mA).
    b. Kilovoltage (kVp).
    c. Collimation.
    d. Filtration.
    e. Exposure time.
    f. Target-panel distance.

5. The technical factors which indirectly influence the radiation dose rate by impacting on the use of factors listed above are:

    a. Lighting in the fluoroscopy room.
    b. Poor image receptor quality.
    c. Low absorption tabletop.

6. Patient and operator shielding are important exposure reducing considerations:

    a. Gonad shield.
    b. Bucky slot cover.
    c. Three-phase generator.

B. Milliamperage (mA).

Milliamperage (mA) is a measure of X-ray tube current of which the intensity of an X-ray beam is directly proportional to the milliamperage used. It is a measure of the **quantity** of X-rays. The product of the current of the beam (mA) and the time during which the beam strikes an object (seconds or "s") is milliampere seconds (mAs). The mA is one of the primary factors utilized in every fluoroscopic study.

The X-ray output is directly proportional to the mA used. If the mA setting is reduced from 5 mA to 3 mA, the radiation dose rate is correspondingly reduced by 40 percent of the initial dose rate. The mA setting for fluoroscopy is typically less than 5. For cassette loaded spot films the mA setting is generally greater than 100.

The radiation dose rate at the input phosphor will increase with increased X-ray tube current in milliamperes. This will produce a brighter image on the screen (image receptor) but will also increase patient radiation dose and hence, operator dose.

Generally speaking, image quality is improved as the size of the X-ray beam (X-ray field) is tightly coned or well collimated because scattered radiation reaching the output phosphor of the image intensifier is reduced. **The image will not become brighter if the exposure field is enlarged.**

C. Kilovoltage (kVp).

Kilovoltage peak (kVp) is a measure of X-ray tube potential. It refers to the maximum or peak value in kilovolts. It determines the penetrating ability of X-rays and refers to the **quality** of X-rays. The term kilovoltage peak is often used interchangeably with the term kilovoltage (kV). Kilovoltage is the electrical potential difference in voltage by factors of 1,000. Kilovoltage peak (kVp) refers to the maximum or crest value in kilovolts. It is the correct term to use when specifying the operating voltage for a fluoroscopic examination. The kVp is a primary factor utilized in every fluoroscopic study.

Producing high-quality fluoroscopic examinations largely depends upon proper selection of kilovoltage peak, so that the effective X-ray energy will result in maximum differential absorption by the tissue. Overall, high kVp techniques tend to reduce patient dose because the improved X-ray beam quality allows the use of lower X-ray tube current (mA). Differential absorption in the patient increases as the kVp is lowered, but lowering kVp results in increased patient dose, assuming, of course, that all other factors remain constant. Since subject contrast is decreased with increasing kVp, an optimum kVp exists for a given procedure with a particular image-receptor system.

The consensus is that while higher kVp does slightly increase internal organ dose, it is more than offset by the marked reduction in patient skin dose. Although increased kVp does decrease the patient's skin dose, the higher energy photons that are scattered internally can travel farther prior to their complete interaction with the tissue of the body. This results in an increase in internal organ dose.

Radiation dose rate at the input phosphor will also increase with increased peak kilovoltage. This is due to both increased output from the X-ray tube and the greater penetrating power of the X-ray beam through the patient.

D. Collimation.

The fluoroscopic X-ray beam collimation must be adjusted so that an unexposed border on the fluoroscopic screen or input phosphor on the image intensifier is visible when the screen carriage is positioned 14 inches above the tabletop and collimators are fully open [section 30307 (a) (4) (B) & (D)]. For automatic collimating devices, such an exposed border should be visible at all heights above the tabletop.

The radiation dose rate at the input phosphor is almost independent of the X-ray beam size. Consequently, the image will not be brighter with a larger beam size; however, the total volume of the patient that is exposed to radiation will increase, and with it, the amount of radiation scattered toward the operator. In addition, image quality is improved as the size of the X-ray beam is reduced, because there is a reduction in the amount of scattered radiation reaching the input phosphor.

Thus, during fluoroscopy, the X-ray beam size should be restricted to the smallest size practicable for the examination at hand. Increasing the exposure area also increases patient dose. If the exposure area is doubled by opening the collimator, total patient **integral dose** will double.

Integral dose: When the beam of radiation enters the patient, energy is absorbed by the tissue irradiated. The total energy absorbed from the beam by the patient is called the integral dose. The integral dose to a mass of tissue is the product of the mass of tissue and the dose which it receives. The unit of integral dose is the **gram rad** (1 gm rad = 100 ergs). For example: A 10 gram block of tissue is given an absorbed dose of 3 rads, then the integral dose is 3 (rads) x 10 (grams) = 30 gram rads. If the irradiated area is doubled, that is, 20 gram block of tissue is given an absorbed dose of 3 rads, then the integral dose would be 3 (rads) x 20 (grams) = 60 gram rads.

E. Filtration.

A filter is defined as material placed in the useful (primary) X-ray beam to preferentially absorb the less penetrating radiations [section 30306 (f)]. It is usually made of aluminum or equivalent material and placed in the useful or primary beam (see Figure 14, page 40). The **main** purpose of a filter is to reduce the number/amount of low-energy (long wavelength) X-rays from reaching the patient. Low energy X-rays cannot completely penetrate through a body to reach the image intensifier and, therefore, contribute nothing to the diagnostic image. A large portion of these useless, "soft", long wavelength X-rays can be filtered out of the X-ray beam if the X-ray tube aperture is intercepted with at least 2.5 mm of aluminum or equivalent material. Thus, appropriate amounts of filtration reduce patient dose.

Appropriate filtration also accomplishes the following (these are subtle effects):

- o Reduces scattered radiation
- o Improves the image quality

Filtration Regulatory Requirements.

The total filtration of an X-ray beam includes inherent filter and added filter.

Inherent filter: Inherent filtration includes the X-ray tube and its housing such as the glass envelope (window) through which the X-ray beam passes.

Added filter: Added filtration includes sheets of metal (usually aluminum) placed in the direct path of the X-ray beam.

Regulations require that the total filtration permanently in the useful X-ray beam at normal operating voltages may not be less than 2.5 millimeters aluminum equivalent for fluoroscopy. Since normal operating voltages for an average adult patient vary from 80 to 120 kilovolts, this requirement may be assumed to have been met if the half-value layer is not less than 3.0 millimeters aluminum. The intensity of the X-ray beam at the tabletop of a fluoroscope should not exceed 2.2 rads/min for each mA of operating tube current at 80 kVp.

Half-Value Layer (HVL).

The **quality** of X-rays is characterized by the half-value layer (HVL). The HVL is defined as the thickness of absorbing material necessary to reduce the X-ray intensity to half its original value. The concept of a half-value layer (HVL) is also used in shielding, where lead is the material of choice to attenuate X-rays. For example: In order to reduce a 100 millirads per minute radiation dose rate to 25 millirads per minute of radiation dose rate, two half-value layers would be required (see Appendix No. 4, Time - Distance - Shielding, page 80).

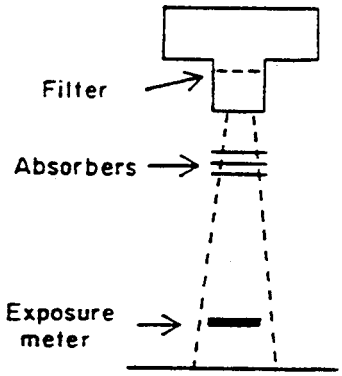

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Figure 14. The procedure for determining the half-value layer (HVL) of an X-ray beam.

F. Exposure Time.

The X-ray beam **"on"** time should be restricted to a minimum. Doubling the exposure time also doubles the total radiation dose to the patient. Usually, the X-ray beam need not be on continuously, and fluoroscopy can be accomplished with a series of short spurts of X-radiation. Very crudely, five "looks," assuming 12 seconds per look, approximates one minute exposure time. This translates (assuming 5 rads/minute exposure) to approximately 400 millirad dose to the patient per "look".

A cumulative manual-reset timer activated by the exposure switch must be provided that, after a predetermined time limit, (1) produces an audible signal or (2) temporarily interrupts the X-ray beam. **The predetermined time limit** may not exceed five minutes [section 30307 (a) (6)]. The cumulative manual-reset timer is designed to protect the patient by making sure that the fluoroscopist is aware of the X-ray beam **"on"** time during each fluoroscopic procedure.

Example: You are fluoroscoping a patient. The fluoroscope emits 1.4 rads per minute (rads/min) at the tabletop for every milliampere (mA) of operation. If you change the mA setting to 2.8 and take 5 minutes of fluoroscopy time to complete the examination, you would have given the patient a dose of 19.6 rads!

G. Allowable Exposure Rates.

For routine fluoroscopy, the dose rate measured at the panel or tabletop shall be as low as practicable and may not exceed five rads per minute. This limit does not apply during magnification procedures or recording of fluoroscopic images where higher exposure rates are required [section 30307 (a)(7)(A)]. However, using 80 kilovolt peak (kVp), the intensity of the X-ray beam at tabletop should not exceed for each milliampere (mA) of current 2.2 rads per minute.

Fluoroscopic equipment manufactured after August 1, 1974, equipped with automatic exposure rate controls shall not be operable at any combination of tube potential and current which will result in an exposure rate in excess of 10 rads/minute at the point where the useful X-ray beam enters the patient, except during recording of fluoroscopic images, or when an optional high level control or "boost position" is provided. When high level control or "boost position" is provided, the equipment shall not be operable at any combination of X-ray tube potential and current that will result in an exposure rate in excess of 5 rads/minute at the point where the useful X-ray beam enters the patient unless the high level control is activated. Special means of activation of high level control shall be required. The high level control shall only be operable when continuous manual activation is provided by the operator. A continuous audible signal to the fluoroscopist shall indicate that the high level control is being employed [section 30307 (a)(7)(B)].

Fluoroscopic equipment manufactured after August 1, 1974, without automatic exposure rate controls shall not be operable at any combination of X-ray tube potential and current which will result in an exposure rate in excess of 5 rads/minute at the point where the center of the useful X-ray beam enters the patient, except during recording of fluoroscopic images, or when an optional high level or "boost position" control is activated. Special means of activation of high level controls shall be required. The high level control shall only be operable when continuous manual activation is provided by the operator. A continuous signal audible to the fluoroscopist shall indicate that the high level control is being employed [section 30307 (a)(7)(C)].

Devices which indicate the X-ray tube potential and current must be provided, and should be located in such a manner that the operator may monitor the tube potential and current during fluoroscopy [section 30307 (a)(9)].

For fluoroscopes with automatic exposure control (automatic brightness control), the operator must monitor the X-ray tube current and potential at least once each week with a designated phantom in the beam during use to ascertain that they are in the normal range for a given set of operating parameters. Logs must be kept of all monitored readings [section 30307 (b)(2)].

The above mentioned measurements of tabletop or patient (phantom) dose rate shall be made by a qualified health or medical physicist at least once each year for units with automatic exposure control, and at least once each 3 years for units without automatic exposure control, and immediately following alteration or replacement of a major component, such as the X-ray tube, exposure control, the imaging assembly, and the power source [section 30307 (b)(3)].

On cineradiography equipment, the exposure rates to which patients are normally subjected shall be determined by a qualified individual at least once each year, and immediately following alterations or replacement of a major component such as the X-ray tube, the exposure controls, the imaging assembly, and the power source [section 30307 (b)(4)].

H. Target-to-Panel Distance (TPD).

Target-to-panel distance is only an over the table tube or C-arm (portable) concern as under-the-table tubes are fixed. Shorter target-to-panel distances (TPD) result in a greater skin dose to a patient and greater distortion of image, than longer TPDs. The following example will illustrate this principle. Assuming that the exposure rate requirements at the image receptor are the same for both TPD's or automatic exposure control, when the TPD is increased from 12 inches to 18 inches, the skin entrance exposure is reduced by approximately 30 percent. This is why regulatory provisions specify that the target-to-panel or target-to-tabletop distance should not be less than 18 inches and shall not be less than 12 inches [section 30307 (a) (2)]. It should be clearly understood that while the target (tube) distance may be varied, the image intensifier should be positioned as close as possible to the patient to keep exposures low. For the same fluoroscopic screen brightness, patient dose can be reduced if the target-to-skin distance is increased.

I. Lighting in the Fluoroscopy Room.

Provisions must be made to eliminate extraneous light that interferes with the fluoroscopic examination.

The ability to perceive fine detail is called **visual acuity**. The visual acuity of rods is poor compared to that of cones which require daylight (photopic) levels of light in order to function. Photopic visual acuity is about 10 times greater than scotopic acuity.

It is important to obtain high image brightness with the use of image intensifiers that bring the illumination of the image into the cone vision region. In this region the visual acuity is dramatically improved.

For image intensified fluoroscopy, the room lighting should be dim to enhance visualization of the black and white television images. Excessive light decreases the ability of the eye to resolve detail on the television screen and thus may indirectly cause the operator to change technical factors to produce a brighter image. Increasing the technical factors will directly affect patient exposure.

The eye contains two types of light receptors, rods and cones. Cones function in daylight or photopic vision, while rods function in night or scotopic vision. Cones perceive color while rods perceive grays. Both of these structures are found in the retina. The cones are concentrated on the center of the retina whereas the rods are concentrated on the periphery of the retina. This physiologic arrangement explains why dimly lit objects are seen better when viewed peripherally (where rods are located on the retina) and when they are not looked at directly (where cones are located on the retina). For additional information see Appendix No. 1, Visual Physiology, page 77.

The normal viewing distance of an image is 12 to 15 inches. The time required by the eye for recognition of an image is approximately 0.2 second. Thus, if a fluoroscopic image is not bright enough for diagnostic imaging purposes, prolonged observation will not improve it.

J. Poor Image Receptor Quality.

An inadequate image receptor system (e.g., poor conversion gain due to age, maladjusted image intensifier) will require the use of higher mA or kVp which will increase exposure to the patient and also to the operator.

K. Low Absorption Tabletops.

The aluminum equivalence of the tabletop when a cassette tray is used under-the-tabletop, or the aluminum equivalence of the front panel of the vertical cassette holder, may not be more than 1 mm at 100 kVp [section 30308 (a) (9)]. Carbon fiber tabletop, for example, significantly reduce patient radiation dose.

L. Gonad Shield.

Suitable protective devices, must be provided to shield gonads in potentially procreative patients when gonads cannot be excluded from the X-ray beam and the shielding of gonads does not interfere with the diagnosis. The rationale for this requirement is that an average dose rate to the male gonads during a barium enema fluoroscopic examination is approximately (assume that gonads are outside direct beam) 50 millirads per minute. The best suited gonad shield for a male patient undergoing a fluoroscopy examination is a shaped contact shield within an athletic supporter.

The gonad shield may not be less than 0.5 mm lead equivalent [section 30308 (b) (4)]. (Consult Appendix No. 8, Summary of Gonad Shielding in Diagnostic Radiology, page 87.)

The best type of gonad shielding for use during fluoroscopy is a shaped contact gonad shield. The use of 0.5 mm lead equivalent gonad shielding reduces gonad dose by approximately 97 percent, e.g., for a primary X-ray beam of 100 kVp and 3 mm aluminum filter, the transmission through the shield is 3 percent, assuming that the shielding material encloses the testes. The testes under a lead sheet gonad shield can receive internally scattered radiation up to about five percent of the incident primary X-ray beam. Therefore, total gonad dose reduction for a 0.5 mm sheet of lead is 97% - 5% = 92%.

The ovaries in female patients are situated in the abdomen at varying depths so that shielding would more frequently interfere with diagnosis. However, whenever possible gonad shielding appropriate for females should also be utilized. Various designs of gonadal shielding are available from commercial manufacturers.

M. Bucky Slot Cover.

During fluoroscopy, on a stationary fluoroscopy unit with an undertable X-ray tube, the cassette (Bucky) tray under-the-able top is moved and parked at the end of the examination table, leaving an opening in the side of the table approximately two inches wide at the gonad level. This opening must be automatically covered with at least 0.25 mm lead equivalent material [section 30307 (a) (10)].

N. Three-Phase Generator/High Frequency Generator.

X-ray generators supply electrical power to the X-ray tube. There are certain technical advantages of three-phase generators and high frequency generators over the single phase generators, e.g.:

- Near constant potential is available
- High mA available for very short exposures, which is useful in angiography, and spot film radiography
- Higher effective kV

However, from the standpoint of patient dose and radiographic quality (when radiographic technique is adjusted to same density and contrast), there is no appreciable improvement with the three-phase generator or high frequency generator in standard imaging techniques.

CHAPTER V

BASIC OPERATIONAL PROCEDURES

Operators of fluoroscopic equipment must reduce unnecessary radiation dose to the patient, themselves and others by observing and following these operational procedures:

- Minimizing the total X-ray beam "**on**" time by using short "looks" whenever practical rather than using continuous observation and continuous exposure of the patient. (Human eye **integration time** or recognition time of a fluoroscopic image on a monitor is approximately 0.2 seconds and therefore short "looks" usually will accomplish the same as a continuous observation.)

- Employing a cumulative manual-reset timer to determine actual fluoroscopy time. This timer must be activated by the exposure switch to sound an alarm when a predetermined time limit, not to exceed 5 minutes, is reached. (A digital readout of cumulative fluoroscopic time should be incorporated on the TV monitor.)

- Maintaining adequate contrast by using the lowest milliamperage (mA) (generally not more than 2-3 mA) and highest peak kilovoltage (kVp) technique appropriate for fluoroscopic examination.

- Restricting the X-ray beam to the smallest size practicable or collimating to the area of clinical interest by using the following procedures: (1) selecting the largest field of view (non-magnification mode) coupled with the smallest manually collimated field size appropriate for the examination to be performed (the non-magnification mode has highest conversion gain) and (2) when the automatic collimation mode is not selected, using the collimator shutter devices to manually collimate the X-ray beam so that the shutter blades are visible on the TV monitor.

- Maintaining the radiation dose rate as low as practicable but not exceeding 5 rads per minute for a typical (average - 70 kilograms or 150 pounds) patient. Standard fluoroscopy radiation dose rates for the average size patient should range from 1 rad/min to 5 rads/min.

- Using magnification (geometric or electronic) and optional high level exposure only when absolutely necessary to obtain additional diagnostic information.

- Using last frame hold techniques or video storage methods of electronic radiography whenever continuous exposure is not absolutely necessary. These techniques can significantly reduce patient dose.

- Using photospot film cameras with film sizes of 70, 100 or 105 millimeters rather than spot film cassette devices to record images. Photospot film camera recording generally requires 20 to 50 percent of the radiation exposure per individual image than the regular spot filming.

- Using video tape recording if there is a need for later review and image analysis.

- Using digital photospot recording, that has the same dose savings characteristics of photospot cameras with instantaneous viewing of the image.

- Using only image intensifiers that can provide adequate contrast. Brightness gain and contrast gain must be tested as needed but not less than annually to ensure that the image intensifiers provide adequate contrast.

- Using television camera/monitor or mirror-optic systems. Direct view systems should not be used.
- Daily monitoring and adjusting controls on television monitor for brightness and contrast.
- Minimizing the patient-image intensifier distance. (The image intensifier should be positioned as close to patient as possible.)
- Prior to the exposure of the patient, positioning the anatomical area of clinical interest in the center of the image intensifier.
- Preventing patient motion by giving the patient clear instructions.
- Utilizing gonad shield properly whenever indicated, especially on children.
- Reducing extraneous light in the X-ray room.
- Using appropriate compression devices, when indicated or necessary, with due consideration to the part being fluoroscoped.
- Handling films/cassettes carefully to eliminate artifacts.
- Moving the under-table cassette holder, if equipped, to either end of the table.

Operational procedures for mobile fluoroscopic equipment.

In addition to the above, mobile fluoroscopic equipment should include at least all of the following:

- An audible indicator when radiation is being produced.
- A fluoroscopic time accumulator which incorporates a digital display into the video display.
- Analog or digital video storage system.
- "Last frame hold" feature that allows the fluoroscopist to view a static image for a long period of time without using the continuous fluoroscopic exposure.
- Longest possible cone to increase source-to-skin distance. (The spacer used to maintain correct source-to-skin distance should never be removed.)
- Sterile wraps when C-arm or U-arm system is used in a sterile field.
- Waterproof protective wraps for the portion of the X-ray system that is under the patient.
- Properly functioning locks which must be secured during use of the equipment.

CHAPTER VI

PEDIATRIC FLUOROSCOPY

The radiation doses received by children for fluoroscopic examinations are generally significantly less than those received by adults for an equivalent study. However, the longer life span of a child allows more time for manifestation of long term detrimental effects of radiation. In addition, as the law of Bergonié and Tribondeau (see Chapter XI, page 64) suggests, children are more sensitive to the effects of radiation since their tissues undergo higher rates of mitotic activity than those of adults. For these reasons, it is especially important to keep radiation doses to children to a minimum particularly during fluoroscopy since these procedures give much larger doses of radiation to the patient than radiography. Fluoroscopy should only be performed if radiography cannot provide the necessary information.

A. Motion.

For children, motion accounts for more imaging problems during fluoroscopy than for adults. Whenever possible, establishing a friendly, non-threatening rapport with the child in order to obtain optimum cooperation is quite worthwhile. Practicing the necessary breath-holding or position changing required during the procedure will prevent unnecessary radiation exposure. Depending on a child's age, however, they may be incapable of understanding instructions to remain motionless for the required period of time necessary for the examination. In some cases where long examination periods are necessary or when the examination itself is particularly uncomfortable, it may be necessary to use anesthesia or sedation. There are several methods of achieving mechanical immobilization.

Mechanical means of securing infants and small children are available commercially or may be easily made. These devices range from simple boards with Velcro straps to more complex positioning aids which move in a variety of angles and positions. The use of sandbags and compression bands has also been found useful.

B. Personnel and Parental Protection.

Often, as in the case of premature or severely ill infants and children, when sterile conditions must be maintained, it is impossible to employ mechanical methods of immobilization and not medically practical to use sedation or anesthesia. In such cases, hospital personnel or parents must physically restrain the infant or toddler during the radiation exposure. It is important to remember that the scattered radiation from fluoroscopic examinations can be significant for those standing near the patient. Therefore, leaded gloves and aprons should be worn by whoever holds the patient and all other personnel who are standing in close proximity to the patient. If hospital personnel are frequently involved in holding patients, their radiation dose equivalent shall be carefully monitored.

C. Gonad Shield.

Gonad shield of at least 0.5 mm lead equivalent must be used whenever possible when it does not interfere with the examination. The importance of utilizing gonad shielding for children cannot be stressed enough. The genetic effects of radiation are thought to be cumulative. Therefore, it is absolutely necessary to protect the child's gonads from radiation which may produce deleterious effects in their offspring.

D. Artifacts.

The exposure settings for fluoroscopic examinations of children are generally low. It is therefore important to remove all clothing, bandages and diapers from the area to be examined prior to fluoroscopy. These items may produce artifacts which degrade the diagnostic quality of the examination.

E. Automatic Brightness Control (ABC) – Automatic Brightness Stabilization.

ABC is particularly valuable for use in fluoroscopy of children since choosing the correct exposure factors is much more difficult for children than for adults. This is because so much more variation in children's sizes is possible. It is important to note that ABC will not function properly unless the child covers the entire exposure detection device. Fluoroscopy of infants and very small children may therefore not be possible with equipment utilizing ABC.

There is one important exception to using ABC to reduce radiation dose. This exception occurs when very radiopaque structures are in the field. When this happens, exposure controls will increase exposure to a maximum. Therefore it is important to avoid having contrast-filled structures fill up the center or a large portion of the screen.

F. Distance.

The shortest possible patient-to-image intensifier distance should be used. When longer distances are used the radiation dose to the patient and X-ray operator will increase. Increasing distance also increases motion and penumbra blur.

G. Other Special Technical Considerations.

Utilizing the smallest possible beam size is an extremely important technical consideration in fluoroscopy of children. Even small increases in field size from the area of interest can dramatically increase the child's total radiation dose since we are dealing with a smaller patient size. For children, it is important to collimate to the anatomical area of interest only and not to collimate to the entire image intensifier field. Manual override of automatic collimators may be necessary to achieve this end.

Keeping cine frame rates to the minimum necessary for the examination will reduce patient radiation dose. Even though 16 mm filming provides a lower dose and is often sufficient for most examinations, 35 mm film is typically used, particularly for cardiac examinations.

Grids, whose use increases radiation dose to the patient, are not necessary when exposing infants due to the small volume being irradiated. The omission of grids can significantly decrease radiation dose.

Use of spot film cameras and digital photospot cameras whenever possible in lieu of conventional spot filming for children will reduce radiation dose significantly. In addition, use of spot film cameras allows the use of shorter exposure times which decreases motion blurring.

CHAPTER VII

MOBILE FLUOROSCOPIC EQUIPMENT

A. Structural Provisions.

The structural shielding required for fluoroscopic units is for scattered radiation and is generally minimal if any, since the entire primary beam is intercepted by the image receptor. However, there are certain regulatory provisions which should be noted. These are:

- o When mobile equipment is to be used routinely in one location, shielding must be provided as for a fixed installation [section 30308 (b) (5)].
- o When mobile equipment is routinely used in operating rooms, appropriate structural shielding must be provided for these rooms [section 30308 (b) (6)].

B. Equipment Provisions ("C-Arm").

These are the basic regulatory provisions regarding the mobile fluoroscopic equipment:

- o Inherent provisions must be made so that the machine cannot be operated at a source-skin distance of less than 30 cm (12 inches) [section 30307 (a) (8) (A)]. (A spacer attached to the X-ray tube on a portable C-arm fluoroscope must limit the minimum X-ray source-to-patient distance to 12 inches.)
- o Image intensification must be provided [section 30307 (a) (8) (B)]
- o Conventional fluoroscopic screens are not permitted [section 30307 (a) (8) (B)]
- o It shall be impossible to operate the fluoroscope when the collimating cone or diaphragm is not in place [section 30307 (a) (8) (C)]
- o It shall be impossible to energize the useful beam of a mobile fluoroscopic unit unless the entire useful beam is intercepted by the image receptor [section 30307 (a) (8) (D)]
- o The maximum permissible dose rate of 5 rads per minute may not be exceeded as measured at 30 centimeters from the input surface of the fluoroscopic image assembly [section 30307 (a) (7) (D) (3)]
- o Personnel monitoring is required for all persons operating mobile X-ray equipment [section 30309 (b) (3)]
- o Protective aprons of at least 0.25 mm lead equivalent must be worn if one is likely to receive 5 millirads/hr or more [section 30307 (b) (1)]

In procedures where observation of actual motion is not needed, such as most orthopedic examinations, many urological examinations and parts of some surgical cardiac procedures (e.g., pacemaker implant), users of mobile fluoroscopic equipment may incorporate an image storage video disc recorder with "Electronic Radiography" option for significant reduction in patient dose.

C. Boost Position (or High Level Control Button).

When a boost position (or high level control button) is provided on a mobile fluoroscope to increase the maximum X-ray exposure level, the correct way to employ this option is to first use the normal mode to locate the area of interest, and use the boost position only when it is necessary to achieve the quality of image required.

CHAPTER VIII

RESPONSIBILITIES OF X-RAY SUPERVISOR (REGISTERED USER)

A. General Supervision.

Definition. Supervision, by law, has been defined as "responsibility for, and control of, quality, radiation safety, and technical aspects of all X-ray examinations and procedures."

1. Chief radiologist or their designees are responsible for ensuring that the fluoroscopic equipment under their jurisdiction is used safely and effectively. In establishing the procedures manual for the use of fluoroscopic equipment, they shall be guided by the ALARA (As Low As Reasonably Achievable) concept and all of the applicable provisions noted in the syllabus.

2. Licentiates (doctors) who may use and supervise the use of fluoroscopic and ancillary equipment:

   a. Holders of current and valid Radiology Supervisor and Operator certificates.

   b. Holders of current and valid Fluoroscopy Supervisor and Operator permits within the limits of their professional licenses and their competency regarding the use of fluoroscopic equipment.

3. Use of fluoroscopy equipment by holders of technologist fluoroscopy permits.

   Diagnostic radiologic technologists who hold current and valid technologist fluoroscopy permits may use fluoroscopy equipment under the supervision of individuals noted in paragraph 2, above.

4. Supervisors and Operators as well as technologists who hold fluoroscopy permits are required to prominently display a copy of their certification document at every facility where they use fluoroscopic equipment.

B. Specific supervisory responsibilities.

1. Establishment of a fluoroscopy procedures manual.

2. Annual review and updating of the procedures manual.

3. Assurance that technologists do not practice medicine, that is, perform fluoroscopic procedures without specific standing or direct orders, as applicable.

4. Observance of technologist performance at regular intervals, but not less than monthly to assure that technologists carry out their fluoroscopic duties as required.

5. Assurance that technologists are offered in-service training to maintain their competency.

6. Assurance that all fluoroscopic and ancillary equipment monitoring are adhered to as described in Appendix No. 10, page 97, Guidelines for Establishing Fluoroscopy Quality Assurance (QA) and Quality Control (QC) Programs.

C. **Personnel Protection.**

Regarding personnel protection, supervisors shall ascertain all of the following:

1. The operator is adequately protected from scattered radiation.

2. The operator, and other individuals who must remain in the X-ray room during the exposure, should wear a protective apron of 0.50 millimeters lead equivalent and shall wear a protective apron of at least 0.25 millimeters lead equivalent..

3. Personnel monitoring equipment (film badge or TLD badge) is worn on the collar and **outside** the protective apron.

4. The following protective devices are used, as appropriate:

   a. Protective apron.

   b. Thyroid shield.

   c. Overhang shield (ceiling supported).

   d. Mobile screen.

   e. Hinged or sliding panel.

   f. Protective gloves.

   g. Lead glasses or goggles.

The medicolegal aspects of taking X-rays are of two general types: (a) civil law, not discussed in this syllabus, and (b) administrative or regulatory law.

Anyone possessing a Supervisor and Operator Radiology certificate or Supervisor and Operator Fluoroscopy permit is subject to a wide variety of state and federal laws and appropriate regulations. In some instances, they may also be subject to county statutes and ordinances regarding radiation safety.

It is not within the scope and intent of this syllabus to discuss any medico-legal implications beyond what is clearly stated in the California Radiation Control Regulations and Regulations Relating to Radiologic Technology. Also, this syllabus will not be concerned with local (county and municipal ordinances) or federal regulatory provisions beyond stating the following:

Public law 90-602, formally cited as The Radiation Control for Health and Safety Act of 1968, is aimed at minimizing patient and operator X-ray exposure, without sacrificing diagnostic information. This law primarily pertains to "assemblers", which are the manufacturers or other individuals who are engaged in the business of assembling components into X-ray systems. If you desire additional information, please contact the Regional Radiological Health Representative, Food and Drug Administration, 50 United Nations Plaza, San Francisco, CA 94102.

The State of California regulations regarding the diagnostic X-ray equipment and operator certification fall into the following broad categories:

1. Persons authorized to operate X-ray equipment on human beings in California and restrictions which apply to them.

2. The display of documents.

3. The record-keeping requirements and radiation incident notification.

4. The training and/or information an X-ray supervisor is required to provide to the fluoroscopy equipment operators.

5. Fluoroscopy equipment safety provisions.

6. X-ray room shielding provisions.

7. Registration and vendor obligations.

8. Supervision of X-ray operators who use fluoroscopy equipment.

9. Formal training of X-ray personnel who use or assist in the use of fluoroscopy equipment.

D. Who is Authorized to Operate Fluoroscopy Equipment on Human Beings in California?

Except for stated exemptions [section 106975 (old section 25672) of the California Health and Safety Code (H&SC)], only persons who possess proper, valid, and up-to-date Supervisor and Operator Radiology certificates, Supervisor and Operator Fluoroscopy permits or Technologists Fluoroscopy permits issued by the State are authorized to expose human beings to X-rays in fluoroscopy mode for diagnostic purposes (see paragraph A of this Section, page 49). (There are laws which govern human use of radionuclides, sealed sources, and X-ray therapy, not discussed in this syllabus.)

NOTE: Limited Permit X-ray Technicians are prohibited from performing fluoroscopic procedures (section 30447, CCR, Title 17).

E. Restrictions.

Section 30305 (b) (1) states that only persons who are adequately instructed in safe operating procedures and who have shown competency in the safe use of the equipment may operate it.

X-ray Supervisors and Operators may expose human beings to X-radiation and supervise the activities of technologists who hold technologist fluoroscopy permits only within the scope of their certification documents issued by the Radiologic Health Branch and within the scope of their professional licenses.

Other restrictions pertaining to holders of a technologist fluoroscopy permit [section 106980 (old section 25672) of the Health and Safety Code (H&SC)]:

1. Technologists may use X-ray equipment only under the supervision of a Certified Supervisor and Operator.

2. Technologists may not interpret any radiograph or make a diagnosis based upon it, or report any diagnosis to a patient except as ordered by a licentiate of the healing arts.

3. Technologists may not use any title or designation implying or indicating the right to practice any of the healing arts.

F. **The Display of Documents.**

1. **Display of Certification Documents.**

Section 30404 requires that certificates and permits issued by the Radiologic Health Branch of the California Department of Health Services be prominently displayed in the place of employment or work.

If a person is employed or works in more than one facility, a photocopy of the certification document must be displayed at each additional place of employment or work.

When facilities have large numbers of certified individuals, that facility may opt to display a single list that includes all of the following:

- o Names of certificate and permit holders
- o Certificate and permit numbers
- o Expiration dates
- o Notice as to where the actual certification documents are on file

2. **Display of Laws and Regulations.**

A current copy of the California Radiation Control Regulations and a copy of operating procedures applicable to working with fluoroscopy equipment and procedures must be posted or must be readily available to X-ray personnel.

3. **Display of "Notice to Employees."**

A current copy of Department Form RH-2364 "Notice to Employees" must be conspicuously posted. (Note: Copies of Form RH-2364 may be obtained from the Department of Health Services, Radiologic Health Branch - see address on page 54.)

G. **Record Keeping Requirements.**

Each user/registrant/supervisor is required to maintain accurate and complete records as follows:

1. The results of each required calibration, survey, and test.

2. Each receipt, transfer, and disposal of a source of radiation (X-ray machine).

3. Radiation exposures of all individuals for whom personnel monitoring is required.

4. The exposure records must be kept in a manner which includes all of the applicable information regarding occupational exposure.

5. Each personnel monitoring entry must be for a period of time not exceeding one calendar year. However, preferably and advisably monitoring should be recorded monthly. Dose equivalents must be recorded in rems or millirems and dose equivalent rates in rems or millirems per hour.

6. Each required record of dose equivalent received by individuals must be kept (preserved) indefinitely. Each other required record must be preserved for a period of three years following the date of the occurrence that is the subject of such record.

7. The user is required to provide reports to any individual of his/her radiation exposure data.

H. Incident Notification Requirements.

The State Department of Health Services must be notified when individuals are exposed to radiation, for other than prescribed medical purposes, in excess of the limits noted below.

Immediate notification means a prompt reporting by telephone (916) 445-0931 and confirmation by letter to the State Department of Health Services (see address on page 54). Twenty-four hour notification means telephoning the Department within 24 hours and a prompt confirming letter of the incident.

An overexposure of a film badge dosimeter or other type of dosimeter assigned to an individual is considered to be presumptive evidence of exposure to the individual. Overexposures should be investigated to determine the conditions under which the overexposure occurred, and the findings reported to the Radiologic Health Branch within 30 days.

1. Immediate notification is required if an individual has received:

(a) A total effective dose equivalent of 25 rems (0.25 Sv) or more, or

(b) An eye dose equivalent of 75 rems (0.75 Sv) or more, or

(c) A shallow-dose equivalent to the skin or extremities of 250 rads (2.5 Sv) or more.

2. Twenty-four hour notification is required if an individual has received within 24 hours:

(a) A total effective dose equivalent exceeding 5 rems (0.05 Sv), or

(b) An eye dose equivalent exceeding 15 rems (0.15 Sv), or

(c) A shallow-dose of equivalent to the skin or extremities exceeding 50 rems (0.5 Sv).

I. Formal Training and/or Information a Registered User is Required to Provide to Radiologic Technology Personnel.

Education and training requirements for radiologic technology certification and for fluoroscopy permits are governed by school standards set by the State. No informal training is permitted. However, continuing education courses and supplementary training of persons who already possess certificates or permits is encouraged.

J. Responsibilities Regarding X-Ray Equipment.

1. X-ray machine registration requirements and vendor obligations.

X-ray equipment must be registered, within 30 days of acquisition, with the State of California Department of Health Services, Radiologic Health Branch, (see address on page 54). Request Form RH 2261, "Registration of Radiation Machines". There is an initial registration fee and a renewal fee collected biennially.

The sale, transfer, or disposal of any X-ray machine must be reported to the State of California Department of Health Services on forms available from the Radiologic Health Branch.

It is your responsibility to inform the person who acquires your X-ray machine that it must be registered with the Department of Health Services in his/her own name.

2. Renewal of individual certificates and/or permits.

Requests for renewal of any certificate or permit must be filed at least 30 calendar days prior to the expiration date of each certificate or permit, and must be on forms furnished by the Department. Renewal notices, before the expiration date of the certificate or permit, will be mailed to the last address listed in the Radiologic Health Branch's records.

3. X-ray equipment safety provisions.

No user shall operate or permit the operation of X-ray equipment unless the equipment and installation meet the applicable requirements of the California Radiation Control Regulations and are appropriate for the procedures to be performed [section 30305 (b) (3)]. A summary of fluoroscopy safety provisions is found in Appendix No 9, page 89.

4. Safety inspections.

In order to ensure compliance with the California Radiation Control Regulations, persons authorized by the State Department of Health Services are permitted, without a warrant, at all reasonable times, to inspect X-ray machines, activities, facilities, premises, and records pertaining to radiography and/or fluoroscopy, and associated supervisory activities.

5. X-ray room shielding provisions.

Structural shielding and other shielding problems are of such a specialized nature that it is appropriate and advisable to consult a qualified health physicist (or qualified radiological physicist), should a shielding problem arise. A list of qualified health physicists is available upon request from the Department of Health Services, Radiologic Health Branch.

K. Communication with Radiologic Health Branch (RHB).

1. Communications - address of RHB.

All communications relating to California Radiation Control Regulations or Regulations Relating to Radiologic Technology should be sent to:

California State Department of Health Services
Radiologic Health Branch
601 North 7th Street, MS - 178
Post Office Box 942732
Sacramento, CA 94234-7320

2. Change of Name or Address.

Individuals who hold certification documents issued by Radiologic Health Branch must report any change of name or address to the Department of Health Services, Radiologic Health Branch in Sacramento, within 30 days of that change [section 30403 (b)].

Regarding the change of name of installation, or sale, transfer, etc., of your X-ray machine, see "X-Ray Machine Registration Requirements and Vendor Obligations," page 53.

L. **Enforcement Authority and Disciplinary Action.**

1. **Health and Safety Code.**

   a. Section 106970 (old section 25671.1) - states that it shall be unlawful for any person to direct, order, assist, or abet a violation of certification provisions.

   b. Section 107075 (old section 25692) - states that any person who violates or aids or abets the violation of any of the provisions of the law or regulations is guilty of a misdemeanor.

2. **California Code of Regulations (CCR), Title 17.**

   a. Section 30305 (b) (1) - states that the user shall assure that all X-ray equipment under his or her jurisdiction is operated only by persons adequately instructed in safe operating procedures and are competent in safe use of the equipment.

   b. Section 30305 (b)(2) - states that the user shall provide safety rules to each individual operating X-ray equipment under his or her control, including any restrictions of the operating technique required for the safe operation of the particular X-ray apparatus, and require that the operator demonstrate familiarity with these rules.

   c. Section 30305 (b)(3) - states that no user shall operate or permit the operation of X-ray equipment unless the equipment and installation meet the applicable requirements of these regulations and are appropriate for the procedures to be performed.

CHAPTER IX

SUPERVISION OF HOLDERS OF TECHNOLOGIST FLUOROSCOPY PERMITS

It is the responsibility of the X-ray Supervisor to ascertain that all technologists under his/her jurisdiction possess proper, up-to-date, and valid authorizations (radiologic technologist fluoroscopy permits) issued by the California State Department of Health Services. Diagnostic radiologic technologist certificates are required to expose human beings to radiographic procedures. **Technologist fluoroscopy permits are required if they position the patient, select technical factors or exposure the patient during fluoroscopic procedures.**

Section 30400 of the California Code of Regulations (CCR), title 17, define fluoroscopy to mean " a radiological examination utilizing fluorescence for the observation of the transient image."

Since there are restrictions as to the scope of a certificate or permit, it is the X-Ray Supervisor and Operator responsibility to ascertain that no technologist works out-of-scope of his/her certificate and permit.

Supervision is defined as the responsibility for, and control of, radiation protection and safety, including use of properly maintained and registered X-ray equipment, the technologists's performance, the use of state authorized technologists only, and quality and technical aspects of all X-ray examinations and procedures.

Fluoroscopy equipment should be in compliance with state regulatory provisions at all times. Satisfactory operation of all X-ray equipment should be checked periodically by examining a number of features, some of which are covered in Appendix No. 10, page 97, Guidelines for Establishing Fluoroscopy Quality Assurance (QA) and Quality Control (QC) Programs.

As a Fluoroscopy Supervisor and Operator, it is your responsibility to ascertain that all X-ray technologists under your jurisdiction are competent and comply with all of the following:

1. Know exactly which examination you want them to make before they make an exposure.

2. Clear the fluoroscopy room of all nonessential persons prior to generating X-rays.

3. Collimate the useful X-ray beam to the area of clinical interest.

4. Use gonad shield, where appropriate and applicable.

5. Use correct technique factors - optimum kVp and lowest mA possible for low dose fluoroscopy, consistent with obtaining a diagnostic quality image.

6. Position the patient correctly for the requested examination before making the actual exposure.

7. Take steps to avoid patient motion by carefully instructing patient not to move, by using appropriate immobilization or positioning aids, and by keeping the patient comfortable and under constant observation.

A. **Definitions.**

"Direct supervision" means that the supervisor is observing the performance of the technologist and can verbally instruct the technologist what to do or not to do.

"Immediate and personal supervision" means that the supervisor is readily available for direct supervision.

"Positioning" means aligning the X-ray tube, anatomical part and image receptor for a specific purpose.

B. **Direct Supervision Requirements.**

Under direct supervision, holders of technologist fluoroscopy permit may use fluoroscopy equipment only as instructed by the supervisor for procedures for which they have been specifically trained.

C. **Immediate and Personal Supervision Requirements.**

Under immediate and personal supervision, holders of technologist fluoroscopy permit may use fluoroscopy equipment for spot filming or video taping procedures for which the technologist has been specifically trained.

D. **Technologist Performance and Restriction Requirements.**

1. **Holders of technologist fluoroscopy permit shall comply with all of the following:**

   a. Perform all of the assigned duties correctly and conscientiously.

   b. Wear a plead apron of at least 0.25 millimeters lead equivalent (preferably 0.5 mm lead equivalent) and a personnel monitoring device outside the apron on the collar during fluoroscopy.

   c. Not hold either patient or film during the exposure.

   d. Follow standing orders and repeat spot film exposure policies.

   e. Know what views are required and position patients correctly both for fluoroscopy and spot filming.

   f. Use optimum film and/or image processing techniques.

2. **Technologist Restrictions.**

   Technologists who perform fluoroscopic procedures are prohibited from doing any of the following:

   a. Performing fluoroscopic procedures without a specific order from a supervisor.

   b. Using fluoroscopic equipment without written standing orders and repeat spot film policies.

   c. Making a diagnosis based on a fluoroscopy image or any radiograph.

d. Operating fluoroscopic equipment without having been trained to operate the particular fluoroscopic and ancillary equipment safely and effectively.

e. Reporting any diagnosis to a patient. Technologists may report a diagnosis to a patient if specifically ordered by a licentiate of the healing arts.

f. Performing fluoroscopic procedures without having posted a current and valid technologist fluoroscopy permit issued by the Department of Health Services, Radiologic Health Branch.

g. Performing fluoroscopic procedures without appropriate supervision.

E. Technologist Protection.

Technologists should observe a number of precautions to reduce their own personal radiation exposure. Some of the actions they can take are listed below:

1. A protective apron of at least 0.25 millimeters lead equivalent (preferably 0.5 mm lead equivalent) must be worn by each person in the exam room, except the patient, when fluoroscopy is being performed. The personnel monitoring device should be fastened to the **outside** of the apron at the shoulder level. During fluoroscopy, the technologist should remain behind the protective barrier, or if that is not possible, must stand as far from the table as practicable or behind the fluoroscopist.

2. Additional personnel protective devices (such as leaded glasses, gloves, and thyroid shields) should be worn, as appropriate.

F. Technologist Fluoroscopy Clinical Instruction.

1. The supervisor shall offer a competency based supervised clinical instruction and education which shall be completed within one year following completion of the didactic instruction and shall include at least the following hours of specialized instruction in fluoroscopic positioning:

	Category	Hours of Instruction
a.	Gastrointestinal tract	3
b.	Vascular and angio systems	3
c.	Orthopedic procedures	3

2. The supervisor shall issue a clinical training completion document to all technologists who have successfully completed the competency based clinical education. (See Appendix No. 2, page 78, regarding a sample of Statement of Competency - Technologist Use of Fluoroscopy Equipment.)

All activity in an X-ray department should be designed, procedures established, and the supervisory activities carried out to achieve the maximum diagnostic information from fluoroscopic examinations. At the same time it is essential to minimize the radiation dose to the patient, the fluoroscopist, and others who must remain in the X-ray room during exposure.

CHAPTER X

HEALTH EFFECTS OF LOW-LEVEL RADIATION DOSE

It has been established beyond any doubt that exposure to ionizing radiation can result in damage to the individual irradiated and produce undesirable effects in future generations. These two broad classes of biological impact are referred to as **somatic** and **genetic** effects, respectively.

The proper significance of various radiation dose expressions is dependent upon which of these two classes of biological effects is involved and the extent of the radiation dose received.

A. Somatic Dose Indicators.

Concern about the effect of the irradiation an individual receives can be expressed in those doses that may induce somatic change such as:

- Injuries to the superficial tissue
- Induction of cancer
- Other deleterious effects such as cataract formation, impaired fertility, and life-span shortening
- Injuries to the developing fetus/embryo

Most somatic dose indicators are based on measurements of the dose at specific locations, points, or small volumes. The bone marrow, skin, and the thyroid are examples of anatomical points and locations that have been used for such measurements. However, the measurement of a dose at a single anatomical point cannot express the total somatic effect which may result from exposures due to diagnostic radiology examinations. In diagnostic radiology, the doses are not uniformly distributed throughout the body for several reasons:

1. The primary X-ray beam is normally restricted to the anatomical area of interest and does not uniformly expose the whole body. Thus, measurement of the radiation dose received by the testes during a chest examination (internal scatter) provides no indication of the dose received by the bone marrow. In other words, examinations which do not include the measured point in the primary X-ray beam provide incomplete information as to the full biological effect of the radiological procedure.

2. Shielding or protection may be used to cover particular parts of the patient during an examination. For example, shielding of the testes might be used during a pelvis examination; thus, measurement of the dose received by the testes would not be indicative of the dose received by surrounding tissue which is not shielded or vice versa.

3. Some natural shielding of particular organs is provided by overlying tissue. For example, measurement of the skin dose in the primary X-ray beam during an abdominal examination produces a higher value than measurement of the ovarian dose.

Nevertheless, the somatic dose indicators are useful in their own right as long as their limitations are understood and are indicative of the major effect.

1. Bone Marrow.

Irradiation of the bone marrow will result in a hematological depression. Lymphocytes will be depressed most severely. Evaluation of data regarding the irradiation of the bone marrow suggests that a strong correlation exists between the incidence of leukemia and the mean radiation dose received by the active bone marrow.

The bone marrow dose is a reasonable indicator of doses to other internal organs which are sensitive to cancer induction (lung, GI tract). Considering the mortality rates associated with these cancers, bone marrow dose may be singled out as a reasonable indicator of somatic effects. **(High bone marrow dose examinations are: barium enema, Upper GI series, abdominal angiography.)**

2. Thyroid and Skin.

The measurement of radiation doses to other organs of the body such as the skin and thyroid may be useful to determine the probability of certain effects occurring. A skin dose is often determined for a procedure since it may indicate the level of doses received by organs near the point of interest. For example, measurement of the dose to the skin of the anterior chest is a reasonable indicator of the breast dose or measurement of a skin dose obtained from an esophagus examination may be indicative of the absorbed thyroid dose. Appendix No. 13, page 116, lists organ doses from some diagnostic radiology procedures.

B. Genetic Dose Indicators.

The genetic dose refers to effects exhibited in future offspring of persons who have been irradiated. It does not refer to the individual or embryo/fetus which directly received the radiation exposure. These effects which are manifested in subsequent generations are referred to as **inherited or genetic** effects. The effects in individuals whose gonads have been irradiated are slightly different for the male and female. Although the sperm precursors, the spermatogonia, are among the most radiosensitive cells in the body, the mature spermatozoa are quite radioresistant. The BEIR Report states the following regarding exposure of the testes:

> "Spermatogonia are drastically depleted by small amounts of radiation; i.e., a dose of 50 rads delivered in a single brief exposure may result in cessation of sperm formation. Fertility is not impaired, however, until the preexisting sperm cells and those found from the maturation of surviving spermatocytes and spermatids are eliminated from the genital tract, which takes several weeks. The sterility ensuing after such a dose may be expected to be only temporary, since enough spermatogonia survive to restore spermatogenesis through eventual regeneration of the seminiferous epithelium."

Regarding the female, the BEIR Report has the following to say: The female possesses:

> "...its entire supply of germ cells, or oocytes, early in life and lacks the ability to replace them as they are lost subsequently. Hence, since oocytes are relatively radiosensitive, irradiation causes a lasting reduction in the reproductive potential of the affected ovary, varying in severity with species, age, and other factors."

It is important to note that acute doses on the order of 30 rads to the gonads may produce temporary sterility. These are not doses which would be encountered in routine diagnostic **radiographic** examinations (see Appendix 13, page 116). If one is concerned about reduced fertility, measurement of doses to the testes and ovaries is needed.

As one would expect, examinations that expose the gonads to primary X-ray beam irradiation produce the highest gonad exposures (barium enema examination, IVP, lumbar spine, hips and upper femur). However, even the high dose radiographic examinations result in doses to the gonads which are below those that will reduce or impair fertility.

Review of worldwide data on gonad dose from various X-ray examinations reveals that doses vary by many orders of magnitude for the same examination from one facility to another. The data show, for example, that the testicular dose from a barium enema examination can vary by a factor of 100. The same variation may be noted in the ovarian dose resulting from hysterosalpingography. These wide ranges can be in part accounted for by variation in the selection of exposure factors, variation in the restriction of the primary X-ray beam, use of improper X-ray beam filtration, and failure to use gonad shields during the examination.

When the reproductive cells are irradiated, changes may be produced in the genes or in the chromosomes of these cells and subsequently be transmitted to the descendants of the irradiated individual. The effects that are manifested in subsequent generations are referred to as inherited or genetic effects.

C. Genetically Significant Dose (GSD).

When the reproductive cells are irradiated, changes may be produced in the genes or in the chromosomes of these cells and subsequently be transmitted to the descendants of the irradiated individual.

A statistic called the genetically significant dose (GSD) has been developed to estimate the magnitude of genetic effects caused by exposure of the population to radiation. The GSD is defined as the "gonad dose which, if received by every member of the population, would be expected to produce the same total genetic effect on the population as the sum of the individual doses that are actually received." It does not include the dose the population receives from background radiation.

The GSD is a function of three parameters:

- Number of future children
- X-ray examination rate
- Mean gonad dose per examination

It is assumed that future child expectancy is the same for all individuals of the same age–sex–class.

Since radiation can induce deleterious mutations which will be expressed in future generations, it can be deduced that the lower the GSD, the lower the number of mutations. This is why the concept of the GSD is currently receiving great emphasis as an important statistic. However, it should be kept in mind that the GSD is not a prediction or forecast of adverse effects on any individuals or their unborn children.

CHAPTER XI

BIOLOGICAL EFFECTS AND SIGNIFICANCE OF RADIATION DOSE

The physical basis for the biological consequences of ionizing radiation exposure is the transfer of energy to the biological organism (deposition of energy in tissue). The energy transferred to matter from ionizing radiation produces **ionizations** of atoms (electrons removed from an atom) and molecules. The deposited energy also produces **excitations** (electron vacancies in shells) of atoms and molecules in the absorbing material.

Basically, radiation could pass through the cell without producing any damage or radiation could kill the cell or damage the cell but such damage could be repaired adequately. However, these ionizations and excitations can lead to permanent changes in the tissue which may result in demonstrable biological injury (see Appendix No. 5, Stepwise Effects of Radiation Injury, page 83).

The specific mechanisms involved in radiobiological injury are not completely understood; however, nucleic acids are probably involved in the more serious effects. Small modifications of DNA structures can have widespread consequences for the cell because the structure of a DNA molecule constitutes the cell's operational "program." In addition, since DNA is replicated during mitosis, any mutation may be perpetuated in the cell's progeny. For example, a particular alteration could result in the synthesis of enzymes which differ from normal in time of production, spatial distribution, or configuration. Depending upon the relative importance of particular enzymes, their activity, and the frequency of their production, the effects upon the cell, as a whole, can range from insignificant metabolic alterations to severe interruption of normal function.

Biological effects from exposure to ionizing radiation appear to follow a linear, nonthreshold dose pattern and are influenced by:

- Dose rate to the tissue exposed
- Total dose received by the tissue exposed
- Type of cell irradiated

A. Radiobiological Injury.

The severity of radiobiological injury is also clearly dependent upon the specific location of the initial radiation interaction. For example, small alterations in the protein synthetic mechanism occurring in the cytoplasm of the cell might cause localized damage but would be unlikely to generate large-scale changes in cellular activity.

1. Cellular amplification.

Cellular damage at the point of the initial radiation interaction usually involves only a very small percentage of the total number of molecules in the cell. At this stage, therefore, any biological consequences of radiation-induced changes may be relatively insignificant. Subsequently, normal cellular metabolic processes may amplify this damage, causing the injury to develop from the molecular to the microscopic anatomical level, ultimately resulting in possible gross cellular malfunction.

2. Gross cellular effects of radiation - cellular, molecular and organic.

The phenomenon seen most frequently in growing tissue exposed to radiation is the cessation of cell division. This may be temporary or permanent, depending upon the magnitude of the absorbed dose of radiation.

Other factors observed are:

- o Chromosome breaks
- o Clumping of chromatin
- o Formation of giant cells or other abnormal mitoses
- o Increased granularity of cytoplasm
- o Nuclear disintegration
- o Changes in motility or cytoplasmic activity
- o Vacuolization
- o Altered protoplasmic viscosity
- o Changes in membrane permeability

3. Latent period.

Following the initial radiation exposure event, and before the first clinically detectable effects occur, there is a time lag referred to as the **latent period**. The biological effects of radiation are arbitrarily divided into short-term (sometimes called immediate or early effects of radiation) and long-term effects (sometimes called delayed or late effects of radiation) on the basis of the latent period. Those effects which appear in a matter of minutes, days, or weeks are called **short-term effects** and those effects which appear years, decades, and sometimes generations later are called **long-term effects** (see Appendix No. 5 - Stepwise Effects of Radiation Injury, page 83).

B. Determinants of Biological Effects.

1. The dose-effect curve.

For any biologically harmful agent it is useful to graph the dosage administered against the probability of effect. With radiation, an important question has been the nature and shape of the resulting graph or curve. Figure 15, below, is a typical sigmoid "threshold" curve. The point at which the curve intersects the abscissa is the threshold dose, that is, the dose below which there is no detectable effect.

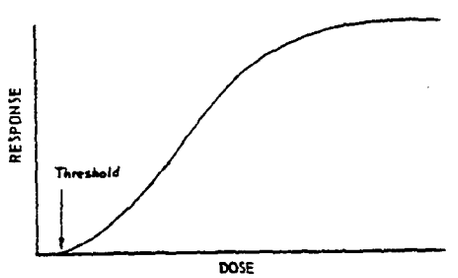

Figure 15.

Threshold, Nonlinear Dose-Effect Curve.

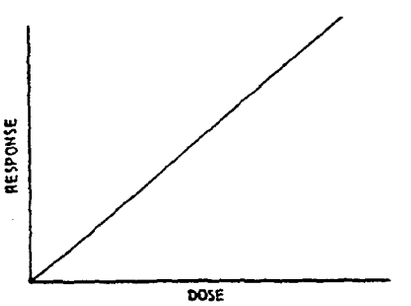

Figure 16.

Nonthreshold, Linear Dose-Effect Curve.

Figure 16, represents a linear, nonthreshold dose-effect relationship in which the curve intersects the abscissa at the origin. According to the nonthreshold hypothesis, any dose, no matter how small, is considered to involve some degree of effect. There is some evidence that the genetic effects of radiation constitute a nonthreshold phenomenon. One of the underlying assumptions in the establishment of radiation protection guides has been to take the conservative approach and consider that any radiation absorbed will exhibit a nonthreshold effect. Under this assumption, some degree of risk is presumed to be present when large populations are exposed to even very small amounts of radiation.

It is important to note that controversy surrounds radiation dose/effect curves and the presence or lack of a threshold. However, regulatory radiation guides are based on the nonthreshold dose-effect relationship.

2. Area exposed and shielding of radiosensitive organs and body parts.

The extent of the effect is measured by the total radiation received by the patient and primarily depends upon the total area exposed. Of equal importance is the nature of the organs in the body area exposed. Even partial shielding of the radiosensitive blood-forming organs such as spleen and bone marrow can mitigate the total effect, especially when X-raying children.

3. Variations in cell sensitivity.

There is wide variation among different types of cells in the amount of radiation required to produce radiation damage. For example, cells which are rapidly dividing, or have a potential for rapid division, are more sensitive than those which do not divide, and cells which are non-differentiated (i.e., primitive or nonspecialized) are more sensitive than those which are highly specialized. The factors which generally influence the radiosensitivity of cells and tissues were recognized as early as 1906 by two French scientists. Their findings are expressed in the law of Bergonié and Tribondeau, which states:

> "The radiosensitivity of tissues depends on the number of undifferentiated cells which the tissue contains, the degree of mitotic activity in the tissue, and the length of time the cells of the tissue stay in active proliferation."

Radiation-induced mitotic delay in the life cycle of a cell is usually reversible.

Based on these factors, it follows that blood forming organs (spleen, and red bone marrow), gastrointestinal tissue, and the developing embryo/fetus (especially during the first trimester) will be more radiosensitive than tissues whose cells have a slower renewal rate.

Various kinds of cells may be grouped as follows, in order of **diminishing sensitivity**:

- Lymphocytes or white blood cells
- Erythrocytes or red blood cells, granulocytes
- Epithelial cells
- Endothelial cells
- Connective tissue cells
- Bone cells
- Nerve cells
- Brain cells
- Muscle cells

4. Short-term effects.

With each routine diagnostic X-ray examination there is a very small probability of an individual receiving an acute injurious effect. The dose range for diagnostic fluoroscopic examinations usually is a few rads (radiation absorbed dose).

Most of the data pertaining to the short-term effects of radiation comes from animal experimentation, but there are human data which confirm the extrapolation of the animal data to human populations. In general, at 25 rads or less, ordinary laboratory or clinical methods will show no indications of injury.

5. Long-term effects.

Long-term effects of radiation exposure are those which may manifest themselves years after the original exposure. The latent period, then, is much longer than that associated with the acute radiation syndrome. Delayed radiation effects may result from previous acute, high-dose exposures or from chronic low-level exposure over a period of years.

From the standpoint of public health significance, the possibility of long-term effects on many people receiving low, chronic exposures is cause for greater concern than the short-term effects of a few individuals receiving a high dose. This is because of possible deleterious genetic and carcinogenic effects.

With the exception of radiation induced cataracts which may be differentiated from other types of cataracts, there is no unique disease associated with the long-term effects of radiation; these effects manifest themselves in human populations as a statistical increase in the incidence of certain diseases or pathology.

Many epidemiological investigations on irradiated human beings have provided convincing evidence of exposure to ionizing radiation does indeed result in an increased risk of certain diseases long after the initial irradiation. This evidence supplements and corroborates that gained from past and present animal experimentation which demonstrates these same effects.

Among the long-term effects thus far observed are:

(1) Somatic damage, which may result in an increased incidence of cancer, embryological effects, cataracts, and life-span shortening.
(2) Genetic mutations, which may be expressed many generations after the original radiation damage.

6. Carcinogenic effects.

There is human evidence that radiation may contribute to the induction of various kinds of neoplastic disease. This evidence includes the following:

(1) Early radiologists and dentists manifested a significant increase in skin malignancies and leukemias as compared to physicians who did not use radiation.
(2) Radium dial painters, who ingested significant amounts of radioactive radium, had subsequently shown an increased incidence of bone malignancies.
(3) Uranium miners have shown an increased incidence of lung cancer.
(4) The Japanese survivors of Hiroshima and Nagasaki have an increased incidence of leukemia and other neoplasms.

The most frequently occurring radiation-induced cancers include, in **descending** order of susceptibility:

- Female breast
- Thyroid gland (especially in women and young children)
- Hemopoietic tissue
- Lungs
- Gastrointestinal tract
- Bones

7. Embryological effects.

Considering the fact that immature, undifferentiated, and rapidly dividing cells are highly sensitive to radiation, it is not surprising that embryonic and fetal tissues are readily damaged by even relatively low doses of radiation. Absorbed doses of about 50 rads to the fetus could result in a spontaneous abortion. It has been shown in animal experiments that deleterious effects may be produced with doses of as little as ten rads delivered to the embryo. There is no reason to believe that the human embryo is not equally susceptible to radiation damage.

The specific type of fetal radiation damage is related to the dose and to the stage of pregnancy during which the irradiation takes place. In terms of embryonic death, the earliest stages of pregnancy, perhaps the first few weeks in human beings, are the most radiosensitive.

From the standpoint of practical radiation protection, this early sensitivity is of great significance, because pregnancy may well be unsuspected. Appendix No. 6, page 84, addresses special considerations concerning scheduling women of childbearing capability for X-ray examinations. During the second through sixth weeks of human gestation (organogenesis), the production of morphological defects in the newborn is a major consideration.

During later stages of pregnancy, fetal tissue is more resistant to damage by radiation. However, functional damage, particularly those involving the central nervous system, may result from such late exposure. They usually involve subtle alterations in such phenomena as learning patterns and development, and may have a considerable latent period before they manifest themselves.

8. Cataractogenic effects.

The required dose for formation of cataracts in humans is probably on the order of several hundred rads of acute dose for X-rays in the diagnostic energy range. The fibers which comprise the lens of the eye are specialized to transmit light. Damage to these, and particularly to the developing immature cells which give rise to them, can result in cataracts. Optically clear protective lenses of 0.25 mm lead-equivalence that reduce personnel eye radiation exposure by 85-90 percent, during catheterization, angiographic, pacemaker insertion and similar procedures, are commercially available. These protective lenses should be utilized during fluoroscopy.

9. Life-span shortening.

In a number of animal experiments, radiation has demonstrated a life-span shortening effect. The mechanisms involved in radiation life-span shortening are uncertain, however, irradiated animals appear to die from the same diseases as the non-irradiated controls but at an earlier age. How much of the total effect is due to premature aging and how much to an increased incidence of radiation-induced damage is still unresolved and quite controversial.

10. Genetic effects.

The precursor cells of mature gametes or the mature gametes themselves are susceptible to nuclear damage (genetic mutations) from external influences such as radiation. When this occurs in those gametes which subsequently are utilized in conception, the altered genetic information is reproduced and passed on to all of the cells of the offspring.

Most geneticists agree that the greatest preponderance of genetic mutations are harmful. By virtue of their damaging effects, they can be gradually eliminated from the population through natural selection.

The more severe the defect produced by a given mutation, the more rapidly it will be eliminated, while the reverse is true for mildly damaging mutations which may require a great many generations before they disappear.

Animal experimentation remains our chief source of information concerning the genetic effects of radiation. As a result of extensive experimentation, certain generalizations may be made:

(1) There is no indication of a threshold dose for the genetic effects of radiation, i.e., no dose below which genetic damage does not occur.

(2) The degree of mutational damage which results from radiation exposure seems to be dose-rate dependent (i.e., a given dose is less effective in producing damage if it is protracted or fractionated over a long period of time).

Radiation and other mutagenic factors have always been present on earth. It is reasonable to expect that all mutations have been expressed in the past so that man-made radiation would only add to the natural incidence of previously expressed mutations rather than create new ones. In general, mutations tend to be deleterious, that is, can produce undesirable effects in future generations. **Therefore, the goal is clear -- keep the radiation exposure of the gonads to a minimum.**

CHAPTER XII

PERSONNEL RADIATION PROTECTION

A. ALARA.

ALARA is an acronym for "As Low As Reasonably Achievable". ALARA means that any radiation dose (including occupational dose equivalent) be kept as low as reasonably achievable. It is assumed that there is no threshold of radiation dose necessary to achieve a biological effect. Even the lowest radiation dose is assumed to result in some effect, though this effect may be too slight to measure. This concept is the basis for the radiation protection goal of reducing exposure whenever possible in order to reduce any associated risk. It stresses that all radiation doses (X-ray operator and patient) be kept as far below legal limits as possible.

B. Basis for Radiation Protection Requirements.

The radiation protection objective is to **prevent** detrimental nonstochastic or deterministic effects and to limit the probability of stochastic effects to a level deemed acceptable.

Stochastic effects mean the probability of an effect occurring, rather than its severity. It is regarded as a function of radiation dose without a threshold. Examples: somatic effects, carcinogenesis.

Nonstochastic effects mean those effects for which the severity of an effect varies with radiation dose, and for which a threshold may occur. Examples: cataracts, non-malignant skin damage, bone marrow cell depletion.

In order to **prevent** detrimental nonstochastic or deterministic effects, the supervisor must set the dose equivalent limits sufficiently low so that no threshold will be reached.

In order to **limit** the probability of stochastic effects, the supervisor must abide by the following:

(1) Keep all justifiable radiation doses ALARA (as low as is reasonably achievable), economic and social factors taken into account, and

(2) Ascertain that no occupationally exposed individual receives more than 5 rems in one calendar year.

C. Operator Exposure.

The chief danger to the operator during fluoroscopic procedures is the exposure to the scattered radiation coming primarily from the patient and to a lesser degree, other scattering media such as the collimator, X-ray tabletop, Bucky tray, and the X-radiation coming from the X-ray tube housing [leakage radiation - section 30306 (h)]. The irradiation can occur only when the fluoroscopic unit is activated (during exposure only, that is, while the dead-man exposure switch is being activated). The fluoroscopist should remember that his or her radiation dose from the scattered radiation is directly proportional to patient radiation dose.

D. Operator Protection During Fluoroscopic Examinations.

The fluoroscopist should stand as far as practical from the radiation sources (primarily patient) and all individuals who must remain in the fluoroscopy room during the procedure must wear a protective apron of at least 0.25 mm lead equivalent (preferably 0.5 mm).

Further, the fluoroscopist shall:

(1) Monitor the X-ray tube current and potential of the automatic brightness control mode (ABC) at least once each week with a designated phantom during use to ascertain that they are in the normal range, and keep logs of all such weekly monitoring readings for at least three years [section 30307 (b) (2)].

(2) Wear personnel monitoring device(s). If only one monitoring device is worn, it must be located at the shoulder or collar **outside** the protective apron.

(3). Ascertain that Bucky slot cover and protective curtains are provided [section 30307 (a) (10), (11)].

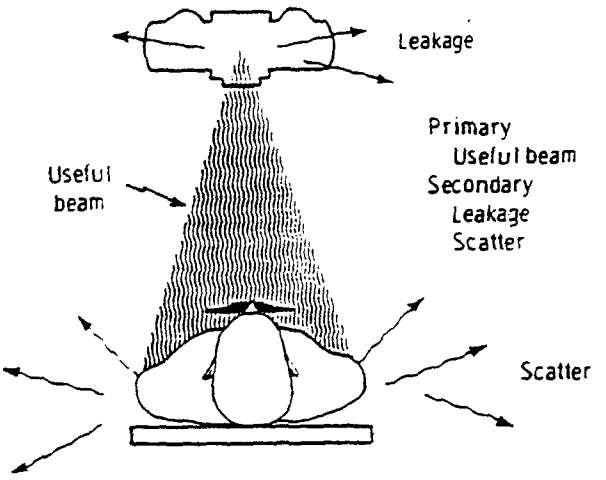

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Figure 17. Three types of radiation - the useful X-ray beam, leakage radiation, and scatter radiation.

The following illustration, (Figure 18), depicts isoexposure contours during a fluoroscopic examination and shows the places where a technologist would receive the least radiation exposure should he/she have to stay in the room during the fluoroscopic examination (as in the case of assisting in a barium enema examination).

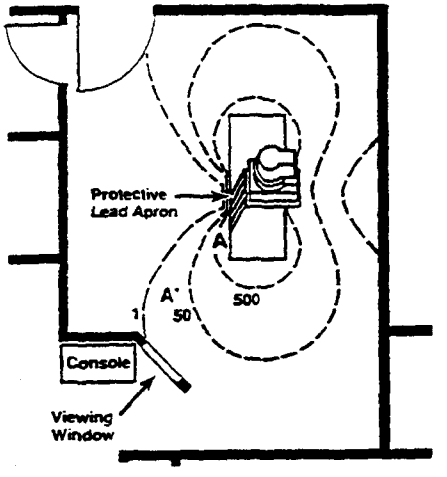

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Figure 18. Typical isoexposure contours in mrad/hour during the fluoroscopic examination.

A - represents the location of the technologist providing backloaded spot films.
B - represents the probable position of the fluoroscopist.

E. Protective Apparel and Accessories.

1. Protective aprons.

If the operator is wearing protective clothing, substantial exposure reduction from **scattered radiation** can be achieved. A typical exposure reduction is 97 percent. For example: If the minimum lead equivalent of protective clothing is 0.25 mm of lead, the transmitted exposure would be lessened by approximately 97 percent. On the other hand, if the minimum lead equivalent of the protective clothing is 0.5 mm of lead, the transmitted exposure reduction to scattered radiation is 99.9 percent. The normal thicknesses for protective apparel are 0.25 mm, 0.5 mm and 1.0 mm of lead equivalent. However, there are also on the market lead aprons with 0.35 mm and 0.75 mm lead equivalent. Of course, the maximum exposure reduction would be obtained by the use of 1.0 mm lead equivalent clothing; however, such clothing is quite heavy and cumbersome. It is important to remember that scattered and leakage radiation are not of much lower energy than that of the primary beam. Since lead aprons are generally only exposed to scattered and leakage radiation and not the primary beam, these aprons are quite effective at attenuation. See Appendix No. 18, page 124, regarding Primary Fluoroscopic Beam Attenuation Factors.

Hangers for protective aprons should always be used. These help in at least two ways: (1) they prevent excessive local strain on the apron or coat shoulders and thus help to prevent cracking of the protective lead material, and (2) they make putting the apron on much easier.

In lieu of holding patients during fluoroscopy examinations, mechanical holding devices, positioning aids, and similar accessories should be employed whenever possible.

During fluoroscopy, the operator is generally standing beside the examination table where he/she can conveniently operate the equipment. The distribution of scattered radiation in the transverse plane, shown in Figure 18, page 69, should be kept in mind by the operator and any other personnel who are required to stand near the patient during fluoroscopy. The scatter from the patient contributes significantly to the radiation exposure of persons standing near the patient. A lead apron covers about 80 percent of the active bone marrow of the body. The bone marrow outside the apron is contained primarily in the skull, the arms, and the clavicles, assuming that the operator is facing the patient.

2. Other protective apparel and accessories:

- **Overhanging shields** which are ceiling supported leaded glass and/or lead aprons offer good protection and are more convenient to use than roll-around shields (mobile screens).
- **Mobile screen desks** usually of 1.0 or 2.0 mm lead equivalent, are available. These are useful not only because they protect the operator; they also provide a convenient shelf for gloves or small cassettes.
- **Protective curtain (overlapping protective drapes)** or hinged or sliding panel of at least 0.25 mm lead equivalent should be positioned between the patient and the fluoroscopist or others who are required to remain in the room during exposure [section 30307 (a) (12)].
- **Protective gloves** of 0.25 mm and 0.5 mm lead equivalent are available and must be worn if a hand must be placed within the primary X-ray beam..
- **Lead glass protective goggles and glasses** are available from commercial companies to protect the lens of the eyes from radiation.
- **Thyroid shields** of 0.25 mm and 0.5 mm lead equivalent are available to protect the thyroid from radiation. These devices are generally utilized when the wearer is in close proximity to the patient during fluoroscopy.

CHAPTER XIII

PERSONNEL MONITORING

Because human senses do not detect ionizing radiation, other means for determining radiation exposure must be provided. As a result, radiation monitoring equipment [section 30100 (l)] have been designed to measure the radiation level or accumulated exposure to the individual by taking advantage of the ionization of matter by radiation. The monitoring devices do not provide any protective or shielding ability from radiation, they simply measure the radiation incident upon it. Personnel radiation monitoring is performed to verify that monitored individuals receive less than the maximum permissible dose equivalent.

A. Personnel Radiation Monitoring Equipment.

Personnel radiation monitoring equipment means devices designed to be worn or carried by an individual for the purpose of measuring the dose equivalent received by that individual. Personnel monitoring equipment (film badges, pocket chambers, pocket dosimeters, film rings, thermoluninescent badges) **must be worn only when on the job** and the equipment (device) should be stored in a safe place at the X-ray facility.

Ideally, personnel monitoring devices should fulfill at least four criteria:

(1) Record the exposure (quantity) to ionizing radiation that has occurred.
(2) Measure the accumulated exposure (quantity) over a specified period of time.
(3) Provide some indication of the type and energy (or quality) of the incident radiation and the rate at which it was received (acute or chronic).
(4) Provide a legally acceptable record of personnel exposure.

The fluoroscopy supervisors should remember that a personnel monitoring device only records the radiation exposure to a small body area in the vicinity of the device. If only one personnel monitoring device is worn, a notation of the position at which it is worn should be made. The real exposure the individual receives may be many times the amount recorded if significantly more radiation is received at a location remote from the monitoring device.

Any personnel radiation monitoring device's reading (unless specifically identified otherwise) is considered to be a whole-body radiation dose.

Acceptable personnel monitoring devices are:

- Film badge
- Thermoluminescent dosimeter (TLD)

For other special purposes the following personnel monitoring devices may be worn **in addition to** the above:

- Pocket chamber or dosimeter
- Audible warning device

It is important to remember that the pocket chamber or dosimeter, while providing an immediate indication of the exposure received, does not provide a permanent record and therefore is not acceptable for legal monitoring purposes. Also, the audible warning devices give only an indication that radiation is present and by the frequency or pitch of sound indicates only the intensity of radiation. Each of these devices may only be used **in addition** to a film badge or TLD.

1. Film badge.

Film badges of personnel dosimetry (monitoring) utilize a comparison of film which has been exposed to a known (measured) amount of radiation at the supplier origin to a film which was worn by an individual as a personnel monitoring device and exposed to an unknown amount of radiation.

The film badge has two essential components:

(1) The film holder with a variety of filters.

(2) The packaged film.

The film holder is usually made of lightweight, low atomic number plastic material and is quite rugged. The holder has various filters embedded which act like filters for low energy X- and gamma rays, as well as beta particles. The primary purpose of filters in the film badge is to permit dose measurements over a wide range of energies. The attenuation of radiation that occurs from various filters results in different film densities after the film is developed. Measurements using this information permit calculation of personnel exposure regardless of energy or type of radiation. Comparison of these densities permits the estimates of radiation energy and type. Under certain conditions, the actual shadow cast by the filters on the developed film allows some estimate of the direction from which the radiation was incident upon the film and may indicate whether the film was exposed once or more than once.

Prepackaged film is the recording medium for the radiation exposure. Films that are presently used for film badge dosimetry purposes are sensitive to exposure equivalent to doses as low as 10 millirad and up to as high as 700 rads. (The dose in rads can then be converted to rems by using an appropriate quality factor which is based on the type of radiation detected. One rem of X-rays is approximately equivalent to one rad.)

2. Thermoluminescent dosimeter (TLD).

The most common material used in the thermoluminescent dosimeters is lithium fluoride in the form of solid chips. Some TLD materials are hygroscopic and light sensitive, and must therefore be placed in hermetically sealed, light-tight holders.

Thermoluminescent dosimeters function on the principle that as ionizing radiation interacts with lithium fluoride crystals, some electrons of the crystal are raised to higher energy states of excitation, in which they become trapped. Later, when the crystals are heated in a special measuring device, these trapped electrons return to their normal energy levels and, in the process, emit light. The amount of light emitted is proportional to the amount of radiation that the crystal absorbed. The average accuracy of TLDs is about ± 9%. This far exceeds the average accuracy of film badges, which may be as high as ± 25%.

However, TLDs are more costly than film badges. A major disadvantage of utilizing TLDs is that once the TLD exposure has been read, it cannot be read again (the exposure information is lost). Thus, it does not provide a truly permanent record of exposure.

3. Pocket ionization chamber.

The pocket ionization chamber is a small pencil-sized instrument that discharges a capacitor by ionization of air within the chamber when in the presence of ionizing radiation. The rate of discharge depends primarily on the intensity of the incident radiation.

Two types of pocket ionization chambers are commonly used for personnel monitoring, the self-reading type and one in which the reading is accomplished only with a special device. Both work on the same principle. There are certain basic and important **disadvantages** in using pocket ionization chambers as personnel monitoring devices. These are:

- o No permanent record
- o Must be periodically calibrated
- o Sensitive to mechanical shock
- o Subjective evaluation of reading by wearer
- o Limited dose range
- o Possible loss of information in the event of exposure over its maximum range

For these reasons, pocket ionization chambers are used **in addition to** (not as a substitution for) a film badge or TLD badge, especially when an immediate reading is desired or needed.

4. Audible warning device.

The drawback of film and TLD badges is that the exposure results are available only after they are processed by vendors. It normally takes about two-three weeks to get the results, so that it is very difficult to pinpoint the cause of any overexposure or determine the time when it occurred. When an immediate warning is needed to indicate the presence of radiation, an audible type of exposure measuring device may be used.

The most practical audible warning device is the dose-rate meter, usually a Geiger-Mueller tube, which gives audible signal as well as visual digital display when the wearer is in the presence of radiation. This small device is encased in a rugged plastic or aluminum case which can be worn by a clip attached to the garment or belt or placed in a pocket. It is advisable to wear this type of device **in addition to** a film or TLD badge during certain special procedures such as vascular studies or cardiac catheterization, in order to make sure that one does not remain in an intense radiation field for an unnecessary period of time.

5. Location for a personnel monitoring device.

It is important to remember that, unless specifically proven otherwise, any personnel monitoring device reading is considered to be a whole-body dose. Therefore, it may be advisable to wear two or more personnel monitoring devices (as in the case of pregnant radiation workers or during performance of special examinations).

Many X-ray personnel wear their personnel monitoring devices (usually film badges) in front of the waist or chest level, because it is convenient to clip the badge over a belt or a pocket. However, **when wearing a lead apron, the personnel monitoring device shall be positioned on the collar above the protective apron or on the top of the protective apron itself. If the exposure under the apron must be determined**, as is advisable from time to time, then a second personnel monitoring device should be used.

In some clinical or other situations, it may be advisable to wear more than one type of personnel monitoring device. For example: (1) monitoring of the abdomen during pregnancy could use the self-reading type to obtain day-to-day indication of the accumulated exposure, or (2) monitoring extremities during some special procedure work in which the operator's hands may be in close proximity to the useful X-ray beam (dosimeters attached to finger rings are available for this purpose).

B. Occupational Exposure.

1. Definitions.

"Whole-body dose" for the purposes of external exposure means exposure to **any** of the following:

- o Head
- o Trunk (including male gonads)
- o Arms above the elbow
- o Legs above the knee

2. Maximum permissible dose equivalent.

The primary objective in establishing maximum permissible dose equivalent (MPD) values for occupational exposure is to keep the radiation dose of occupationally exposed individuals well below a level at which adverse effects are likely to be observed during the lifetime of the radiation worker. While the risk of individuals exposed is considered small, it is worth remembering that risk increases gradually with the dose received, that is, the maximum permissible dose limits are based on a linear nonthreshold dose relationship.

It is essential to keep radiation exposure to occupationally exposed persons as low as practical (ALARA). For this reason, section 20.1201, 10 CFR 20, established the following **annual** occupational dose equivalent limits:

- o Whole body (total effective dose equivalent) - 5 rem or 0.05 Sv
- o Skin and extremities (shallow-dose equivalent) - 50 rem or 0.5 Sv
- o Lens of the eye (eye dose equivalent) - 15 rem or 0.15 Sv

Thus, it is the essential aim of radiation safety to prevent injury from ionizing radiation. The Regulations establish four types of maximum permissible dose equivalent:

(1) Occupational dose equivalent limits for adults (persons **over 18** years of age).
(2) Occupational dose equivalent limits for persons **under** 18 years of age (may receive 10 percent of the adult occupational dose limits).
(3) Dose equivalent limits for general population.
(4) Radiation dose to an embryo/fetus (prenatal radiation exposure - see Appendix No. 7 - Occupationally Exposed Women of Procreative Age, page 85).

Occupational dose is defined as the dose received by any individual in the course of employment.

Exception: Radiation dose received for the operator's own personal medical or dental diagnosis or medical therapy is not considered to be occupational exposure. If the radiologic technologist is a patient then he/she must, before being exposed, remove the personnel monitoring device and store it outside the X-ray room.

3. Radiation dose limits for individual members of the public.

Each supervisor shall conduct X-ray operations so that no individual member of the public will receive more radiation dose in unrestricted area as indicated:

- o 0.1 rems (1 mSv) in a year, or
- o 0.002 rem or 2 millirems in any one hour

4. Frequency of exposure recording.

The personnel monitoring devices are worn in order to ensure that the maximum permissible dose equivalent or occupational dose equivalent limits have not been violated. The California Radiation Control Regulations do not specify the minimum or maximum monitoring time period. **Usually (and advisably) film badges or TLD badges are changed once every month.**

5. Overexposure of a personnel monitoring device.

Any reading indicating overexposure of a film badge or other type of dosimeter assigned to an individual is considered to be presumptive evidence of exposure to the individual and must be reported to the Radiologic Health Branch (RHB). Practically all overexposure reports to the RHB were as result of poor working practice of the X-ray supervisor and operator who conducted the fluoroscopic examination.

C. Supervisory Responsibilities.

There are two broad provisions which deserve emphasis:

(1) Each supervisor must take all precautions necessary to provide reasonably adequate protection to the life, health, and safety of all individuals subject to exposure to radiation.

(2) Each supervisor is responsible for radiation protection and safety in his/her X-ray department, including use of properly maintained and registered X-ray equipment, the operator's performance, the use of State authorized operators only, and quality and technical aspects of all X-ray examinations and procedures [section 114850 (g) (old section - 25661 (h)) of the Health and Safety Code].

1. Monitoring requirements.

The question of who must be monitored and under what conditions persons must be monitored confronts every X-ray supervisor whose employees run a risk of exposure to radiation. As is often the case with regulations, there are many implied provisions. To a very great extent, this is true with personnel monitoring requirements. Radiologic Health Branch thinks that you should ask yourself: "Would you, as a supervisor want the responsibility of risking any person's safety by not monitoring that person?"

Those who are not convinced that a realistic and comprehensive monitoring of personnel is advisable should refer to the U.S. Department of Health, Education, and Welfare publication (DMRE 69-3) entitled "Medical Radiation Information for Litigation."

In addition, there are two other classifications of personnel who must be monitored regardless of the exposure they are likely to receive:

(1) Persons who enter a high radiation area.

(2) Persons who operate mobile X-ray equipment [section 30309 (b) (3)].

"High radiation area" means any area, accessible to individuals, in which there exists radiation levels that could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates. (X-ray rooms where fluoroscopy procedures are being carried out are considered to be high radiation areas.)

"Radiation area" means an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

"Exposure" means being exposed to ionizing radiation or to radioactive material.

2. Personnel monitoring services.

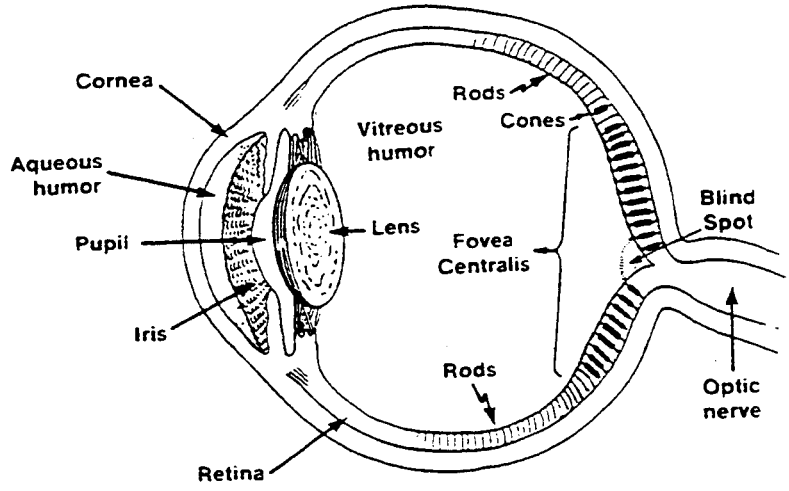
If personnel monitoring is not performed in-house, it is recommended to utilize a personnel monitoring service vendor that is certified by the National Institute of Standards Technology (NIST) through the National Voluntary Laboratory Association Program (NVLAP) and/or certified by the National Sanitation Foundation Testing Laboratory as having met NSF Standard No. 16. Many of these vendors also provide other services such as TLD, area monitoring, computer interaction capability and a wide range of monitors for detection of various types of radiation.

A list of commercial personnel services vendors is available upon request from the Radiologic Health Branch (see address on page 54).

APPENDIX NO. 1

VISUAL PHYSIOLOGY

The eye contains two types of light receptors, rods and cones (see Figure 19). Cones function in daylight or **photopic vision**, while rods function in night or **scotopic vision**. Cones perceive color while rods perceive grays. Both of these structures are found in the retina. The cones are concentrated on the center of the retina whereas the rods are concentrated on the periphery of the retina. This physiologic arrangement explains why dimly lit objects are seen better when viewed peripherally (where rods are located on the retina) and when they are not looked at directly (where cones are located on the retina).



Reproduced, by permission, from Bushong, S. C.: **Radiologic Science for Technologists**, 5th ed., 1993, Mosby Year Book, Inc., St. Louis, Missouri, pg. 355.

Figure 19. The human eye.

The ability to perceive fine detail is called **visual acuity**. The visual acuity of rods is poor compared to that of cones which require daylight (photopic) levels of light in order to function. Photopic visual acuity is about 10 times greater than scotopic acuity. Thus it is important to obtain high image brightness with the use of image intensifiers which bring the illumination of the image into the cone vision region, dramatically improving visual acuity.

For image intensified fluoroscopy, the room lighting should be dim to enhance visualization of the black and white television images. Excessive light decreases the ability of the eye to resolve detail on the television screen and thus may indirectly cause the operator to change technical factors to produce a brighter image. Increasing the technical factors (mA, kVp) will directly affect patient radiation dose.

The normal viewing distance of an image is 12 to 15 inches. The time required by the eye for recognition of an image **(integration time)** is 0.2 second. Thus, if a fluoroscopic image is not bright enough for diagnostic imaging purposes, prolonged observation will not improve it.

Provisions must be made to eliminate extraneous light that interferes with the fluoroscopic examination.

APPENDIX NO. 2

STATEMENT OF COMPETENCY - TECHNOLOGIST USE OF FLUOROSCOPY EQUIPMENT

I, _____, holder of
(Please print name)

[ ] Radiology Supervisor and Operator certificate;

[ ] Fluoroscopy Supervisor and Operator permit,

Document number_____, expiration date _____,

do hereby attest that _____, CRT
(Please print technologist's name)

has successfully completed supervised competency based clinical education and

training given from _____ till _____.

at _____
(Name and address of clinical facility)

in the following areas and procedures:

[ ] Gastrointestinal tract _____

_____

[ ] Vascular and angio systems _____

_____

[ ] Orthopedic procedures _____

_____

[ ] Other (please specify) _____

_____

_____

_____

Signature of doctor who supervised or offered clinical training:

_____ Date signed _____

Business telephone number (_____) _____ x _____

APPENDIX NO. 3

UNITS OF RADIATION DOSE

For the purpose of radiation hazard evaluation, two units of radiation dose and dose equivalent have been introduced to account for several methods of measuring and assessing the effects of different types of radiation. Two of the most important quantities and corresponding units regarding the use of radiation equipment are:

A. Absorbed dose - rad (or gray - SI units)
B. Dose equivalent - rem (sievert - SI units)

Definitions:

Gray (Gy) is the SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 joule/kilogram (100 rads).

Rad is the special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 0.01 joule/kilogram (0.01 gray).

Rem is the special unit of any of the quantities expressed as dose equivalent. The dose equivalent in rems is equal to the absorbed dose in rads multiplied by the quality factor (1 rem = 0.01 sievert).

Sievert is the SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 Sv = 100 rems).

Quality factor (Q) for X-, gamma, or beta radiation is 1. Absorbed dose in rad is equal to 1 rem or the absorbed dose in gray is equal to 1 sievert.

A. The Rad.

The rad, an acronym for Radiation Absorbed Dose, is the special unit of absorbed dose. The quantity significant in biological and medical work is not the amount of radiation passing through a point in air; rather, it is the amount of energy absorbed by the medium at the particular point, that is, absorbed dose. An absorbed dose of one rad corresponds to the absorption of 100 ergs of energy per gram of tissue or other material and is of primary importance in radiation dosimetry.

B. The Rem--Dose Equivalent.

The unit " rem" was devised to allow for the fact that the same absorbed dose in rads delivered by different kinds of radiation does not produce the same degree of biological effect; some types of particulate radiation are biologically more effective than others. The determination of dose equivalent is especially important when considering doses to critical organs. Occupational dose equivalent limits are all stated in terms of rems. It is important to make a distinction between radiation dose measured in rads and dose equivalent measured in rems; however, their biological impact is evaluated in rems.

C. Dose Rate.

An important aspect of irradiation is the radiation dose rate, which is the radiation dose delivered to the medium per unit time. Dose rate is expressed in rems per hour, the absorbed dose rate in rads per hour (rad/h).

APPENDIX NO. 4

TIME - DISTANCE - SHIELDING

There are three basic principles, which can be used singly or in combination, to reduce dose to X-radiation: time, distance, and shielding.

A. Time.

Basic principle: Keep the time of the X-ray exposure as short as possible.

During fluoroscopic examination, the dose to the patient is directly related to the dose rate and the duration (time) of the exposure. The operator exposure to scattered radiation is directly proportional to patient exposure. The cumulative manual-reset timer has been designed to protect the patient by making the fluoroscopist aware of the X-ray beam "**on**" time during each fluoroscopic procedure. However, since the operator exposure is directly proportional to the patient exposure, the following example should be kept in mind. A fluoroscopist at the position he/she occupies is exposed at a rate of 100 millirads per hour (100 mrads/hour). If the fluoroscopist remains at that position for 12 minutes, his or her occupational exposure would be approximately 20 millirads.

B. Distance.

Basic principle: Keep the distance between the source of radiation (X-ray tube, or any scattering medium such as a patient) and the exposed individual as long as practicable.

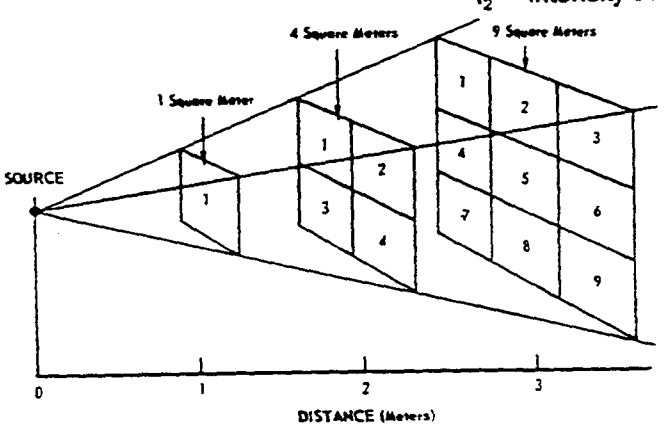
The intensity of radiation varies inversely with the square of the distance. It is obvious that the farther the person is from the X-ray source, the less radiation dose per unit of time he/she will receive. Also the target-to-panel distances on fluoroscopes usually are as long as practicable (should be at least 18 inches).

The inverse square law: At points distant from a common source of X-radiation, the intensities of radiation at these points vary with the square of their respective distances from the X-ray source.

As one moves farther away from an X-ray source the radiation he/she receives will be less because the X-ray beam **diverges** as it travels away from its source. The inverse square law can be expressed by a mathematical relationship:

$$\frac{I_1}{I_2} = \frac{(D_2)^2}{(D_1)^2} \quad \text{or} \quad I_1 (D_1)^2 = I_2 (D_2)^2$$

where: I_1 - intensity at distance D_1
I_2 - intensity at distance D_2



It is easy to see that if the distance from an X-ray source is doubled, the radiation intensity is reduced to 1/4 of the intensity at the original distance. If the distance from the source is tripled, the intensity is reduced to 1/9. If the distance from the source is quadrupled, the intensity is 1/16, etc. On the other hand, if the distance from the source is halved, then the exposure intensity is quadrupled.

Most radiation sources are point sources, the X-ray tube target, for example. However, the scattered radiation generated within a patient during an X-ray exposure comes from an extended area.

During special procedures work or during fluoroscopy, the technologists may be required to remain in the X-ray room during the exposure. In such cases, it is important to remember the configuration of isoexposure curves (see Chapter XII - Personnel Radiation Protection, page 67) and stand where the radiation levels would be the lowest. As a rule of thumb, the technologist should remain as far from the examination table as practical.

C. Shielding.

Basic principle: Insert shielding material between the source of the radiation and the exposed person, as applicable.

Shielding is one of the most important principles for radiation protection. Shielding refers to the different means used to stop radiation or to prevent exposure to it. To be able to apply shielding methods, one must have some understanding of the manner in which X-radiation is attenuated (absorbed) in an absorbing medium. Energy is lost by three methods:

- **The photoelectric effect.** A collision between an X-ray photon and an inner orbital electron of an atom, where the electron is knocked out of its orbit and the photon loses all its energy.

- **Compton scattering.** Interaction of an X-ray photon with an outer orbital electron of the absorber atom producing a recoil electron and a photon energy which is less than that of the incident photon.

- **Pair production.** Incident photon is annihilated in the vicinity of the nucleus of the absorbing atom with subsequent production of an electron and positron pair.

The photoelectric effect is the most important at low energies (up to 100 kVp) which are utilized to produce fluoroscopic images. As X-rays pass through an absorber, their decrease in number is governed by:

- The energy of the radiation
- The specific medium (density of the material)
- The thickness of the absorber traversed

Mathematically, the absorption can be expressed by the equation:

$I = I_o e^{-\mu x}$ where: I - intensity after absorption
I_o - incident intensity
μ - absorption coefficient(linear attenuation coefficient of the material for indirectly ionizing particles)
x - thickness of absorber traversed
e - natural logarithm (base = 2.72)

In discussing shielding, there are a few facts to keep in mind:

1. Persons outside the shadow cast by the shield are not protected.

2. A wall or partition is not necessarily a safe shield for persons on the other side.

3. Radiation can bounce around corners; that is, it can be scattered.

The third fact is so important that it merits further clarification.

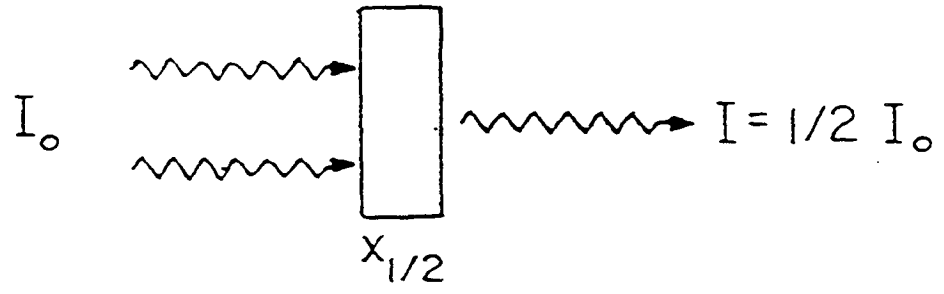
Scattered radiation is present to some extent whenever an attenuating medium is in the path of radiation. **The attenuator (patient during irradiation) then acts as a new source of radiation.** Frequently, room walls, the floor, and other solid objects are near enough to a source of radiation to make scatter appreciable.

D. Half-value layer (HVL).

Half-value layer (HVL) is used in two different situations:

- Determining the **quality** (average penetrating ability of an X-ray beam)
- Determining the **barrier thickness** (amount of shielding needed to attenuate radiation to the required degree).

The quality (average penetrating ability) of an X-ray beam is usually specified in terms of half-value layer (HVL). **The HVL is defined as the thickness or layer of a specified material which attenuates the X-ray beam to such an extent that the exposure is reduced to one half.**



It is commonly expressed in millimeter thicknesses of aluminum. A higher HVL for an X-ray beam means that it can penetrate a given thickness of material to a greater extent than a lower HVL layer. All X-ray tubes have a minimum HVL requirement so that attenuation/absorption of X-rays in the body is minimized yet image quality is not affected adversely.

The **barrier thickness** is usually expressed in terms of inches or millimeters of a specified material (usually lead) required to attenuate radiation to a specific degree where persons on the other side of that barrier will not be exposed to greater than permissible amount of radiation.

APPENDIX NO. 5

STEPWISE EFFECTS OF RADIATION INJURY

	Time	Exposure to radiation
S H O R T T E R M	10^{-12} seconds	Physical effects at molecular level ↓ Absorption of radiation energy ↓ Ionization and excitation process ↓
	10^{-9} seconds	Primary radiochemical reactions Formation of active radicals ↓
	10^{-8} seconds	Disruption of molecular bonds Biochemical changes in cells ↓
	seconds minutes	**Cellular damage** ↓ Functional damage of cells ↓ Damage to genetic structures (mutations) ↓
	minutes hours	**Cell death** Functional damage and morphological changes in cells ↓ Appearance of atypical cells ↓
	hours months	**Pathological changes in the whole organism** ↓ Functional disturbances ↓ Morphological changes ↓ Destruction of the organism
L O N G T E R M	lifetime of the organism	**Late somatic changes** - cancer - leukemia - life span shortening - cataract formation ↓
	future generations	**Genetic changes**

APPENDIX NO. 6

SPECIAL CONSIDERATIONS CONCERNING X-RAY EXAMINATION OF THE PREGNANT OR POTENTIALLY PREGNANT PATIENT

A. Scheduling of X-Ray Examinations for Women of Childbearing Capability.

The radiobiological literature suggests that there is no time period during which a radiological examination can be conducted with **no** biological risk accruing to the real or potential embryo/fetus or to a future fertilized ovum. This statement is predicated on three assumptions:

- o There is always a small potential for adverse biological effects to occur following exposure to X-radiation
- o There is no threshold for such effects
- o Such effects are directly proportional to absorbed radiation dose

Major adverse effects include leukemia, congenital malformations, cancer induction, resorption or death of the embryo, and genetic considerations.

Evidence from the literature indicates that ovarian cells may be affected prior to fertilization of the embryo, and the embryo may be affected at all times after fertilization. While the **kind** of effect may vary with the stage of embryo/fetus development and in fact one or more effects may overlap or superimpose, there is no time that radiation is absolutely safe.

Since there is no absolutely "safe" period for the conduct of diagnostic X-ray examinations in fertile women, the question arises, should women who have a potential to be pregnant have abdominal area X-ray examinations scheduled according to their menstrual period or postponed to reduce the possibility of exposing an unsuspected embryo/fetus to diagnostic levels of X-radiation?

Recommendation:

Diagnostic X-ray examinations that have been requested after full consideration of the clinical statues of the patient, including the possibility of pregnancy, need not be postponed or selectively scheduled, except in those few instances where the examination may be related to the patient's current illness.

This statement is not substantially different from the 10 and 14 day rules previously suggested by the ICRP and NCRP which state that 10 or 14 days after the onset of menses it is improbable that a woman would be pregnant and thus these are "safer" times to perform X-ray examinations.

B. Therapeutic Abortions.

Another important issue facing diagnostic radiology is the question of whether or not therapeutic abortions should be recommended and performed because of exposure of the embryo/fetus to diagnostic levels of X-radiation?

Conclusion:

Interruption of pregnancy is never justified because of radiation dose to embryo/fetus to a diagnostic X-ray examination. This includes radiation doses from both abdominal and peripheral examinations.

APPENDIX NO. 7

OCCUPATIONALLY EXPOSED WOMEN OF PROCREATIVE AGE

Section 30255 of the California Radiation Control Regulations states that each user/supervisor must instruct radiologic technologists (occupationally exposed individuals) in the health protection problems associated with radiation. A special situation arises with occupationally exposed young women. The precautions should be taken to limit exposure to young women, especially if they could be pregnant. Exposure to the abdomen of such workers to X-rays would involve radiation dose to the embryo or fetus.

Radiology or Fluoroscopy Supervisor and Operators are responsible for the following:

A. Following California Radiation Control Regulations (CCR), title 17, requirements (section 20.1208, 10 CFR 20, incorporated in California Regulations by reference).
B. Providing the employees with reasons for the requirements.
C. Explaining the options.

A. Dose to an embryo/fetus.

1. Definition:

Declared pregnant woman means a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

Deep-dose equivalent, which applies to external whole-body exposure, is the dose equivalent at a tissue depth of 1 cm (100 mg/cm^2).

Embryo/fetus means the developing human organism from conception until the time of birth.

2. Regulatory provisions (section 20.1208, 10 CFR 20):

a. The licensee (user/supervisor) shall ensure that the dose equivalent to an embryo/fetus during the entire pregnancy, due to occupational exposure of a declared pregnant woman, does not exceed 0.5 rem (5 mSv).

b. The licensee (user/supervisor) shall make efforts to avoid substantial variation above a uniform monthly exposure rate to a declared pregnant woman so as to satisfy the limit in paragraph (a) of this section.

c. The dose to an embryo/fetus shall be taken as the sum of:

(1) The deep-dose equivalent to the declared pregnant woman; and

(2) The dose to the embryo/fetus from radionuclides in the embryo/fetus and radionuclides in the declared pregnant woman.

d. If the dose to an embryo/fetus is found to have exceeded 0.5 rem (5 mSv), or is within 0.05 rem (0.5 mSv) of this dose, by the time the woman declares the pregnancy to the licensee (user/supervisor), the licensee (user/supervisor) shall be deemed to be in compliance with paragraph (a) of this section if the additional dose to the embryo/fetus does not exceed 0.05 rem (0.5 mSv) during the remainder of the pregnancy.

B. Reasons for Requirements.

Once a pregnancy becomes known, radiation dose of the embryo-fetus shall be no greater than 0.05 rem (50 mrems) in any month (excluding medical exposure).

Some studies have shown that there is an increased risk of leukemia and other cancers in children if the expectant mother was exposed to a significant amount of radiation. The Radiologic Health Branch wants female employees to be aware of any possible risk so that they can take appropriate steps to protect their offspring.

It is strongly suggested that the instruction be given both orally and in writing. Also each individual should be given an opportunity to ask questions and should be asked to acknowledge in writing that the instruction has been received.

The following facts should be given to the female employees:

- The first three months of pregnancy are the most important as the embryo-fetus is most sensitive to radiation at this time
- In most cases of occupational exposure, the actual dose received by the embryo-fetus is less than the dose received by the mother, because some of the dose is absorbed by the mother's body
- At the present occupational dose equivalent limits, the risk to the unborn baby is considered to be small, but experts disagree on the exact amount of risk
- There is no need for women to be concerned about sterility or loss of ability to bear children.
- The 0.5 rem (500 mrems) dose equivalent limit applies to the full nine months of pregnancy
- Once a pregnancy becomes known, radiation dose of the embryo-fetus shall be no greater than 0.05 rem (50 mrems) during the remainder of the pregnancy [section 20.1208 (d), 10 CFR 20]

C. Options.

The available options are usually:

- Delay having children as long as one works around radiation
- If pregnant, leave the job. (If this is a realistic option, it should be done immediately - the embryo-fetus is most sensitive to radiation at the outset of pregnancy and continues to be radiosensitive throughout the gestation period.)
- Could be temporarily reassigned to tasks which involve less risk of being exposed to radiation
- Use protective apron (full-size, half-size, wrap-around, or any other protective clothing appropriate to the situation) while actually exposing patients
- Never hold patients
- Not perform portable or surgical X-ray procedures
- Not assist in special procedures or fluoroscopic procedures
- Use two personnel monitoring devices such as a pocket chamber worn at the abdomen and film badge worn at the regular place
- Whenever possible stay out of the X-ray room and behind protective barriers while the X-ray beam is activated

Addendum to: **SYLLABUS ON FLUOROSCOPY RADIATION PROTECTION**

Page 86 The last bullet under *The following facts should be given to the female employees* should read:

If the dose to the embryo/fetus is found to be 0.5 rem ± 0.05 rem (5 mSv ± 0.5mSv)) at the time the woman declares her pregnancy, she shall be deemed in compliance if the additional dose to the embryo/fetus does not exceed 0.05 rem (0.5 mSv) during the remainder of the pregnancy.

APPENDIX NO. 8

SUMMARY OF "GONAD SHIELDING IN DIAGNOSTIC RADIOLOGY"

The use of gonad shield is an important radiation protection technique, intended to reduce unnecessary X-ray exposure to the gonads of patients from diagnostic X-ray procedures without adversely affecting medical radiologic diagnosis.

A gonad shield is any material placed between the X-ray source and the gonads that attenuates radiation to the required degree. Its main purpose is to protect the gonads from exposure to the **primary X-ray beam** when the gonads are within the limits of the **properly collimated** X-ray beam. The use of the gonad shield in California is mandatory as is the restriction (collimation) of the X-ray beam to the area of clinical interest [section 30308 (b) (3) and (4)].

Gonad shields can be classified into three basic types: flat, contact shields; shaped, contact shields; and shadow shields. The advantages and disadvantages of each type are briefly summarized here:

1. Flat, contact shield.

These consist of uncontoured, lead-impregnated material, placed on or taped to the patient to cover the gonads. This type of shield is most effective for AP or PA views where the patient is recumbent. Such shields can be fashioned from readily available material or can be purchased commercially. Since flat, contact shields are difficult to secure in place, they are **not** well suited to fluoroscopy, to nonrecumbent projections, or to views other than AP or PA.

2. Shaped, contact shield.

These consist of radio-opaque material contoured to enclose the male gonads. Recently, shaped contact shields have become commercially available that can be contained within various carriers such as athletic supporters. This type of shield offers effective protection during lateral and oblique projections as well as AP views. **Since the shield is secured in place by the carrier, it does not have to be repositioned for each view of an examination. This feature makes this shield acceptable for use during selected fluoroscopic procedures.**

3. Shadow shield.

A shadow shield consists of some radio-opaque material, suspended over the patient's body to cast a "shadow" in the primary X-ray beam over the area of the gonads. There are commercially available shields which can be attached to the X-ray tube head. Shadow shielding offers the advantage of use in a sterile field and for use with incapacitated patients. Since the shadow shields are attached to the X-ray tube housing, they are always available for use and can be used without any embarrassment to the patient or the operator. However, proper positioning of the patient is essential as is the accurate alignment of the light localizer. As with flat, contact shielding, shadow shielding is **not** suited to gonad protection during fluoroscopic procedures.

Each facility can select and use any or all of these kinds of shields to implement an effective patient protection program.

It is recommended that each X-ray facility establish the instructions and procedures to be followed by X-ray operators regarding the use of gonad shielding.

Some of the criteria and rationale for establishing such guidelines are listed in the Federal Register:

The material presented below is excerpted from the Federal Register, Friday, July 23, 1976, Vol. 41 – No. 143 and U. S. HEW publication "Specific Area Gonad Shielding". Paragraph 1000.50 (a) recommends that specific area gonad shielding be used if the gonads of the patient lie within the primary X-ray beam, or within close proximity (about 5 cm) despite proper X-ray beam collimation.

1. Specific area testicular shielding should always be used during those examinations in which the testes usually are in the primary X-ray beam, such as examinations of the pelvis, and upper femur, or other examinations where testes could not be excluded from the primary X-ray beam.

2. Specific area testicular shielding may also be warranted during abdominal, lumbar spine or lumbosacral spine examinations, intra-venous pyelograms, and abdominal scout films for barium enema and upper GI series. Each X-ray facility should evaluate its procedures, techniques, and equipment and establish guidelines when testicular shielding should be routinely done.

3. Specific area gonad shielding should never be used as a substitute for careful patient positioning, the use of correct technique factors and film processing, or proper X-ray beam limitation (collimation).

4a. Specific area gonad shielding should provide attenuation of X-rays at least equivalent to that afforded by 0.25 mm[1/] of lead.

4b. Specific area gonad shielding should be used only if the clinical objective of the examination will not be compromised.

1) The decision concerning the applicability of shielding for an individual patient is dependent upon consideration of the patient's characteristics and the diagnostic information needed of the examination.

2) While in many instances ovarian shielding is impractical, it may be possible to use the specific area ovarian shielding during selected views in some examinations.

[1/] Note: State of California regulations require 0.5 mm lead equivalent gonadal shielding.

APPENDIX NO. 9

OVERVIEW OF CALIFORNIA RADIATION CONTROL REGULATIONS.

The California Radiation Control Regulations are contained in the California Code of Regulations (CCR), title 17, and are generally referred to as "laws" or "statutes." The Regulations are administered by the California Department of Health Services, Radiologic Health Branch (RHB).

The Regulations are not recommendations but provisions that must be complied with. Section 115215 (a) [old section 25865 (a)] of the Health and Safety Code specifically states that any person who violates any part of the provisions of these regulations is guilty of a misdemeanor.

A. Registration of x-ray machines

Item	Provision	Section
-X-ray machine registration	Must be registered	30108
-Initial registration	Must be registered with the Department (Radiologic Health Branch) in Sacramento within 30 days of acquisition	30110
-Renewal of registration	Registration must be renewed during July of every even-numbered year	30111
-Report of change	The registrant shall report in writing to the Department (Radiologic Health Branch), within 30 days, any change in: registrant's name, address, location of the installation, or receipt, sale, transfer, disposal or discontinuance of use	30115
-Vendor obligation	Must inform the receiver of registration requirement	30118
-Records to be maintained	Shall keep records of receipt, transfer, or disposal of X-ray equipment	30131
-Fees	"High priority radiation"	30145(a)
-Payment of fees	Must pay the required fee	30146

B. General definitions

Item	Provision	Section
-Department	The State Department of Health Services (usually Radiologic Health Branch)	30100(c)
-Human use	Administration of radiation to human beings	30100(f)
-Installation	The place/location where fluoroscopy machine is located	30100(g)
-Other official agency	An agency with which the Department has entered into agreement to carry out inspections of fluoroscopy equipment	30100(j)
-Person	Any individual, corporation, partnership, firm, group, etc.	30100(k)

B. General definitions (continued)

Item	Provision	Section
-Personnel monitoring equipment	Film or TLD badges, pocket chamber or dosimeter	30100(l)
-Possessing a reportable source of radiation	Having physical possession or having control of a fluoroscopy equipment	30100(n)
-Radiation	X-rays or X-radiation	30100(o)
-Radiation machine	Any X-ray machine capable of producing radiation	30100(p)
-Registrant	Any person who has registered with the Department a fluoroscopy equipment	30100(r)
-Reportable source of radiation	Any X-ray machine, when installed in such manner as to be capable of producing radiation	30100(s)
-Source of radiation	A single radiation machine	30100(v)
-This regulation	California Code of Regulations (CCR), title 17, chapter 5, subchapter 4	30100(y)
-User	Any person who has registered with the Department a fluoroscopy equipment	30100(z)
-Worker	Any individual who use fluoroscopy equipment to expose patients to X-rays	30100(aa)
-Dead-man switch	Terminates exposure when pressure is released	30306 (d)
-X-ray tube housing	Diagnostic type, <100 millirads leakage at one meter	30306 (e)
-Filter	Material placed in the useful beam to absorb preferentially the less penetrating radiation	30306 (f)
-Leakage radiation	All radiation coming from tube housing except the useful beam	30306 (h)
-Protective barrier	Attenuating materials used to reduce radiation exposure	30306 (i)
-Primary protective barrier	Used to attenuate the useful beam to the required degree	30306 (j)
-Scattered radiation	Radiation that, during passage through matter, has been deviated in direction	30306 (k)
-Secondary protective barrier	Used to attenuate stray radiation to the required degree	30306 (l)
-Stray radiation	Includes leakage and scattered radiation	30306 (n)
-Shutter	A device, generally of led, fixed to an X-ray tube housing to intercept the useful beam	30306(m)
-Useful beam	Radiation which passes through the X-ray window, aperture, cone or other collimating device	30306 (p)
-Absorbed dose	The energy imparted by ionizing radiation per unit mass of irradiated material [The unit of absorbed dose are the rad and the gray (Gy)]	20.1003
-Adult	An individual 18 or more years of age	20.1003

B. General definitions (continued)

Item	Provision	Section
-ALARA	Making every reasonable effort to maintain exposures to radiation as far below the dose limits as is practical	20.1003
-Collective dose	Is the sum of the individual doses received in a given period of time by a specified population to a specified source of radiation	20.1003
-Controlled area	An area, outside of a restricted area access to which can be limited by the licensee for any reason	20.1003
-Declared pregnant woman	A woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception	20.1003
-Dose equivalent	The product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest [The unit of dose equivalent are the rem and sievert (Sv)]	20.1003
-Embryo/fetus	The developing human organism from conception until the time of birth	20.1003
-Exposure	Being exposed to ionizing radiation or to radioactive material	20.1003
-Eye dose equivalent	Applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 centimeters (300 mg/cm^2)	20.1003
-Individual	Any human being	20.1003
-Member of the public	An individual in a controlled or unrestricted area. An individual is not a member of the public during any period in which the individual receives an occupational dose	20.1003
-Minor	An individual less than 18 years of age	20.1003
-Nonstochastic effect	Health effect, the severity of which varies with the dose and for which a threshold is believed to exist. Radiation-induced cataract formation is an example of a nonstochastic effect (also called a deterministic effect)	20.1003
-Occupational dose	The dose received by an individual in a restricted area or in the course of employment	20.1003
-Stochastic effects	Health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects	20.1003

B. General definitions (continued)

Item	Provision	Section
-Unrestricted area	An area, access to which is neither limited nor controlled by the licensee	20.1003
-Whole body	For purposes of external exposure, head, trunk (including male gonads), arms above the elbows, or legs above the knee	20.1004
-Gray (Gy)	Is the SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 joule/ kilogram (100 rads)	20.1004(a)
-Rad	The special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 0.01 joule/kilogram (0.01 gray)	20.1004(a)
-Rem	The special unit of any of the quantities expressed as dose equivalent. The dose equivalent in rems is equal to the absorbed dose in rads multiplied by the quality factor (1 rem = 0.01 sievert)	20.1004(a)
-Sievert	The SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 rem = 0.01 sievert)	20.1004(a)

C. Use of fluoroscopy requirement

Item	Provision	Section
-ALARA	Each X-ray Supervisor and Operator and radiologic technologists who holds a Fluoroscopy Permit shall use, to the extent practicable, procedures and controls to achieve occupational doses and doses to members of the public as low as is reasonably achievable	20.1101(b)
-Radiation protection program	Each X-ray Supervisor and Operator shall develop, document, and implement a radiation protection program commensurate with the scope and extent of activities and sufficient to ensure compliance with the regulations	20.1101(a)
-Periodic review of program	Each X-ray Supervisor and Operator shall at least annually review the radiation protection program's content and implementation	20.1101(c)
-Occupational dose limits	Annual whole body - 5 rems	20.1201
-Dose limits for individual members of the public	Annual - 0.1 rems	20.1301

C. Use of fluoroscopy requirement (continued)

Item	Provision	Section
-Assurance of competency to use X-rays on human beings	Each X-ray Supervisor and Operator shall assure that only persons adequately instructed in safe operating procedures and competent in safe use of the fluoroscopy equipment are allowed to use it	30305(b)(1)
-Providing safety rules	Each X-ray Supervisor and Operator shall provide safety rules for the safe operation of the particular fluoroscopy equipment	30305(b)(2)
-Adequate X-ray equipment	Each X-ray Supervisor and Operator shall assure that fluoroscopy equipment is in safe operating order and is appropriate for the procedures to be performed	30305(b)(3)
-Prohibition	Deliberate exposure of an individual for training or demonstration without a prescription by a physician is prohibited	30305(b)(4)
-X-ray caution signs	All X-ray rooms shall have posted signs "CAUTION- X-RAY"	30305 (c)
-Posting of current regulations	A copy of current regulations must be posted conspicuously	30305 (b)(2)
-Posting of Form RH-2364	Form RH-2364(available from Radiologic Health Branch) must be posted conspicuously	30305(b)(3)

D. Fluoroscopy Equipment Provisions

Item	Provision	Section
-X-ray tube housing	Diagnostic type, i.e., <100 mrads/hr leakage at one meter	30307 (a)(1)
-Target-to-panel or target-to-tabletop distance	Shall not be less than 12 inches; should not be less than 18 inches	30307 (a)(2)
-Total filtration	At least 2.5 mm Al equivalent or HVL must be at least 2.5 mm aluminum at normal operating voltage	30307 (a)(3)
-Useful beam	The entire cross section must be attenuated by a primary barrier (The primary barrier is the image intensification mechanism)	30307 (a)(4)
-Scattered radiation	Special attention must be paid to possible leakage coming from the intensifier	30307 (a)(4)(A)
-Collimators, adjustable, diaphragms, shutters	Restrict the useful beam to less than the size of the barrier Must provide the same degree of protection as the tube housing For image intensified fluoroscopy: restricted to the visible portion of the image receptor	30307 (a)(4)(B)(D)

D. Fluoroscopy Equipment Provisions

Item	Provision	Section
-Barrier/useful beam congruence	Exposure must automatically terminate when the barrier is removed	30307 (a)(4)(C)
-Exposure switch	Dead-man type (terminates exposure when pressure is released)	30307 (a)(5)
-Manual-reset cumulative timing device	Must be available that after 5 minutes either turns off or gives an audible signal	30307 (a)(6)
-Exposure rate for fluoroscopy settings	As low as practicable; shall not exceed 5 rads/minute	30307 (a)(7)(A)
-Useful beam exposure rate compliance:		
-with AEC and high level activation	No combination of tube current and potential may produce a radiation dose rate in excess of 5 rads/minute except when the high level control is activated	30307 (a)(7)(B)
-with AEC and without high level activation	No combination of tube current and potential may produce a radiation dose rate in excess of 10 rads/minute	30307 (a)(7)(B)
-without AEC	No combination of tube current and potential may produce a radiation dose rate in excess of 5 rads/minute except when the high level control is activated	30307 (a)(7)(C)
-High level control	Shall only be operable when continuous manual activation is provided by the operator A continuous signal audible to the fluoroscopist shall indicate that the high level control is being employed	30307 (a)(7)(B)(C)
-Device indicating tube potential and current	Must be located so that the operator can monitor during fluoroscopy	30307 (a)(9)
-Bucky-slot cover	Of 0.25 mm Pb equivalence must cover Bucky-slot during fluoroscopy	30307 (a)(10)

D. Fluoroscopy Equipment Provisions (continued)

Item	Provision	Section
-Protective drapes	Of 0.25 mm Pb equivalence must be provided between the patient and the fluoroscopist and others near the machine	30307 (a)(11)
-Structural shielding	Only secondary barriers are necessary **except** when the unit is a combined fluoro-radiographic unit (then **primary** barriers are necessary)	30307 (b)
-Protective apron	0.25 mm Pb equivalent must be worn by all but the patient	30307 (b)(1)
-Tube current and potential monitoring	At least once a week; make sure they are in the normal range Logs must be kept of all monitoring readings	30307 (b)(2)
-Tabletop or patient useful beam exposure rate measurement	With automatic exposure control - once a year; without automatic exposure control - once each 3 years Replacement, alteration of a major component (X-ray tube, exposure control, imaging assembly, power source) - immediately	30307 (b)(3)
-Cine exposure rate	Once each year Replacement, alteration of a major component - immediately	30307 (b)(4)

E. Mobile (C-arm) Fluoroscopic Equipment Provisions

Item	Provision	Section
-Mobile fluoroscopy equipment	Where applicable, must meet requirements as a stationary unit	30307 (a)(8)
-Source-to-skin distance	Inherent provisions must ensure a minimum of 12 inch distance	30307 (a)(8)(A)
-Image intensification	Must always be provided	30307 (a)(8)(B)
-Conventional fluoroscopic screens	Are not permitted	30307 (a)(8)(B)
-Collimation, diaphragm	If not in place, fluoroscope shall not function	30307 (a)(8)(C)
–Useful beam interception	The entire useful beam must be intercepted by the image receptor	30307 (a)(8)(D)

D. Fluoroscopy Equipment Provisions (continued)

Item	Provision	Section
-Exposure rate	As low as practicable; shall not exceed 5 rads/minute as measured at 30 cm from the input surface of the image assembly	30307 (a)(7)(D)(3)
	For exposure rate measurement use a phantom 9 inches of water or 7.9 inches of Lucite to simulate a patient	30307 (a)(7)(A)(1)
-Personnel monitoring	Is required for all persons operating mobile X-ray equipment	30309 (b)(3)
-Protective aprons	Aprons of at least 0.25 mm lead equivalency shall be worn if one is likely to receive 5 mrads/hr or more	30307 (b)(1)

A P P E N D I X NO. 10

GUIDELINES FOR ESTABLISHING FLUOROSCOPY QUALITY ASSURANCE (QA)

AND

QUALITY CONTROL (QC) PROGRAMS

I. General Provisions.

Quality assurance (QA) and quality control (QC) are management tools that include policies and procedures designed to optimize the performance of X-ray facility personnel, and fluoroscopic and ancillary equipment operation. QA includes all of the following:

- o Quality control (QC) of fluoroscopic and ancillary equipment
- o Administration
- o Education of personnel
- o Preventive maintenance methods

Standardized quality control (QC) tests - carried out with care at prescribed intervals, are designed to detect slowly evolving functional X-ray and ancillary equipment abnormalities and to permit corrective action **before** significant deterioration of image quality occurs.

The major reason for a QA program is to optimize diagnosis and therefore the benefits obtained. A QA program warrants the **expenditures** which include:

- o Personnel costs - QA duties include not only performance of QC tests but also initial education and training
- o Test equipment - QC test equipment cost is relatively small in comparison with the total capital outlay of a radiology department
- o Decrease in patient flow from testing - QC tests should be done outside the regular working hours, if possible

The primary **cost saving** of a QA is the result of avoidance of unnecessary radiation dose to the patient and the operator. Other cost savings include also:

- o Wear and tear of the equipment
- o Less.downtime of equipment
- o X-ray personnel time
- o Improvement in patient flow
- o Decreased cost of equipment service

Quality assurance (QA) has four major steps:

- o Acceptance testing
- o Establishment of baseline performance of equipment
- o Diagnosis of changes in equipment performance before they become fluoroscopically apparent
- o Verification of correction of causes of deterioration in equipment performance

II. Responsibilities of User/Supervisor.

A. The user/supervisor of each facility in which fluoroscopic X-ray procedures are performed shall establish and maintain a quality assurance (QA) and quality control (QC) program.

B. The user/supervisor is responsible for assuring that the fluoroscopic and ancillary equipment under his/her jurisdiction has been inspected and QC tests performed by a qualified individual such as medical or health physicist or an individual with reasonably equivalent qualifications.

C. Any individual who is performing quality control (QC) tests should be qualified by special training and continuing education in diagnostic X-ray physics and quality assurance regarding fluoroscopic and ancillary equipment.

D. Any individual specified in paragraph II. B. shall verify in writing that the fluoroscopic and ancillary equipment is in safe and proper operating condition:

1. Prior to initial use of the equipment.
2. At least yearly after the initial verification.
3. After repair of major components that will influence X-ray output

III. Quality Assurance (QA) Manual.

Each fluoroscopy facility shall have a QA manual (can be incorporated into master QA file or manual). The QA manual shall include at least the following:

A. A list of names and qualifications of individuals responsible for:

1. Supervision of QA.
2. Performing QC tests.
3. Repairing or servicing of fluoroscopic and ancillary equipment.

B. General QA program requirements:

1. Brief description of the QC tests to be performed.
2. Frequency of each QC test.
3. Limits or parameters of acceptability for each QC test.
4. A protocol for correcting each QC finding that does not fall within the acceptable limits.
5. Forms to be used for each QC test.
6. A list of equipment to be used for performing QC tests including at least the following:

    a. Penetrometer (Aluminum step wedge).
    b. Homogeneous phantom.
    c. Stop watch.
    d. Densitometer.
    e. Sensitometer (blue or green, as appropriate).
    f. Wire mesh contact tool.
    g. Thermometer (dial, digital or electronic but **not** alcohol or mercury thermometer)
    h. Dosimeter.
    i. Aluminum filters.

IV. Fluoroscopic and Ancillary Equipment Records, All Systems.

A. Records of all QC tests shall be maintained for fluoroscopic X-ray equipment and shall include at least the following:

1. The fluoroscopic equipment performance evaluation, including acceptance testing and radiation safety surveys.

2. Verification that fluoroscopic equipment is in safe operating condition.

3. Subsequent QC test results.

B. Records or written logs of maintenance and/or repairs of X-ray equipment shall be kept for at least three years.

C. All QA and QC records shall be readily available for review by representatives of the Radiologic Health Branch (RHB) or an agency designated by the RHB.

V. Records for Quality Control (QC) Test Equipment.

The following records shall be maintained:

A. Evidence that QC test equipment shall be in good operational order.

B. Evidence of each repair and/or calibration of QC test equipment shall include at least the following:

1. Date of repair and/or calibration.
2. Criteria used in repair and frequency of calibration.
3. Name of individual who performed repair and/or calibration.

C. Records of each repair and/or calibration of QC test equipment shall be kept for at least three years.

D. The following QC tests shall be performed, after the repair and/or replacement of any component of the fluoroscopic X-ray system, prior to using the equipment on human beings if such repair and/or replacement affects the following:

1. Automatic fluoroscopic collimation.
2. Automatic brightness control (ABC).
3. Automatic gain control (AGC) system and TV performance.
4. High and low contrast resolution.
5. Phototimer reproducibility.
6. Exposure timer accuracy.
7. Milliampere-seconds (mAs) linearity.
8. Kilovolt peak (kVp) accuracy.
9. Radiation dose rates.
10. Focal spot size.
11. Half-value layer.

VI. Darkroom Quality Assurance (QA) Requirements (General Provisions).

The darkroom QA test is essential to ensure the production of high quality radiographs. These are the rules that must be adhered to:

1. No smoking, eating or drinking in the darkroom.
2. Daily cleaning of the darkroom to keep it free of dust.
3. Daily cleaning of counter tops and processor feed trays.
4. Ascertain that hands are clean and dry before touching film.
5. Ascertain that the darkroom safelight is equipped with an appropriate filter and bulb combination.
6. Keep screens free of artifacts. Screens must be cleaned regularly (not less than monthly) with a screen cleaner recommended by the manufacturer of the screens.
7. Load only one film per cassette.
8. Handle films very carefully (with clean and dry hands, and by the edges only) to prevent artifacts due to static electricity, fingerprints, crinkling, creasing, bending, or scratching.

VII. Cine Film Processor.

A. Cine film processor control charts and control films shall be used to regulate proper processor function.

B. Cine film processor maintenance logs shall include all of the following records:

1. Preventive maintenance.
2. Corrective maintenance.
3. Cleaning and chemistry replacement.

C. Each record entry shall be dated and signed or initialed by the individual who performed the QC test.

VIII. Film Processor Records.

1. Film processor control charts and control films shall be used to regulate proper processor function, and shall be kept for at least one year.

2. Film processor maintenance logs shall include all of the following records, and these records shall be kept for at least one year:

   a. Preventive maintenance.

   b. Corrective maintenance.

   c. Cleaning and chemistry replacement.

3. Each record entry shall be dated and signed or initialed by the individual who performed the QC test.

IX. Acceptance Testing and Consultation With a Physicist.

A. Initial Consultation.

1. The consulting physicist should assist the user/supervisor in the development of the Fluoroscopic Procedures and Quality Control Manual.

2. The consulting physicist should assist the facility in establishing the protocol for fluoroscopic and ancillary equipment monitoring. This should include at least all of the following:

   a. Establishing the "house phantom." The specific phantom to be used for monitoring should be a six to ten inches of water in a plastic container or equivalent Lucite phantom or 1.5 inches of aluminum block measuring 6 x 6 inches.

   b. Establishment of an acceptable penetrometer (aluminum step wedge).

   c. Developing consistent machine set-up such as monitoring beam size, image intensifier position, control panel setting, and other required parameters.

   d. Developing a log form for entry of measured data.

   e. Entering the baseline data (calibration) to which weekly readings must be compared.

   f. Establishing means to recognize a 25 percent increase in output rate over calibrated output rate.

   g. If calibrated output rate is >4.0 rads/minute, provide means to test for exceeding 5 rads/minute ceiling.

   h. Indicating what procedures have to be followed in the event that either of the two proceeding tests is positive.

B. Acceptance Testing.

1. Complete machine performance tests must include at least those items required by the Regulations:

   a. Diagnostic tube housing.

   b. Target-to-panel (tabletop) distance of at least 12 inches for under table X-ray tubes.

   c. For overhead X-ray tubes, the target to skin distance shall be at least 12 inches.

   d. Adequate filtration (see requirements of section 30307 for filtration requirements at various tube potentials).

   e. Primary barrier protection efficiency.

f. Collimators (shutters) providing protection equal to diagnostic tube housing.

g. Collimator beam size restrictions.

h. Automatic tracking of beam size linked to image intensifier distance from tabletop.

i. Collimator blade centering to the primary beam.

j. Barrier link interlocks.

k. Five (5) minute cumulative timer.

l. Measurement and recording of panel (tabletop) dose rate and the mA and kVp factors which produce it.

m. Measurement and recording of maximum achievable output rate and the factors which produce it.

n. Checking of protective barriers (Bucky slot covers, lead curtains, lead panel).

o. Measuring high contrast and low contrast resolution for each television monitor during the acceptance testing procedure.

p. Scatter measurements must be made indicating individual measurements at distances clearly marked and/or environmental survey of the room indicating isoexposure curves or profiles for procedures commonly used with a particular unit, taking into consideration where operators and other essential personnel will be placed during a given procedure. The results of measurements must be conspicuously posted either on the equipment or in the room.

q. Automatic brightness control (ABC).

r. Focal spot size.

s. X-ray output waveform.

t. Relative conversion, if feasible (invasive measurement necessary).

u. Television performance and video signal.

C. Proper Use of Protective Devices.

The consulting physicist should illustrate the proper use of at least these protective devices:

1. Aprons.
2. Gloves.
3. Thyroid shield.
4. Leaded plexiglass shields.

D. Care and Use of Personnel Dosimeters.

The consulting physicist should discuss and establish procedures for proper use of the following:

1. Personnel monitoring equipment (film badges, thermoluminescent dosimeters, audible warning devices, pocket dosimeters).
2. Storage of personnel monitoring equipment.
3. Proper use of personnel monitoring equipment/devices.
4. Record keeping of personnel monitoring exposure.
5. Interpretation of personnel monitoring records.
6. Overexposure reporting requirements and procedures.
7. Overexposure investigation procedures.
8. Implementation of radiation safety measures that would preclude recurrence of overexposures.

E. Establishment of ALARA (As Low As Reasonably Achievable).

The consulting physicist should explain the following regarding the establishment of ALARA or As Low As Reasonably Achievable concept of radiation protection:

A. A 5 rad/minute ceiling permitted by the Regulations does not imply that such a high rate is either desirable or recommended.

B. Regulations require that **every effort be** made to keep radiation exposures as low as is reasonably achievable.

C. The physicist should determine the lowest output rate consistent with an adequate, diagnostic-quality image, and use that rate as the benchmark to which weekly monitored values are compared.

X. Fluoroscopic Equipment Quality Control (QC) Tests and Frequency (X-ray tube and image intensifier system).

The following fluoroscopic equipment quality control (QC) tests should be performed as outlined below or more frequently as necessary.

A. Daily.

NOTE: These tests should be performed while warming up the tube at the beginning of daily fluoroscopy work.

	Test	Test tool
1.	**Brightness/contrast optimization of television monitor**	**Phantom, penetrometer (Aluminum step wedge)**

Adjust all TV monitors to show as many steps on the step wedge as possible.

This test should be done before the first fluoroscopic case of the shift.

2. Verification by observation of the following protective devices:

a. Lead curtains.

b. Lead panel.

c. Bucky slot cover.

Verify that these protective devices are located in proper place and/or working properly.

3. Fluoroscopic tower locks observation barrier link interlock

Manual operation of the locks to ascertain/ensure that the fluoroscopy tower locks are functioning properly and that the fluoroscopy power does not drift when positioned.

Interlocks should provide protection from accidental exposure to operators when barrier is not in place or not centered to the primary beam.

4. Compression device/spoon observation

Observation and manual operation of the compression device/spoon to ascertain/ensure that the compression device moves in and out easily, and is not damaged or splattered with contrast material.

5. Automatic fluoroscopic phantom collimation

With phantom in the X-ray beam check shutters to assure that they are visible inside the edges of the fluoroscopic image with the tower in the lowest and highest source-to-image distance (SID) positions.

a. When shutters are fully open, a shutter tangent must be seen at all edges of the monitor.

b. In "auto shutter" mode the size of the field seen on the monitor should not change appreciably regardless of whether the image intensifier is close to the tabletop or at its maximum condition.

	Test	Test tool
6.	**Low contrast performance**	**Phantom, aluminum sheet (1 mm) containing 1 to 7 mm holes sandwitched by two 2 cm aluminum plates**

Determine the reproducibility of low contrast performance by comparing the current to previous (baseline) image.

7.	**Kilovoltage (kVp) and milliamperage (mA) Monitoring**	**Phantom (low contrast test object)**

Under specified standard measuring conditions monitor fluoroscopic kVp and mA during any procedure that call for an average-patient control settings. The readings should be entered in a log and compared to reading taken at time of calibration and evaluated for:

a. Compliance with <25 percent increase in output rate.

b. If calibrated output rate was >4.0 rads/minute, compliance with the requirement not to exceed an output rate of 5.0 rads/minute.

c. Changes must be reported to the responsible individual for immediate correction.

8.	**Mobile spacer for C-arm fluoroscopes**	**Observation**

Ascertain that spacer frame or cones, providing for a source-skin distance of not less than 12 inches, are permanently attached, so that their removal would require tools.

B. **Semi-Annually.**

	Test	Test tool
1.	**Shutters**	**Phantom, cardboard film holder**

When shutters are fully open, a shutter tangent must be seen at all edges of the monitor. In "auto shutter" mode the size of the field seen on the monitor should not change appreciably regardless of whether the image intensifier is close to the table top or as far away as possible.

The maximum fluoroscopic beam size must not exceed the size of the image intensifier.

	Test	Test tool
2.	**Automatic brightness control (ABC) tracking**	**Dosimeter, homogeneous phantom, aluminum sheets, lead blocker, acrylic sheets, ion chamber**

Ascertain that ABC responds to variations in simulated changes in tissue densities. Take readings of kVp and mA with only 50 percent thickness of house phantom in beam, then place entire phantom in beam, then add more attenuating material in the beam. The readings should be proportional to the amount of material placed in the beam.

ABC-AEC (Automatic Exposure Control) system should function similarly to the same installations and other similar systems. AGC (Automatic Gain Control) should be able to compensate from 3 to 9 inches of acrylic.

3.	**Gain control system**	**Dosimeter and homogeneous patient-equivalent phantom.**

Either automatic brightness control (ABC) or automatic exposure control (AEC) is used on most fluoroscopic imaging systems to control the technical factors - kVp and/or mA - or pulse width - to ensure that radiation sufficient to form an adequate image reaches the image intensifier. Many fluoroscopic systems are also equipped with automatic gain control (AGC) which rapidly varies the gain of the video system to maintain a bright image on the video display - TV monitor.

A high quality AGC system should be able to compensate for at least an additional 7.5 cm of acrylic on top of the standard 15 cm phantom.

4.	**High contrast resolution (sensitivity)**	**Phantom or scattering material, resolution test pattern (copper mesh) or a relatively thick (0.05 to 0.10 mm) lead resolution pattern at a relatively low kVp - 50 to 60. Penetrometer.**

Determine the unit's ability to reproduce thin lines and spaces that are practically black lines and white spaces in the image.

NOTE: Resolution patterns with a maximum frequency of 5.0 cycles per millimeter (c/mm) are adequate. If copper mesh patterns are used, the pattern should contain at least 15 to 20 mesh per cm for fluoroscopic systems and at least 25 mesh per cm for cine and photofluorospot (PFS) film devices.

NOTE: **Resolution** can be affected by: focal spot, imaging geometry (source-to-object and source-to-image distance), the quality and focus of the optical system, image intensifier, video camera, and television monitor, and, for conventional spot films, screen-film contact.

	Test	Test tool
5.	**Low contrast resolution (detectability)**	**Rest pattern such as a thin (0.01 to 0.02 mm) lead resolution pattern with some additional scattering material or with a penetrometer consisting of two 2 cm aluminum plates and a 1 mm aluminum sheet containing holes ranging in size from 1.0 to 7.0 mm. Penetrometer, aluminum wafer containing a series of holes, placed between two aluminum plates.**

Determine the unit's ability to resolve relatively large objects that differ slightly in radiopacity from the surrounding area(s).

Look for the smallest diameter hole discernible.

6.	**Five (5) minute timer**	**Stop watch, homogeneous phantom**

The cumulative timer should sound audible alarm at the end of a pre-set time interval.

CAUTION: Use precautions against damaging image intensifier, by placing an attenuator such a phantom in the beam or, if possible, closing shutters completely.

7.	**Actual fluoroscopic beam size (field restriction performance)**	**Alignment template (with a scale visible under or nine pennies and tape measure**

Automatic beam limitation and accuracy of X-Y scales should be ± 3% of source-to-image distance.

8.	**Filtration (HVL measurement)**	**1100 aluminum sheets, dosimeter/ion chamber, semi-log paper**

Determine the amount of aluminum equivalent filtration in the X-ray beam for various kilovoltages used.

Unit is in compliance if HVL is not less than value specified in section 30308 (a) (3).

9.	**Minimum source-to-tabletop distance**	**Tape measure, spot films, radiopaque spacers**

Determine the actual distance of the source-to-tabletop distance by congruent triangles.

	Test	Test tool
10.	**Kilovoltage (kVp) (tube potential) accuracy**	**kVp cassette or direct reading, non-invasive kVp device**

Physicist should ascertain that measured kVp matches indicated value with a tolerance of ± 5%.

The actual vs. indicated kVp shall be maintained as specified by the X-ray equipment manufacturer.

± 5%; less over limited range, e.g.: ± 2 kVp for 60 to 100 kVp

11.	**Typical (standard) patient exposure rates (panel dose rate)**	**Dosimeter/ion chamber capable of measuring the exposure rate, homogeneous patient-equivalent phantom [9 inches of water or 7-7/8 inches of Lucite or 21-cm Lucite or 15 cm (6 inch) of acrylic and 3 mm aluminum]**

Determine the fluoroscopic exposure rate with the unit for the typical patient under conditions specified in Regulations.

To optimize contrast and minimize patient exposure. (Exposure rate is affected by: age, design, kVp, and filtration.)

2 to 3 rads/min, 6-inch mode with grid; 1.5 o 2.5 rads/min, 9-inch mode without grid. Maximum ABC should be set at 80 to 90 kVp.

The exposure rates for a single room should be constant.

Most fluoroscopy systems should be able to produce adequate images with entrance exposures of 2 to 3 rads/min in the 15 cm mode.

Differences in exposure rates exceeding ± 25% between rooms should be investigated.

Systems operating with a grid in place the exposure rates will be 1.5 to 2 times higher.

12.	**Maximum exposure rate**	**Dosimeter/ion chamber, lead sheets, aluminum attenuators**

Determine the highest possible exposure rate(s) the unit can deliver to the patient.

13.	**Apron/glove integrity**	**X-ray film**

Determine that protective devices do not have voids or cracks which would compromise protection desired.

	Test	Test tool
14.	**Distortion**	**Coarse copper mesh (such as screen-film contact mesh or a copper mesh with 7-mm spacing between the wires**

Pincushion, barrel, or stretching of the image, can be caused by: image intensifier tube, optics, video camera and circuitry, and television monitor.

NOTE: It is difficult to quantify the amount of acceptable distortion. Distortion should be vertically and horizontally symmetrical and should appear the same for fluoroscopic, cine, and photofluorospot film images.

XI. Fluoroscopic Imaging Equipment Quality Control (QC) Tests and Test Frequency for Television and Mirror Optics.

	Test	Test tool
1.	**Flare**	**Flare, lead disc, video waveform monitor**

Flare is additional scattered or reflected light within the imaging system which reduces contrast.

Use a lead disc that is equal to 10 % of the image intensifier input surface diameter and image it on film or with the video system. The amount of flare is then determined with photographic film or with a video waveform monitor and analysis of the video signal. Flare often increases with age.

Imaging system flare should be measured as part of the acceptance testing of a new room and periodically thereafter.

2.	**Image lag**	**Lag shutter, storage oscilloscope and camera**

Lag is a phenomenon associated with video imaging systems. Lag degrades the quality of the fluoroscopic images and is defined as the percent video signal remaining in the video field after light is removed from the photocathode. Vidicon exhibits more lag than plumbicon. The TV monitor should be set up using a commercially available video signal generator.

XII. Fluoroscopic Imaging Equipment Quality Control (QC) Tests and Test Frequency for Spot Filming Devices, Spot Film Cameras, Cine Film Processing.

	Test	Test tool
1.	**mAs linearity**	**Ion chamber or digital timer**

The ratios of exposure to the indicated milliampere-seconds product (mrads/mAs) obtained at any two consecutive tube current settings shall not differ by more than 0.10 times their sum.

	Test	Test tool
2.	**Exposure reproducibility**	**Dosimeter**

Coefficient of variation should not exceed ± 5%

3.	**Phototimers**	**Dosimeter, lead sheets, homogeneous phantom**

Coefficient of variation should not exceed ± 5% in exposure.

4.	**Spot film and film camera exposures**	**Dosimeter, homogeneous phantom**

13 to 50 millirads/image at image intensifier, film density of 1.20 ± 0.15 O.D.

5.	**Cine film exposure**	**Dosimeter, homogeneous phantom**

Approximately 4 microrads/frame at image intensifier for 9-inch mode; Approximately 7 microrads/frame at image intensifier for 6-inch mode.

Need high quality, relatively low noise images for cardiac diagnosis. Large number of frames per second - 30 to 60 in about 10 seconds for each view or injection.

Patient entrance exposures range from 50 to 150 rads or more.

USE: Dosimeter capable of measuring the exposure rate of a pulsed X-ray beam, and a homogeneous patient phantom.

There is a general agreement that approximately 15 microrads/frame is required at the entrance to the image intensifier for adequate cine studies using the 23-cm mode.

6.	**Spot film and cine image and beam limitation**	**Radiopaque template, direct size exposure X-ray film**

Displayed diameter not less than 1 cm smaller than specified diameter. Error between beam and image size should be no greater than 3% of SID for all modes and at any tower height.

7.	**Spot film and cine resolution and distortion**	**High and low resolution patterns, homogeneous phantom, distortion grid**

Distortion symmetric, same for fluoroscopic, spot film, and cine images.

Factors that affect the size of the fluoroscopically imaged area: lenses, adjustments in the video camera and electronics, and adjustments of the video monitor.

USE: A template with radiopaque markings (in inches or centimeters), and a direct exposure X-ray film (such as therapy localization film)

	Test	Test tool
8.	**Cine film processor**	**Densitometer, sensitometer thermometer, film (same film as used for spot filming)**

Parameters to be included in daily cine film processor QC tests include:

a. Checking solution temperatures.

The developer and fixer temperatures should be as recommended by any of the following for the film-developer combination being used:

i. Film manufacturer.
ii. Processing solution manufacturer.
iii. Processor manufacturer.

NOTE: Mercury or alcohol thermometers shall not be used for determining solution temperatures because they may break and contaminate solutions.

b. Determination and recording of the speed step.

Control limits ±0.15 optical density (O.D.).

c. Calculation and recording the contrast index or density difference.

Control limits ±0.15 optical density (O.D.).

d. Measuring and plotting the base + fog.

Maximum density shall not exceed 0.25 optical density (O.D.) and should not exceed 0.20 optical density (O.D.).

9.	**Grid alignment**	**Alignment spacer, homogeneous phantom**

Uniform films, density of 1.0 ± 0.10 O.D. perpendicular to anode-cathode axis.

10.	**Grid uniformity**	**Homogeneous phantom**

Uniform films, no grid lines, density 1.20 ± 0.10 O.D.

11.	**Image quality**	**Homogeneous phantom**

Image quality shall be compared to the "standard" image to assure detail and resolution consistency.

NOTE: Films should be viewed on the viewbox and under the viewing conditions used for reading spot films and using a magnifier.

	Test	Test tool
12.	**Film/screen contact**	**Contact test tool**

Film/screen contact shall be verified by use of wire mesh tool placed outside the cassette and across the entire film/screen surface.

13.	**Exposure timer - automatic exposure control (phototiming)**	**Digital timer or mAs meter or ion chamber, homogeneous phantom**

The exposure timer/phototimer control must be checked for reproducibility.

The coefficient of variation of exposures shall not be greater than ± 5 percent as measured on 4-6 consecutive exposures at a commonly used setting.

14. Spot film and spot film cameras

The exposures for conventional spot films (screen-film images) are determined by the speed of the image receptor, the kVp, and the grid.

The exposures for spot film camera images [photofluorospot (PFS) film cameras] that record the images from an image intensifier depend on these and other variables and on the aperture of the camera-lens system.

A small aperture will require greater patient exposure and produce a low noise image.

In order to obtain optimal image quality while minimizing patient and staff exposure it is necessary to ensure that the appropriate patient and image intensifier entrance exposure are being used, while, at the same time, assuring that the film density is appropriate for the examination.

PROBLEM: When using a contrast medium. If the automatic exposure control system detector is covered by a bolus of barium or by a contrast-medium-filled bladder in pediatric cystogram, the kerma for a single image may be as high as 2 to 6 rads.

Typical image intensifier entrance exposure should be in the range of image 50 to 200 microrads/image depending on image intensifier size and film quality requirements.

Angiography systems may need more exposure to reduce the image signal-to-noise ratio.

The film density obtained when a uniform capacity and thickness phantom is used should be about 1.20 ± 0.15 O.D.

XIII. **Recorded Image Viewing (Visual Display) Equipment Quality Control (QC) Tests and Test Frequency for Cine Projectors.**

	Test	Test tool
1.	**Cine projectors**	**SMPTE cine test film**

Resolve all resolution elements in image, minimal jitter, clean lenses, prism, and projection surface, projection bulb clean without metallic deposits.

Final image can be degraded by dirty projector optics. Erratic motion of the film in the projector film gate (jitter) will reduce resolution.

Explanation: Normally expressed as a ratio of output luminescence (Candela/m^2) in SI units or nit, as recommended by the International Commission on Illumination) to exposure rate. This ratio depends on the energy of the X-ray beam and observation characteristics of the intensified input phosphor, the electronic gain (or amplification) of the intensifier, and the electron to light conversion efficiency of the output phosphor.

Look for changes over time indicating deterioration of intensifier.

Video signal levels and line termination.

Should comply with the RS-170 broadcast standard.

All composite video signals should be 1.0 volt peak to peak including synch.

APPENDIX NO. 11

FOCAL SPOT SIZE ACCEPTABLE LIMITS (NEMA, 1984)

Nominal size (mm)	Minimum focal spot dimensions	
	Width (mm)	Length (mm)
0.05	0.0075	0.0075
0.10	0.15	0.15
0.15	0.23	0.23
0.20	0.30	0.30
0.25	0.40	0.40
0.30	0.45	0.65
0.40	0.60	0.85
0.50	0.75	1.10
0.60	0.90	1.30
0.70	1.10	1.50
0.80	1.20	1.60
0.90	1.30	1.80
1.00	1.40	2.00
1.10	1.50	2.20
1.20	1.70	2.40
1.30	1.80	2.60
1.40	1.90	2.80
1.50	2.00	3.00
1.60	2.10	3.10
1.70	2.20	3.20
1.80	2.30	3.30
1.90	2.40	3.50
2.00	2.60	3.70

Definitions:

Nominal focal spot is the manufacturer's stated anode target size.

Measured focal spot is the projected focal size measured along the central axis of the X-ray tube at the image receptor.

Effective focal spot is the length and width of the X-ray beam as projected down the central axis of the X-ray tube.

Actual focal spot is the actual area on the anode that is struck by the X-ray beam.

APPENDIX NO. 12

ISOEXPOSURE CURVES OR PROFILES
(Exposure from scattered radiation)

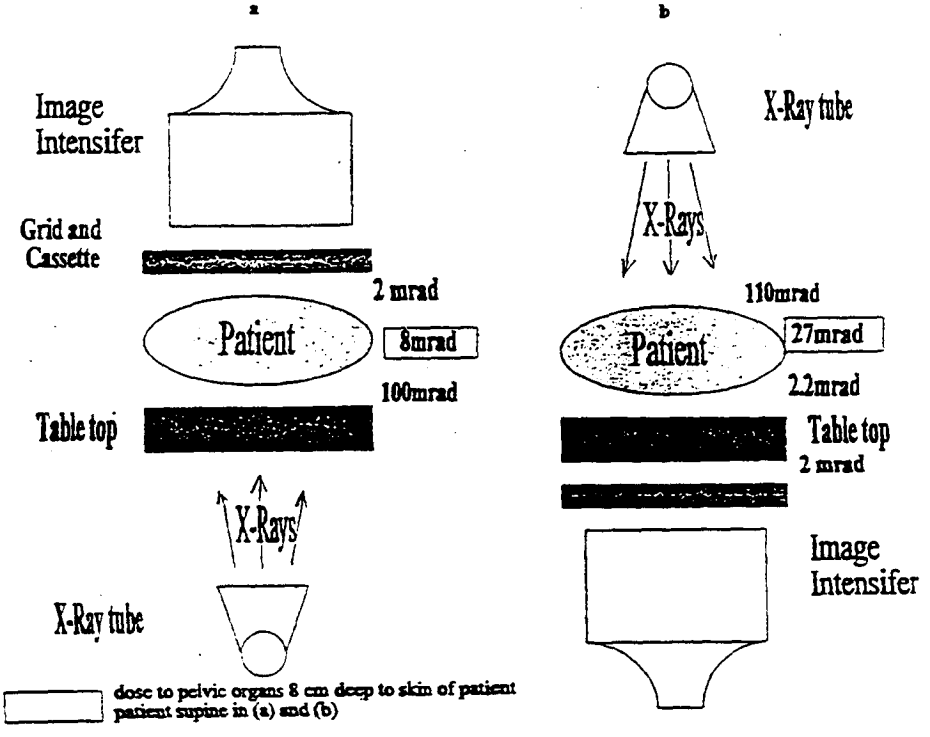
Scattered radiation is present whenever any material is in the path of radiation. During fluoroscopy the patient is the main source of scattered radiation. Most radiation sources are point sources; however, scattered radiation from the patient during an X-ray exposure comes from an extended area. Therefore, it is essential that operators of a fluoroscopy equipment know the isoexposure curves or profiles for the types of examinations they are conducting.

It is important to remember the following:

- Operator exposure to scattered radiation is directly proportional to patient exposure. The amount of radiation scattered from the patient is influenced by the kilovoltage used, area exposed, the thickness of body part being exposed and the time of the examination.

- Protective aprons do not eliminate all exposure. Thus, at 75 kVp a protective apron of 0.25 mm of lead equivalent will eliminate only 96 percent while a 0.5 mm apron will eliminate 99 percent; at 100 kVp a protective apron of 0.25 mm will eliminate only 91 percent and 0.5 mm apron will eliminate 95.3 percent (see Appendix No. 18, page 124).

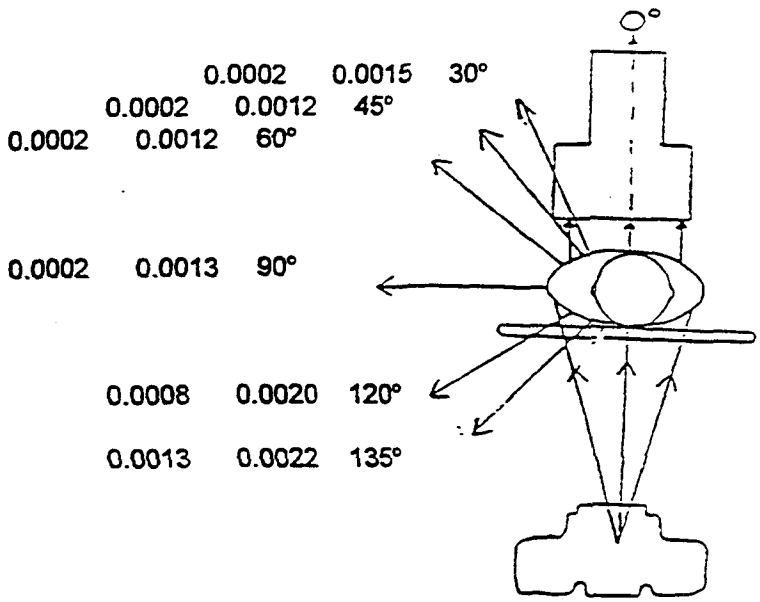
Another important factor in reducing scattered radiation is the physical location of the X-ray tube (under-the-table or over-the-table). As the following illustration clearly shows, the configuration of choice for minimizing radiation exposure to the patient and operator would be where the X-ray tube is located under the table:



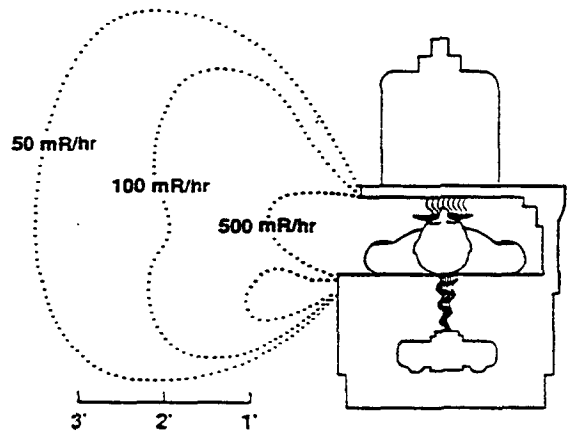
For a tube located under-the-table, the maximum intensities are received below the tabletop at angles of 135 and 120 degrees from the primary beam. In the area above the table, 30 degree represents the angle where the most intensity is received. Minimum intensities are received at scatter angles of 45, 60 and 90 degrees, in that order. The operator always stands during fluoroscopy at right angles to the patient. The figure below illustrates the intensity distribution during fluoroscopy for a tube located **under** the tabletop.

200 cm^2 400 cm^2 = Beam area (at phantom)

Stanford NCRP No. 49

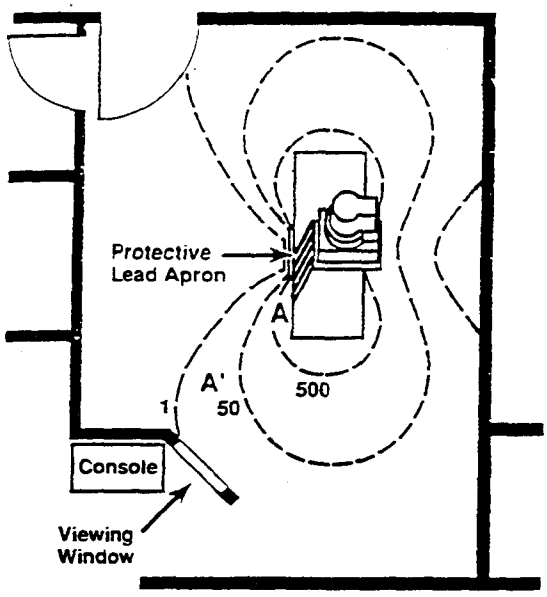


The basic isoexposure curves or profiles for stationary fluoroscopic equipment are illustrated below and on page 115.



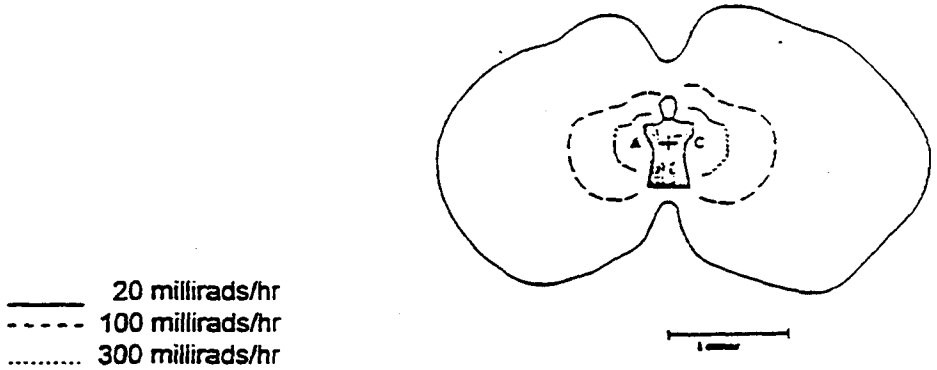
Reproduced, by permission, from Bushong, S. C.: **Radiologic Science for Technologists**, 5th ed., 1993, Mosby Year Book, Inc., St. Louis, Missouri, pg. 631.

Isoexposure profiles for typical fluoroscope demonstrating need for protective curtains and Bucky slot cover.

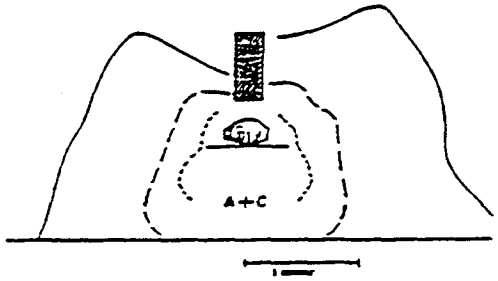


Reproduced, by permission, from Bushong, S. C.: **Radiologic Science for Technologists**, 5th ed., 1993, Mosby Year Book, Inc., St. Louis, Missouri, pg. 631.

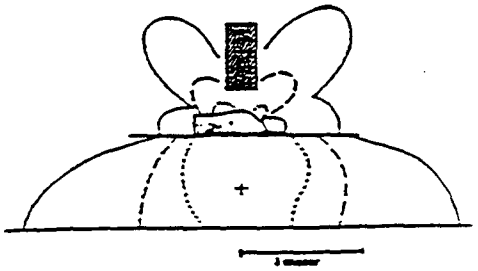
The basic isoexposure curves or profiles (in mrad/hour) for stationary fluoroscopic equipment.



Isoexposure distribution of scattered radiation in the frontal plane



Isoexposure distribution of scattered radiation in the transverse plane



Isoexposure distribution of scattered radiation in the sagittal plane

APPENDIX NO. 13

SPECIFIED ORGAN DOSES FROM DIAGNOSTIC RADIOLOGY

		Organ Dose (uGy)*						
Examination	Films #	Thyroid	Active Marrow	Lung	Breast	Testes	Ovaries	Embryo
Chest	1.5	60	40	200	140	-	0.6	0.6
Ribs	3.0	1,500	450	3,000	4,100	-	4	5
Shoulder	1.8	600	60	350	750	-	-	-
Skull	4.1	2,200	300	20	-	-	-	-
Paranasal sinuses	4.0	7,900	1,200	100	100	10	20	-
Cervical spine	3.7	4,000	100	150	-	-	-	-
Thoracic spine	2.1	800	450	4,000	5,400	-	10	1
Lumbar spine	2.9	3	1,200	1,400	-	70	4,500	4,100
Lumbosacral spine	3.4	1	2,200	350	-	450	6,400	6,400
Pelvis	1.3	-	250	10	-	550	1,500	2,000
Hip	2.0	-	150	-	-	3,700	800	1,300
Mammo-graphy	2.0	-	-	-	1,000	-	-	-
KUB	1.7	1	500	100	-	150	2,100	2,600
Upper GI	4.3	70	1,200	5,000	550	4	450	500
BE	4.0	2	3,000	500	-	600	7,900	8,200
IVP	5.5	-	1,200	350	-	500	6,400	8,200
CT brain	5.0	-	1,400	-	-	70	70	-

* Average examinations, excluding contribution of fluoroscopy.
* 10 uGy = 1 millirad

APPENDIX NO. 14

RELATIVE SOMATIC DETRIMENT OR CARCINOGENIC POTENTIAL FROM COMMON X-RAY EXAMINATIONS (in arbitrary units)

RELATIVE SOMATIC DETRIMENT	Male	Female	
10			
9			
8			
7			
6			
5			
		450	Mammography
4			
	350		**Barium enema**
3		300	Thoracic spine
	300		**Upper GI**, Lumbosacral spine
2	200		Lumbar spine
	180		Thoracic spine, ribs
	160		Full spine (chiropractic)
		150	**Barium enema**
		140	Lumbosacral spine
1		100	Full spine (chiropractic)
	50		KUB, skull cervical spine
		50	Cervical spine, skull, shoulder
	40		Shoulder, hip
	30		Chest, hip
	20		Chest

APPENDIX NO. 15

SOME POSSIBILITIES FOR DOSE REDUCTION IN MEDICAL DIAGNOSTIC USES

Type of procedure	A c t i o n	Reduction factor
All types	Eliminate medically unnecessary procedures	1.2
	Proper processing of films	1.1 - 1.3
	Introduction of quality assurance program (general)	2.0
Fluoroscopy	**Acoustic signal related to dose rate**	**1.3**
	Replacement of film/screen technique	**2.0 - 5.0**
	Variable aperture iris on TV camera	**3.0**
	High and low dose switches	**1.5**
	Radiologist technique	
Radiography (general)	Decrease of rejected films through quality assurance program	1.1
	Beam collimation	1.5 - 3.0
	Increasing peak kilovoltage	1.5
	Use of rare earth screens	2.0 - 4.0
	Increasing filtration	1.7
	Rare earth filtration	2.0 - 4.0
	Use of carbon fiber material	2.0
	Replacement of $CaWO_4$ screens with spot film technique	4.0
	Entrance radiation dose guidelines	15.0
	Gonadal shielding (to gonads)	100.0
(pelvimetry)	Use of CT tomogram or scout view	5.0 - 10.0
	2.0 - 10.0	
Digital radiography	Decrease in contrast resolution	2.0 - 3.0
	Use of pulsed systems	2.0
Computed tomography	Gantry angulation to exclude eye from primary beam (to eye)	2.0 - 4.0
Mammography	Intensifying screens	2.0 - 5.0
	Optimal compression	1.3 - 1.5
	Filtration	3.0

From: NCRP Report No. 100. "Exposure of the U.S. Population from Diagnostic Medical Radiation," page 37.

APPENDIX NO. 16

SUMMARY OF STATE BUILDING CODE REGARDING STRUCTURAL SHIELDING

Excerpts from: "State Referenced Standards Code (Part 12, Title 24, California Code of Regulations".

Chapter 12-91 – Radiation Shielding Standards.

Section 12-91-101 – All Healing Arts X-Ray Installations.

All radiation shielding barriers in rooms and enclosures housing radiation machines shall comply with the mandatory standards and appendices in Report No. 35, "Dental X-RAY Protection"; Report No. 49, "Structural Shielding Design and Evaluation for Medical Use of X-Rays and Gamma Rays of Energies up to 10 MeV"; Report No. 51, "Radiation Protection Design Guidelines for 0.1-100 MeV Particle Accelerator Facilities". Published by the National Council on Radiation Protection and Measurements, 7910 Woodmont Avenue, Bethesda, Maryland 20814.

Section 9102 – Scope.

For the purposes of this chapter, the following terms shall have the meaning indicated:

Primary Protective Barrier – A barrier to attenuate the useful beam.

Secondary Protective Barrier – A barrier to attenuate stray radiation.

Useful Beam – The radiation which passes through the window, aperture, cone, or other collimating device of the tube housing.

Stray Radiation – Radiation not serving any useful purpose, which includes leakage and secondary radiation.

Section 9103 – Radiation Shielding Barriers.

All radiation shielding barriers in rooms and enclosures housing machines shall meet the requirements of Section 12-91-101, Chapter 12-91, Part 12, State Referenced Standards Code. The Department of Health Services is the only agency that may grant a variance or exemption to these standards.

Section 9104 – Medical Radiographic and Photofluorographic Installations.

(a) **Operator Station.** The operator's station at the control shall be behind a protective barrier either in a separate room, in a protective booth, or behind a shield which will intercept the useful beam and any radiation which has been scattered only once.

(b) **Patient Observation and Communication.** Provisions shall be made for the operator to observe and communicate with the patient without leaving the shielded position at the control panel. When an observation window is used, it must be provide radiation attenuation equal to that required in the surrounding barrier.

APPENDIX NO. 17

EXCERPTS FROM TITLE 22, CALIFORNIA CODE OF REGULATIONS
(Health Facilities and Referral Agencies)

Section 70251. Radiological Services Definition.

Radiological services means the use of X-ray, other external ionizing radiation, and/or thermography, and/or ultrasound in the detection, diagnosis and treatment of human illnesses and injuries with appropriate staff, space, equipment and supplies. Ultrasound although properly the province of physical medicine, may be considered part of the radiological services.

Section 70253. Radiological Services General Requirements.

(a) All hospitals shall maintain diagnostic radiological services.

(b) Written policies and procedures shall be developed and maintained by the person responsible for the service in consultation with other appropriate health professionals and administration. Policies shall be approved by the governing body. Procedures shall be approved by the administration and medical staff where such is appropriate.

(c) The responsibility and the accountability of the radiological services to the medical staff and administration shall be defined.

(d) The use, storage and shielding of all radiation machines and radioactive materials shall comply with the California Radiation Control Regulations, Subchapter 4, Chapter 5, Title 17, California Code of Regulations.

(e) All persons operating or supervising the operation of X-ray machines shall comply with the requirements of the Regulations Relating to Radiologic Technology, Subchapter 4.5, Chapter 5, Title 17, California Code of Regulations.

(f) Diagnostic radiological services may be performed on the order of a person lawfully authorized to give such an order.

(g) Reports of radiological service examinations shall be filed in the patient's medical record and maintained in the radiology unit (department).

(h) X-ray films, or reproductions thereof, shall be retained for the same period of time as is required for other parts of the patient's medical record.

(i) Periodically, an appropriate committee of the medical staff shall evaluate the services provided and make recommendations to the executive committee of the medical staff and administration.

Section 70255. Radiological Service Staff.

(a) A physician shall have overall responsibility for the radiological service. This physician shall be certified or eligible for certification by the American Board of Radiology. If such a radiologist is not available on a full-time or regular part-time basis, a physician, with training and experience in radiology, may administer the service. In this circumstance, a radiologist, qualified as above, shall provide consultation service at suitable intervals to assure high quality service.

(b) Sufficient certified radiologic technologists shall be employed to meet the needs of the service being offered.

(c) There shall be at least one person on duty or on call at all times capable of operating radiological equipment.

Section 70257. Radiological Service Equipment and Supplies.

(a) There shall be sufficient equipment and supplies maintained to adequately perform the radiological services that are offered in the hospital. As a minimum, the following equipment shall be available.

(1) At least one radiographic and fluoroscopic unit. On and after January 1, 1977, fluoroscopic units shall be equipped with image intensifiers.

(2) Film processing equipment.

(b) Proper resuscitative and monitoring equipment shall be immediately available.

Section 70259. Radiological Service Space.

(a) There shall be sufficient space maintained to adequately provide radiological services. This shall include but not be limited to the following:

(1) A separate X-ray room large enough to accommodate the necessary radiographic equipment and to allow easy maneuverability of stretchers and wheelchairs.

(2) Toilet facilities located adjacent to or in the immediate vicinity.

(3) Dressing room facilities for patients.

(4) Film processing area.

(5) Sufficient storage space for all the necessary X-ray equipment, supplies and for exposed X-ray films and copies of reports.

(6) If X-ray examinations are to be performed on outpatients, outpatient access to the radiological spaces shall not traverse a nursing unit.

APPENDIX NO. 18

PRIMARY FLUOROSCOPIC BEAM ATTENUATION FACTORS

kVp	mA	mm Pb equivalent	% beam attenuation normal*	hardened**
50	2	0.0	0.0	0.0
50	2	0.25	99.4	92.9
50	2	0.30	99.5	98.0
50	2	0.50	99.9+	99.0
50	2	1.00	99.9+	99.9+
75	2	0.0	0.0	0.0
75	2	0.25	96.1	70.0
75	2	0.30	96.7	78.1
75	2	0.50	99.2	88.0
75	2	1.00	99.9+	98.2
100	2	0.0	0.0	0.0
100	2	0.25	91.4	62.7
100	2	0.30	92.4	70.7
100	2	0.50	97.3	80.3
100	2	1.00	99.6	95.0

* HVL @ 80 kVp, 2 mA: 3.6 mm Al.

** Approximately 2 mm Cu filter added to 50 kVp beam and 4 mm Cu filter added to 75 and 100 kVp beam.

Measurements performed by Brannon, T. L. and Steward, K. of Valley Sierra Health Services, Sacramento, February 1984, for the Radiologic Health Branch of the California Department of Health Services.

APPENDIX NO. 19

PERSONNEL MONITORING DEVICES -- SUMMARY

A. Film Badge.

Radiation detected: X-rays, gamma, beta, thermal neutrons, fast neutrons.

Range: 0.0 to 700 rad.

Minimum energy detected: 10 keV for gamma rays, 200 keV for beta rays.

Advantages: Inexpensive, give estimates of integrated dose, provides permanent record, allows objective review, detects problems.

Possible disadvantages: Moderate directional dependence, strong energy dependence for low energy X-rays, false readings produced by heat, pressure, and certain vapors.

B. Thermoluminescent Dosimeter (TLD).

Radiation detected: X-rays, gamma, beta, thermal neutrons, fast neutrons.

Range: 10 mrads to 10^5 rad.

Minimum energy detected: 10 keV.

Advantages: Infinite shelf life within the useful range, small size and low directional dependence, small energy dependence, reusable, inexpensive, give estimate of integrated dose over long periods.

Possible disadvantages: System supplied as commercial service, cancellation of dose upon reading, dose range depends on the sensitivity of the reader, radiation detected depend on type of TLD material, increased sensitivity with each use, fading, subjective information of exposure is not available.

C. Pocket Ionization Chamber.

Radiation detected: X-rays, gamma, beta, thermal neutrons, fast neutrons.

Range: 0.001 to 2000 rads (theoretical); for X-ray use: 0.001 to 200 millirads.

Minimum detected energy: 30 keV for gamma rays, 20 keV for fast neutrons.

Advantages: Yield fairly accurate information quickly, small size, low directional dependence, reasonably uniform in response to radiation in the energy range of 50 keV to 2 MeV, economical for long-term use, require little maintenance, reusable.

Possible disadvantages: No permanent record, frequent reading tabulation, recharging may be required, subject to accidental discharge (through shock and electrical leakage), range of measurement is limited.

APPENDIX NO. 20

GLOSSARY

NOTE: 1. 10 CFR 20 refers to the Nuclear Regulatory Commission Regulations incorporated by reference in the California Code of Regulations (CCR), title 17.

2. Sections 30xxx refer to the California Code of Regulations (CCR), title 17.

Aberration: An undesirable characteristic of a lens or optical system. It prevents the lens from providing an exact reproduction of the original subject, by degrading or distorting the image.

Absorbed Dose: Means the energy imparted by ionizing radiation per unit mass of irradiated material. The unit of absorbed dose are the rad and the gray (Gy). See also dose. **10 CFR 20** [The SI unit of absorbed dose is the gray (Gy)].

Absorption (differential, rare earth screen, specific rate of, visible light): The transfer of energy from an X-ray beam to the atoms or molecules of the matter through which it passes. The process whereby radiation is stopped and reduced in intensity as it passes through matter. Lead, which is denser than most materials, is one of the best absorbers of X-rays.

Active Trace: That part of the television scanning system utilized to reproduce the subject.

Adult: Means an individual 18 or more years of age. **10 CFR 20**

ALARA: Acronym for "as low as is reasonably achievable" means making every reasonable effort to maintain exposures to radiation as far below the dose limits in this part as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest. **10 CFR 20**

Algorithm: A formula or set of steps for solving a problem.

Aluminum Equivalent: The thickness of type 1100 aluminum alloy affording the same attenuation, under specified conditions, as the material in question.

Ambient: The natural or inherent environment in which some event or activity is to take place. For example, ambient lighting would refer to the normal level of illumination in a particular area.

Ampere: The unit of electrical current equal to the steady current produced by one volt applied across a resistance of one ohm. This electrical current determines the quantity of X-rays produced at the anode (target) of the X-ray tube.

Amplifier: A device by which an electrical signal may be strengthened.

Analog: A continuous variable electronic signal.

Analog-to-Digital Converter (ADC): Device that converts an analog signal into a digital signal.

Angstrom (Å): A unit of length used primarily to indicate the wavelength of the visible or shorter wavelength portion of the spectrum. One angstrom equals 10^{-10} meters.

Angular Magnification: A measure of the angle subtended at the eye by an object compared to some fixed standard reference. The object for the eye may be a real or virtual image created in the optical instrument.

Anode. A positive electrode, also referred to as a target, toward which electrons are accelerated from the cathode. The target is usually composed of tungsten. When these electrons hit the anode or target some of their kinetic energy is converted to X-rays.

Aperture: (For computed tomography) - The opening in the collimation that allows radiation to reach the detector.

Artifact: Any density or mark on a radiograph that is caused by something not belonging to the part being X-rayed.

> **Image intensifier tube artifact:** Minute particles of imperfection within an image tube. They appear as small dark spots on the output screen of the image intensified tube.

Attenuation: The process by which an X-ray beam of radiation is reduced in intensity by absorption or scattering when passing through material. (See absorption).

Attenuation Block: A block or stack of material with a cross section larger than the beam with a total thickness equivalent to 3.8 cm of type 1100 aluminum.

Automatic Exposure Control (AEC): Means a device which automatically controls one or more technical factors in order to obtain at a prescribed location(s) a required quantity of radiation. **30306(a)**

Bandwidth: The total number of cycles per unit of time (usually one second) which may be used to modulate the electron beam in a television camera.

Barrier, Protective: Barrier of attenuating materials used to reduce radiation exposure.

> **Primary:** Barrier sufficient to attenuate the useful beam to the required degree.
>
> **Secondary:** Barrier sufficient to attenuate stray radiation to the required degree.

Base Density: The optical density of a film is the optical density that would result if an unexposed film were processed through the fixer, wash, and dryer, without first passing through the developer. The optical density is due to the supporting base of the film alone.

Base Plus Fog Density: The optical density of a film due to its base density plus any action of the developer on the unexposed silver halide crystals. The base plus fog density can be measured by passing an unexposed film through the entire processing cycle and measuring the resultant optical density with a densitometer.

Beam: A flow of electromagnetic radiation. See useful beam.

Beam Limiting/Defining Device: A device which provides a means to restrict the dimensions of the useful beam. In regions outside the beam the device, if an integral part of the radiation-producing equipment, shall provide shielding adequate to meet the leakage requirements of the source assembly to which it is attached.

Beam Splitter: An optical element used to divide a beam of light so that it may be simultaneously projected in two different directions.

Bergonié and Tribondeau, Law of: The empirical rule which states that the radiosensitivity of tissues depends on the number of undifferentiated cells which the tissue contains, the degree of mitotic activity in the tissue, and the length of time the cells of the tissue stay in active proliferation. Generally, the more undifferentiated the cell line, the greater the radiosensitivity.

Black Level: The level in the composite video signal at which the kinescopic electron beam is completely extinguished.

Blanking: That period of time during the television scanning process when the electron beam is automatically driven to the black level for retrace.

Blind Spot: The point where the optic nerve enters the retina. Since there is an absence of all light sensitive cells, no vision is developed.

Bone Marrow: A soft tissue which constitutes the central filling of many bones and serves as a producer of red blood cells. Bone marrow is especially sensitive to X-rays.

Boost Position: The high level control setting of fluoroscopic equipment that enables it to override routine exposure limits.

Bucky: See grid.

Caliper: An instrument used to measure patient thickness. The measurement should be done where the central ray (CR) enters and exits the body part.

Carcinogenic: Producing cancer.

Cassette: A light-tight film holder containing intensifying screens mounted within front and back structures that are hinged together and which are made of low X-ray absorption material.

Cataract: A clouding of crystalline lens of the eye which obstructs the passage of light.

Cathode: A negative electrode; electrode in the X-ray tube from which electrons are emitted. It consists of one or two filaments and a focusing cup.

Centigray: 0.01 gray. 1cGy equals one rad.

Central Ray (central beam) (CR): Refers to the X-rays in the center of the useful or primary beam.

Certified Source Assembly: A source assembly certified by an assembler to comply with the leakage requirements of the Radiation Control for Health and Safety Act of 1968 (FDA, 1986).

Chamber, Pocket Ion: A small, pocket-sized ionization chamber used for monitoring radiation exposure of personnel. Before use it is given a charge and the amount of discharge during the period of use is a measure of the total radiation exposure during the period.

Characteristic Curve: A type of input-output curve used to express the change in density with the change in radiation dose of the photographic or X-ray film. Also sometimes known as an H & D curve. The characteristic curve graphically demonstrates the relationship between the density and radiation dose. In technical terms: Characteristic curve is a graph of photographic density against logarithm of radiation dose. Also known as an H & D curve.

Chromosome: Important macromolecules found in all body cells. Chromosomes contain the genes of heredity-determining units.

Chronic Exposure: Irradiation that is spread out over a period of years.

Cine Camera: A camera used for recording motion - in cinefluoroscopy one that usually visualizes either 16 or 35 mm film. Frame rates may be on the order of 15 to 60 frames per second.

Cinefluorography or Cine: The production of motion picture photographic records of the image formed on the output phosphor of an image intensifier by the action of X-rays transmitted through the patient (often called cineradiography).

Cineradiography: Means the making of a motion picture record of the successive images appearing on a fluorescent screen. **30306(b)**

Closed Circuit: The distribution of a television signal by means of a coaxial cable or microwave transmission. Permits selective transmission as compared to a normal broadcast.

Coaxial Cable: A type of special cable used to transmit the composite video signal from the camera to the monitor and/or magnetic recorders. The signal conductor, in the center of the cable, has a protective grounded metallic sheath around it.

Collective Dose: Is the sum of the individual doses received in a given period of time by a specified population from exposure to a specified source of radiation. **10 CFR 20**

Collimating Lens: A highly corrected lens used to collect light from some source and project it into space as a family of parallel-light beams.

Collimator: A device for restricting/confining/limiting a beam of radiation within an assigned solid angle.

Color Translation: A technique for rendering a fluoroscopic or radiographic image in a more dramatic manner. The original gray scale is converted into a multicolored scale.

Compliance Test: A compliance test is performed on X-ray equipment to ensure that the X-ray unit meets the radiation safety regulations.

Composite Video Signal: The composite television signal transmitted from the camera, consisting of three parts: video, blanking, and synchronizing pulses.

Compression Cone: This device is an attachment for use in fluoroscopy of the GI tract and serves to permit the examiner to apply pressure to various parts being examined, displace some of the overlying structures, and improve the examination.

Compton Effect or Scattering: An interaction between an incoming X-ray photon and an outer shell electron of an atom of the irradiated object in which the photon surrenders a portion of its kinetic energy to dislodge the electron from its orbit and then continues on its way but in a new direction. This process accounts for most of the scattered radiation produced during diagnostic X-ray examinations.

Computed Tomography (CT): See tomography.

Cone: A round/circular metal tube/shield attached to the X-ray tube housing or placed in front of the X-ray tube to limit the size of the X-ray beam to a predetermined size and shape.

Cones: One of the two types of cells contained in the retina of the human eye. Cones are less sensitive than are the rods, but are responsible for creating color differences.

Contrast: In radiology, contrast is defined as the difference in density between light and dark areas on the processed film. Contrast can be measured from a characteristic or H & D curve by finding the tangent of the straight line portion of the curve.

Contrast (fluoroscopy image): The ratio of the brightness on the open field at a given exposure to the brightness underneath a lead disk covering 10 percent of the useful central imaging area in a second exposure. Contrast for modern image intensifiers exceeds 15:1.

Contrast Agents or Media: Low toxicity materials such as barium or iodine that possess high atomic numbers and thus decrease the transmission of X-rays. The absorption of X-rays in barium and iodine is much greater than that in bone and tissue which have much lower effective atomic numbers. When these materials are administered to vessels or organs they allow increased visualization of their structures. The use of contrast agents in diagnostic radiology is derived from their ability to enhance the photoelectric effect.

Control Chart: A chart used to record and control the performance of a radiographic processor as a function of time.

Controlled Area: Means an area, outside of a restricted area but inside the site boundary, access to which can be limited by the licensee for any reason. **10 CFR 20** (It is an area in which radiation safety rules are enforced.)

Coulomb: Means a unit of electric charge equal to 1 ampere-second (the quantity of electricity transferred by a current of one ampere in one second).

Conversion Factor (of an image intensifier): The quotient of the luminescence of the output phosphor of the image intensifier divided by the kerma rate at the input phosphor. The recommended means of expressing the luminance gain of an image intensifier tube. Defined as being the ratio of the output screen luminance in candela per square meter to the input exposure rate in millirads per second.

Creep: The horizontal or vertical movement of fluoroscopic equipment during an X-ray examination.

CT Number: One of a set of numbers on a linear scale which are related to the linear attenuation coefficients calculated by a computed tomographic device. One of the specific set of CT numbers on a scale from -1000 for air to + 1000 for bone, with water equal zero, which is called a Houndsfield unit.

Cycle: A complete set of events, or changes, during which some process of a periodic nature returns to its original starting point. In the case of a television system, it is used to measure the length of time it takes to start, stop, and prepare to start an electrical signal.

Dead-Man Switch: Means a switch so constructed that a circuit-closing contact can only be maintained by continuous pressure by the operator. **30306(d)**

Deflection: In television, a sweeping movement of an electron beam through an angle in order to generate the raster. The beam deflection is usually caused by creating a magnetic field around the electron beam.

Declared Pregnant Woman: Means a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception. **10 CFR 20**

Deep-Dose Equivalent (H_d): Applies to external whole-body exposure and is the dose equivalent in a tissue depth of 1 cm (1000 mg/cm^2). 10 CFR 20

Definition: See detail.

Densitometer: An instrument used to measure film density that is the degree of blackening of film by measuring the ratio of the light intensity incident on the film to the light intensity transmitted through the film. (The densitometer is a device designed to measure the optical density of an exposed and processed film. It measures the density of the individual steps on films exposed by a sensitometer, and is commonly used for daily processor quality control.)

Density: Film blackening or the amount of light transmitted through the film. (The density on a radiograph is related to the amount of silver deposited on the film base.)

Department: Means the State Department of Health Services. 30301 (c)

Depth of Focus: The allowable out-of-focus condition in the image plane that may be tolerated and still maintain a specified resolving power.

Detail (definition): In radiography, detail refers to the sharpness of structure lines or contour lines on the processed films.

Developer: The chemical solution (alkaline) used in film processing that makes the latent image visible.

Developer Replenishment: The purpose of developer replenishment is to maintain the proper alkalinity, chemical activity, and level of solution in the developer tank.

Diagnostic Source Assembly: A diagnostic source housing (X-ray tube housing) assembly with a beam limiting device attached. This assembly shall be so constructed that the leakage radiation air kerma measured at a distance of one meter from the source does not exceed 1 mGy (0.1 rad) in one hour when the source is operated at its leakage technique factors.

Diagnostic-Type Tube Housing: Means an X-ray tube housing so constructed that the leakage radiation measured at a distance of 1 meter from the source cannot exceed 100 millirads in 1 hour when the tube is operated at its maximum continuous rate of current for the maximum rated tube potential. 30306(e)

Diaphragm: A plate, usually lead, with a central aperture so placed as to restrict the useful X-ray beam. See collimator.

Diffraction: The spreading of a beam of light or other electromagnetic radiation when passing through an aperture or over an opaque edge.

Diffuse Reflection: One of two types of reflection realized when light strikes a diffusing or matte surface such that light is reflected in a scattered pattern.

Digital: Input that has a restricted number of discrete, or limited, values.

Digital Radiography: A diagnostic procedure using an appropriate radiation source and an imaging system which collects, processes, stores, recalls and presents image information in a digital rather than analog fashion.

Digital Subtraction: An image processing procedure used to improve image contrast by subtracting one digital image from another.

Digital-to-Analog Converter (DAC): Device that converts digital signals into analog signals.

Diopter: A measurement of the power of a lens; defined as being the reciprocal of the focal length of the lens measured in meters.

Direct Effect: The effect of ionizing particles interacting directly with (transferring their energy to) biologic macromolecules such as DNA, RNA, ATP, proteins or enzymes: the chemical bonds of these macromolecules break and they become abnormal structures.

Dispersion: The decomposition of white light into its component colors, most commonly done by passing the light through a prism.

Distortion: Unequal magnification of different portions of body area being X-rayed. A variation in magnification across the field of an image. If a camera lens has distortion, the image it produces, of a square object, will have curved lines leading to either barrel or pin cushion shapes.

Dominant Mutation: A genetic mutation that will probably be expressed in the offspring.

Dose or Radiation Dose: Is a generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, or total effective dose equivalent, as defined in other paragraphs of this section. **Section 20.1003, 10 CFR 20**

> **Absorbed dose:** The amount of energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are the rad (1 rad equals 100 ergs per gram) (see rad) and the gray (Gy). The SI unit of absorbed dose is the gray (Gy); 1 Gy = 1 joule/kg. There are 100 rads per Gy.
>
> **Dose equivalent (H_T):** Means the product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and sievert (Sv) (1 rem = 0.01 Sv). **10 CFR 20**
>
> **Gonad dose:** The amount of radiation absorbed by the gonads resulting from any part of the body being exposed to X-rays.
>
> **Dose rate:** Absorbed dose (or dose equivalent) delivered per unit of time.

Dosimeter: An instrument used to detect and measure accumulated radiation exposure.

> **Personnel dosimeters:** Devices designed to be worn or carried by an individual for the purpose of determining the dose equivalent received (e.g., film badges, pocket chambers, pocket dosimeters, ring badges, thermoluminescent dosimeters, etc.).
>
> **Personnel dosimetry:** The use of instruments and associated procedures (including calibration and quality assurance) to ascertain the radiation dose absorbed by personnel.

Dosimetry Processor: Means an individual or organization that processes and evaluates individual monitoring equipment in order to determine the radiation dose delivered to the equipment. **10 CFR 20**

Dropouts: Minute blank spots in the magnetic recording media. They cause the loss of part or all of a horizontal line.

Dual Field Tubes: One type of X-ray image intensifier tube in which the input screen is a fixed size, but having the capability of displaying this input screen on the output screen at two different sizes. The two field sizes are created by changing the "crossover" point of the electron beam.

Duty Factor: The ratio of on-to-off time of some machine or process. A 100 percent duty factor would indicate continual usage. A 50 percent duty factor would indicate an average of 1/2 off and 1/2 on.

Dynamic Radiography: Radiographic procedures that allow the visualization of motion.

Dynamic Range: The maximum black-to-white range of which the television system is capable.

Dynode: That section of a photomultiplier tube in which secondary electrons are emitted, thus providing amplification.

Effective Dose Equivalent (H_E): Is the sum of the products of the dose equivalent to the organ or tissue (H_T) and the weighting factor (W_T) applicable to each of the body organs or tissues that are irradiated ($H_E = \sum w_T H_T$). **10 CFR 20**

Elective Examination: An examination not requiring immediate execution and therefore able to be planned for the patient's convenience and safety.

Electromagnetic Radiation: See radiation.

Electron Volt: A unit of energy equivalent to the energy gained by an electron in passing through a potential difference of one volt.

Embryo/Fetus: Means the developing human organism from conception until the time of birth. **10 CFR 20**

Embryological Effects: Damage to an organism that occurs as a result of exposure of the organism to ionizing radiation during its embryonic stage of development.

Emulsion: The sensitive layer of photographic film containing tiny crystals of a silver compound embedded in a layer of gelatin.

Entrance Pupil: See pupil.

Erg: The amount of work done by a force of one dyne acting through a distance of one cm. Unit of energy and work which can exert a force of one dyne through a distance of one cm. It is equal to 10^{-7} joules (unit of work).

Exit Pupil: See pupil.

Exposure: Means being exposed to ionizing radiation or to radioactive material. **10 CFR 20**

Acute exposure: Radiation exposure of short duration.

Chronic exposure: Radiation exposure over a long duration by fractionation or protraction.

Medical exposure: Intentional physician prescribed exposure of an individual to radiation for diagnostic or therapeutic medical purposes.

Exposure or irradiation time: The time interval in a radiological examination within which X-rays are incident upon the body part under examination.

External Dose: Means that portion of the dose equivalent received from radiation sources outside the body. **10 CFR 20**

Extremity: Means hand, elbow, arm below the elbow, foot, knee, or leg below the knee. 10 CFR 20

Eye Dose Equivalent: Applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 centimeters (300 mg/cm). 10 CFR 20

F-Number: The term used to denote the relative speed of a camera lens. A lens' f-number is equal to its focal length divided by its diameter. (See relative aperture.)

Field: See television field.

Field Curvature: A lens aberration in which the image surface of a plane object is not a plane but rather is curved. Its shape curvature may be frequently measured as an angle.

Field of View: The area over which a lens can create a usable image.

Film Badge: A personnel monitoring device. The film badge device records radiation exposure accumulated at a low rate over a long period of time (usually one month). The assembly contains a packet of unexposed photographic film and a variety of filters (absorbers).

Film Speed: The reciprocal of exposure needed to produce a film density of 1.0 O.D. above the base plus fog - used for screen types, medical X-ray films.

Filter: Means material placed in the useful beam to absorb preferentially the less penetrating radiations. 30306(f)

> **Added filter:** Sheets of metal (usually aluminum or its equivalent) that are placed in the direct path of the X-ray beam.
>
> **Inherent filter:** The X-ray tube and its housing such as the glass envelope (window) through which the X-ray beam passes.
>
> **Total filtration:** The sum of the inherent and added filters.

Fixer: A chemical solution (acidic) which removes the unexposed and undeveloped silver halide crystals from the film so it will not discolor or darken with age or exposure to light. Fixer also hardens the gelatin containing the black metallic silver so film may be dried and resist damage from abrasions.

Fixer Retention: The inadequate removal of fixer from the film by the water in the wash tank of the processor. Retained fixer causes eventual brown discoloration of the radiograph.

Fluorography: The production of a photographic record of the image formed on the output phosphor of an image intensifier by the action of X-rays transmitted through the patient.

Fluoroscopy: A radiological examination utilizing fluorescence for observation of the transient image.

Flux Gain: Increase in output image brightness from an image intensifier tube expressed as a ratio of the number of light photons at the output screen to the number of light photons produced at the input phosphor.

Focal Length: A property of all lenses. That distance from the lens at which the lens will image an infinitely distant object.

Focal Spot: A small area on the target of the anode toward which the electrons from the focusing cup of the cathode are directed. X-radiation originates at the focal spot.

> **Effective focal spot:** The apparent size of the radiation source when viewed from the central axis of the useful radiation beam.

Fog or Fogging: A cloudy appearance of the finished radiograph caused by several factors such as old or contaminated processing solutions, exposure to chemical fumes, faulty darkroom safelight, or scatter radiation.

> **Gross fog:** Base density plus emulsion fog on an X-ray film.

Format: The film frame size of a photographic camera; or, the scanning area of a pickup tube in a television camera.

Frame: See television frame.

Frame Rate: In cine or television cameras, that number of sequential pictures per unit of time (usually one second) that are recorded and displayed.

Framing: In cinefluorography, the registration of the circular image of the output phosphor on the rectangular film element or frame.

> **Framing frequency:** The number of frames of film per second (f/s).
>
> **Underframing:** The circular image is entirely within the rectangular frame.
>
> **Overframing:** The entire rectangular frame is filled with the circular image extending beyond the edges of the frame.

Frequency: A means of expressing the number of times, during some unit of measure, that an even occurs. Most often refers to a number of events per second (temporal or time frequency). It may also refer to a number of events per unit of length (spatial frequency).

Gain: The original method of expressing the increase in luminescence of the image intensifier tube as compared to a standard fluoroscopic screen. Typical values of gain for image intensifier tubes may be three to six thousand or more.

Gamma: Output rate of change, with respect to an input rate of change. In a television system, it could be comparison of the relative image contrast on the kinescope to the original subject scene.

Geiger-Mueller (GM) Counter: Highly sensitive, gas-filled radiation detection device.

Generator, X-Ray: See X-ray generator.

Genes: Parts of chromosomes that determine the inherited traits of the offspring. Genes are contained in the nuclei of cells. (Changes in reproductive cells that may result in abnormal offspring of persons.)

Genetic Effects: Mutations or other changes that are produced by irradiation of the genes in a cell which might reproduce.

Geometric Unsharpness: Unsharpness of the recorded images due to the combined optical effect of finite size of the radiation source and geometric separation of the anatomic area of interest from the image receptor and the source.

Gonad Dose: See dose.

Gonad Shield: Devices used during radiologic procedures to protect the reproductive organs from exposure to the useful X-ray beam. (A radiologist shall establish a list of all diagnostic X-ray examinations for which testicular/ovarian shielding shall be routinely used.)

Gradient: The measure of the slope of a line tangent to the characteristic curve (H & D curve).

> **Average gradient:** Average of all gamma measurements in the diagnostic density range for X-ray films.
>
> **Film gamma:** The greatest gradient.

Gram: A metric unit of mass and weight nearly equal to one cubic centimeter of water at its maximum density.

Gray: (Gy) is the SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 Joule/kilogram (100 rads). **10 CFR 20**

Grid: A series of lead strips separated by spacers transparent to X-rays. A grid's function is to remove scattered radiation from the radiographic field that would impair the clarity of the image on the X-ray film. A grid's structure is characterized by many relationships, the most important being the grid ratio. Generally, the higher the grid ratio the better the scatter cleanup, but also the higher the patient radiation dose.

> **Bucky (also known as Potter-Bucky Diaphragm):** A grid that moves during an exposure in order to eliminate grid lines (blur) from the image.
>
> **Stationary grid:** A grid which does not move during the exposure.
>
> **Grid ratio:** A grid ratio is defined as the ratio between the height of the lead strips and the interspace distance between them. Thus, grid ratios denote the ratio of depth of lead strips to the width between the strips. The higher the grid ratio the higher the patient exposure.
>
> **Grid pattern:** Grid pattern refers to the orientation of the lead strips in their longitudinal axis.
>
> **Linear grid:** Linear grid is a grid in which lead strips are parallel to each other in their longitudinal axis.
>
> **Focused grid:** Is a grid made up of lead strips that are angled slightly so that they focus at some distance.
>
> **Parallel grid:** Is a grid in which the lead strips are parallel when viewed in cross section.

Guard Band: A space between adjacent tracks of a magnetic recording, to prevent cross talk between them.

Half-Tone Screen: A continuous tone photograph converted into a pattern of dots of varying distribution density. Used in newspaper and magazine printing.

Half-Value Layer (HVL): The thickness of a specified substance/material usually aluminum (for X-ray beam quality) or lead (for shielding purposes) which, when introduced into the path of a given beam of radiation reduces the exposure rate by one-half.

H & D Curve: See characteristic curve.

Health Physicist: A professional who is specially trained in radiation and health physics and concerns himself/herself with problems of radiation protection.

Health Physics: The science of protecting human beings from injury by radiation, and promoting better health through beneficial applications of radiation. (Also called Radiological Health).

Heel Effect: The heel effect refers to the unequal intensity of the X-ray beam, the intensity being higher on the cathode side of the beam and less intense on the anode side of the beam. (Non-uniform intensity observed because a small fraction of the X-ray beam emitted in a direction nearly parallel to the angled target surface must pass through more target material before escaping from the target than does the major portion of the beam which is emitted more perpendicularly. NOTE: In addition to the non-uniform intensity the angled target also procures non-uniform image resolution due to variations in apparent focal spot size as viewed from various positions on the film.)

Helical Scan: A type of video tape recorder. Takes its name from the fact that the tape is wrapped around the recording drum in a helical pattern.

Hertz (Hz): The unit used to measure temporal (time) frequency. One Hertz is equivalent to one cycle per second.

High Radiation Area. An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates. **10 CFR 20**

Horizontal Resolving Power: Also known as horizontal resolution. The ability of a television system to resolve vertical lines.

Horizontal Retrace: That period of time, during which the electron beam is repositioned following the completion of one horizontal line, in preparation for starting the next horizontal line.

Hounsfield Units: See CT number.

Human Use: Means the internal or external administration of radiation or radioactive materials to human beings. **30100 (f)**

ICRP: The initials of the International Commission on Radiological Protection which was established in 1928 by the Second International Congress of Radiology. It prepares recommendations to deal with the basic principles of radiation protection.

Image Intensifier (II): A device used to convert an X-ray image into a light image, then to an electron image and then back to a light image of smaller size and increased brightness. An X-ray image receptor that increases the brightness of a fluoroscopic image by electronic amplification and image minification.

Image Intensifier Tube: An evacuated electronic tube, capable of converting an input beam of X-ray energy into a visible light image of increased brightness. Typical tubes have input screen diameters of 6 or 9 inches.

Image Orthicon: One type of television pickup tube, usually 3 or 4 inches in diameter and 15 to 18 inches long. Includes a photomultiplier section for extremely sensitivity to low levels of light.

Image Receptor: A system for deriving a diagnostically usable image from the X-rays transmitted by the patient. Examples: screen-film system; stimulable phosphor; solid state detector.

Image Receptor Assembly: An image receptor in a specialized container necessary for proper operation of the receptor.

Incandescence: The emission of visible light when a body or object is heated to a sufficiently high temperature.

Index of Refraction: The ratio of the velocity of light in air to the velocity of light in some material. For ordinary glass, the index of refraction is approximately 1.5.

Indirect Effect: Destructive chemical changes in body molecules which result when a specific molecule such as DNA is acted upon by free radicals that were previously produced from the interaction of radiation with water molecules.

Individual Monitoring Device (individual monitoring equipment): Means devices designed to be worn by a single individual for the assessment of dose equivalent such as film badges, thermoluminescent dosimeters and personal ("lapel") air sampling devices. **10 CFR 20**

Inherent Filtration: See filter.

Input Screen: The surface, in which X-radiation is absorbed and in which the X-ray image is converted into a light image for amplification in an image intensifier tube.

In-phase: Two or more items or components, usually having some periodic mode of operation, operating exactly in synchronism.

Installation: Means the location where one or more reportable sources of radiation are possessed. **30100 (g)**

Integral Dose: A calculated dose for a portion of the body, determined by (1) the size of the field exposed, (2) the skin dose, and (3) the depth of tissue at which the dose falls to one-half the skin dose.

Integration Time: The time required by the eye for recognition of an image on the monitor. The integration time of the human eye is approximately 0.2 seconds

Intensifying Screens: Devices which increase the brightness of the image produced by the action of X-rays upon a phosphor.

Interface: A location or means of interaction between two points or systems.

Interlace: The method by which sequential television fields are displayed on the kinescope. Two types: positive interlace and random interlace.

Interlock: Means a device for precluding access to an area of radiation hazard either by preventing entry or by automatically removing the hazard. 30306 (g)

Inverse Square Law: The intensity of the radiation is inversely proportional to the square of the distance from the source.

Ion: An atom of a positive or negative electric charge as a result of having lost or gained one or more electrons or a free electron or other subatomic charged particle. (An atom or molecule that has one or more of its surrounding electrons separated from it and therefore carries an electric charge.)

Ion Pair: A positively charged atom or molecule (ion) and an electron formed by the action of radiation upon a neutral atom or molecule.

Ion/Ionization Chamber: An X-ray measuring device in which gas is ionized in proportion to the quantity of X-ray energy passing through (lost in) the chamber.

Ionization: The process whereby one or more electrons is removed from a neutral atom by the action of radiation (the conversion of atoms to ions).

Ionizing Radiation: See radiation.

Joule (J): The unit of work equal to one newton (N), expended along a distance of one meter (1J = 1N x 1m).

Kell Factor: A factor used to correct idealized vertical resolving power to that which would be realized in actual usage. Generally taken to have a value of 0.7.

Kerma: The sum of the initial kinetic energies of all the charged ionizing particles liberated by uncharged ionizing particles per unit mass of a specified material. Kerma is measured in the same unit as absorbed dose. The SI unit of kerma is joule per kilogram and its special name is gray (Gy). Kerma can be quoted for any specified material at a point in free space or in an absorbing medium.

Kilo Electron Volt (keV): One thousand electron volts (1,000 eV).

Kilogram (kg): One thousand grams (1,000 gm).

Kilovolt: A unit of electrical potential difference equal to 1,000 volts.

Kilovolt Peak (kVp): A unit of maximum or crest value of electrical potential difference between the anode and cathode of an X-ray tube. Kilovolt peak (kVp) determines the maximum penetrating ability of X-rays and refers to the "quality" of X-rays.

Kinescope: The display or picture tube of the monitor.

Kinescopic Recording: The technique of making a cine film by photographing a kinescope.

Lag: The undesirable quality of most vidicon (television) tubes that occurs because it takes a certain amount of time for the image to build up and decay on the vidicon target. This results in image blurring when the camera is moved rapidly during fluoroscopy.

Lambertian Source: A special class of light source that emits energy in a direction with an intensity proportional to the cosine of the angle of that distance as measured from a perpendicular to the radiation source.

Lateral Chromatic Aberration: A type of lens aberration created when beams entering the lens at oblique angles create different size images for different colors of light contained in the incident beam.

Lateral Magnification: The ratio of the image size to the object size.

Latitude: The property of an X-ray film to have a great number of units of density produced within certain log-relative exposure numbers; longer latitude films have lower contrasts.

Lead Equivalent: The thickness of lead affording the same attenuation, under specified conditions, as the material in question.

Lead Oxide Vidicon: A particular type of vidicon pickup tube having a lead monoxide target material (also called plumbicon).

Leakage Radiation: Means all radiation coming from the X-ray tube housing except the useful beam. **30306 (h)**

Lens: In television and photographic cameras, a highly corrected set of optical elements in a mount. Used to form an image of the subject on some light sensitive surface for reproduction.

Lens Axis: The line defined by connecting the curvature centers of all the lens elements.

Lens Speed: See relative aperture.

Leukemia: A blood disease that is characterized by overproduction of white blood cells. It may result from overexposure of the bone marrow to radiation.

Limits: (Dose limits) means the permissible upper bounds of radiation doses. **10 CFR 20**

Line Pair: A means of expressing resolution or resolving power. Considered to consist of one black line of some width and an adjacent white line of equivalent width. The white line may also be thought of as a space.

Line Rate: The rate at which horizontal lines are drawn to create a television frame. Note that it is a rate and does not indicate the actual number of lines used to scan the image.

Linear Hypothesis: The assumption that a dose-effect curve derived from data in the high dose-rate ranges may be extrapolated through the low dose range to zero. This implies that any amount of radiation can cause some damage.

Linearity: The ability of a television system to faithfully reproduce an object with the correct dimensions and proportions. Pool linearity will cause a non-uniform elongation or foreshortening of the image.

Longitudinal Chromatic Aberration: A failure of the lens to bring light of different wave length to a common focal point.

Longitudinal Magnification: The change in position of an object along the optical axis and the corresponding change caused in the image position.

Low Reflection Coatings: Special chemical coatings deposited on the lens surface to reduce the amount of light reflected from the surface. Typically, a coated surface will reflect less than 1 percent of the incident light while an uncoated surface will reflect 4 percent.

Luminosity Curve: The curve depicting the relative sensitivity of the human eye to various colors of light in the visible region of the electromagnetic spectrum.

Macula Lutea: A concentration of cones in the eye slightly to the side of the optic nerve having the region of greater visual acuity.

Magnetic Recording: A means of obtaining a permanent record of an electrical signal. Converts the signal to a magnetic field, which is used to permanently magnetize some storage medium. Common devices are video tape recorders and video disc recorders.

Magnification: The ratio of image size to object size. The image may be larger than, smaller than, or equal in size to the object; so magnification can be greater than, equal to, or less than 1.

Magnification Mode: Occurs when the useful area of the input phosphor is decreased (6 inch mode) while the output phosphor remains the same size, thus increasing the effective magnification of the resultant image. Concurrently, the collimator automatically reduces the X-ray field to the useable input phosphor area.

Maximum Permissible Dose Equivalent (MPD): See dose.

Member of the Public: Means an individual in an uncontrolled or unrestricted area. However, an individual is not a member of the public during any period in which the individual receives an occupational dose. **10 CFR 20**

Meter: A unit of length equivalent to 39.37 inches.

Milliampere (mA): The electron current (measured in milliamperes) flowing across the X-ray tube from the cathode to the anode. Milliampere (mA) multiplied by the time during which the beam strikes an object (measured in seconds) is milliampere-seconds (mAs) and is a measure of the "quantity" of X-rays.

Millirad (mrad): A division of the rad, equal to one one-thousandth of a rad (see rad).

Millirem (mrem): A division of the rem, equal to one one-thousandth of a rem (see rem).

Minification Gain: The increase in output image brightness from an image intensifier tube that results from reduction in image size; expressed as the ratio of $(d_i/d_o)^2$.

Minor: Means an individual less than 18 years of age. **10 CFR 20**

Mobile Intensifier: An integrated system of X-ray generator, X-ray tube, and image intensifier. A self-contained unit that may be moved readily to different locations.

Modulate: To regulate or modify some process by means of an external influence of signal. In a television system, it has to do with varying intensity in the kinescope. Accomplished by modulating its electronic beam with the signal from the television camera.

Modulation Transfer Function (MTF): A mathematical entity that expresses the relative responses of an imaging system or system component to sinusoidal inputs as a function of varying spatial frequency, which is often expressed in line pair per millimeter (lp/mm). The MTF can be thought of as a measure of spatial resolution of the detector system.

Monochromatic: Electromagnetic radiation of a single wavelength or frequency.

Monitor: The display device that receives the electronic signal from the camera. Similar to a television receiver, except it has no audio components and no tuning section.

Monitoring (radiation monitoring, radiation protection monitoring): Means the measurement of radiation levels, concentrations, surface area concentrations or quantities of radioactive material and the use of the results of these measurements to evaluate potential exposures and doses. **10 CFR 20**

Mutation: A transformation of the gene which may be induced by radiation and may alter characteristics of the offspring.

NCRP: The initials of the National Council on Radiation Protection and Measurements which is a nonprofit corporation chartered by Congress in 1964. The concern of NCRP is with the scientific and technical aspects of radiation protection.

Newton: The unit of force, which when applied to a one kilogram mass will give an acceleration of one meter per second squared.

Nonstochastic Effect: Means health effects, the severity of which varies with the dose and for which a threshold is believed to exist. Radiation-induced cataract formation is an example of a nonstochastic effect (also called a deterministic effect.) **10 CFR 20**

Objective Lens: In an image intensifier, the lens which collects the light from the output screen and projects it into the camera lens or into the optical viewer.

Occupancy Factor (T): The factor by which the workload should be multiplied to correct for the degree of occupancy (by any one person) of the area in question which the source is in the **"on"** condition and emitting radiation. This multiplication is carried out for radiation protection purposes to determine compliance with the dose equivalent limits.

Occupational Dose: Means the dose received by an individual in a restricted area or in the course of employment in which the individual's assigned duties involve exposure to radiation and to radioactive material from licensed and unlicensed sources of radiation whether in the possession of the licensee or other person. Occupational dose does not include dose received from background radiation, as patient from medial practices, from voluntary participation in medical research programs, or as a member of the general public. **10 CFR 20**

Out-of-Phase: Opposite to in-phase. The periodic motions do not occur in each compartment at the same time. One hundred eighty degrees out-of-phase means that at any given time they are exactly opposite.

Over-Framing: See framing.

Pan and Tilt Controls: Motorized motions of the television camera. The camera may be aimed at different directions to change the field of view.

Ohm: The practical meter-kilogram-second unit of electrical resistance equal to the resistance of a circuit in which a potential difference of one volt produces a current of one ampere.

Operator: Any individual who personally utilizes or manipulates a source of radiation.

Operator's Station: The area where the control panel for the operation of an X-ray machine is located. The operator's station at the control shall be behind a protective barrier either in a separate room, in a protective booth, or behind a shield which will intercept the useful beam and any radiation which has been scattered only once.

Other Official Agency Specifically Designated by the Department: Means an agency which the Department has entered into an agreement pursuant to section 114990 (old section 25810) of the Health and Safety Code. **30100 (j)**

Panel: The tabletop of the imaging unit as a whole.

Parallel Light: A beam of light emerging from the collimating lens, so that all rays which originated from one point of the light source are parallel to each other.

Persistence: The momentary storage, or retention, of some signal, or image, after the stimulus has been removed.

Person: Means any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, agency, political subdivision of this State, any other state or political subdivision or agency thereof, and any legal successor, representative, agent, or agency of the foregoing, other than the United States Nuclear Regulatory Commission, the United States Department of Energy, or any successor thereto, and other than Federal Government agencies licensed by the United States Nuclear Regulatory Commission, under prime contract to the United States Department of Energy, or any successor thereto. **30100 (k)**

Personnel Dosimeters: See Dosimeters.

Personnel Monitor. Also known as personal monitor. An appropriately sensitive device used to estimate the absorbed dose received by an individual.

Personnel Monitoring Equipment: Means devices designed to be worn or carried by an individual for the purpose of measuring the dose received by that individual (e.g., film badges, pocket chambers, pocket dosimeters, film rings, etc). **30100 (l)**

Phantom: An object used to simulate the absorption and scatter characteristics of the patient's body for radiation measurement purposes.

Photo Conductive Material: A conducting material whose conductance is a function of the amount of light incident upon it.

Photocathode: A material, rich in electrons, which can be made to emit electrons under the action of incident light.

Photoelectric Absorption: An interaction between an X-ray photon and an orbital electron in which the photon surrenders all of its kinetic energy to the electron and ceases to exist. The atom responds by ejecting the electron from the shell. Photoelectric absorption is the process most responsible for the dose of radiation the patient receives during a radiographic procedure.

Photoemissive: A type of radiation detector having the ability to emit electrons, when stimulated by incident radiation. The best known photoemissive detectors are photo tubes and photomultiplier tubes.

Photometry: The science of the measurement and study of the quantity and intensity of radiation visible to the human eye.

Photomultiplier: A type of vacuum tube used to achieve electron gains. For example, one incident electron will create two secondary electrons which may in turn be used to create four secondary electrons, etc.

Photon: A quantity of energy emitted in the form of electromagnetic radiation. X-rays are examples of photons.

Phototimer: A device which automatically terminates an exposure when the required film density has been achieved. It accomplishes this by measuring the amount of radiation which has reached the film.

Photospot: See spot film camera.

Pick-up Tube: The sensitive element in the television camera that converts a light image to an electrical signal.

Pincushion Distortion: Is a form of spatial distortion that warps the appearance of the image.

Pixel: A two-dimensional picture element in the presented image.

Pocket Ion Chamber: A small, pocket-sized ionization chamber used for monitoring radiation exposure of personnel. Before use it is given a full charge and the amount of discharge during the period of use is a measure of the total radiation exposure during the period.

Positive Interlace: One type of interlace pattern in which two or more fields are precisely positioned among each other. The most common positive interlace is a two-to-one type, wherein two television fields are used to create one television frame.

Possess: Means to receive, possess, use, transfer or dispose of radioactive material pursuant to this regulation. **30100 (m)**

Possessing a Reportable Source of Radiation: Means having physical possession of, or otherwise having control of, a reportable source of radiation in the State of California. **30100 (n)**

Primary Protective Barrier: Means a barrier sufficient to attenuate the useful beam to the required degree. **30306 (j)**

Protective Apron: An apron made of radiation absorbing materials, used to reduce radiation exposure.

Protective Barrier: Means a barrier of attenuating materials used to reduce radiation exposure. **30306 (i)**

Protective Glove: A glove made of radiation absorbing materials used to reduce radiation exposure.

Pupil, Entrance: The image of the limiting aperture in a lens of optical system formed by all of the optical elements ahead of that limiting aperture. The entrance pupil determines the maximum beam size which will be transmitted by the lens.

Pupil, Exit: The image of the limiting aperture in a lens of optical system formed by all of the lenses beyond that limiting aperture.

Quality: A term used to describe the penetrating power of X-rays and is related to the energies of the photons in the useful or primary X-ray beam.

Quality Assurance (QA): Quality Assurance (QA) is a management tool that includes policies and procedures designed to optimize the performance of facility personnel and equipment. QA includes all of the following:

- o Quality control (QC)
- o Administration
- o Education of personnel
- o Preventive maintenance methods

Quality Control (QC): Quality Control (QC) refers to routine performance and interpretation of test equipment function and to corrective action needed and taken.

Quality Factor (Q): Means the modifying factor (listed in tables 1004(b).1 and 1004(b).2 of section 20.1004) that is used to derive dose equivalent from absorbed dose. **10 CFR 20**

Quantity: A term used to describe the number of photons in an X-ray beam.

Quantum Mottle/Noise: Statistical fluctuations in the radiographic image that result in a grainy or blotchy appearance caused by insufficient radiation to produce an uniform image. Mottle is more visible in a high-resolution, high-contrast image. The random noise pattern is created by insufficient absorption of the X-ray beam in the input screen of the image intensifier.

Quantum Sink: The variation in optical density, brightness, CT number, or other appropriate parameter in an image that results from the random spatial distribution of the X-ray or light quanta absorbed at the start of the imaging chain containing the minimum information content. [The "quantum sink" of a correctly tuned fluoroscopy imaging system with closed-circuit television (TV) camera is the number of X-ray photons absorbed by the image intensifier input phosphor.]

Quantum Yield: Measure of the efficiency of conversion of incoming X-ray photons to light photons.

Rad: Is a special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 0.01 joule/kilogram (0.01 gray). **10 CFR 20**

Radiation (ionizing radiation): Means gamma rays and X-rays, alpha and beta particles, high speed electrons, neutrons, protons, and other nuclear particles; but not sound or radio waves, or visible, infrared, or ultraviolet light. **30100 (o)**

> **Background radiation:** A term used to describe the radiation present in the natural environment. It is produced by radioactive substances in the earth's crust, in water, in air, and by cosmic rays from outer space.
>
> **Electromagnetic radiation:** A traveling wave motion resulting from changing electric or magnetic fields. Familiar electromagnetic radiations range from X-rays of short wavelength, through ultraviolet, visible and infrared regions, to radar and radio waves of relatively long wavelength.
>
> **Ionizing radiation:** Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter.
>
> **Non-ionizing radiation:** Electromagnetic or other radiation of insufficient energy to cause ionization or excitation of atoms with which it interacts; e.g., sound, microwaves.

Radiation Area: Means an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates. **10 CFR 20**

Radiation Machine: Means any device capable of producing radiation when the associated control devices are operated, but excluding devices which produce radiation only by the use of radioactive material. For fee purposes, when a radiation machine is equipped with two or more tubes that can be used separately, each tube shall be considered as a single machine, except for machines used solely for research and teaching. **30100 (p)**

Radiation Protection Survey: See survey.

Radiation Safety Officer: The person responsible for the radiation protection program at a licensed facility.

Radiobiology: That branch of biology which deals with the effects of radiation on biological systems.

Radiograph: A film or other recording produced by the action of X-rays transmitted through the patient.

Radiography: Utilizing ionizing radiation, this technique involves making shadow images on photographic emulsions. The image is the result of differences in attenuation of the radiation as it passes through the object in its path. (The production of images on film by the action of X-rays transmitted through the patient.)

Raster: The scanning pattern developed in the television kinescope. In most cases, the scan pattern is from upper left to lower right, as a series of horizontal lines.

Radiopaque Medium: A material which absorbs X-rays and hence casts a shadow on the X-ray film or fluoroscopic screen.

Radiosensitivity: The susceptibility of cell, tissues, organ systems, organisms, or any living substance to the injurious action of radiation.

Real Image: An image created by the actual intersection of light rays and defined as being one which can be displayed on a diffusing screen.

Record/Playback Head: The device in the magnetic recorder which transforms electrical current from the television camera into a magnetic field which may be permanently recorded. In the playback mode, if recorded material is moved past the head, it generates an electric current very similar to that which made the original recording.

Reflection: The change in direction of incident radiation upon striking an object which neither transmits nor absorbs all of the incident radiation. See also specular reflection and diffuse reflection.

Refraction: The bending of a beam of energy which passing across an interface of material with different indices or refraction.

Reference Man: Means a hypothetical aggregation of human physical and physiological characteristics arrived at by intentional consensus. These characteristics may be used by researchers and public health workers to standardize results of experiments and to relate biological insult to a common base. **10 CFR 20**

Region of Maximum Resolution: The area, when projected into object space, subtended by that area of the retina containing a high concentration of cones.

Registrant: Means any person who is registering or who has registered with the Department pursuant to Group 1.5, Registration of Sources of Radiation. **30100 (r)**

Relative Aperture: A measure of the light gathering ability of a lens. Expressed mathematically as the ratio of the focal length divided by the diameter of the lens entrance pupil. The number determined by this calculation is frequently referred to as "f' number.

Rem: Is the special unit of any of the quantities expressed as dose equivalent. The dose equivalent in rems is equal to the absorbed dose in rads multiplied by the quality factor (1 rem = 0.01 sievert). **10 CFR 20**

Remnant Radiation: That part of the X-ray beam which has passed through the patient and reaches the film. It consists of non-interacting and small-angle scattered photons.

Remote Control Diagnostic System: An integrated system of X-ray generator, table, and image intensifier. It permits fluoroscopy, spot-filming and radiography to be done from a console, located at some distance from the table.

Repeats/Retakes: Additional radiographs taken because of technical or mechanical error leading to increased radiation dose for the patient and the radiation worker.

Reportable Sources of Radiation: Means radiation machines, when installed in such manner as to be capable of producing radiation. **30100 (s)**

Resolution: The process or capability of distinguishing closely adjacent optical images. [In the context of an image system, the output of which is finally viewed by the eye, it refers to the smallest size of highest spatial frequency of an object of given contrast that is just perceptible. The intrinsic resolution, or resolving power, of an imaging system is measured in line pairs per millimeter (lp/mm), ordinarily using a resolving power target. The resolution actually achieved when imaging lower contrast objects is normally much less, and depends upon many variables such as subject contrast levels and, noise of the overall imaging system.]

Resolving Power: This term refers to the ability to distinguish separate images of line pairs (lines and spaces) per millimeter. (The resolving power of an image intensification system is expressed in terms of line pairs per millimeter.)

Restricted Area: Means an area, access to which is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. **10 CFR 20** (The area in which radiation safety rules are enforced.)

Retrace: That part of the scanning system during which the electron beam is returned to a starting point, after completing a line or field.

Rods: One of two kinds of light sensitive cells contained in the retina of the human eye. The rods are the most sensitive, but do not evoke a color response.

Scattered Radiation: Means radiation that, during passage through matter, has been deviated in direction. **30306 (k)**

Secondary or Stray Radiation: Means radiation not serving any useful purpose. It includes leakage and scattered radiation.

Secondary Protective Barrier: Means a barrier sufficient to attenuate stray radiation to the required degree. **30306 (l)**

Sensitometer: An instrument used to expose film to precisely controlled steps of increasing light intensity. (An instrument that produces a series of controlled exposures on a sheet of photographic material.)

Sensitometric Curve: The visual line graph produced by plotting density-exposure relationships for photographic films. Also referred to as characteristic curve or H & D curves.

Sensitometry: The act, the art, or the science of measuring sensitivity, as of photographic material.

Serial Radiography: A radiographic procedure in which a sequence of radiographs is made rapidly by using an automatic cassette changer, image intensifier/TV chain, etc.

Shallow-Dose Equivalent (H_s): Applies to the external exposure of the skin and an extremity, and is taken as the dose equivalent at a tissue depth of 0.007 centimeter (7 mg/cm^2) averaged over an area of 1 square centimeter. **10 CFR 20**

Shield/Shielding: Material which is interposed between a radiation source and an irradiated site for the purpose of minimizing the radiation hazard (used to prevent or reduce the passage of radiation). Shielding is usually made of lead which is dense and absorbs radiation easily. Shielding is often used to protect the reproductive organs, testes or ovaries, from the X-ray beam during an examination.

Shoulder of Curve: The portion above the straight line of the sensitometric curve.

Shutter: Means a device, generally of lead, fixed to an X-ray tube housing to intercept the useful beam. **30306 (m)**

Signal: Usually refers to an electric current varying at some frequency. Used to modulate another process, or converted through a transducer into some form of energy to which the human senses can respond.

Signal-to-Noise Ratio: For video cameras, the ratio of input signal to background interference. The greater the ratio, the clearer the image.

Sievert: Is the SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 Sv = 100 rems). **10 CFR 20**

Simulator: Diagnostic energy X-ray equipment used to simulate a therapy treatment plan outside the treatment room.

Single Field Tube: One type of X-ray intensifier tube in which the size of both the input and output screens is fixed.

Skin Dose: See dose.

Slice: The single body section imaged in a tomographic procedure.

Somatic: Pertaining to the body tissue other than reproductive cells.

Source-to-Image Distance (SID): The distance measured along the central ray from the center of the front of the surface of the source (X-ray focal spot or sealed radioactive source) to the surface of the image detector.

Source of Radiation: Means a discrete or separate quantity of radioactive material or a single radiation machine. **30100 (v)**

Source-Surface Distance (Source-Skin Distance) (SSD): The distance measured along the central ray from the center of the front surface of the source (X-ray focal spot) to the surface of the irradiated object or patient.

Specular Reflection: One of two types of reflection realized when radiation strikes a highly polished surface, thus maintaining the "coherency" of the original beam.

Speed Factor: With intensifying screens, the speed factor is defined as the ratio of the exposure required without screens to the exposure required with screens to get the same degree of blackening of X-ray films.

Spherical Aberration: Failure of the lens to bring all rays incident upon the lens to a common focal spot.

Spot Film: A radiograph taken during a fluoroscopic examination for the purpose of providing a permanent record of an area of interest or to verify the filling of a void with contrast media. (An image taken to document the patient's anatomy at specific moments during fluoroscopy. Spot films may be obtained by using a radiographic cassette or by photographing the output of the image intensifier with a spot film camera.

Spot Film (or Photospot) Camera: Camera mounted on the fluoroscopic tower that allows the output of the image intensifier tube to be recorded on film.

Static (or Plain Film) Radiography: Radiographic procedure that does not allow the visualization of motion.

Step Wedge (Penetrometer): A device made up of different density filters shaped in a step-like form. (A device made up of different density filters shaped in a step-like form where each step or filter differs in density by the square root of 2.)

Sterility: Inability (either temporary or permanent) to reproduce.

Stochastic Effects: Means health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects. **10 CFR 20** (General definition of "stochastic effect": Effect, the probability of which, rather than the severity, is a function of radiation dose without threshold. More generally, stochastic means random in nature.)

Straight Line Portion of a Sensitometric Curve: On medical, screen-type X-ray film, the part of the curve from a density of 0.25 to a density of 2.0 above the gross fog.

Stray Radiation: Means radiation not serving any useful purpose. It includes leakage and scattered radiation. **30306 (n)**

Supervision: According to section 114850 (g) [old section 25661 (h)] of the Health and Safety Code, supervision means responsibility for, and control of, quality, radiation safety, and technical aspects of all X-ray examinations and procedures.

Survey: Means an evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present. **10 CFR 20**

Synchronization: The condition in which two or more events are operating in an identical pattern such as by interlaced scanning.

> **Cinefluorography:** The operation of camera shutters at the same frequency as X-ray pulses.

Synchronizing Pulse: A momentary pulse created in the television camera. Transmitted to the monitor in order to keep the two electron beams synchronized and scanning the same parts of the picture at the same time.

Target: Material at which electrons from the cathode in an X-ray tube are aimed in order to produce X-rays. (The part of an X-ray tube anode assembly impacted by the electron beam to produce the useful X-ray beam.) See anode.

Target-Film Distance (TFD): The distance from the X-ray tube target (anode) to the X-ray film measured either in inches or centimeters.

Target-Skin Distance (TSD): The distance from the X-ray tube target (anode) to the skin of the patient where the X-ray beam enters the body.

Television Camera: That part of the television chain that converts a scene to an electronic signal.

Television Field: That portion of the scanning cycle in which the picture is scanned once from upper left to lower right.

Television Frame: That portion of the scanning system in which the subject scene is completely scanned one time. In most cases, a television frame consists of two or more television fields, in some interlace pattern.

Television Lines: The horizontal lines used to create the television raster. Created by the path of the electron beams used to scan the pickup and kinescope tubes.

Tenth Value Layer (TVL): Thickness of a specified substance which, when introduced into the path of a given beam of radiation, reduces the kerma rate to one-tenth of its original rate.

Thermoluminescence: The property of certain inorganic crystals to emit light when heated following exposure to ionizing radiation. The quantity of light is related to the total absorbed dose. The light emitted is proportional to the radiation dose that the material has received.

Thermoluminescent Dosimetry (TLD): A dose measurement system utilizing certain inorganic crystals, such as lithium fluoride (LiF). Energy is accumulated by radiation induced dislocation of electrons. Upon heating the TLD material, the dislocated electrons return to their original locations releasing the stored energy in the form of light. The quantity of emitted light is proportional to the absorbed radiation. A crystalline material used for dosimetry by the thermoluminescent method. TLDs are usually LiF but are also available as CaF_2, BeO, and $CaSO_4$. They are available as ribbons, rods, chips, powder, or extrusions.

Tissue Dose: See dose.

Track: The path on a magnetic tape, or disc, which is converted into the magnetic reproduction of the input signal. If the track is scanned with the playback head, the original recording signal will be reproduced.

This Regulation: Means California Administrative Code, title 17, chapter 5, subchapter 4. **30100 (y)**

Toe of the Sensitometric Curve: Portion below the straight line of the sensitometric curve.

Tomography: A special technique to show in detail images of structures lying in a predetermined plane of tissue, which blurs or eliminates detail in images of structures in other planes.

Tomography, Computed (CT): The method of imaging which utilizes narrow X-ray beam images taken over a 360 degree projection of an object. These images are not recorded like any other radiographic or fluoroscopic images, instead, the X-ray beam detectors feed the images directly into the computer. The computer reconstructs the X-ray beam images to produce transaxial images of the object.

Total Brightness Gain: Minification gain multiplied by flux gain.

Transducer: A device for converting energy from one form to another. For example, a light bulb converts electrical energy into visible light. A loudspeaker converts electrical energy into audible sounds.

Transient: A sudden change or fluctuation in some event or phenomenon.

Underframing: See framing.

Unrestricted Area: Means an area, access to which is neither limited nor controlled by the licensee. **10 CFR 20**

Use Factor (beam direction factor) (U): Fraction of the workload during which the useful beam is directed at the barrier under consideration.

Useful Beam: Means that part of the radiation which passes through the window, aperture, cone, or other collimating device of the tube housing. **30306 (p)**

User: Means any person who is licensed to possess radioactive material or who has registered as possessing a reportable source of radiation pursuant to groups 1.5 and 2 of this subchapter, or who otherwise possesses a source of radiation which is subject to such licensure or registration. **30100 (z)**

Vertical Resolving Power: Also known as vertical resolution. The ability of a television system to resolve horizontal lines.

Vertical Retrace: That period of time during which the electron beam is blanked and repositioned, after the completion of one television field, to the starting point for the next television field.

Very High Radiation Area: Means an area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in 1 hour at 1 meter from a radiation source or from any surface that the radiation penetrates. **10 CFR 20**

Video: Strictly speaking, the picture portion of the television signal. Also a general term, it is frequently used interchangeably with television.

Video Camera Tube: Electronic device used to convert a visible image into an electronic signal.

Video Disc Recorder: A type of magnetic recorder. Recording is done on concentric tracks of a rigid disc coated with magnetic material. It is basically a single frame device. However, frames may be recorded at normal television frame rates for short-duration dynamic motion recording.

Video Tape Recorder: A type of magnetic recorder. Recording is done as adjacent parallel tracks on a magnetically sensitive plastic tape. In playback, the image is displayed on a monitor, or receiver, with normal motion.

Vidicon: One type of television pickup tube, usually one inch in diameter by six inches long.

Vignetting: A decrease in light intensity at the periphery of an image. A condition, created in an optical system, on which the intensity of illumination at the edge of the field is less than at the center.

Virtual Image: A type of image usually found in visual optical instruments in which the light rays do not actually intersect, but only appear as if they had.

Visual Acuity: The ability of the eye to resolve the angular separation of two objects. For the human eye, it is usually between one and two minutes of arc.

Voxel: A volume element in the object being imaged. The mean attenuation coefficient of the voxel determines the CT (Hounsfield) number of the pixel.

Week: Means 7 consecutive days starting on Sunday. **10 CFR 20**

Weighting Factor: For an organ or tissue (T) is the proportion of the risk of stochastic effects resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly. For calculating the effective dose equivalent, the values of W are:

Organ Dose Weighting Factors

Organ or tissue	w_T
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	0.30 [1/]
Whole Body	1.00 [2/]

1/ 0.30 results from 0.06 for each of 5 "remainder" organs (excluding the skin and the lens of the eye) that receive the highest doses.

2/ For the purpose of weighting the external whole body dose (for adding it to the internal dose a singe weighting factor w = 1.0 has been specified. The use of other weighting factors for external exposure will be approved on a case-by-case basis until such time as specific guidance is issued.

Whole Body: Means for purposes of external exposure, head, trunk (including male gonads), arms above the elbow, or legs above the knees. 10 CFR 20

Worker: Means any individual engaged in activities subject to these regulations and controlled by a user/registrant/supervisor but does not include the user/registrant/supervisor.

Workload (W): The degree of use of a radiation source.

X-Rays: Penetrating electromagnetic radiation whose wavelengths are shorter than those of visible light. For radiographic purposes, X-rays are usually produced by bombarding a metallic target with fast electrons in a vacuum.

X-ray Generator: A device which supplies electrical power to the X-ray tube. It does not, as the name implies, actually generate X-rays.

X-Ray Personnel: The following individuals are legally allowed to use fluoroscopy and ancillary on human beings:

- Doctors (MD's, DO's, DPM's, DC's) who hold current and valid Supervisor and Operator Fluoroscopy Permit or Supervisor and Operator Radiologist Certificate issued by the Radiologic Health Branch.

- Radiologic technologists who hold Diagnostic or Therapeutic Radiologic Technologist Certificate and Technologist Fluoroscopy Permit issued by the Radiologic Health Branch.

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