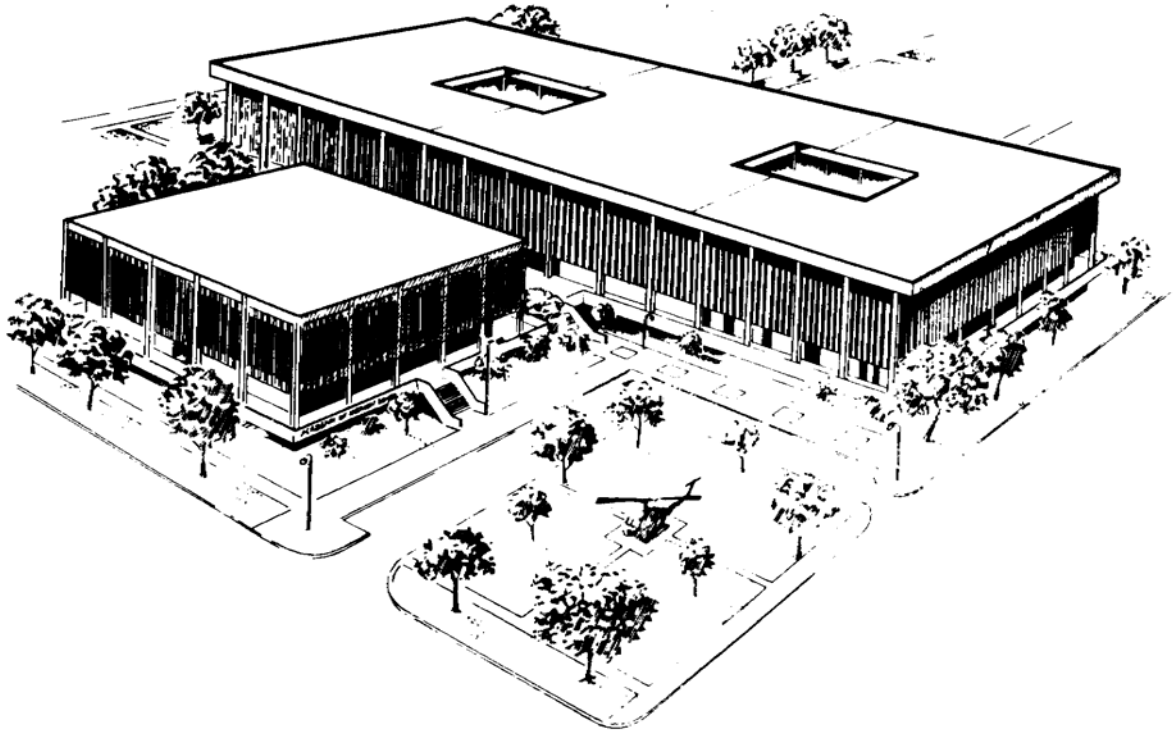


**U.S. ARMY MEDICAL DEPARTMENT CENTER AND SCHOOL
FORT SAM HOUSTON, TEXAS 78234-6100**



X-RAY FILM PROCESSING

SUBCOURSE MD0954

EDITION 100

DEVELOPMENT

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**CORRESPONDENCE COURSE OF THE
U.S. ARMY MEDICAL DEPARTMENT CENTER AND SCHOOL**

SUBCOURSE MD0954

X-RAY FILM PROCESSING

INTRODUCTION

In Subcourse MD0950, Fundamentals of X-Ray Physics, the fundamentals of radiation, electricity, and circuitry as they apply to diagnostic radiography were discussed. In Subcourse MD0952, Principles of Radiographic Exposure, the many factors and principles involved in the establishment of a latent image on an x-ray film were considered. This subcourse considers the processing of the film, which makes the latest image visible and stable.

The processing of radiographs involves a number of chemical reactions and changes, which must take place under carefully controlled conditions if a satisfactory radiograph is to be produced. Such factors as location and construction of the processing room, good organization of the materials to be used, efficient use of the room and the x-ray specialist's skills, and satisfactory adjustment to adverse environmental conditions enter into the efficient production of satisfactory radiographs. Just as the military pilot has long since ceased to "fly by the seat of his pants," the proficient x-ray specialist no longer processes film by means of "a little bit of this a little bit of that and wait 'til it looks right." Given properly exposed film and workable facilities and supplies, the proficient x-ray specialist can be depended upon to produce radiographs of a quality and uniformity that are desired by the radiologists.

Subcourse Components:

This subcourse consists of four lessons. The lessons are as follows:

- Lesson 1, The Chemistry and Handling of X-Ray Film.
- Lesson 2, The X-Ray Film Processing Room.
- Lesson 3, Automatic X-Ray Film Processing.
- Lesson 4, X-Ray Film Processing under Adverse Field Conditions and Other Special Methods.

Credit Awarded:

To receive credit hours, you must be officially enrolled and complete an examination furnished by the Nonresident Instruction Branch at Fort Sam Houston, Texas. Upon successful completion of the examination for this subcourse, you will be awarded 9 credit hours.

You can enroll by going to the web site <http://atrrs.army.mil> and enrolling under "Self Development" (School Code 555).

A listing of correspondence courses and subcourses available through the Nonresident Instruction Section is found in Chapter 4 of DA Pamphlet 350-59, Army Correspondence Course Program Catalog. The DA PAM is available at the following website: <http://www.usapa.army.mil/pdffiles/p350-59.pdf>.

LESSON ASSIGNMENT

LESSON 1

The Chemistry and Handling of X-Ray Film.

TEXT ASSIGNMENT

Paragraphs 1-1 through 1-21.

LESSON OBJECTIVES

After completing this lesson, you should be able to:

- 1-1. Outline procedures for manual processing of x-ray films.
- 1-2. Discuss the chemical reactions involved.
- 1-3. Indicate why various procedures are used.

SUGGESTION

After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

Section I. INTRODUCTION

1-1. SCOPE

Figure 1-1 illustrates the complete cycle of production, utilization and safekeeping of radiographs. Two other subcourses, MD0950, Fundamentals of X-Ray Physics, and MD0952, Principles of Radiographic Exposure, cover steps 1 through 4 and steps 6 through 8, respectively. This subcourse is concerned with step 5 and steps 9 through 15. They cover three major areas of discussion:

- a. The chemistry of x-ray film and the chemistry of film processing (Lesson 1).
- b. The processing room, its facilities and its equipment (Lesson 2).
- c. The activities involved in the processing of x-ray film (Lessons 3 and 4).

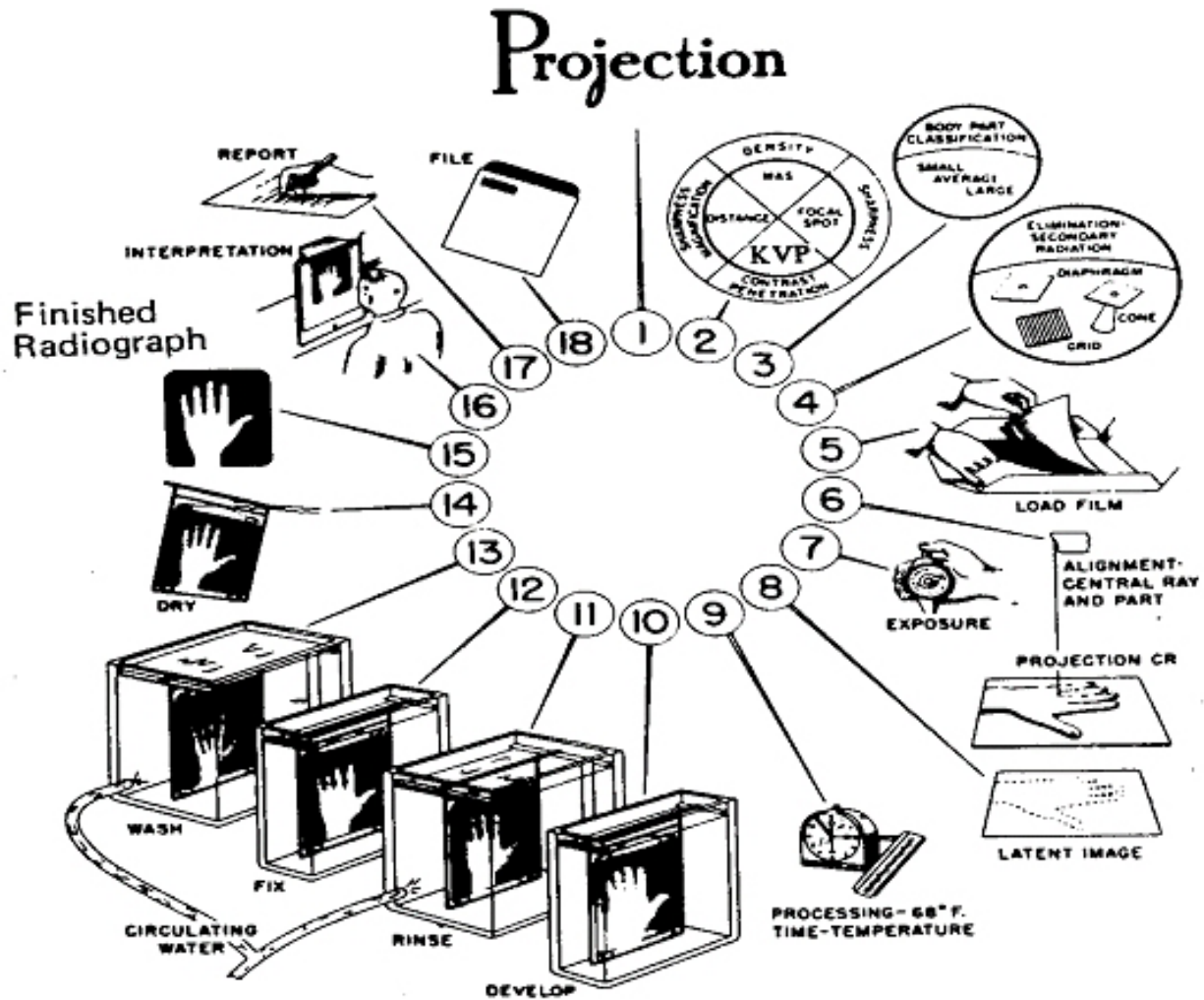


Figure 1-1. Steps in production of a radiograph.

1-2. GENERAL

X-ray film must be characteristically different from film used in photography, since x-ray exposure is different from light exposure. Because of its importance to medicine, x-ray film is manufactured with consistent uniformity and quality, which facilitates standardization of exposure and processing.

Section II. COMPOSITION OF X-RAY FILM

1-3. CHEMICAL COMPONENTS OF FILM

In general, x-ray film is a double-emulsion film consisting of a transparent base with adhesive subcoating, sensitized emulsion, and protective coating on both surfaces (figure 1-2).

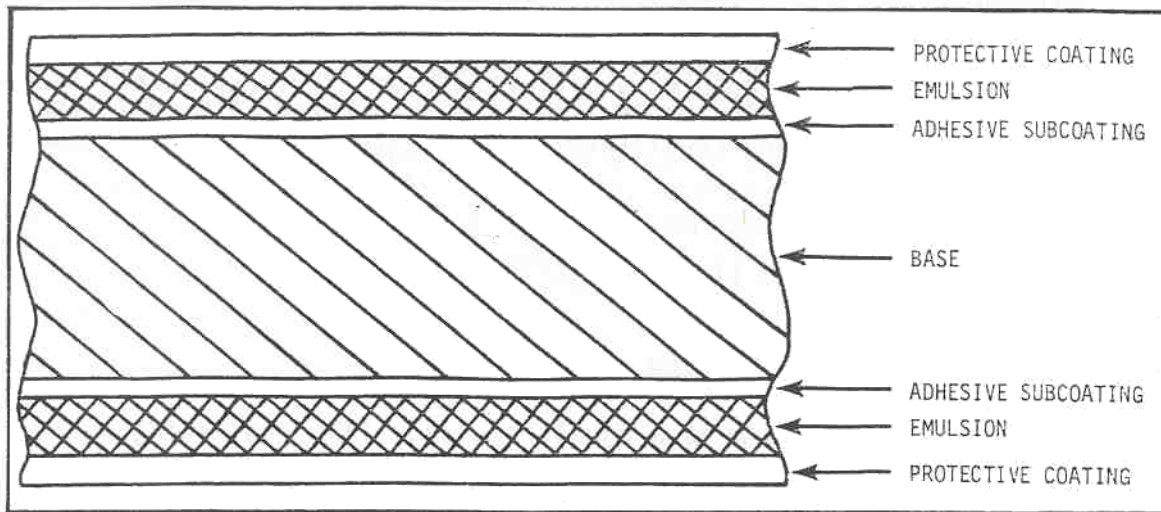


Figure 1-2. Magnified cross-section of x-ray film.

a. **Film Base.** The film base supports the emulsion and provides the correct degree of stiffness for handling purposes. It is composed of either cellulose acetate or polyester, both of which are transparent and blue-tinted.

(1) Cellulose acetate. Dissolving cotton in acetic acid makes cellulose acetate. The cotton cellulose combines with the acid to form cellulose acetate, which is then dissolved in a volatile solvent containing blue dye. The solution of cellulose acetate is poured onto huge heated drums where it solidifies to a thickness of about 0.008 inch. Cellulose acetate does have a tendency to become saturated with liquids during processing, which results in frequent problems in automatic processors.

(2) Polyester. The polyester base is made by "cracking" crude oil forming the substance parazylylene. When this substance is mixed with methyl alcohol and other chemicals, a product of dimethyl-terebthalate (DMT) is formed. This DMT is one-half of

the final preparation. Ethylene glycol is the other major ingredient. This is commonly called antifreeze. It is produced from oil and natural gas in a process of oxidizing and hydrolizing ethylene gas. When DMT and ethylene glycol are mixed in heat for a long period of time, polyester is formed. The polyester is reheated and given a two-way stretch until its thickness is .007 inch.

b. **Emulsion.** When examined under a microscope (figure 1-3), countless tiny crystals of silver bromide embedded in gelatin can be seen. Upon exposure and development, these crystals are changed into irregular clumps and strands of black metallic silver, which all together form the radiographic image. Figure 1-4 shows a cross-section of an exposed and developed emulsion layer. Each emulsion layer is about 0.001 inch thick. Since x-rays pass readily through x-ray film--and also through intensifying screens--an emulsion layer is coated on both sides of the film base. This provides a greater effect upon exposure to x-rays than would be possible with an emulsion coated only on one side. Actually, when intensifying screens are used, the fluorescent light they emit accounts for most of the exposure.

(1) Silver bromide crystal. In the early stages of emulsion manufacturing, a solution of silver nitrate and potassium bromide is produced. This results in the formation of silver bromide crystals and potassium nitrate. The potassium nitrate is then washed out and the result is a silver bromide crystal consisting of bound atoms of silver and bromide.

(2) Gelatin. Gelatin is a necessary consistent of the x-ray film emulsion. It is an ideal suspension medium for the silver bromide crystals for three primary reasons: It provides an even suspension for the crystals; it has the ability to swell, shrink, and harden; and it increases the sensitivity of the silver bromide crystals.

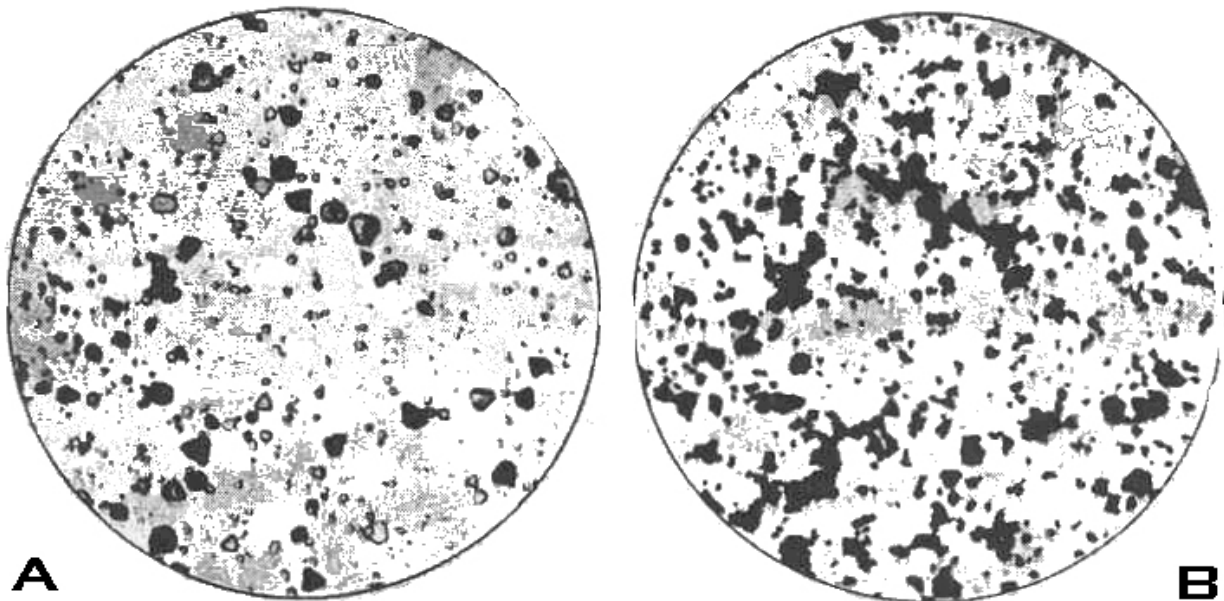
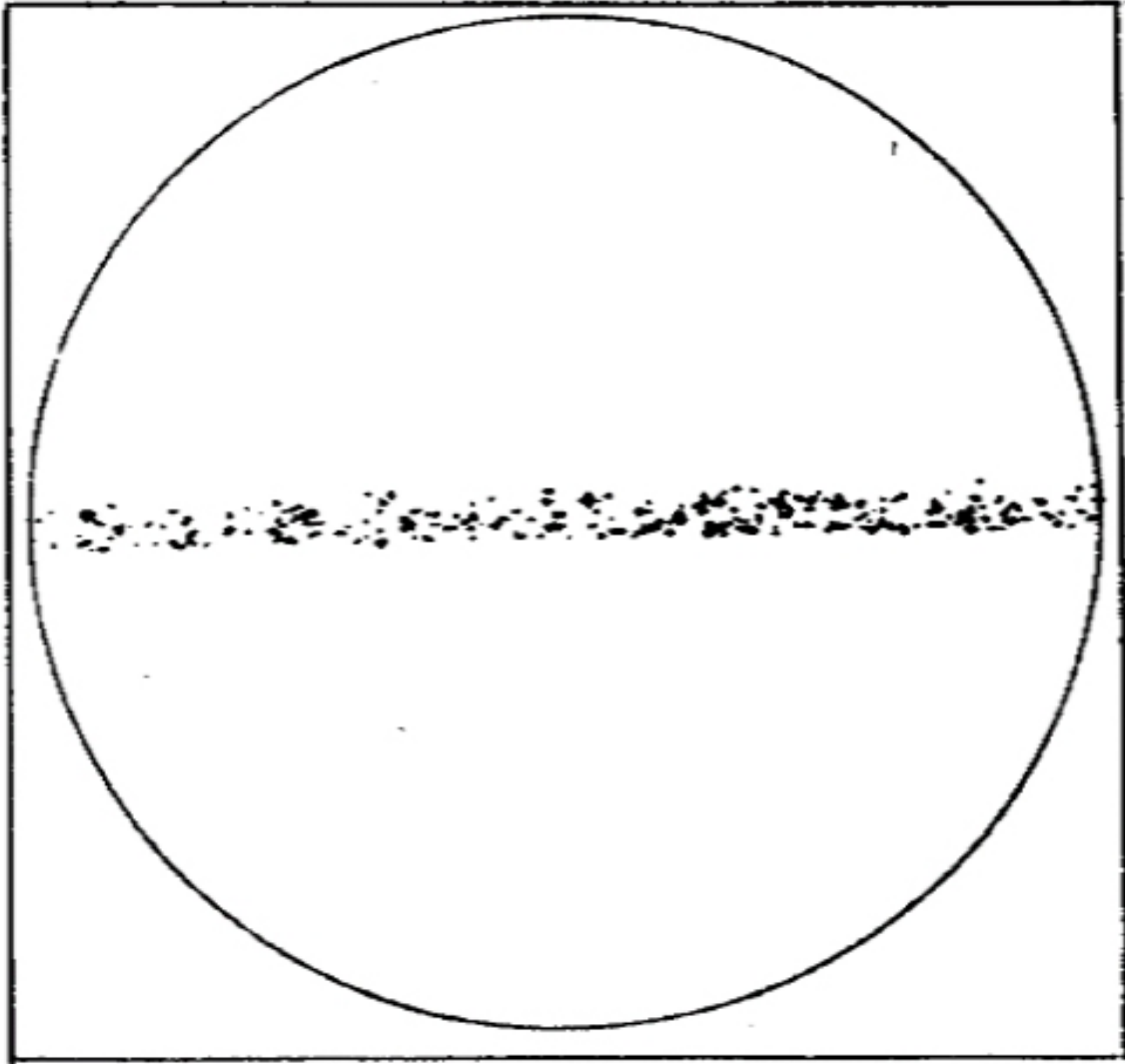


Figure 1-3. Photomicrograph (2500X) of film emulsion.



NOTE: The black particles represent small quantities of black metallic silver.

Figure 1-4. Photomicrograph (400X) of a cross-section of an x-ray film showing an exposed and developed emulsion layer.

c. **Protective Coating.** The emulsion is coated with a thin, transparent material to protect it during handling and storage. Figure 1-5 shows the composition of x-ray film.

1-4. PRODUCTION OF THE LATENT IMAGE

a. When the x-ray film emulsion is sensitized during manufacture, the silver bromide crystals are left in a state of suspended animation awaiting the x-ray stimulus to start them on their way to becoming a radiographic image. The potentiality for this activity exists in the tiny sensitization "specks" at the surface of the crystal (A, figure 1-6). When x-ray exposure occurs, the latent image is produced.

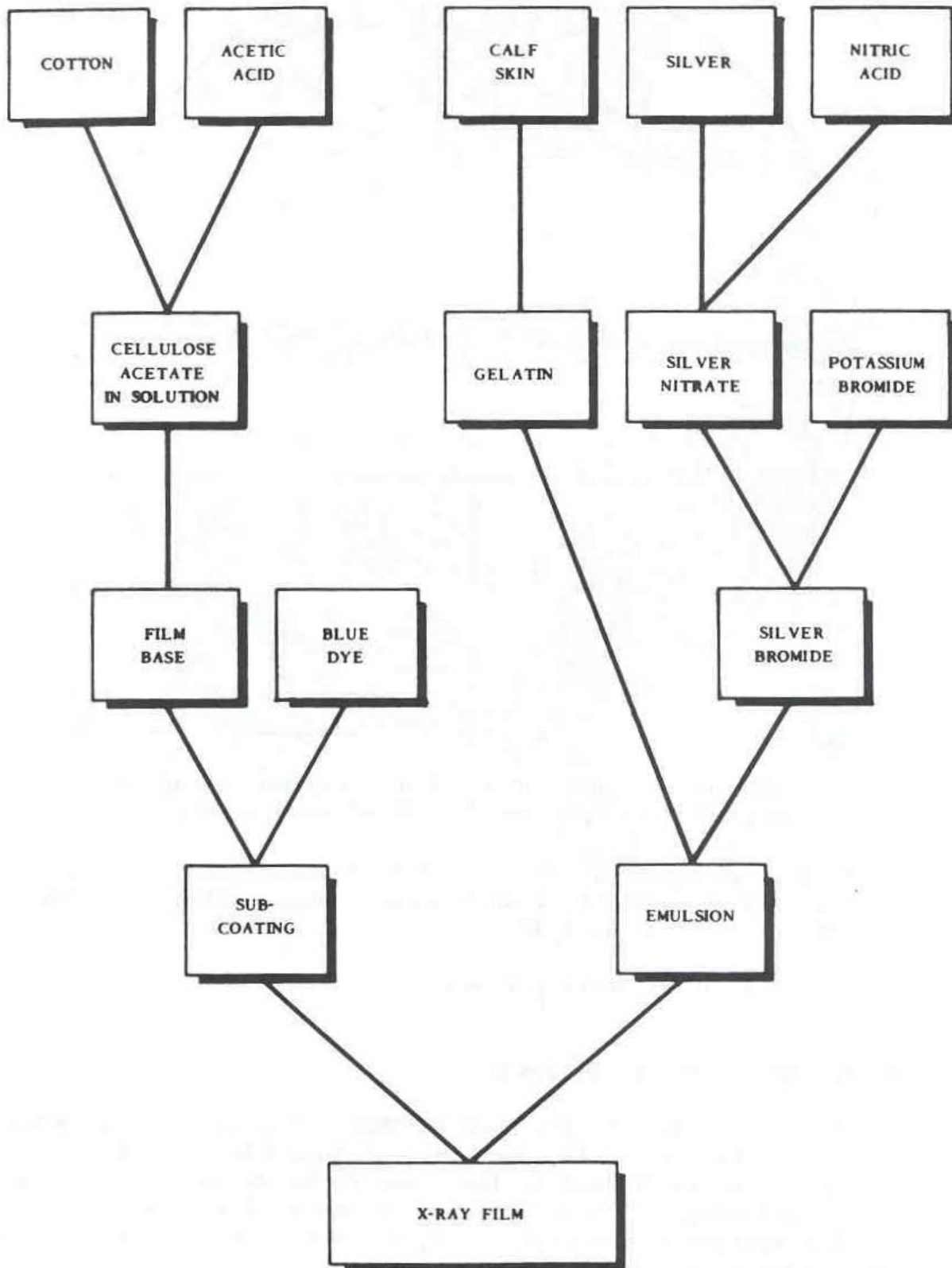


Figure 1-5. Composition of a-ray film.

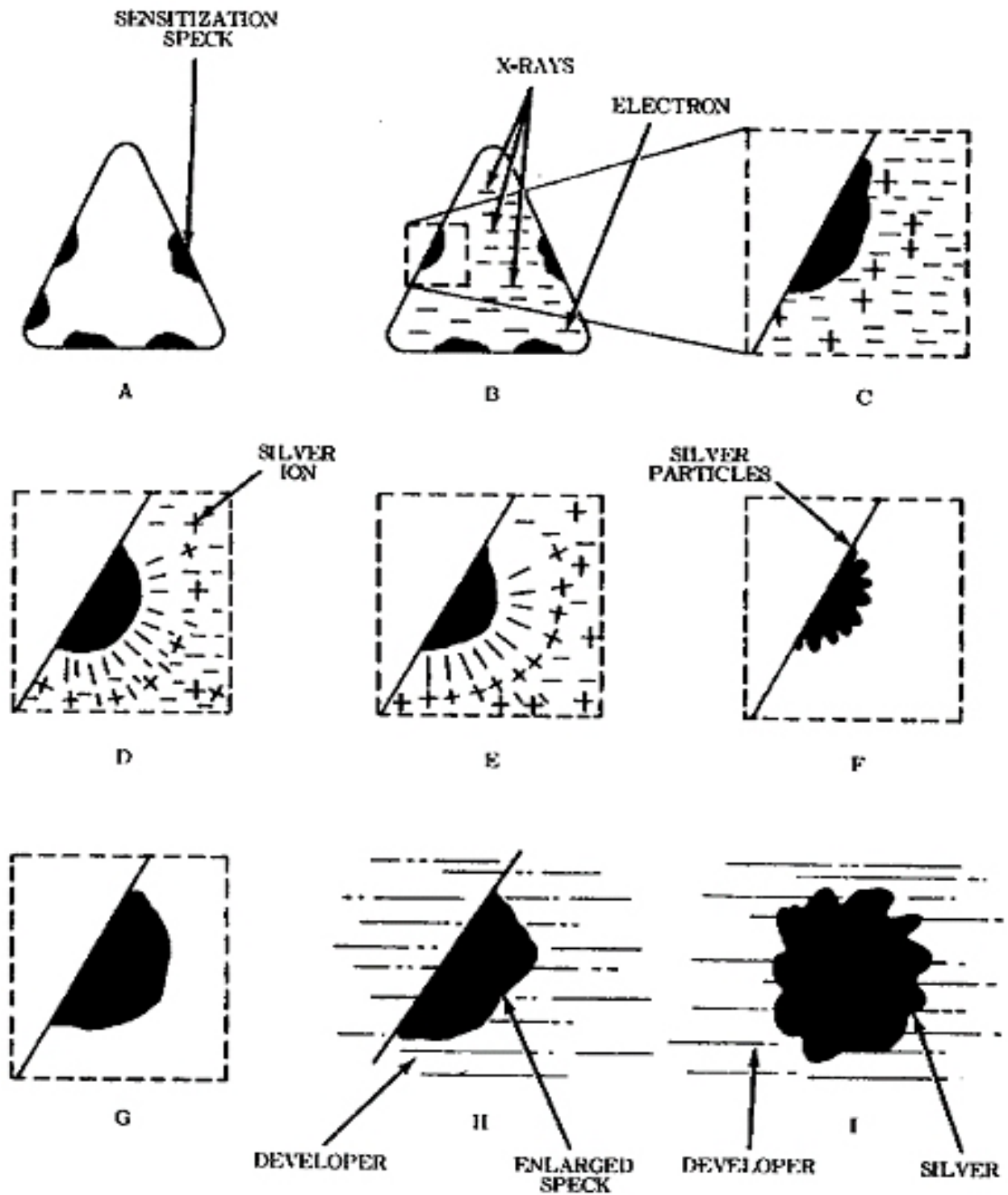


Figure 1-6. Changes occurring within silver bromide crystal upon exposure to x-rays and subsequently developer.

b. The generally accepted theory as to the nature of changes occurring in the production of the latent image is that, when the silver bromide crystals are atomically activated by exposure to x-rays (and usually, the fluorescent light of intensifying screens), electrons fly out of their normal atomic orbits and wander at random throughout the crystals. These are known as photoelectrons (B, figure 1-6), one of which (in dotted box, B, figure 1-6) is theoretically represented in C through I, figure 1-6. Normally, the silver bromide crystal is a nonconductor of electricity. Upon exposure to x-rays or light, however, it becomes a weak conductor and the photoelectrons, released from the individual atoms in the crystal flow within the crystal as a tiny electric current (C, figure. 1-6). Ultimately, some of these electrons are trapped or acquired by the "speck" (D, figure 1-6). A negative electrostatic field is now set up around the "speck." Other activities also occur in the crystal for the slower-moving silver ions with a positive charge travel (E, figure 1-6) to the negatively charged "specks" where they are neutralized (F, figure 1-6) to form tiny particles of atomic silver, while the bromide portions of the crystal are absorbed elsewhere. As more silver ions are neutralized, the "speck" grows with silver (G, figure. 1-6). In I, figure 1-6, the silver has been reduced to metallic silver by the action of the developer.

c. The latent image cannot be seen or detected by ordinary physical means, but it can be changed into a visible silver image by chemical processing.

1-5. DENTAL X-RAY FILM

Even though most radiographers do not perform dental radiographs, Radiographers should be aware of the different sizes and types of dental film. Dental x-ray films are available in different sizes and types.

a. **Periapical Film.** The periapical film is used to radiograph the crown root and supporting structure of the teeth. It is particularly useful to determine abscesses, cysts, or granulomas located at the root apices. Additionally, periapical film has great value in diagnosing bone loss caused by periodontal disease. Full mouth periapical series are also used as a record of the progression of such diseases.

b. **Bitewing Film.** The interproximal or bitewing film is used principally to locate cavities on the interproximal surfaces of the teeth (surfaces facing other teeth). These include the crown portion of the tooth and a small area of the root. To hold the film in position, the patient's teeth close on the tab,, which is attached to the film packet.

c. **Occlusal Film.** The occlusal film is a larger film, which is placed horizontally between the occlusal (chewing) surfaces of the upper and lower teeth. The occlusal film provides a general view of the maxillary (upper jaw) and mandibular (lower jaw) arches, so it is especially useful in locating foreign bodies in the floor of the oral cavity and impacted teeth, cysts, et cetera, in the palate. There are usually two films in the occlusal packet, which allow for different developing times. In medical radiography, occlusal film is also used for examination of the nasal bones and to demonstrate stones in the salivary tracts.

1-6. PHOTOFLUOROGRAPHIC FILM

Photography of the x-ray image on a fluorescent screen (photography) requires the use of either of two types of single-coated photographic film. One type is more sensitive to the blue fluorescence of one kind of fluorescent screen; the other is most sensitive to the green fluorescence of another kind of screen. These films are usually supplied in rolls or sheets.

1-7. FILM CHARACTERISTICS

At the time of manufacturing, the manufacturer determines not only the speed of sensitivity of the film, but also other characteristics such as density, contrast, detail, and inherent film fog. The characteristic of film is important since it has a bearing on the quality of the finished radiograph. Manufacturers express the characteristics of their films through a "characteristic curve" which is commonly referred to as an "H and D curve," so named after Hurter and Driffield who first used it to describe the response of the film to varying amounts of radiation.

SECTION III. CHEMISTRY OF FILM PROCESSING

1-8. MANUAL DEVELOPER SOLUTION

The chemistry of the solutions in automatic and manual processing is basically the same. There are a few variations between the two and these occur in the developer. Because of these variations, the developer solution will be addressed in detail from both manual and automatic processing. The manual developer solution is composed of four basic agents: an activator, reducers, a restrainer, and a preservative. Each of the agents is mixed with water, which acts as a solvent. Because each of the agents has its own specific function, each one will be dealt with in a separate paragraph.

a. **Activator.** The activator (or alkali), sodium carbonate, softens the gelatin of the emulsion and provides the necessary alkaline medium to the solution so that the reducing agents can diffuse into the emulsion and attack the exposed silver bromide crystals. In general, the more alkaline the developer, the more powerful and rapid is its action. A disadvantage of sodium carbonate is that when a film is processed in an x-ray developer containing it and then transferred to a warm acid-fixing bath, tiny bubbles of carbon dioxide gas may form in the soft gelatin. As the bubbles escape, they form tiny craters or pits in the emulsion, thereby breaking up the normal character of the silver image. The finished film or radiograph is blistered. To overcome this effect, the temperature of the developer, rinse, and fixer solutions should be approximately the same.

b. Reducers.

(1) Reduction process. As described previously, the latent image site is a speck of silver capable of initiating development. The latent image site provides a place where the reducers accomplish the process of breaking down the silver bromide crystal to black metallic silver. The reducing agents act as electron donors to the latent image site, giving it a negative charge. Thus, the positively charged silver ions may move into the areas of the sensitivity speck and become attracted to it. As this process continues, more silver ions are attracted and deposited as atoms of silver. The final result is the breakdown of the entire crystal to black metallic silver.

(2) Reducing agents. The agents commonly used are Elon™ (another trade name is Metol™) and hydroquinone. The activity of these chemicals requires their presence in an alkaline solution. Chemical functions differently in attacking the emulsion. The Elon™ starts development by attacking the exposed silver bromide crystals swiftly with resultant production of gray tones in the image. Elon™ is unpredictable above 75°F and hydroquinone ceases its activity below 60°F. The activity of the hydroquinone is slower, but it serves to build up the black tones required in the image. The reducers, acting as a team, produce a good image with satisfactory contrast in a minimum of time, as long as the temperature of the solution remains in the optimum range. Reducers are not too stable in the presence of oxygen, which they can readily absorb from the air or from the water.

c. **Restrainer.** The restrainer (potassium bromide) limits the action of the reducing agents to the breaking up of the exposed silver bromide crystals only without attacking the unexposed crystals in the emulsion during the normal development. If the restrainer is omitted, the reducers are hyperactive and break down the unexposed crystals, fogging the film. If the film is left in the developer too long, the reducers will override the restrainer and chemical fog will result. Also, the bromide released from the crystals into the solution will gradually restrain the action of the reducing agents to a point where they no longer function efficiently. Therefore, when a replenisher solution is mixed, it should not include the restrainer.

d. **Preservative.** The preservative (sodium sulfate) retards the activity of the reducing agents to within controlled limits so that the “life” of the developing solution is maintained over a reasonable period of time. Since the reducing agents react quickly with oxygen, this reaction must be controlled or the developing solution will not last very long. Sodium sulfate works very well as a preservative because it retards oxidation of the reducing agents and prevents the formation of stains on the film.

1-9. AUTOMATIC DEVELOPER SOLUTION

Because of the increased speed and temperatures used for automatic processing, the chemicals used in the manual developer are not adequate. Therefore, although the functions of the chemicals are basically the same, some of the chemicals

used are different. The automatic developer consists of five chemicals: an activator, reducers, a restrainer, a preservative, and a hardener.

a. **Activator.** The activator is the same chemical (potassium hydroxide) used in manual developer solution and it serves the same purpose. It swells and softens the emulsion so that the reducing agents can enter and act upon the silver bromide crystals. It also provides the necessary alkaline medium for the solution.

b. **Reducer.** The reducer (phenidone and hydroquinone) reduces the exposed silver bromide crystal to black metallic silver. Elon™, used in manual developing, is unpredictable above 75°F and is replaced by phenidone in automatic processors. Phenidone, which functions effectively at temperatures of 80° and 100°F, builds up the gray tones of the image. Hydroquinone, used in both manual and automatic solutions, bring out the black tones, producing contrast.

c. **Restrainer.** The restrainer (potassium bromide) is also known as the starter solution. The same chemical is used in both automatic and manual solutions. Its function remains the same, to restrain the action of the reducers on unexposed silver bromide crystals. It is not used in replenisher solutions for the reason explained above.

d. **Preservative.** The preservative is once again the same chemical with the same function as in the annual developer. It prevents rapid oxidation of the chemicals and prolongs their useful life.

e. **Hardener.** Gluteraldehyde, a hardening agent, is used in automatic system but not in manual developer. Its function is to control the swelling of the emulsion, thereby reducing film transportation problems and preventing emulsion damage during processing.

f. **Solvent.** The chemicals in both kinds of developer solutions are all dissolved in water. This is necessary both for the action of the chemicals and for the softening of the emulsion.

1-10. FIXER SOLUTION

Although the concentration of the fixer solution varies for the two methods of processing, the chemicals used are basically the same. The fixer has four chemical agents: an acidifier, a clearing agent, a hardener, and a preservative. All of the chemicals are mixed with water, which serves as the solvent.

a. **Acidifier.** The acidifier (acetic acid) neutralizes any alkaline developer that may be carried over from the developing solution and provides the required acidity for the other chemicals to function. The acidifying action quickly stops development and prevents formation of stains.

b. **Clearing Agent.** The clearing agent (sodium thiosulfate or ammonium thiosulfate) dissolves the residual unexposed silver bromide crystals in the emulsion without damage to the silver image. The unexposed crystals have of course, been unchanged by the developer. If the film is not properly cleared, the remaining unexposed silver bromide crystals will darken on exposure to light and obscure the radiographic image. These chemicals are commonly known as "hypo." The clearing action of hypo involves a chemical reaction between the sodium or ammonium thiosulfate and the silver bromide in the emulsion, wherein silver thiosulfate is formed and remains in solution.

c. **Hardener.** The hardening agent (platinum alum, chrome alum, or aluminum chloride) decreases the possibility of physical injury to the gelatin emulsion. A swollen emulsion is easily scratched or distorted during the washing and drying process. The hardener restrains swelling of the gelatin and hardens it so that it can withstand the normal effects of processing.

d. **Preservative.** The preservative (sodium sulfite) prevents decomposition of the clearing agent by the acid with a resultant precipitation of sulfur, as long as normal developing temperatures are maintained. It assists in clearing the film and prevents the residual developer carried over in the film from oxidizing and discoloring the fixing bath.

Section IV. HANDLING AND STORAGE

1-11. GENERAL

X-ray film is packaged in hermetically sealed foil and paper wrappings to protect it from light and moisture in quantities of 25 and 75 sheets. Each film is in a folder of chemically pure interleaving paper. (Some manufacturers omit the interleaving paper.) Each quantity of either 25 or 75 sheets is placed between cardboard, wrapped in protective paper, and placed in a metal foil bag sealed to ensure approximately 50 percent relative humidity inside the package. The package is then wrapped in paper and placed in a metal foil bag sealed to ensure approximately 50 percent relative humidity inside the package. The package is then wrapped in paper and placed in a cardboard carton. Packed in this manner, x-ray film will be free from any defects due to excessive humidity as long as it remains in the unopened foil wrapping. For overseas shipments, each carton is sealed in heavy waterproof paper for additional protection.

1-12. HANDLING

X-ray film is delicate and should not be handled carelessly or roughly. Avoid touching its surfaces, holding it as near the edges as possible with clean, dry hands. It is sensitive to maltreatment of any kind; heat and light adversely affect the emulsion. It can be handled safely and rapidly for all radiographic purposes as long as the x-ray specialist uses precaution to avoid the production of foreign marks (artifacts) on the film.

(Radiographically, an artifact is a mark on the film which is foreign to the x-ray image and which is not necessarily imposed on the film by the action of x-ray.) Artifacts caused by bending and crinkling will be dark.

1-13. STORAGE PRECAUTIONS

a. **Heat.** Unexposed and unprocessed x-ray film should always be kept in a cool, dry place. It should never be stored in basements or near steam pipes or other sources of heat. In extremely warm climates, only small quantities of film should be ordered at one time, so that a rapid turnover takes place. High temperatures damage the emulsion, causing fog and lack of contrast. Unexposed x-ray film is not usable after a few weeks when it has been subjected to temperatures of 90° to 100°F or after a few days of 110° to 120°F. A relatively brief period of excessive heat in transit or storage may ruin the film regardless of how well it is protected. Sealed containers protect film from moisture and other contaminants as long as they are unbroken, but they do not protect against high temperatures. The following may be used as a guide.

(1) If film is to be used in two months, it can withstand temperatures up to 75F without deterioration. °

(2) If stored at 60F, it can be kept six months; at 50°F, for one year.

(3) Ideal storage conditions prevail at temperatures of 50° to 75°F with relative humidity of 40 to 60 percent.

b. **X-Rays.** Film must be suitably protected from the unwanted actions of x-rays or radium by lead-lined walls or chests. Film bins located in the processing room should be protected by sheet lead.

c. **Fumes.** X-ray film must never be stored in drug rooms or other places containing fumes of any kind. Illuminating gas, formalin, ammonia, volatile oils, sewer gas, and similar substance will fog film, which is stored in an atmosphere containing them.

d. **Pressure.** Film should never be subjected to extreme pressure such as wrinkling, bending, or rolling, because changes take place in the emulsion, which, upon development, appear as tree-like artifacts on the finished film. To avoid pressure markings, packages of unexposed film should always be stored on edge; they should never be stacked one upon another.

e. **Expiration Date.** All film should be used before its expiration date.

f. **Refrigeration.** Storage of unexposed packages of film in refrigerators is satisfactory provided packages are removed from 24 to 36 hours before they are to be used. This procedure is to avoid condensing moisture on the film. Open boxes of film should not be stored in refrigerators because of high humidity. Once a box of film is

opened, it should be used as soon as possible. If unexposed boxes of x-ray film must be stored in refrigerators, the refrigerators should contain nothing else and some kind of dehydrator should be used to reduce the humidity.

1-14. SAFEGUARDS AGAINST LIGHT FOG

Any form of white light creeping into a processing room through cracks around the edges of partitions or doors may fog x-ray film, casting a dark veil over it. Only that light from a properly constructed safelight equipped with a filter that is compatible with the screen/film system that is being permitted to fall on the film during its handling, but even this light may fog film if permitted to shine on a particular area too long. No film should be exposed to the safe light for longer than it takes to unload a film and place it in the automatic processor.

1-15. PRECAUTIONS AGAINST STATIC DISCHARGES

In the manufacture and packaging of x-ray film, every precaution is taken to avoid the accumulation of static electricity is removed so that static charges have no opportunity to accumulate on the film and lead to static marks on the finished radiograph. The film is coated and dried in a dust-free atmosphere and at an optimum and constant temperature and humidity, all calculated to hold static electricity to a minimum. A static electricity discharge emits visible light capable of sensitizing the film. The resulting artifacts assume various shapes. They are usually tree-like with finger-like processes emanating outward from the point of discharge, which always has the greatest density. Often static marks assume the character of black smudges. Discharges are most likely to occur in cold, dry period and it is then that particular care must be taken to handle film carefully and to avoid friction on its surface. The loading bench in the processing room should be grounded so that any static charges will be dissipated before the cassette is opened.

1-16. LOADING AND UNLOADING THE CARDBOARD FILM HOLDER

In today's modern radiology clinic, generally the cardboard film holder will not be utilized. There may be situations when the radiographer may encounter the use of the cardboard, and should have the knowledge of the proper loading and unloading technique.

a. The cardboard film holder consists of two pieces of radiotransparent paperboard held together with heavy cloth. A metal clip is attached to one cover and laminated to the inside of the cover is a thin lead foil lining.

b. In loading, the film with the paper around it is placed in the open holder, the large flap of the envelope is turned down, and then the side flaps are brought together and clipped.

c. Since the backs of holders (and cassettes) contain thin sheets of lead to prevent backscatter fogging, you should take care not to use the folder upside down. If you do this, the lead will absorb most of the radiation, leaving the film underexposed. Be sure to place the side marked "tube side" facing the x-ray tube and you will avoid this problem.

1-17. REMOVAL OF FILM FROM CARTON

In taking the film (to be used in a cassette) from the carton, always remove the film slowly. Rapid movement can cause a build-up of static electricity. When the film is removed from its carton, it should be held vertically at the middle of the top border with the fingertips of the right hand and placed in the cassette. Careful handling will prevent many kinds of marks on the film.

1-18. LOADING AND UNLOADING THE CASSETTE

a. **Loading.** When loading a cassette, the film is placed in the bottom of the cassette on the front intensifying screen. The lid carrying the back screen is gently closed and locked by means of the back springs. When placing the film in the cassette, care should be exercised to avoid scraping or sliding the film over the edges of the cassettes or the surface of the screen. The procedure for correctly loading a cassette is illustrated in figure 1-7.

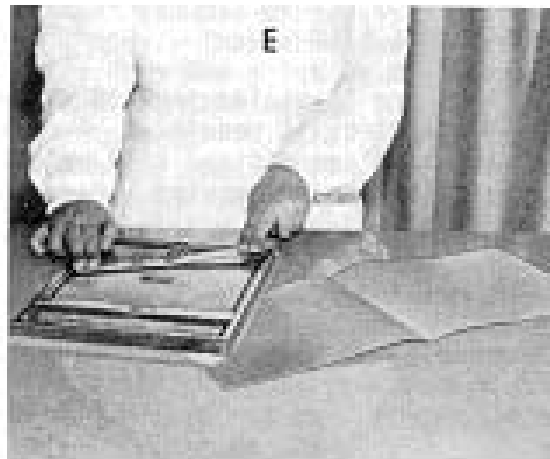
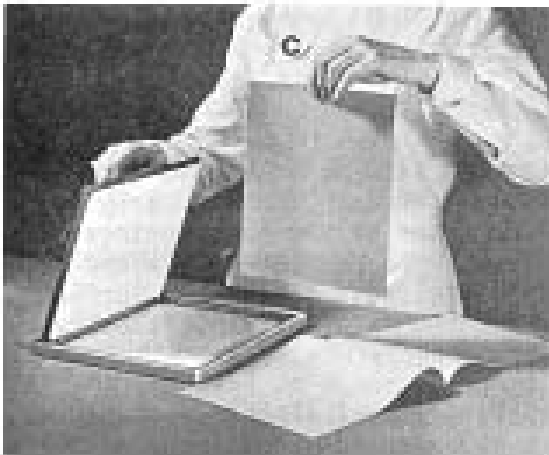
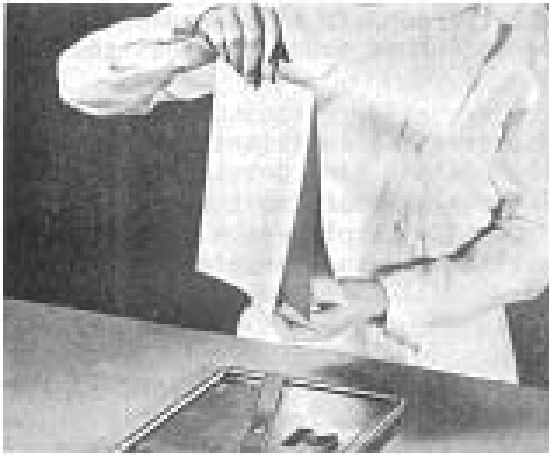
b. **Unloading.** The correct procedure for removal after exposure of the x-ray film cassette is to be sure hands are dry and not come in contact with the screens.

1-19. REMOVING AND LOADING DENTAL FILM

Since dental x-ray films are in sealed individual wrappings, a special procedure for removing these wrappings is required. A dental film hanger consists of a bar of metal, which is affixed to film-holding clips for insertion of exposed dental x-ray films for processing. Care should be taken not to make any finger marks on the film.

1-20. LOADING PROCESSING HANGERS WITH REGULAR FILM

When an unexposed film is removed from the cassette or exposure holder, it is held vertically with the left hand at the upper left corner while a processing hanger of proper size is taken from the storage rack. The upper left corner of the film is inserted in the bottom left clip and the right film corner is inserted in the right bottom clip. The hanger is then inverted and the procedure repeated. The procedure for loading the hanger is shown in figure 1-7. The film is now ready to be developed, but before immersing it in the developer, the surface of the film should be checked to see that it is taut and does not bulge. If it bulges, straighten it by readjustment at the bow and clips. Since cleanliness is of utmost importance and the presence of extraneous marks or artifacts on the radiograph are objectionable, clips must be kept scrupulously clean.



Using both hands to avoid kink marks, place the film carefully in the cassette. Gently close and latch the cassette.

Figure 1-7. Loading a cassette.

1-21. IMMERSION OF HANGERS IN SOLUTIONS

When placing hangers loaded with film in solutions, dip them quickly and carefully. After complete immersion, raise and lower the films about two inches several times to remove air bells and completely bathe the surfaces of the film. Make sure hangers are separated by about three-fourths inch. Do not remove them entirely from the solution until you are ready for the next operation. By keeping the level of the solutions one-inch below the tops of the tanks, the crossbars of the hangers are not covered by the developer or fixer solutions. However, the crossbars should be immersed in the wash water.

Continue with Exercises

EXERCISES, LESSON 1

INSTRUCTIONS: The following exercises are to be answered by marking the lettered responses that best answers the question or best completes the statement or by writing the answer in the space provided.

After you have completed all the exercises, turn to "Solutions to Exercises," at the end of the lesson and check your answers.

1. X-ray film must be characteristically different from photographic film because:
 - a. X-ray specialist are not trained in photography.
 - b. X-ray exposure is different from light exposure.
 - c. It is used under different temperature conditions.
 - d. It is susceptible to high humidity.

2. In x-ray film, the film base is usually composed of polyester or:
 - a. Silver bromide.
 - b. Emulsion.
 - c. Cellulose acetate.
 - d. Gelatin.

3. What suspension material is used to hold the silver bromide crystals?
 - a. Cotton cellulose.
 - b. Cellulose acetate.
 - c. Silver iodine.
 - d. Gelatin.

4. When x-rays are taken using intensifying screens, _____ account(s) for most of the exposure.
- X-rays.
 - Gamma rays.
 - Beta rays.
 - Fluorescent light.
5. The emulsion x-ray film is coated with a thin, transparent material to:
- Allow visual inspection of the latent image.
 - Allow the passage of light.
 - Protect it during handling and storage.
 - Maintain the purity of the emulsion.
6. The x-ray film emulsion is sensitized during:
- Exposure.
 - Manufacture.
 - Development.
 - Fixing.
7. The latent image on an exposed x-ray film:
- Can be seen only in the darkroom under safelight.
 - Can be viewed safely under normal light.
 - Can be detected by ordinary physical means.
 - Cannot be seen or detected by ordinary physical means.

8. Which type of dental film is used to show cavities between the teeth?
 - a. Periapical.
 - b. Occlusal.
 - c. Panarex.
 - d. Interproximal.

9. Which of the following types of dental film would be useful in locating an impacted tooth?
 - a. Periapical.
 - b. Interproximal.
 - c. Occlusal.
 - d. Photofluorographic.

10. The "H and D curve" indicates the:
 - a. Response of the film to varying amounts of radiation.
 - b. Proper temperatures for processing solutions.
 - c. Response of the film to various chemicals.
 - d. Optimum humidity for storage of the film.

11. Reducing agents in the developer change silver bromide crystals to black metallic silver and also act as electron donors to the latent image site. In this latter function, their action results in a:
 - a. Negative charge in the exposed area.
 - b. Positive charge in the exposed area.
 - c. Softening of the gelatin base.
 - d. Release of secondary radiation.

12. Because of the chemicals released by the developing process, which of the following ingredients included in a fresh developer solution is not used in the replenisher?
- a. Elon™.
 - b. Potassium bromide.
 - c. Sodium sulfite.
 - d. Hydroquinone.
13. In the developer solution, sodium sulfite works well as preservative because it:
- a. Increases the activity of the reducing agents.
 - b. Reduces oxidation of the reducing agents.
 - c. Allows the reducers to work at a higher temperature.
 - d. Cuts down on the emulsion swelling.

Check Your Answers on Next Page

SOLUTIONS TO EXERCISES, LESSON 1

1. b (para 1-2)
2. c (para 1-3a(1))
3. d (para 1-3c(2))
4. d (para 1-3b)
5. c (para 1-3c)
6. b (para 1-4a)
7. d (para 1-4c)
8. d (para 1-5b)
9. c (para 1-5c)
10. a (para 1-7)
11. a (para 1-8b)
12. b (para 1-8c)
13. b (para 1-8d)

End of Lesson 1

LESSON ASSIGNMENT

LESSON 2

The X-Ray Film Processing Room.

TEXT ASSIGNMENT

Paragraphs 2-1 through 2-14.

LESSON OBJECTIVES

After completing this lesson, you should be able to:

- 2-1. Describe features and arrangement of an X-ray film processing room along with associated equipment and supplies.
- 2-2. Identify processing accessories, their characteristics, functions and related procedures.

SUGGESTION

After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

Section I. PROCESSING ROOM, ITS FACILITIES, AND ITS EQUIPMENT

2-1. GENERAL ARRANGEMENT OF THE DARKROOM

A plan for an ideal arrangement of an x-ray film processing room (darkroom) can only serve as a guide for use in adapting available facilities to the needs of a particular medical organization. This lesson presents such an ideal plan. This plan is designed for a permanent installation; however, much of the information will be useful in a variety of situations. In the field, processing rooms will usually be set up in tents and a great deal of improvising may be necessary. In any event, the flow of x-ray films from the exposure room, through the processing facilities, and ultimately to the viewer should be as simple, direct, and smooth as possible, involving the fewest possible steps and motions. The routine can be greatly expedited by locating the processing room within the x-ray department itself and efficiently arranging all the equipment. The actual amount of processing equipment is usually allocated to an x-ray department in accordance with the equipment authorization list provided the particular hospital installation.

2-2. PROCESSING ROOM LAYOUT

a. The processing room should be adjacent to the exposure room and must have a source of electricity for operating its apparatus. Lightproofing is an absolute necessity. In the field, a lightproof tent is usually available; in an emergency, it may be necessary to use blankets or tarpaulins for lightproofing.

b. Figure 2-1 shows a layout for an automatic processor darkroom. Normally, the darkroom for automatic processing is smaller than for manual processing. The layout provides for a "dark side" and a "light side." Film holders will be loaded and unloaded on the workbench area (items 7, 8, and 9).

c. In some field situations, an automatic processor may not be available. Consequently, processing will have to be accomplished manually. Figure 2-2 shows a plan for a small manual processing room (approximately 10 by 15 feet) that will permit a daily production of about 200 finished radiographs. The plan provides for the entire operation in one room, divided into a "dry side" and a "wet side." The minimum separation between these two areas should be four feet. In a wider room, the dryer may be positioned across one end. In a large square room, the bench (item 2, figure 2-1) and the processing tanks (item 14, figure 2-2) could be installed along adjoining walls, but care must be taken to separate "wet" and "dry" equipment either by a partition or by sufficient space. In the layout shown, a cassette-transfer cabinet (item 8, figure 2-1) is near the film-loading bench (item 2, figure 2-1), which is located on the "dry" side. After the films are loaded on hangers, it is but a step or two to the developing tank (figure 2-1). Storage compartments (item 7, figure 2-1) next to the cassette transfer cabinet are useful for storing cassettes, film holders, and intensifying screens. Wastepaper receptacles can be incorporated into the loading bench to save floor space. The efficiency of this layout can be maintained by following the workflow line. The loading bench, processing tank unit, and dryer should be so arranged that steps can be kept to a minimum. In figure 2-2, the dotted lines indicate the route the x-ray specialist should normally follow in handling and processing films.

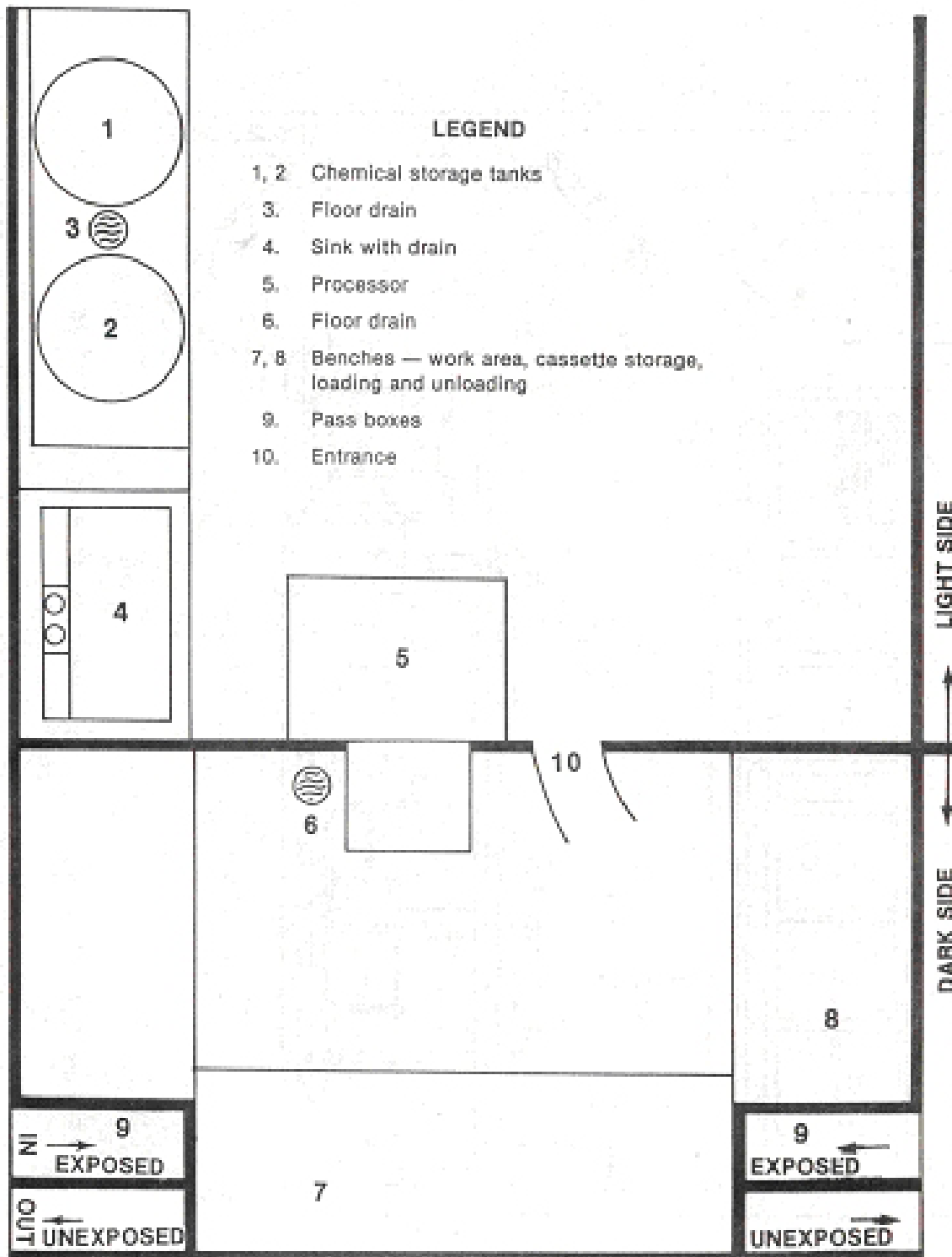
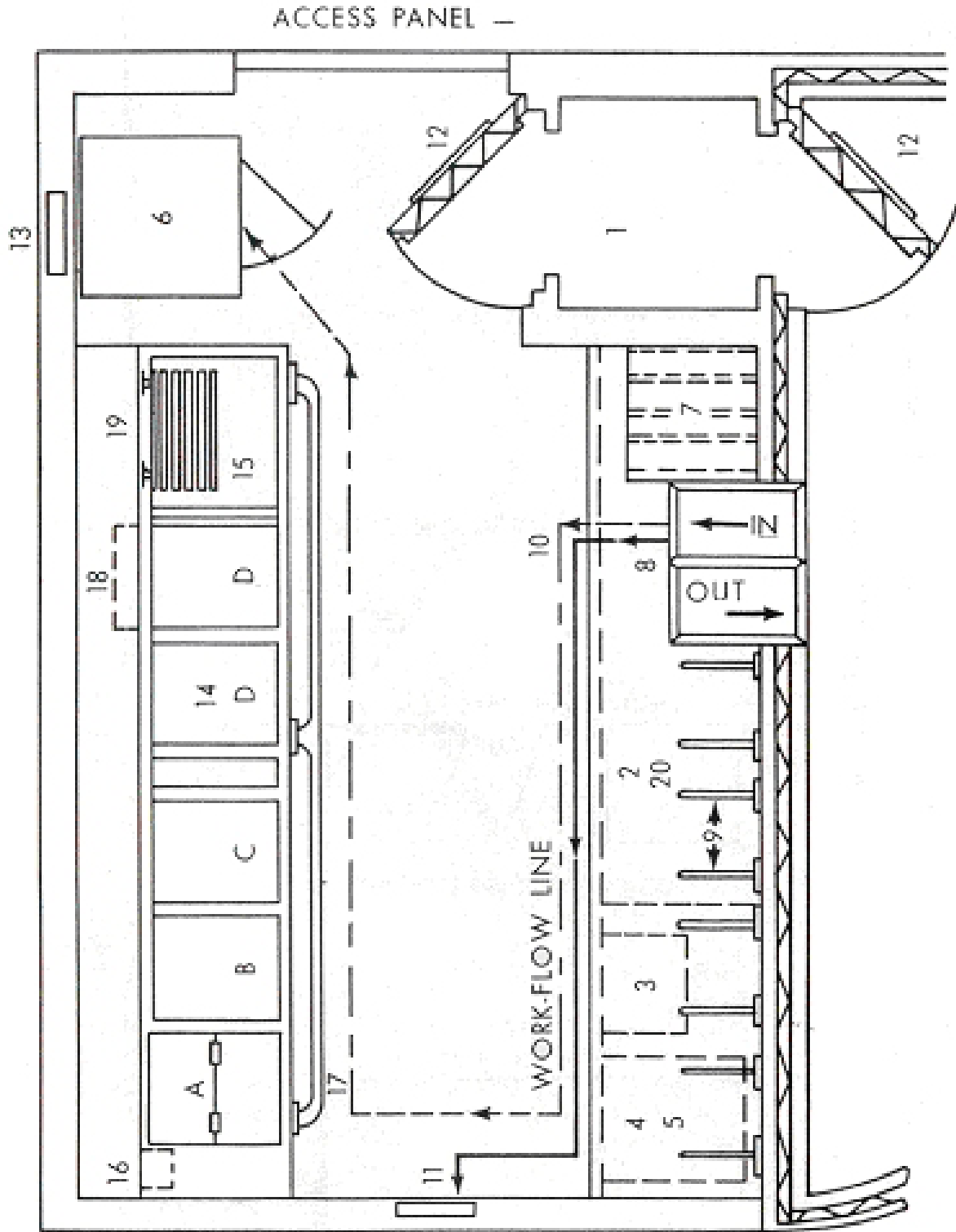


Figure 2-1. A schematic diagram of an automatic processing darkroom and adjacent light room area.



NOTE: Dotted workflow line indicates course of exposed film during the processing procedure.

Figure 2-2. Plan for a processing room showing tank and loading bench sections.

2-3. LIGHTPROOF ENTRANCES

An entrance, which provides easy accessibility while at the same time providing complete protection from outside white light, is essential. Commonly used entrances are of three general types: the single door, the lightlock (double doors), and the labyrinth or maze. The one best suited for a particular situation will be determined largely by the number of people using the processing room and by the floor space available.

a. **Single Door.** If the radiologist and x-ray specialists are the only persons who routinely use the processing room, a single lightproof door with an inside bolt or lock will usually suffice. (Figure 2-3).

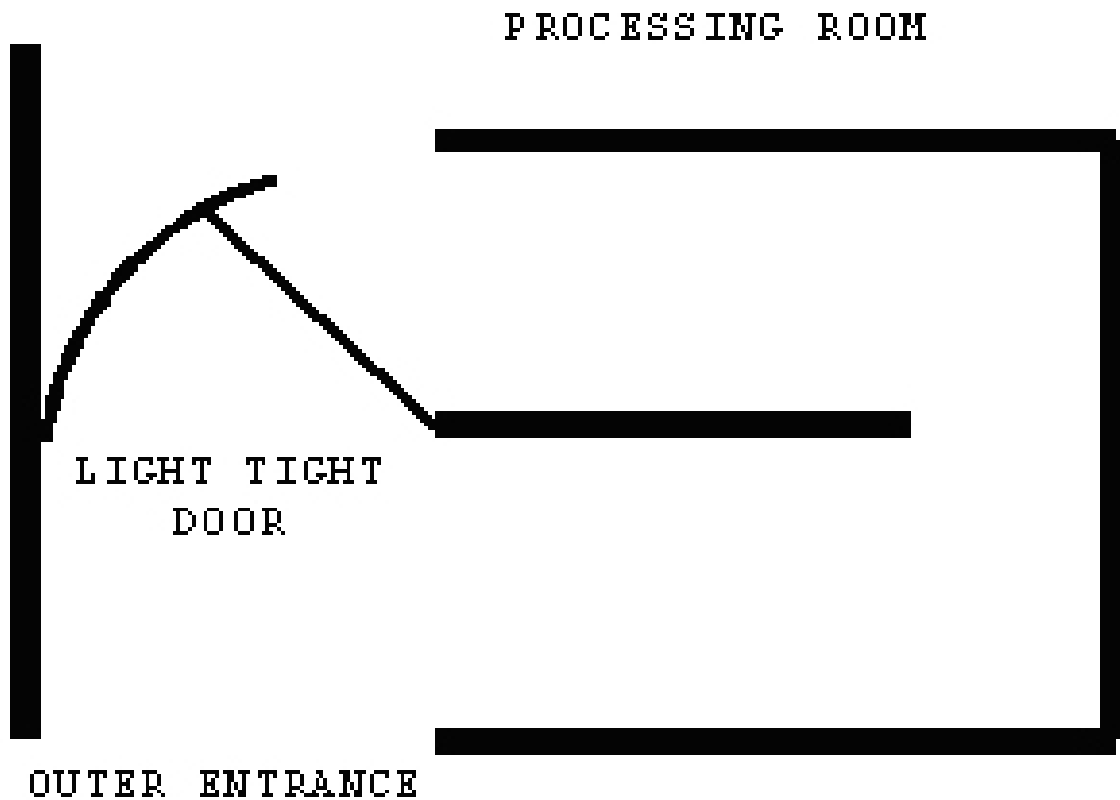


Figure 2-3. Diagram of typical entrance maze.

b. **Lightlock.** This type of entrance may consist of a small hall with two doors, one opening into the processing room and one to the outside. Electric or mechanical interlocking devices can be installed to prevent the accidental opening of both doors simultaneously. However, safety releases must be incorporated into the interlock so that both doors can be opened at the same time to allow the movement of supplies into the processing room or in case of an emergency. If interlocks are not provided, warning lights or buzzers are useful. A lightproof louver should be installed to accommodate changes in air pressure caused by opening and closing the doors and to provide some ventilation. All

of these arrangements can be used with either hinged or sliding doors. If a lightlock opens directly into the exposure room, the lightlock must be equipped with lead-lined doors. Thus, it is simpler if it opens into the control booth, where protection is already provided. The color of the walls in the lightlock is unimportant. Safelight may be used if desired. Minimum dimensions for a lightlock are determined by door size, the smallest practical door being about two and one half feet by seven feet. One door normally swings inward with sufficient room to close it before opening the other.

c. **Labyrinth.** The labyrinth, or maze, is not provided with doors. It prevents the entrance of white light yet provides air circulation. Since it requires at least twice as much floor space as a lightlock, it is seldom used. The height of the entrance should be limited to seven feet to admit the minimum amount of light. The walls and ceiling should be painted with a flat paint and safelight illumination should be provided. A straight passage into the processing room should be made possible by placing a lightproof door in the baffle.

2-4. ILLUMINATION

Illumination of the processing room can be broken down into several individual aspects: white light, safelight, wet film illumination, and wall finish. Each of these elements must be taken into consideration in the design of a processing room.

a. **White Light.** White light is necessary for many operations such as mixing chemicals, cleaning tanks, caring for intensifying screens, and general maintenance of the darkroom. Fixtures for white light should be strategically located and of sufficient intensity to provide general illumination.

b. **Safelight Illumination.** Since x-ray films are sensitive to white light, they must be handled either in darkness or under safelight illumination of the proper quality. Films exposed with intensifying screens are approximately eight times more sensitive to safelight than unexposed film. Therefore, safelight illumination must be designed to give enough visibility in the processing room for the specialist to accomplish his duties, yet be subdued enough to avoid harming unprocessed film.

(1) Light source and filters. A safelight consists of a light source and a suitable filter combined in a lamp housing and giving light of an intensity and spectral quality which will not fog film exposed to it for a reasonably short time. A combination that is recommended and widely used is a 15-watt tungsten bulb with a Wratten 68 filter or Kodak GBX. Light from such safelight is in the yellow or yellow-red portion, not in the same spectral range as the film sensitivity. The wattage is sufficient to provide illumination without undue fogging of the film.

(2) Arrangement. There should be one or more appropriate indirect type safelights in the ceiling for general illumination with others strategically placed over work areas. For specific areas of the room, there are safelights of various design, the choice of

which will depend upon the amount of illumination desired and the angle of which it must fall. An indirect safelight should be used at the loading bench because of the possibility of fairly long exposure of the film to this light.

(3) Safety standards. No safelight is safe if film is left under it too long. Film that cannot be processed immediately should be kept in a lightproof container. Films awaiting processing should be protected by screens, not piled near a safelight.

(4) Checking safelight illumination. A simple method for checking the safety of illumination is to cover part of a film with cardboard and then expose the remainder for one minute at a distance of three feet. This test film is then developed. If no fog shows on the exposed part as compared with covered part, the lighting may be assumed safe. If fog appears, the safelights are not functioning properly. All safelights should be tested periodically for light leaks, fading of the filter, and excess wattage.

c. **Wet Film Illuminator.** In manual processing, a foot switch-operated illuminator mounted above and to the rear of the washing tank is convenient for the inspection of radiographs during the course of hardening and washing (item 18, figure 2-2). The light can then be easily controlled without use of the hands. The illuminator should not be used when unprotected or when unprocessed films are on the loading bench nor should it be used for films that have not yet been cleared in the fixer solution.

d. **Wall Finish.** If the quality of the light from a safelight is "safe," the illumination reflected from any surface is also "safe" regardless of the color or finish of the surface. However, the finish should be an attractive color and should reflect the maximum amount of safelight illumination. To avoid glare, flat paint should be used. Maximum reflection is achieved by choosing a color within the same color spectrum as that of the safelight. In permanent installations, the ceilings and the upper 18 inches of sidewalls should be painted white. The remaining wall surfaces should be a warm, light color.

2-5. VENTILATION

a. Satisfactory ventilation of an x-ray processing room requires consideration if the health and well being of the x-ray specialists are to be maintained. The processing room is subject to certain conditions that directly affect the air in it: uncovered solutions increase the humidity in the room, processing solutions create odors, and film-drying cabinets give off heat.

b. When not properly controlled, temperature and humidity have adverse effects on both the worker and the film. For comfort, humidity between 40 and 50 percent, temperature between 67° and 83°F, and air movement between 15 and 25 feet per minute should be maintained. Greater air velocity would be tolerable at temperatures above 80°. The air in the processing room should be maintained at a positive pressure, that is, air should be pumped in, not out. This helps prevent the entry of dust. The dryer should

have a duct vented outside so that it may be used to exhaust air from the room. Incoming air should be pumped through filters and should be sufficient in volume to change the air in the room from 6 to 10 times each hour.

c. When ventilating ducts are absent, fans with lightproof intakes may be installed in the wall. Doors may be equipped with lightproof louvers to permit passage of air.

2-6. ELECTRICAL WIRING

a. Low-potential electrical outlets and fixtures can be hazardous to personnel. Voltages of 110 and less may prove fatal if contact is made with moist skin. Special care should be exercised to avoid a situation in which the body becomes part of an electrical circuit. Hazards include the proximity of wiring to the solution tanks and plumbing, spilled water on the floor and moisture on the hands. All exposed metal parts of both fixed and portable equipment, such as the metal frames and exteriors of illuminators, safelight lamps, electric timers, and foot switches should be grounded. If such equipment is connected with an armored cable, a separate ground wire is not required because the metallic sheathing should provide an adequate ground. However, if a two-wire cord is used, a separate ground connection should be installed. For ease in installation, the outlet box may be used with the third wire attached to metal on the equipment and the outlet box by means of approved devices, but not held with solder. If a three-wire cable is not feasible, a length of no. 16 stranded fixture wire may be taped along the outside of the two-wire cord. The ground may be fastened to a cold water pipe, if necessary.

b. All outlets, switches, sockets, and similar devices should be insulated and grounded. Despite safety devices, always follow the "one-hand" rule, that is, when operating electrical apparatus with one hand, avoid grounding yourself with the other. Foot switches eliminate the use of hands in operating electrical equipment, but special care must be taken in grounding them because of the likelihood of moisture on the floor.

c. A safelight installed in the ceiling of the entrance lightlock should have its switch at a convenient height on the right side of the inner entrance. The white-light circuit switch, however, should be high on the wall above the safelight switch so it will not be turned on inadvertently. All safelights should be on the same circuit, but should have individual switches. In manual processing, the film dryer should be on a separate circuit of ample capacity. As an extra precaution, it is advisable to have all three main circuits (for white light, safelight, and dryer) controlled by a single heavy-duty disconnecting switch in addition to their individual switches.

2-7. THE LOADING BENCH

a. **General.** The loading bench is the primary component of the "dry" side (manual) and "dark side" (automatic) of the processing room. It contains an area for loading and unloading film holders, a cassette transfer cabinet, a film bin, compartments

for cassettes and exposure holders, storage for hangers, a wastepaper receptacle, and storage for processing materials. Generalized layouts for a loading bench are shown in figures 2-4 and 2-5. In figure 2-4, the racks for storing dry film hangers are above the loading bench and storage compartments are beneath the bench.

b. **Loading Area.** The length of the loading bench depends on the volume of work and the space available. The minimum length of the working surface should accommodate two 14 by 17-inch cassettes, side by side, to permit unloading and reloading of two cassettes. Preferably, it should be long enough to accommodate at least four 14 by 17-inch cassettes, side by side, to preclude piling of cassettes. The working surfaces shown in figures 2-4 and 2-5 require approximately 96 inches, exclusive of transfer cabinet and dryer space. The bench should be about 36 inches high and 24 inches deep. A strip of one-half by one-inch molding placed lengthwise and six inches from the back edge of the bench anchors the cassettes while they are being opened and closed and keeps them at the front of the bench within the working area of maximum efficiency.

c. **Film Bin.** It is customary to keep a supply of opened boxes of film sufficient for immediate needs underneath the loading bench. The most convenient method is to use a lightproof film bin having compartment in which opened film boxes can be kept upright.

d. **Storage Compartments.** The ideal way to store cassettes and exposure holders is in vertical compartment so that they are readily accessible but do not encroach on the working surface of the bench top.

e. **Storage Cabinets.** As shown in figures 2-4 and 2-5, closed cupboards for such items as packaged chemicals, solution-mixing accessories, and towels may be located either above or below the loading bench.

f. **Storage of Hangers.** In manual processing, film hangers are usually stored above or below the loading bench. The hanger should be hung so that the specialist can remove it from the brackets by grasping one of the bottom corners to avoid unnecessary turning. Those stored above the bench hang with crossbars up while those below the bench hang with crossbars down. When hung above the bench, they should clear the bench by 24 inches.

g. **Cassette Transfer Cabinet (Pass boxes).** For convenience, the transfer cabinet should open onto one end of the loading bench. It should open outside into the central booth or some other place directly accessible to the exposure room.

h. **Waste Receptacle.** The best arrangement for a wastepaper receptacle is to incorporate it into the loading bench (figure 2-4). A suitable container will do instead, but it may interfere with traffic and encourage dumping of dust from other rooms.

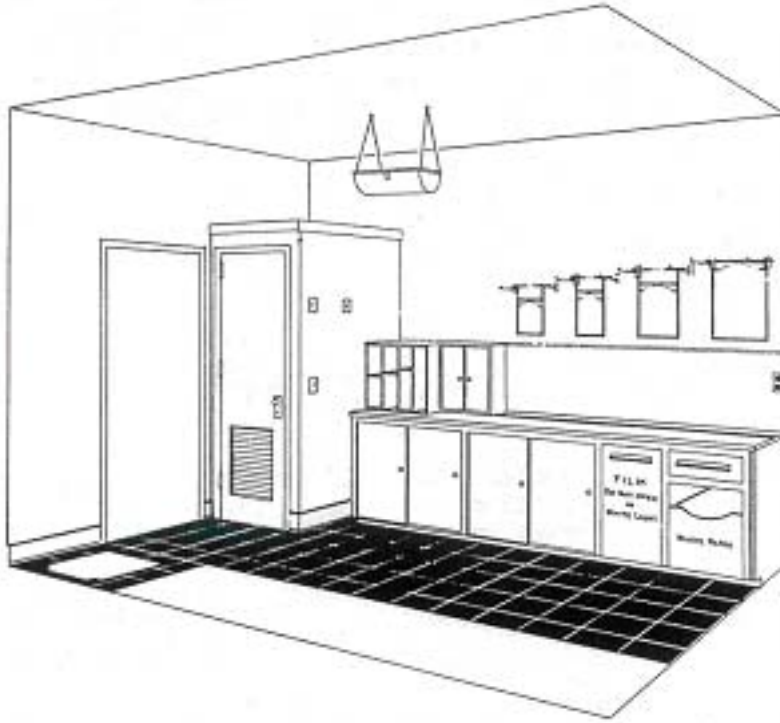


Figure 2-4. Loading bench section with hangers mounted above bench.



Figure 2-5. Loading bench section with hangers mounted below bench.

2-8. PROCESSING TANKS

a. **General.** Processing tanks are used for such operations as developing, rinsing, fixing, washing, and drying x-ray films. Tanks as well as mixing vessels are usually made of stainless steel. These tanks are the "wet side," and are usually used in manual processing. In automatic processing, all of the processing tanks are in a closed compressed unit, and require less maintenance than the manual tanks. The following information will generally apply to manual processing.

b. **Types.** There are two general types of tanks in use:

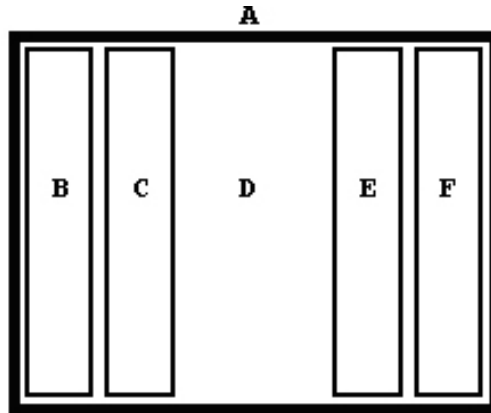
(1) Master tank. The master tank serves as a water jacket for holding insert tanks and usually provides space between the insert tanks for washing and rinsing. If a washing tank is available, washing will be done in it.

(2) Insert tanks. Insert tanks are removable containers for individual solutions, which are placed in the master tank. The stainless steel insert tanks are standardized at a five-gallon capacity. The American Standards Association gives the inside dimensions of a standard 5-gallon tank as 20-1/32 inches deep, 14-1/2 inches long, and four inches wide. To check a tank of unknown size, use the following formula:

$$\text{Capacity of Tank in Gallons} = \frac{\text{Width} \times \text{Length} \times (\text{Depth Minus One Inch})}{231}$$

When the inside dimensions of the tank are correct, the solution level is one inch below the crossbar ledge.

c. **Arrangement of Tank Units.** The tank system usually consists of a master tank containing three basic solution tanks. If a stop bath is used, there will be four (figure 2-6). Water in the space between the developer and fixer sections is used for rinsing or insertion of a stop bath solution tank, as well as for controlling temperature. A separate washing tank, the same size, as the master tank is usually available. It may be provided with a two-compartment cascade arrangement or it may be used as a single-compartment wash tank. Washing arrangements should take into consideration a left-to-right movement of films.



- | | |
|---|--|
| A. Master Tank | D. Water rinse or washing section |
| B. Developer Tank | E. First fixing Tank |
| C. Acid Rinse (stop bath, if used) | F. Second fixing Tank |

Figure 2-6. Conventional arrangement of a small tank unit (top view).

d. **Single-Compartment Wash Tanks.** When the single-compartment wash tank is used, an overflow pipe is provided (figure. 2-7). The water flows from the inlet pipe, between and along the surfaces of the films, and then into the overflow pipe. This arrangement permits rapid washing because of the speed and thoroughness with which fresh water is circulated across the film surfaces.

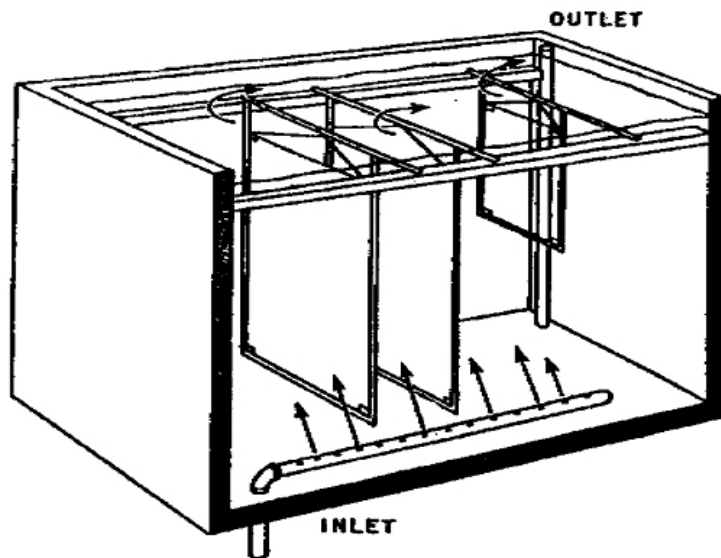
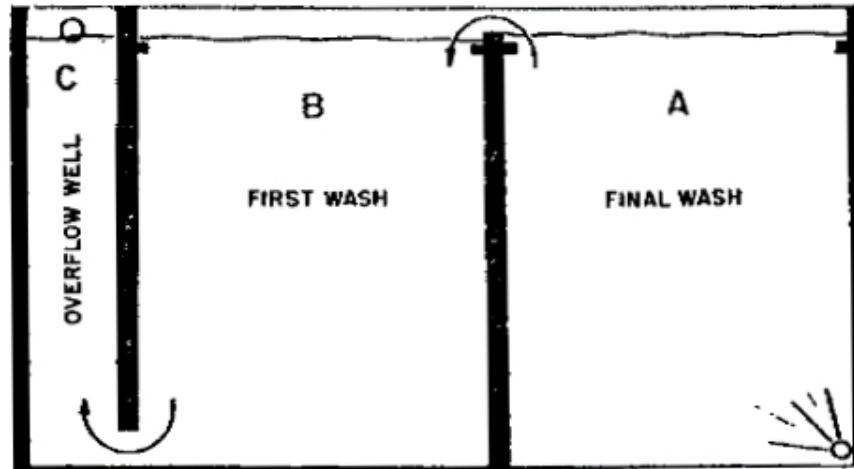


Figure 2-7. Single-compartment wash compartment.

e. **Cascade Wash Tank.** Cascade washing of radiographs is the most efficient method because it rinses the fixer solution off the film with a minimum amount of water. Although an additional operation is required for moving the films from one compartment to the next, the cascade system is especially useful in installations handling a continuous volume of films. The tank (figure 2-8) consists of two washing compartments and an overflow well. The fresh water flows into the bottom of compartment "A," passes upward over the partition into the compartment "B," under the end wall of the tank proper, and through the outlet "C" in the overflow well.



NOTE: Arrows indicated the flow of water.

Figure 2-8. Cascade system of washing.

(1) Washing compartments. Fixer solution is denser than water and normally drifts towards the bottom of the tank after being washed from the radiographs. Preliminary washing should be in compartment "B" where the flow is downward. The radiographs are then placed in compartment "A" for the remainder of the washing period. By placing a film first in compartment "B," those washing in compartment "A" are not contaminated; this overcomes the chief disadvantage of single compartment washing.

(2) Overflow well. The chief purpose of the overflow well in a cascade system is to permit the draining of water from the bottom of the adjacent washing compartment through a standard standpipe or through an overflow pipe in the back of the tank.

NOTE: Arrows indicate water flow from inlet over both film surfaces and to outlet.

f. **Temperature Control.** The temperature of the solutions should be controlled closely. The ideal situation would be to maintain both the air and the tap water at 68°F, which would keep the washing water constant with the solutions. Since this is seldom the case, some method of temperature control becomes necessary.

(1) Refrigeration unit. A detachable refrigeration unit is normally supplied for use with the processing tanks to temper the processing solutions.

(2) Heating unit. In the laboratory, the hot water tap may be utilized. In the field, a suitable immersion-heating unit can readily raise the temperature of the solution above 60°F, the minimum processing temperature.

(3) Thermometer. Processing of radiographs requires that an accurate check on the temperature of the solutions be maintained at all times by the use of a reliable thermometer. The temperature should always be checked when the work is first begun and at intervals throughout the day. The optimum temperature of 68°F, recommended by the American Standards Association, has been adopted. Do not attempt to judge the temperature of a solution by dipping a finger into it.

(4) Tank insulation. The master tank may require insulation, especially when there are wide differences between ambient air temperature and the optimum processing temperature. If the air is much warmer than the processing solutions, an uninsulated tank might condense enough moisture to be annoying and it could be difficult to hold the solutions at the right temperature. Air conditioning solves this problem very effectively. In the field, however, the specialist may find it necessary to improvise insulation with blankets.

g. **Drainage Facilities**. The drain line must be large enough to accommodate the maximum simultaneous flow of water from both the water jacket and the washing tank. Both size and pitch (slope) of the line affect the rate of flow. The pipe should be at least two inches in diameter and the pitch at 1/4 inch per foot. Flushing the drain with rapidly flowing water after old processing solutions have been discarded through it will help prevent corrosion and deposits. In the field, drainage should be into a seepage pit or ditch.

2-9. MAINTENANCE OF TANKS

Trays, tanks, and other processing equipment frequently become discolored and encrusted through use. Frequent rinsing and drying is the best prevention for these conditions. Strong cleaners should be used only when really needed. Exercise care when using these cleaners, because they usually possess strong acids or alkalines.

a. Oxidized developer stains (brown or yellow-brown) can often be removed with soap and water. If not, tray cleaner formula or some similar product will be needed. An effective tray cleaner can be prepared by mixing 32 ounces of water, three ounces of potassium bichromate, and three ounces of concentrated sulfuric acid.

CAUTION: Always add the sulfuric acid to the water and potassium chromate solution, stirring constantly. Never add the solution to the acid as it may cause boiling and spattering, leading to serious burns.

To use, pour a small amount of the solution into the vessel, rinse it around to be sure it reaches all surfaces, pour it out, and wash the vessel six to eight times with water. Do not use the solution on your hands.

b. Developer tanks accumulate a scale of basic calcium sulfite, which is difficult to scrub off. This scale is soluble in acids, but ease of removal varies according to the

conditions under which the scale was formed. Fill the tank with stop-bath solution and allow to stand overnight. A strong stop-bath solution can be prepared by adding 16 ounces of 28-percent acetic acid to one gallon of water. To make 28-percent acetic acid, combine three parts alcohol acetic acid with eight parts water. If this stop-bath solution does not loosen the scale, try a five percent solution of hydrochloric acid. Be very careful, as the acid solution can pit stainless steel.

c. Wash tanks often become coated with algae that may stick to the film. Thorough cleaning and weekly treatment with commercial bleach solution consisting of one part bleach to six parts water, removes algae. Be sure to cover the inside of the intake and overflow pipes with the solution, since algae often grows there. Leave the solution in the tank overnight; drain, scrub, with a stiff brush; and rinse four or five times.

2-10. THE FILM DRYER

a. The drying of radiographs is always important. The dryer is fitted with heating elements and a large fan, both on the same circuit. The dryer duct should vent outside the building to prevent excessive humidity.

b. The small processing room in which only a few films are processed daily usually does not justify installation of a dryer. In such a case, a commercial drying rack is adequate. When a commercial rack is not available, a one-by three-inch board can be drilled with three-eighths inch holes, about four inches apart and mounted on a high wall.

c. The drying unit may be installed along the wall at one end of the processing room or underneath the loading bench. The drying of films is usually considered a "wet film" operation, but with reasonable care can be carried out at a low location on the "dry" side of the room.

d. When air is drawn in rather than blown through the dryer, a uniform air flow results. Airflow should be at least 450 to 500 cubic feet per minute. Air temperature inside the dryer should be maintained at the coolest temperature that will dry the film--never more than 120°F. Heating elements and the fan should be on the same circuit.

e. Suitable insulation is placed around the dryer so that the temperature of the room is not unduly affected. The drip pan underneath each film drawer should be kept clean and free of dust and debris.

Section II. PROCESSING ACCESSORIES

2-11. ARRANGEMENT

Processing accessories should be kept near the section of the processing tank where they are used. Time-temperature guides, exhaustion charts, and other processing information are readily referred to when fastened to a chart board placed near the developing tank. A shelf for the interval timer and thermometers should be located near the developer section. Other accessories may be placed on shelves above and behind the processing tanks.

2-12. PROCESSING HANGERS

a. **Types.** There are three general types of processing hangers:

(1) Sheet film hanger. The sheet film hanger holds the x-ray film taut during processing. It consists of a crossbar and rigid frame to which are attached four clips, two of which are mounted on a bow spring welded to the crossbar (figure 2-9).

(2) Dental film hanger. The dental film hanger consists of a bar to which film clips are attached.

(3) Roll film hanger. When it is necessary to process roll film and a special processing tank is not available, a special adjustable processing hanger may be used. It will accept 35, 45, 50, 60, and 70 mm film widths and any length up to 11 feet. The outer frame is approximately the size of a 14 by 17-inch hanger and can be used in the regular processing tanks. For four by 10-inch short film and 70 mm roll film, there are special hangers, which will fit the same five-gallon tanks.

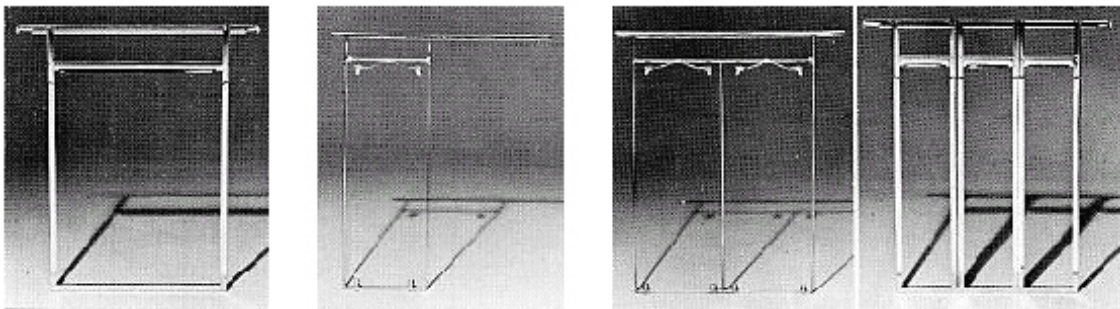


Figure 2-9. Processing hangers.

b. **Hanger Adjustment.** Bow springs of hangers lose tension through prolonged use and must occasionally be adjusted. To adjust the hanger, place it on the loading bench. Insert a sheet of cardboard from a film box (of the same size as that for which the hanger will be used) into the jaws of the lower clips. Bend the bow springs upward until the lower tips of the clips attached to them are about one-eighth inch from the top edge of the cardboard.

c. **Hanger Maintenance.** Metal film hangers and clips tend to accumulate a spongy deposit of silver with use. Chemicals not washed from these deposits can leak out and fog film or foul other solutions. Frequent scrubbing with cleansing powder will prevent this deposit. For really stubborn deposits, there are four possible treatments.

(1) Acetic acid treatment. Soak the hangers or clips for an hour in a tray filled with a 10-percent solution of acetic acid to nine parts water or one part 28-percent acetic acid to two parts water). Then wash with clear water and a stiff brush.

(2) Trisodium phosphate treatment. Boil the equipment for several minutes in a 10-percent solution of trisodium phosphate, wash it with a stiff brush. This method is especially useful for cleaning deposits mixed with gelatin.

(3) Acid bichromate treatment. Tray cleaner formula may be required if silver deposits remain. Dilute the regular formula, one part to two parts water. Soaking for 10 minutes is usually sufficient. Rinse well and brush off any reddish scale. Use a glass or hard rubber tray as enamel is etched by this solution. In addition, this solution should not be used on chromium-plated articles.

(4) Sandblasting. Heavy deposits are best removed by sandblasting.

2-13. THE INTERVAL TIMER

The interval timer is used to regulate the period of development of the exposed x-ray film. The dial face should be marked in minutes, usually up to and including 30, with each minute subdivided into quarter-minute intervals. The timer most commonly supplied is spring wound, usually by depressing the winding lever.

2-14. MISCELLANEOUS PROCESSING EQUIPMENT

a. **Mixing Equipment.** Two 2-gallon stainless steel pails for solutions, a stainless steel or plastic funnel, and two stainless steel mixing paddles are the usual items of mixing equipment supplied.

b. **Filler and Drainer Pump.** When circulating water is available, a small filler and drainer water pump is useful for emptying and filling solution tanks not equipped with outlets. This device consists of a three-branched rubber hose, one for connecting to a water faucet, one for the solution tank, and one for the sink. When the faucet is turned on, the tank drains rapidly because of the suction.

c. **Utility Sink.** A sink for cleaning tanks or mixing chemical solutions is a timesaving convenience.

d. **Laboratory Aprons.** A waterproof apron should be worn during processing operations to prevent solution stains on uniforms or other clothing.

Continue with Exercises

EXERCISES, LESSON 2

INSTRUCTIONS: The following exercises are to be answered by marking the lettered responses that best answers the question or best completes the statement or by writing the answer in the space provided.

After you have completed all the exercises, turn to "Solutions to Exercises," at the end of the lesson and check your answers.

1. It is desirable for the processing room to be adjacent to:
 - a. The surgical suite.
 - b. The exposure room.
 - c. The supply room.
 - d. The radiologist's office.

2. In a processing room, the minimum distance between the "dry side" and the "wet side" is:
 - a. Three feet.
 - b. Six feet.
 - c. Four feet.
 - d. Two feet.

3. In which of the following lightproof entrances would an interlocking device proof useful?
 - a. Lightlock.
 - b. Single door.
 - c. Maze.
 - d. Labyrinth.

4. The labyrinth requires _____ floor space as a lightlock.
- At least twice as much.
 - About half as much.
 - Over three times as much.
 - Approximately the same.
5. Which filter is normally used in a darkroom safelight with a 15-watt tungsten bulb?
- 5A.
 - 6A.
 - 6B.
 - 8B.
6. An easy way to check safelight illumination is to use:
- A film partially covered by cardboard.
 - A film and a white light source.
 - A densimeter.
 - Low and high wattage light bulbs.
7. What effect, if any, does a light-colored wall have on indirect safelight illumination?
- It increases the intensity.
 - It creates reflections, thus clouding the film.
 - It increases the fogging factor of exposed x-ray film.
 - It does not reduce the "safety" of indirect safelight illumination.

8. Hanger bow springs lose tension through:
 - a. A lifetime tension.
 - b. Moisture.
 - c. Dryness.
 - d. Prolonged use.

9. What protective measures should be used to prevent possibly fatal electric shock i in the film processing room?
 - a. Use only low voltage electrical outlets.
 - b. Use only foot switches in the darkroom.
 - c. Ground all processing equipment.
 - d. Keep the hands dry at all times.

10. Which piece of equipment listed below would be located on the "dry side" of a processing room.
 - a. Loading bench.
 - b. Film dryer.
 - c. Timer.
 - d. Sink.

11. For convenience, the cassette transfer cabinet should open onto the end of the loading bench and outside into:
 - a. The radiologist's office.
 - b. Some place directly accessible to the exposure room.
 - c. The surgical suite.
 - d. The orthopedic clinic.

12. Which of the materials listed below would be used in containers for mixing x-ray film processing chemicals?
- a. Tin.
 - b. Aluminum.
 - c. Galvanized iron.
 - d. Stainless steel.
13. Which equipment or functions, listed below would be likely to be located on the "wet side" of a processing room?
- a. Loading bench.
 - b. Processing tanks.
 - c. Film bins.
 - d. Hanger storage.
14. A processing tank has the following dimensions: four inches wide, 14-1/2 inches long, and 20 1/32 inches deep. Using the formula in the text (para 2-8b(2)) what is the capacity of the tank?
- a. 4.7784 gallons.
 - b. 4.9840 gallons.
 - c. 5.0000 gallons.
 - d. 5.1001 gallons.

15. In manual processing of x-ray films, which of the following methods permits the complete washing of films with a minimum amount of water?
- a. Single compartment tank.
 - b. Aeration tank.
 - c. Tray.
 - d. Cascade.
16. If a developer tank coated with a scale of basic calcium sulfite cannot be cleaned with a stop bath solution, what should be used?
- a. Tray cleaner.
 - b. 10-percent solution of sodium hypochlorite.
 - c. 28-percent solution of glacial acetic acid.
 - d. Five-percent solution of hydrochloric acid.
17. The operating temperature for a film dryer should not exceed:
- a. 101°F.
 - b. 120°F.
 - c. 180°F.
 - d. 212°F.
18. Spongy deposits of silver on metal film hangers must be periodically removed or they may:
- a. Hold chemical deposits, which may fog film.
 - b. Injure the hands of the X-ray specialist.
 - c. Scratch the surface of adjacent films.
 - d. Etch the surfaces of the processing tanks.

19. Which of the following is most efficient for regulating the period of development of an exposed film?
- a. The wall clock in the processing room.
 - b. The X-ray specialist's wristwatch.
 - c. The interval timer in the processing room.
 - d. The X-ray specialist's judgment.
20. The filler and drainer pump has one branch of its base to the sink and one branch in the solution tank. For the pump to properly drain the solution tank, the third branch must be:
- a. Connected to the water faucet.
 - b. In the other solution tank.
 - c. Connected to the drain.
 - d. Clamped tightly together at its end.

Check Your Answers on Next Page

SOLUTIONS TO EXERCISES, LESSON 2

1. b (para 2-2a)
2. c (para 2-2c)
3. a (para 2-3b)
4. a (para 2-3c)
5. c (para 2-4b((1)))
6. a (para 2-4b((4)))
7. d (para 2-4b)
8. d (para 2-5b)
9. c (para 2-6a)
10. a (para 2-7a)
11. b (para 2-7g)
12. d (para 2-8a)
13. b (para 2-8a)
14. a (para 2-8b(2))

$$\text{Capacity in Gallons} = \frac{\text{Width} \times \text{Length} \times (\text{Depth Minus One Inch})}{231}$$

$$= \frac{4 \times 14.5 \times (20 \frac{1}{32} - 1)}{231}$$

$$= \frac{4 \times 14.5 \times 19.03}{231}$$

$$= \frac{1103.74}{231} = 4.778 \text{ (Answer)}$$

15. d (para 2-8e)
16. d (para 2-9b)
17. b (para 2-10d)
18. a (para 2-12c)
19. c (para 2-13)
20. a (para 2-14b)

End of Lesson 2

LESSON ASSIGNMENT

LESSON 3

Automatic X-Ray Film Processing.

LESSON ASSIGNMENT

Paragraphs 3-1 through 3-61.

LESSON OBJECTIVES

After completing this lesson, you should be able to:

- 3-1. Select the correct procedures for automatic processing of x-ray film.
- 3-2. Identify the techniques used for processing x-ray film under adverse field conditions.
- 3-3. Choose the appropriate procedures for processing photofluorographic film.
- 3-4. Select the correct procedures to be used in tray processing and high-speed processing x-ray film.
- 3-5. Choose the best method of standardizing processing procedures when working with solution of unknown temperature and/or strength.

SUGGESTION

After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

Section I. AUTOMATIC FILM PROCESSING

3-1. INTRODUCTION

a. One of the critical operations in radiography is the processing procedure that renders visible, as a radiographic image, the latent image created by x-rays. This procedure requires the assistance of photographic chemistry. The field of radiologic technology is continuing to become more automated and mechanized in order to keep up with the ever-increasing workloads of the modern x-ray clinic. As the number of radiographs produced each day increased, a method of processing these films more rapidly became a necessity. As a result, the automatic processor has evolved from manual processing and is now in use in most hospitals.

b. Automatic processing provides a means of processing quality films on a much more timely basis. The equipment is very compact and the process is much cleaner. Processing time varies from machine to machine, ranging from 90 seconds to nine minutes. By comparison, manual processing takes approximately 1 to 1-1/2 hours for a completely dried film.

3-2. BASIC PRINCIPLE

Several companies manufacturer automatic processors and they all operate on the same basic principle. Since there are minor variations between the products of the different manufacturers, our discussion of automatic processors will be general. The manufacturer's handout will give you specific data on the type actually used in your medical facility. Automatic processing uses the same principles as manual processing with changes in solution and temperature to allow a faster processing time. The automatic processor is made up of the basic system--the transport system, the circulation and filtration system, the replenishment system, the tempering system, and the dryer system. These basic systems are found in all processors. Therefore, by learning how one works, you will understand the operation of all others and have little trouble adjusting to them. The systems will be discussed separately so that the role of each system in the processing cycle can be visualized.

3-3. ROLLER-TRANSPORT SYSTEM

The roller-transport system is composed of a feed tray, a main drive, and a number of rollers called crossovers and racks.

a. As the film is placed in the feed tray, two feed rollers draw the film into the machine. A micro switch is usually utilized as a safety device to alert the operator when more than one film is placed in the machine at the same time. Also, the micro switch activates the replenisher system discussed later.

b. The film moves circularly through a crossover and vertically down in the developer by means of a series of rollers composing the rack around and vertically upward, and around another crossover. It moves the same way through the rest of the chemicals.

c. The rollers of the crossovers and racks move by means of a main drive shaft run by a drive motor. Through a series of cogwheels and gears, the energy is transferred to the rollers from this drive shaft.

d. No attempt will be made to cover all the mechanics of the crossovers and racks because of the great variation between models. If a breakdown occurs, maintenance personnel or the manufacturer will repair the processor.

3-4. CIRCULATION-FILTRATION SYSTEM

The roller-transport system squeezes the chemicals into and out of film emulsion, providing an agitating action, which promotes even processing and increases the speed of reactions. A circulation-filtration system is used to boost this action. The circulation pump recirculates the solutions through filters, keeping the chemicals properly mixed and clean as well as in a state of agitation.

3-5. REPLENISHMENT SYSTEM

a. As each film passes through the automatic processor, the chemicals are changed slightly. To offset the resulting deficiencies, new developer and fixer in measured amounts are pumped into the solutions. This is called replenishment.

b. There are two tasks, called replenisher tasks, in which fixer and developer are stored. The tanks are protected by dust covers and a floating lid in the developer tank helps to reduce oxidation.

c. When a film is initially fed into the processor, it activates the micro switch previously mentioned. The micro switch turns on the replenisher pumps and new solutions are pumped into the system, which filter out dirt from the replenisher solutions.

d. Replenishment tanks should be checked weekly and refilled periodically. Care should be exercised to ensure that the solutions are not contaminated.

3-6. TEMPERING SYSTEM

a. The chemistry of the automatic processor is regulated and controlled by the tempering system. As in manual processing, there is a time-temperature relationship. (For example, more active chemicals and/or higher temperatures require less developing time.) To maintain the desired temperature of the developer and fixer, a heating device and automatic thermostat are used. Water is passed through a mixing valve, so that it is 4° or 5° below the desired temperature, and then heated to the desired temperature by the heating element in the machine. The required temperature will vary from machine to machine. Use the manufacturer's recommended temperature depending on the type of chemicals and the time needed for processing. The temperature will usually be higher in faster machines. Through heat exchange, the solutions are kept at similar temperatures. Temperature variation should not exceed 2°.

b. The wash water temperature is controlled by a mixing valve, which mixes the hot and cold water. A thermometer gauge is located between the mixing valve and the wash tank near the mixing valve. Usually a shutoff valve is located between the thermometer and the mixing valve so that readjustment of the mixing valve is not necessary each time the water flow is shut off.

3-7. AIR-DRYER SYSTEM

To dry the film, there is a heater to heat the air and a blower to move the air. There must be a good exhaust system to remove the warm, moist air so that only hot, dry air is directed over the films as they move through the roller-transport system. There are holes at the ends and slits along the sides of the air tubes to direct the air onto the films.

3-8. CHEMISTRY

a. The chemical components are discussed in detail in lesson 1, section III, of this subcourse. The manufacturer will supply instructions covering the sequence for mixing, solution strengths, and temperatures to be used. The chemical components used are usually identified as part A and part B; in some cases, they will be called parts A, B, and C. The last part in a given series (B or C) contains bromides; it will be used in basic solutions but not in replenisher.

b. Contamination of solutions is always a problem. The solutions are separated into individual stainless steel containers similar to those used in manual processing. The movement of film from one tank to another is accomplished by means of crossovers. Tanks will require periodic cleaning to maintain processing quality.

3-9. ELECTRICAL SYSTEM

In order to operate the processor, there must be a source of electricity. The processor itself has a very complex electrical system. Because of the complexity of this system's wiring and circuitry, it will not be discussed in this subcourse. However, the operator should be aware of some very general considerations. The processor will have a circuit breaker and will be properly grounded. Since the various systems are wired and controlled separately, there are separate switches for the main drive motor and for the air-dryer, circulation, tempering, and replenisher systems. The operator should be familiar with the sequence of the switches and fuses for each of the systems.

3-10. OPERATION OF THE AUTOMATIC PROCESSOR

a. Starting.

- (1) Open wash water and replenisher tank valves.
- (2) Turn on all switches.

(3) Allow 15 minutes for solutions to warm.

(4) Remove crossovers. Turn sun gear and wipe crossover rollers with damp sponge or cloth. Wipe stainless steel feed rollers and the guide plates of developer rack(s). This should be done whenever the machine has been idling long enough for chemicals to dry on the roller, even if the machine has been turned on.

(5) Check solution level in processor and replenisher tanks. Check wash water flow.

(6) Check solution filter cartridge(s).

(7) Insert film between stainless steel feed rollers and adjust flow meters for correct replenishment rate.

(8) Reinstall crossovers and visually check operation of racks and dryer rollers.

(9) Be sure all covers and side panels are in place.

(10) Run enough clean-up film to clean rollers, which are out of solution. Do not reuse clean-up sheets.

(11) Be sure developer and wash water have stabilized at proper temperature.

b. Feeding Film.

(1) Place film on feed table and push in until rollers pull it forward. (See manufacturer's recommendations for detailed instructions.)

(2) When the bell sounds, feed another film.

c. During Operation.

(1) Check replenisher and water flow rates occasionally.

(2) Check wash water and developer thermometers occasionally.

d. Stopping.

(1) Turn off all switches.

(2) Remove crossovers and wipe with damp sponge or cloth. Use a nonmetallic pad for stubborn dirt and chemicals.

(3) Wipe stainless steel feed rollers and check that they turn freely and then reinstall crossovers.

(4) Clean the dryer rollers.

(5) Flush out sink below solution tanks.

(6) Wipe up chemical deposits on machine.

(7) Turn off wash water.

(8) To prevent rusting, leave dryer and processor covers open slightly when machine is not running.

e. **Standby Position.**

(1) To allow for emergency work at night or during other slack periods, leave only heat and cool switches on. Then, when other switches are turned on, machine will be ready for processing within 10 minutes.

(2) Also leave the valve(s) open in the cold water supply line to heat exchanger.

(3) To save time, turn other switches on before exposing film.

f. **Clearing a Film Jam.**

(1) Sheet film.

(a) Leave power on.

(b) Remove crossover ahead of pile-up.

(c) Remove film at this point to avoid further pile-up. Put films in a tray of water to prevent them from sticking together.

(d) Clear the film jam. Turn off circulation if a rack is removed.

(e) Feed the removed films into the rack nearest the point of jamming to complete cycle.

(f) Determine the cause of the jam and correct it.

(2) Roll film.

(a) Shut off the power.

- (b) Cut the film at the feed.
- (c) Clear the film from the racks.

3-11. MAINTENANCE

a. **Weekly.** An automatic processor should have thorough cleanup once a week.

(1) Remove the crossbars and wipe with damp sponge or clothe. Use a nonmetallic pad for stubborn dirt and chemicals.

(2) Clean the stainless steel feed rollers and be sure they turn freely.

(3) Remove the solution racks. Check the tanks for foreign matter. Rinse the racks with running water and clean off any chemical deposits and dirt. Use a nonmetallic pad for stubborn deposits.

(4) Check spring tension on the racks. Be sure roller bearings are free. Operate each rack manually to check for binding. Check for loose setscrews. Lay the rack on a flat surface and be sure it is square. Use a fiber or nylon brush to clean gear teeth. Replace worn gears and springs. Reinstall the racks and crossovers.

(5) Clean dryer rollers with a clean damp cloth.

(6) Clean dryer air tubes by removing and agitating vigorously in warm water.

(7) Be sure dryer roller are properly seated.

(8) Go over the entire machine and clean it thoroughly.

b. **Miscellaneous.**

(1) Clean developer rack(s) whenever a soil pattern transfers to film. When normal cleaning is not adequate, use chemical dissolving solutions according to directions. Be careful not to drip solutions into an adjacent tank when removing a rack. Reinstall racks slowly so that solutions will not overflow. Do not interchange developer and fixer racks.

(2) Changer dryer air filers when dirty.

(3) Change solution filter cartridge(s) when circulation is impeded; change at least once for every 2000 average-sized films processed.

(4) When solutions are changed, remove and clean screen in bottom of replenisher tanks. Swirl the screen through solution to remove trapped air bubbles.

(5) When changing solutions, drain tanks and flush thoroughly before refilling.

(6) At least once a month, flush replenisher systems with hot water--not over 150°F. Give special attention to check valves and flow meters, which should be removed and disassembled during cleaning.

(7) Clean the solenoid valve periodically; the frequency of cleaning will depend upon the cleanliness of the water supply.

c. **Lubrication.** Lubricate the processor in accordance with the manufacturer's chart.

Section II. MANUAL FILM PROCESSING

3-12. INTRODUCTION

This section will discuss the techniques of applied chemistry used by the x-ray specialist in manual processing of x-ray films. Although most hospitals now use automatic processors, there may be times when knowledge of manual processing procedures is required.

3-13. MIXING SOLUTIONS

Processing chemicals are compounded according to precise formulas--the correct amount of such chemical is mixed together so that by merely adding water, the correct solutions may be obtained. The x-ray specialist need only read the instructions on the package and mix the bulk chemicals accordingly. These instructions must be read and followed exactly so that a properly functioning solution is obtained. Be sure to read the label! The first step in the processing procedure is the proper preparation of the processing solution. When mixing the chemicals to be made into solutions, the manufacturer's directions should always be carefully followed. There are, however, some general recommendations for making up solutions.

3-14. IMPORTANCE OF CLEANLINESS

Processing of radiographs involves chemical reactions of various solutions on the film, the success of the reaction depending upon the purity of the solutions. Cleanliness and care in the preparation and use of the solutions is of paramount importance. The processing room, as well as the accessories and equipment, must be kept scrupulously clean and used only for the purpose intended. Spilled solutions should be wiped up at once from surfaces, which may result in artifacts on the radiographs. When mixing dry

chemicals, turn off electric fans for chemicals may be blown about the room and contaminate the loading bench, screens, or other equipment. Hands that are wet with chemicals should never be used for handling films, screens, or other accessories.

3-15. WATER SOURCE AND TEMPERATURE

Since water is the solvent for all processing solutions, same care should be exercised in choosing its source. Most city water supplies are suitable, but they should be checked for high concentrations of various salts before use. In general, any water that is good to drink should be satisfactory.

a. **Pure Water.** Distilled water, since it does not contain dissolved chemicals, is pure and therefore ideal for mixing purposes. Rainwater and water melted from clean snow are good substitutes.

b. **Water Impurities.** The chief kinds of impurities usually found in water are as follows:

(1) Suspended material consisting of decayed animal or vegetable matter, mud, rust, or sulfur. Filtration will remove the majority of these substances.

(2) Some solid chemicals found freely in nature are often dissolved by water. These chemicals cause hardness of the water and are composed of calcium and magnesium salts in the form of bicarbonates, chlorides, and sulfates. These salts are not injurious to the image but may produce a scum on the surfaces of the film that reduces its transparency. It must and can be removed before drying by squeegeeing the faces of the radiograph with cotton or a photographic sponge. Circulating the water through a water softener may eliminate the hardness of the water. In general, most metropolitan areas use water containing some minerals, but experience few, if any, problems.

(3) Coloring matter of vegetable or animal origin, usually yellow or brown, is sometimes found. Such water may stain the film and should be avoided.

c. **Mixing Temperature.** The temperature of the water in which chemicals are to be dissolved should be as recommended on the label of the package.

3-16. MIXING UTENSILS

The containers for mixing chemicals should be of corrosion-resistant materials, such as types 316 and 317 stainless steel. Vessels containing tin, copper, zinc, aluminum, or galvanized iron should never be used because small quantities of these metals in the solutions will fog film during the development period. Separate stainless steel, hard rubber, or plastic mixing paddles should be used for the developer and the fixer, after which they should be washed with clear, warm water and hung up to dry.

3-17. MIXING PROCEDURE

Water should always be poured into the tank and the chemicals added slowly while the mixture is stirred vigorously. In this way, the chemicals dissolve rapidly. (To ensure the proper concentration of solution, the volume in gallons of the tank used should be determined mathematically.) Sufficient water should be added to bring the solution to the correct volume and temperature; thorough stirring is necessary to mix the cool water with the chemical-laden solution. Solutions should not be used until all the chemicals are thoroughly mixed and at the optimum temperature of 68°F.

3-18. SOLUTION STORAGE

If the solution is not for immediate use, it should be placed in a clean brown bottle of the proper size, well stoppered, and labeled plainly. Developer should be stored away from radiators, as heat may cause deterioration of the solution.

3-19. MIXING WITH SEAWATER

While not recommended as a routine procedure, seawater can be utilized in the same quantities as fresh water to compound x-ray developers and fixing baths. The resulting solutions are turbid but will clear on standing. It is best to allow the solutions to stand overnight and to decant the clear fluid for use. If turbid solutions are utilized, it is essential that the surfaces of the film be carefully wiped off with a soft wet cloth or photographic cellulose sponge after washing and before drying in order to remove any deposit.

3-20. THE METHOD OF PROCESSING

The tank method of processing is efficient and convenient. Its most important advantage is that it provides facilities for maintaining constant temperatures and for preserving the solutions. Tanks containing the processing solutions are located in a master tank containing water at the prescribed temperature and sufficient space is provided for film rinsing and washing. Water should be circulated in the master tank at a temperature that is controlled by a mixing valve situated in the hot and cold water supply. If the volume of radiographic work justifies it, a separate tank used only for washing purposes should be provided.

3-21. THE DEVELOPMENT PROCESS

As the film is first lowered into the developer solution, it should be rapidly moved up and down a few times to remove the air bells (small air bubbles) from the film. If these were not removed, the film would not correctly be processed at those points. After an exposed x-ray film is placed in the developer, the gelatin in the emulsion becomes swollen and porous due to the presence of water and the activity of the alkali in the developer solution. The exposed silver bromide crystals have become ionized and the reducing agents can attack them. The x-ray exposure causes the sensitization

specks to acquire atomic (photolytic) silver ions from the disintegrating silver bromide crystals are exhausted. The bromine ions are freed from the emulsion and react with the potassium ions from other completion of development; the exposed silver bromide crystals have been reduced to black metallic silver, which constitutes the image. The unexposed and undeveloped silver bromide crystals remain largely unaffected, but are removed by a later treatment (fixing).

3-22. DEVELOPMENT REPLENISHING SYSTEM

The replenishing system is an efficient method of development. In the replenishing system, a solution of greater activity than the original is used to keep the activity of the solution constant. This makes it possible to keep development times constant. The companion replenisher for the developer being used should be the one utilized. Developer from one manufacturer and replenisher from another should not be used, since the formulas may not be compatible.

3-23. DEVELOPMENT REPLENISHING SYSTEM OPERATION

a. When using the replenishing system, film should be removed from the developer quickly and the excess solution should not be drained back into the developer tank, but rather into the waste outlet. Normally, this procedure will remove about the proper amount of solution for efficient use of this system. Approximately one gallon of replenisher should be added for every forty 14 x 17-inch films or the equivalent. If sufficient solution has not been drained to waste by the films, it may be necessary to dip a measured quantity of developer from the tank and to add a comparable amount of replenisher to maintain normal developing activity. However, by the frequent addition of small quantities of replenisher solution, the proper level of the developer and the activity of the solution can be easily maintained. This procedure relieves the specialist of the responsibility for computing the actual quantities needed for replacement; however, a record of the volume of replenisher used must be maintained.

b. It is important that you never add replenisher solution to the developer while films are developing. This may ruin the films with streaks of very high density.

c. A rough estimate of the number of films that can be developed in a properly replenished developer has been determined to be 125 14 by 17-inch films per gallon of solution or 625 films in a five-gallon tank. Beyond this, it is not practicable to replenish. The solution should be discarded and a fresh batch mixed. Another way to compute the life of replenished solutions is to discard them after the replenisher used equals three or four times the quantity of the developer. By carefully reading the manufacturer's instructions for replenishment on the label of the container, the specialist can determine the correct amount of replenisher. It is also recommended that the solution be discarded after three months, regardless of use, because oxidation of the reducing agents results in a decline of developer efficiency. This procedure must be followed even though the total amount of replenisher has not been used during the period.

3-24. RINSING PROCESS

When the film is removed from the developer, the gelatin emulsion is swollen and like a sponge, saturated with all the soluble chemicals of the developer solution. Also, the gelatin contains the black metallic silver image and unexposed, undeveloped silver bromide crystals. The bulk of the soluble developer chemicals should be removed from the film before it is placed in the fixing bath and these chemicals replaced by either fresh or acidified water. Such treatment is necessary to stop the reaction of development, to neutralize the alkalinity of the residual developer, and to remove the oxidation products of development. There are two methods of removing these chemicals--rinsing the film in fresh water and rinsing the film in acidified water.

3-25. WATER RINSE BATH

After development, the film should be rinsed for 30 seconds in circulating fresh water and drained before being placed in the fixer. This rinse should remove the soluble developer chemicals from the surface of the film and the pores of the emulsion. The emulsion on a 14 by 17-inch film holds at least three ounces of developer. To stop development, the residual developer must be quickly diluted with water. If films are insufficiently rinsed and repeatedly placed directly in the fixing bath, the chemical balance of the fixer is eventually upset and its useful life materially shortened. Poor rinsing causes the acidity of the fixer to be rapidly reduced, the hardening action to be destroyed, and stains to appear on radiographs. Still, water should not ordinarily be used for rinsing. An accumulation of developing solution in the rinse bath eventually oxidizes and when it is carried over to the fixing solution, it streaks and stains radiographs because of fixing solution contamination.

3-26. ACID RINSE BATH

a. Acid rinse baths prolong the life of the fixer and ensure maintenance of the hardening action. An acid rinse bath eliminates the need for running water (required by a water rinse bath). The most efficient rinse (stop) bath is one consisting of a dilute solution of acetic acid in water made according to the following procedure. Add two and one-half quarts of 28-percent acetic acid to one gallon of water. Stir thoroughly. Add sufficient water to make five gallons of solution. This bath can be made in a five-gallon tank and placed between the developer and fixer tanks. The bath immediately stops development of the emulsion and neutralizes the alkali in the developer contained in the emulsion.

b. Radiographs should be rinsed in the acid bath for 30 seconds but they may be left in the bath for as long as one and one-half minutes. Do not overwork the acid rinse bath. When the activity of the solution is reduced, it will accentuate rather than prevent stains and streaks. The acid rinse bath will operate satisfactorily within the normal range of processing temperature when the rapid x-ray developer is used. During this useful life, the acid rinse bath will rinse about 200 14 by 17-inch films or their equivalent per five gallons of solution.

3-27. FIXING PROCESS

a. When the film is placed in the fixing solution, it is milky in appearance because of the residual silver bromide crystals; but as it is moderately agitated and both film surfaces are completely bathed by the solution, the milkiness gradually disappears. The action of the acidifier immediately neutralizes the residual alkaline developer and any continuing development action ceases. Since the gelatin is still swollen and porous, the clearing agent dissolves out the unexposed and undeveloped silver bromide crystals, leaving untouched the developed silver image. This is the clearing action.

b. As clearing abates, the hardening action begins, causing shrinking and hardening of the gelatin emulsion containing the silver image. This hardening action is most important, since it prevents swelling of the emulsion to any marked degree in the later washing operation. Do not turn on the white light in the processing room until the film is entirely clear, as white light will streak and fog the film.

c. The duration of the fixing process is dependent upon several factors. These include the strength and nature of the fixer; the temperature of the solution, the amount of film agitation, the volume of fixing agitation is related to the number and surface area of films being fixed, and the emulsion thickness. The minimum fixing time is that needed to clear and harden the film. For best results, the film should remain in the fixing bath three times as long as necessary to clear the film.

d. Although radiographs may be left in the fixer for a slightly longer period, it is not wise to do so, for it will only take longer to wash them free of residual silver and fixing bath salts. The hardness of the emulsion in a given fixing solution decreases with solution exhaustion and the initial fixing time must be extended as the solution is used to maintain normal hardening.

e. Also, the higher the temperature, the greater the speed of fixation; however, the optimum range of temperatures is from 60° to 75°F. With higher temperatures, a fixing solution tends to sulfurize, thereby shortening its life. Therefore, it must be specifically treated when high temperatures prevail.

3-28. SINGLE-TANK FIXING SOLUTION

a. Most processing tank systems only provide for a single tank of fixing solution. The use of a single bath is not the most efficient nor economical method for fixing. The gradual accumulation of silver salts in the bath makes longer washing times necessary because of the difficulty in replacing these salts with pure water.

b. Normally, the usefulness of a single tank fixer ends when the bath loses its acidity or when more than twice the normal times is required to remove the unexposed silver from the film. The bath should then be discarded, especially if it has become turbid. An exhausted fixing bath permits abnormal swelling of the emulsion due to deficient hardening action. Consequently, drying is prolonged and reticulation or

sloughing of the emulsion may take place. Neutralization of acid in the bath invariably causes certain kinds of stains on the radiographs. A good rule to follow is to change the fixing bath when fresh developer is made, if the fixer tank is twice as large as the developer tank and proper temperatures are maintained. When exceptionally high temperatures prevail, the fixing bath should be changed twice during the life of the developer. This assures maximum hardening of the emulsion and freedom from "hot weather troubles."

c. When the volume of the fixing solution is the same as that of the developing solution, the fixing solution should be changed twice during the life of the developer to ensure satisfactory clearing and hardening of the emulsion. Table 3-1 is a guide for determining the clearing time, fixing time, and exhaustion point.

NUMBER OF 14 X 17 INCH FILMS FIXED	CLEARING TIME (MIN)	FIXING TIME (MIN)
0-50	1 ¼-3	5-6
51-100	3-5	6-9½
101-150*	5-8	9½-16
* Make new fixing solution before processing more film.		

Table 3-1. Life of five gallons of unreplenished fixing solution in a single tank at temperature range 60° to 75°F.

3-29. SINGLE-TANK FIXER REPLENISHMENT

A fixing solution gradually loses its acidity because of the carryover of the alkaline developer by the film. It also becomes diluted by water carried over from the rinse bath. Consequently, its hardening properties and fixing rate are gradually affected. The exhaustion of the thiosulfate reduces its ability to dissolve silver salts. The loss in function of the fixing solution can in some measure be restored by replenishment.

a. **Advantages of Replenishment.** By using the replenishment system, fixing time may be kept to a minimum. In the first half of the life of the solution, the clearing and fixing time may be kept relatively constant; in the latter half, the fixing time is slowly increased to its exhaustion limit.

b. **Method of Replenishment.** In replenishing a five-gallon tank of fixing solution, two quarts of solutions are removed and replaced by two quarts of fixer replenisher solution. This solution is made by mixing the amount of chemical normally used for one gallon of fixing solution with 2-1/2 quarts of water instead of one gallon. This solution, therefore, is highly concentrated. If desired, the amount of chemical

normally used to make five gallons of solution can be dissolved in 12-1/2 quarts of water and stored in bottles for future use. The rate of replenishment is illustrated in Table 3-2.

NUMBER 14 X 17 INCH FILMS FIXED PER 5 GALLONS	CLEARING TIME (MIN)	FIXING TIME (MIN)	REPLENISHMENT
0-50	1½-2¾	5	Remove 2 qts old solution; replace with 2 qts replenisher. *
51-100	1¾-3	5	Remove 2 qts old solution; replace with 2 qts replenisher. *
101-150	2-3	5	Remove 2 qts old solution; replace with 2 qts replenisher. *
151-200	2-3½	5	Remove 2 qts old solution; replace with 2 qts replenisher. *
201-225	2½-3¾	7	Remove 2 qts old solution; replace with 2 qts replenisher. *
226-250	3-4	8	Discard fixer solution; make new solution. *
* Replenisher is made by dissolving concentrated fixer in less water than is used in preparing the fixing bath. RESULT: Replenisher is stronger than the fixing bath. See manufacturer's instructions for proper dilution.			

Table 3-2. Replenishment of x-ray fixing solution (five gallons) in a single tank.

3-30. TWO-TANK FIXING SOLUTION

a. **Method.** One of the quickest and most economical ways to remove silver salts from radiographs is the use of the two-tank fixing bath. This bath consists of two equal sized tanks of fixing solution. The first tank is reserved for clearing the film and the second tank for hardening of the emulsion. Radiographs are taken from the rinse bath and placed in the first tank where most of the silver salts removed. When the film is cleared, it is removed to the second bath where the emulsion is hardened. Because of this procedure, the second bath has a very low concentration of salts and the diffusion of the remainder of these salts is exceedingly rapid. Since very few silver salts are carried over to the washing tank, the washing time can be materially reduced.

b. **Replacement.** When 180 14 by 17-inch films, or their equivalent, have passed through the first (number one) tank, discard the solution and move the second (number two) tank to the number one tank's original position. Make new solution in the number one tank, which now becomes the number two tank. The original number two

tank has hardened the equivalent of 180 14 by 17-inch films and then when used as the number one tank can be used for another 180 of the same size films or their equivalent for clearing purposes. Once the routine has been established, this system of rotation between tanks will assure the production of well-fixed films indefinitely.

3-31. WASHING PROCESS

Proper washing ensures the permanence of radiographs as records. Washing of radiographs must be regarded as a chemical operation, the object being to remove residual chemicals and silver salts from the film. If these are not removed, the image will discolor or fade, eventually stain (brown stain of silver sulfide), and the entire film may deteriorate. This is especially true when the radiographs are stored under conditions of high temperature and humidity. As the fixing solution nears the exhaustion point, the concentration of silver salts becomes so high that the washing process should be more thorough at this time.

3-32. WATER FOR WASHING

a. **Supply.** Any drinkable water should be satisfactory for film washing. Normally x-ray films are washed in running water circulated so that the entire emulsion area and every portion of the wash tank receive frequent changes. In tank processing, the bar of the hanger and the top clips should always be covered by the water. When fresh water is in short supply, radiographs may be safely washed in seawater. There is also a special procedure (to be discussed in this sub course), which can be used when water is scarce and which will ensure the processed radiograph's permanence.

b. **Filtration.** The bulk of microscopic and animal matter sometimes contained in tap water or water from other sources should be removed by filtration. Several thicknesses of gauze placed over the outlet of the water supply will provide some degree of filtration if some other is available. The gauze filter should be cleaned or changed daily.

3-33. WASHING TIME

a. **General.** The time required for adequate washing depends principally upon the type of film, the rate of water flow through the tank, and the temperature of the water. If circumstances demand, a shorter washing time may be used. As long as the film is not subjected to high heat and humidity conditions, it may be thoroughly washed at a later time (within three to six months). Generally, if a radiograph is to remain in a temperate zone, less washing is necessary than for those kept in a tropical or subtropical region. However, every effort should be made to wash the film properly during its initial processing, since it is unlikely that at this time the area of ultimate storage can be determined.

b. **Washing in a Single Tank.** If the hourly flow of water through a single tank is four times the capacity of the tank, 30 to 40 minutes is required for washing x-ray film

at a water temperature of about 70F°. When the flow is eight times the tank's capacity per hour, the washing time is 25 to 30 minutes. Shorter washing times than these should not be used no matter how frequently the water in the tank is changed. If the flow of water through the tank is very slow, the films should remain in the water even longer than the above specified times. The washing time should be measured from the immersion of the last film in the wash water, since washed and partly washed films fixing bath chemicals rinsed into water from newly added films.

c. **Washing in a Two-Compartment Tank.** The total volume of water may be divided into several small units, especially when flow is inadequate. In the two-stage cascade system of washing, the flow of water is from right to left while the flow of films in normal processing is from left to right. The film laden with fixing bath is placed in the first compartment of the tank and is bathed with a very dilute solution of water and fixing bath salts. After remaining in the first compartment approximately five minutes, the radiograph is placed in the second compartment. Here it is bathed with uncontaminated fresh water for an additional five minutes--giving a total of 10 minutes washing time. At no time should a film fresh from the fixing solution be placed in the second compartment.

3-34. TEMPERATURE OF WASH WATER

The temperature of the wash water is important. It should range between 68° and 70°F, if possible. This range is about 40 percent more efficient than 40° would be, for instance, and temperatures above 75°F tend to soften the emulsion, leaving it open to damage. In general, the temperature of the wash water should approximate that of the other processing solutions.

3-35. USING SEAWATER FOR WASHING

Film may be washed in seawater, but they should receive an additional final washing in fresh water for at least five minutes. Otherwise, the film may attract excess moisture and the image may fade rapidly. Seawater does remove the chemicals more rapidly than fresh water and washing time may be cut in half. Washing in seawater or other salt water may be done at lower temperatures, even at 5°0F or lower. When processing solutions have been mixed with seawater, it is advisable to wipe the surfaces of the radiograph with a soft, wet cloth after washing.

3-36. THE DRYING PROCESS

The success of any drying operation lies in the rapid removal of the water from the emulsion. The most common procedure is the use of a rapid flow of air (with or without the aid of heat) over the edges of the film surfaces. Drying often takes more than all the other operations together, so it is often a bottleneck in the flow of radiographs through the processing room. The radiographs are wet and vulnerable to damage, so they should not be removed from their hangers. If they are not handled carefully, dust may become embedded in the emulsion or the film may get scratched and abraded.

3-37. DRYING AIDS

a. **Prevention of Emulsion Swelling.** The speed with which x-ray film dries is dependent upon the quantity of water that must be evaporated from the emulsion. This speed is proportional to the combined thickness of the emulsions. It is, therefore, necessary to prevent excessive emulsion swelling. The use of a good fixing bath will keep swelling to a minimum by shrinking and hardening the emulsion. The emulsion should be hardened before excessive swelling can occur. Hardening of a swollen emulsion raises its melting point but does not necessarily reduce its thickness. Consequently, developing and fixing solutions should be within the optimum temperature range. These precautions should especially be observed when processing is done in hot, humid climates where drying always tends to be prolonged. Washing of the film should be adequate but not excessively long. When processing temperatures are above 75°F, special treatment keeps the emulsion hard, provided that short washing times are used.

b. **Wetting Agent.** A wetting agent is a detergent that reduces the surface tension of water so that the water can drain more rapidly from the radiograph after washing. This shortens the drying time and eliminates drying marks. There are a number of wetting agents (labeled under various trade names), which are safe for photographic purposes. A separate tank of dilute wetting agent is to be used as a final rinse after washing is prepared by adding 2-1/2 ounces of the detergent to five gallons of water. After washing, the radiograph is immersed in this solution for 30 seconds and then drained. The radiograph may then be placed in the dryer. When 400 14 by 17-inch films, or their equivalent, have passed through the solution, it should be replaced with a fresh one.

c. **Alcohol.** The use of alcohol for drying is recommended only where some emergency requires the use of a dried radiograph in a minimum of time after processing. Any good grade denatured alcohol may be used for drying films, provided that when diluted with water it does not turn milky. The alcohol concentration should be no greater than 70 percent by volume if opalescence of the emulsion or deformation of the base is to be avoided. After washing, the radiograph is thoroughly drained. Then, the film is immersed in a tray of alcohol for two minutes at temperatures under 70°F. The tray should be rocked to assure uniform bathing of both film surfaces and to prevent the film from sticking to the bottom of the tray. This operation causes the water to diffuse from the pores of the emulsion, and the water is replaced by the alcohol. With the bulk of the water removed, the film is immersed in a second and final tray of alcohol to remove any residual water. The film is then drained. The alcohol will evaporate rapidly to leave a dry emulsion.

d. **Dryers.** X-ray departments are usually provided with cabinet dryers equipped with a fan and heating elements. The dryer should always be vented to the outside of the processing room to prevent excessive humidity. Drawers are provided in which the films are hung in their hangers. Ordinarily, radiographs should be dried with air moderately warm. Heat should be used cautiously when drying films in hot, humid

weather because the water-laden gelatin emulsion may soften and distort the radiographic image. Under these conditions, it is safest to use only the dryer fan. Overheating of the dryer should be avoided because very rapid drying is apt to cause distortion of the radiograph.

e. **Drying Rack.** When a small number of films are to be dried each day and a cabinet dryer is not available, film hangers may be inserted in a wall drying rack. The rack may be simply a board in which holes have been drilled into which one end of the hanger crossbar can be inserted while the film is drying.

3-38. DRYING TIME

The time required to dry a film is dependent upon the efficiency of the hardener in the fixing solution, the amount of water retained in the gelatin emulsion after washing, the velocity and temperature of the drying absorption is reduced to a minimum by the use of a reasonably fresh fixing solution which will assure proper hardening of the emulsion. Ideally, the humidity should be below 50 percent and the temperature under 90°F. When films are dried in cabinet dryers, they should be adjusted so that drying takes place in 10 to 20 minutes. The use of infrared lamps is not recommended, since they cause unequal drying of the film surfaces.

3-39. PREPARING THE RADIOGRAPH FOR FILING

After the radiograph has been dried, the sharp and/or punctured corners caused by the hanger clips should be trimmed with a corner cutter or scissors. This enhances the appearance of the radiograph, facilitates its insertion into an envelope, and precludes its scratching other radiographs with which it may come in contact. After its corners are trimmed, the radiograph should be placed in a heavy manila envelope of proper size and all essential identification written legibly in the space provided on the face of the envelope. Given to the radiologist in this condition, it is ready for subsequent filing.

Section III. FACTORS AFFECTING FILM PROCESSING

3-40. MECHANICS OF SILVER DEPOSITION

a. With the exposed emulsion considered as a whole rather than as its constituent silver bromide crystals, the various stages of development are illustrated in figure 3-1. Assume that an aluminum step wedge (A) is exposed using an x-ray film (B) as the recording medium. If the film is represented in enlarged cross-section, upon exposure, (C) a latent image of the object is produced in the silver bromide emulsion. The latent image is represented by the dotted area, and it consists of representations of the six portions of the wedge. The radiation reaching the film is of varying intensity after its passage through the wedge and the relative absorption of each step of the wedge is represented. The radiation passing through step number one of the wedge (A) is only partially absorbed; hence, more silver bromide is exposed than on that portion of the

film under step number six. Therefore, upon development, the quantity of silver deposited in area number six is less than that under number one. A deposit of silver that is proportional to the exposure represents each step.

b. Upon development (D), the latent image silver bromide is reduced to metallic silver and the unexposed silver bromide (thin diagonal lines) is not affected. (Mixed with the metallic silver deposits are some unexposed and undeveloped silver bromide crystals.)

c. After the film has been fixed (E), all the unexposed and undeveloped silver bromide is dissolved from the emulsion and the metallic silver remaining on the film constitutes the radiographic image of the step wedge shown in (A).

d. When the radiograph (F) is later viewed on an x-ray illuminator, all the various deposits representing the steps of the wedge are seen in their proper concentrations and various degrees of translucency. To obtain an optimum density, full development is required.

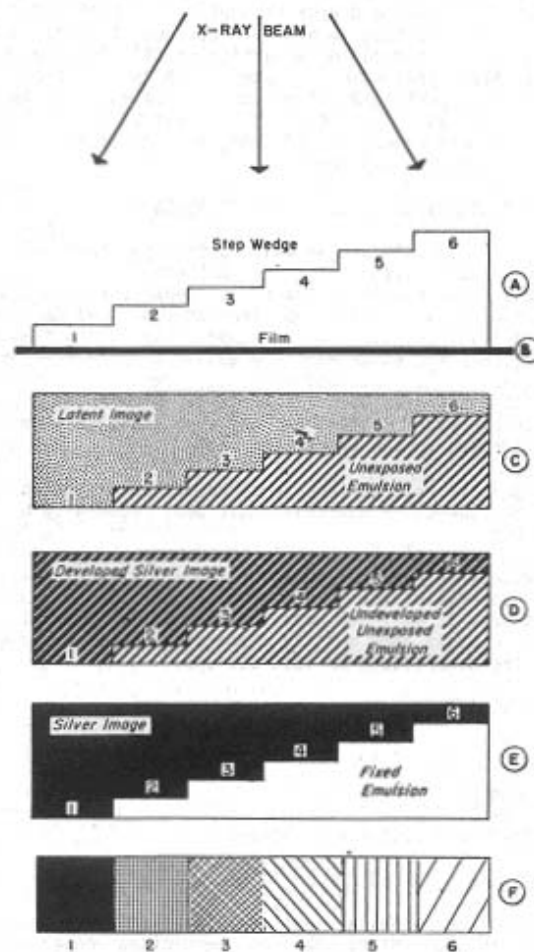


Figure 3-1. Stages of exposure and development of x-ray film.

e. In the preceding diagrammatic examples, the amount of silver deposited by development depended upon length of exposure of the silver bromide crystals to x-rays, the length of time of development, and the temperature of the developing solution. As the development time and/or temperature of the developer increases, the amount of silver deposited increases, and vice versa. Radiographic density and other film characteristics are influenced by the time of development and the temperature of the solution, adequate density control may be obtained by standardization. Once this is achieved, radiographic density as influenced by development may be considered a constant.

3-41. STANDARDIZATION OF PROCESSING PROCEDURES

Uniform radiographic quality can be achieved only through control and standardization of processing procedures. X-ray film is manufactured to produce a consistently uniform degree of density and contrast when correctly exposed and processed according to standard and accepted procedures. Familiarity with the performance of a particular film is necessary for any measure of standardized processing. Since the characteristics of density and contrast provided by a particular film and its developer are inherent, they may be considered constant. The sequence of chemical activities in processing is smooth and organized and produces a desirable image when standardized procedures are followed.

3-42. VALUE OF STANDARDIZED PROCESSING PROCEDURES

a. There are several ways that a film may be developed, but the standard time-temperature method is almost universally used. This method is virtually foolproof and provides an excellent means for checking x-ray exposures. The quality of a radiograph depends upon full development of the x-ray film within a limited temperature range. Variations from the optimum must be carefully compensated to maintain quality. Once standardized, processing rules are established and followed, overall changes in density and contrast can be attributed to exposure factors. Standardized processing of the film can then become a constant as long as a reasonable measure of discipline is exercised in the processing room.

b. Photographic research has so standardized processing procedures that operations in connection therewith have been reduced to noting the time-temperature and setting an interval timer according to a simple time-temperature chart. This procedure, however, is based upon the accumulated knowledge of the many chemical and physical complexities relating to the exposure and the development response of the film. Despite the simplicity of a standard processing procedure, it will not work satisfactorily, if solutions are improperly mixed, contain poor quality chemicals, or not used in accordance with the manufacturer's instructions.

3-43. DEVELOPER CONTRAST

The type of developer solution used produces a degree of image contrast that is considered optimum by the manufacturer. Therefore, developer contrast may be considered a contrast when the solution is used according to the directions outlined by its manufacturer. Full advantage of this constant is usually obtained when complete development of the image takes place.

3-44. TIME-TEMPERATURE PROCESSING

a. **General.** The chemical reactions involved in the processing procedure occur within a limited time and temperature range for optimum results. The effects of overexposure may be easily observed and the best in exposure technique obtained. Although the latitude of the film will compensate in a measure for some errors in exposure, good quality radiographs cannot be consistently secured if processing is not standardized.

b. **Radiographic Uniformity.** Uniformity in radiographic densities between comparative films is obtained only by the use of the standard time-temperature method of development. With this method and with both time and temperature at optimum, films lacking density are the result of underexposure, not underdevelopment, and those having excessive density are the result of overexposure, not over development. Results of this nature make possible changes in the exposure factors so that good quality radiographs can be obtained.

3-45. INFLUENCE OF DEVELOPMENT TIME

The time of development given to an exposed x-ray film materially affects the amount of silver deposited on the radiograph. As the time development increases up to a certain point, the amount of silver increases. In general, the time required to develop a film in a given developer depends upon the emulsion and its thickness. To assure accurate timing of all processing procedures, it is necessary to use a properly functioning interval timer. A series of correctly exposed hand radiographs was made using identical x-ray exposure factors, but each film was developed for a different period of time at temperature of 68°F.

a. The radiograph developed for one minute shows only slight traces of silver deposit. Image detail is lacking and the contrast is low. The streaked background density is characteristic of the underdeveloped radiograph.

b. The radiograph developed for two minutes shows some of the important features of the image and a greater overall deposit of silver (B, figure 3-8). Image detail and contrast are somewhat improved.

c. The radiograph developed for three minutes shows more silver deposited, but the image is still somewhat weak.

d. The radiograph developed for four minutes shows a fairly well defined image.

e. The radiograph developed for five minutes shows all essential details, for the maximum amount of silver has been deposited on the film. The exposure was such as to provide a satisfactory radiograph when development times are not sufficient to justify extension of the development time beyond the basic five-minute period.

3-46. RELATION OF TIME TO ACTIVITY

Development time has a direct relation to the activity of the developer. The reliability of the recommended normal development intervals for an x-ray film is valid only as long as the solution has a reasonable measure of its original developing power. When using the replenisher system, the time should remain the same as long as the activity is restored by frequent additions of a replenisher solution.

3-47. BASIC TIMES OF DEVELOPMENT

Development time intervals should never be guessed at. There are two basic times of development for each type of developing solution. One produces an image with normal speed and contrast, while the other provides maximum speed and contrast.

3-48. EXPOSURE-CONTRAST RELATIONSHIP

The first basic development time provides a short time that is compensated for by 25 percent more x-ray exposure. The second is longer in time, but the x-ray exposure is 25 percent less than the other. When employing rapid x-ray developer, normal speed and contrast are obtained by the basic development time of three minutes at 68°F. To obtain maximum contrast, the time is five minutes at 68°F. The longer basic development period will always provide better radiographic quality than the shorter interval because full development is assured. (See Table 3-3).

3-49. INFLUENCE OF DEVELOPER SOLUTION TEMPERATURE

Chemical reactions are stimulated or retarded by various temperatures. Since film processing is essentially a series of chemical reactions, the temperature of the solutions assumes major importance. Variations in temperature require adjustment in the development time factor so that uniform densities may be maintained. Temperatures should never be estimated; use a good thermometer. The temperature should always be checked when development is first begun and at intervals during the course of the day's work. The optimum temperature as recommended by the American Standards Association is 68F°.

3-50. TIME COMPENSATION FOR TEMPERATURE CHANGES

a. Processing solutions should be maintained at the optimum 68°F, but some compensation can be made for temperature variations within limits by increasing or decreasing the time of development in accordance with Table 3-3. For the higher temperatures, shorter developing times are required, while for lower temperatures, longer times are necessary to maintain uniform radiographic density.

b. The ideal method is to use the time-temperature system that accurately compensates for temperature differences with the correct time of development. X-ray film may be developed satisfactorily without special treatment at any temperature between 60° and 75°F as long as the temperature differences are compensated for by appropriate developing times. The lower temperatures in this optimum range, although permitting shorter development times, are closer to the zone in which processing defects may begin to appear on the radiograph.

TEMPERATURE (FAHRENHEIT)	RAPID X-RAY DEVELOPER BASIC DEVELOPMENT AT 68°F	
	THREE MINUTES	FIVE MINUTES
60°	5 Minutes	8½ Minutes
62°	4½ Minutes	6¾ Minutes
64°	4 Minutes	6½ Minutes
66°	3½ Minutes	5½ Minutes
68°	3 Minutes	5 Minutes
70°	2½ Minutes	4½ Minutes
72°	2¼ Minutes	4¼ Minutes
74°	2 Minutes	3¾ Minutes
75°	1¾ Minutes	3½ Minutes

NOTE: Solution is maintained by frequent additions of replenisher solutions.

Table 3-3. Development times for replenisher systems at various temperatures.

3-51. LOW TEMPERATURES

Temperatures below 60°F inhibit the activity of one of the reducing agents. If the x-ray specialist is not certain of the temperature, the appearance of the film may lead him to believe that insufficient exposure has been given. Hence, the exposure time is usually increased in a futile effort to increase radiographic density and a cycle of overexposure and underdevelopment occurs, resulting in poor radiographic quality. If solutions gradually warm up to a more normal temperature and the fact are not observed, the sequel is that no compensating reduction in exposure time is made. Over development of an overexposed film ensures and results in deposits of excessive density on the radiograph. Know the correct temperature at all times so that optimum developing times and correct exposures can be used.

3-52. HIGH TEMPERATURES

A developer at 80°F requires less time to produce a satisfactory image, but the density of the image is likely to be excessive. This high temperature will cause rapid oxidation of the solution, which will then produce an underdeveloped, fogged radiograph. Besides all this, the emulsion may melt from the film unless the solutions are specially treated. When development must take place with temperatures of 75°F and above, the special procedures described later in this subcourse must be used.

3-53. FACTORS INFLUENCING DEVELOPER ACTIVITY

Developer begins to age as soon as it is mixed and is fresh only while the active chemicals are still in approximately the same concentrations as when the solution was originally mixed. Each film developed not only removes solution by absorption and surface cohesion, but also weakens the developer in the tank. The developer solution should never be used after three months, because a weakened solution will produce weak images and may cause chemical stain or fog. During development, chemical reactions take place, which exhaust the solution. The developing agents are destroyed by their action in reducing the exposed silver bromide crystals in the emulsion to and bromide, as well as oxidation products, slow up the speed of development. Other factors that shorten the usefulness of the developer are high temperatures, dilution with water, and contamination.

3-54. DATE OF DEVELOPMENT

The rate of development is affected by the chemical activity of the developer. This activity is determined by the type and quantity of the ingredients used for the solution, the dilution of the solution, the degree of its exhaustion, and the temperature.

3-55. COMPOSITION OF THE DEVELOPER

The nature and concentration of the reducing agents and the effective alkalinity of the solution affect the composition of the developer.

3-56. DILUTION OF DEVELOPER

The solution is often improperly mixed because of a disregard for the manufacturer's instructions. Poor radiographic quality may result from using solutions, which do not have the required strength. Sometimes this happens because processing tanks have a greater capacity than is supposed. Many so-called "five-gallon" tanks actually have a capacity of six or more gallons. Hence, although the time-temperature method of development is strictly adhered to, the radiographs receive 20 to 25 percent less than normal development because of developer dilution. Always ascertain the exact capacity of the tanks to a level one-inch below the top of the tanks. Dilution of the developer also occurs when water is used to maintain the required level of the solution. If the developer is low, always restore the correct level by adding fresh solution.

3-57. EXHAUSTION OF THE DEVELOPER

The exhaustion of the developer is affected by the rate of oxidation (through contact with the air or by use), the number of films processed and their average density, contaminating substances, and accumulation of by-products of the development reactions as well as secondary changes in the developer (of mechanical or chemical origin such as the formation of sludge or the accumulation of insoluble matter). The manner in which exhaustion of the developer occurs is illustrated in the chemical reaction described earlier in this subcourse. Development of the silver bromide emulsion oxidizes the developing agent; releases acid hydrogen ions (which reduce the alkalinity of the solution) and liberate bromine ions (which accumulate in the solution and inhibit its activity). All of these changes lower the activity of the developer. To maintain a developer solution with good working properties, use the replenisher system.

3-58. AGITATION OF THE SOLUTION

a. To assure uniform activity over the entire surface of the x-ray film during processing, it is necessary after a period of activity to stir the developer and fixer solutions thoroughly, using different paddles. Stirring is particularly important in the case of the developer. When the developer solution is not stirred in the tank, there is a tendency for the lower areas of the film to receive less development than the upper areas because the temperature of the solution is usually lower at the bottom of the tank than it is at the top. Also, the reaction products of development that tend to restrain development are heavy and settle to the bottom of the tank. The lower temperature and higher concentration of reaction products at the bottom of the tank cause unequal development of the film.

b. Some agitation of the developer should be made by moving the hanger up and down several times during the development period because as development takes place, reaction products diffuse out of the emulsion and film downward over the film surface, affecting the development of film areas over which they pass. Some agitation serves to disperse the reaction products throughout the solution as they emerge from the emulsion and thus to prevent local development abnormalities.

3-59. SOLUTION LEVEL

For efficient time-temperature processing, the level of the developer solution in the tank should be kept at a constant point. Absorption and carryover to the rinse bath gradually reduce the level of the developer solution. When radiographs are removed from the developer, the amount of solution carried away by the film depletes the volume. This causes the surface level to drop below the top level of the films contained in the processing hangers. (At least three ounces of solution, for example, are contained in the emulsion of a developed 14 by 17-inch film.) Before the level reaches this point, however, new solution must be added to maintain the original level. If solution is not added, the upper portion of the film is not immersed and thus is not developed. The addition of the developer also restored by the frequent addition of fresh developer or replenisher, depends upon the system being used. Water should never be used to maintain the solution level, since this would dilute the solution. Replenisher should never be added when films are in solution because over development would occur on those areas of film coming in contact with this "strong" solution.

3-60. SECONDARY CHARACTERISTICS OF DEVELOPER SOLUTION

Secondary characteristics of developer solutions frequently cause difficulties that may be considered in two ways--those that affect the chemical balance and composition of the solution and the effects of those chemical conditions on the radiograph.

a. **Effects on Developer Solution.** Various conditions to which developer solution may be subjected can cause a variety of problems.

(1) Low activity. Low activity may be the result of incorrect mixing, an error in dilution, or low temperature. An unusual drop in activity may be attributed to the addition of water instead of fresh developer to raise the solution level, contamination from fixing solution or acid rinse bath, or inadequate replenishment. The remedy is adherence to a correct processing routine.

(2) High activity. High activity is seldom encountered, but it may occur because of high temperature or the addition of more replenisher than is necessary. The remedy is to follow time-temperature processing and a correct replenishment routine.

(3) Crystallization of chemicals. Crystallization of chemicals is caused by insufficient dilution when mixing or by storing the solution at low temperatures. Proper dilution should be maintained when mixing the solution. If crystallization occurs because of low temperatures, warming the solution to 125°F may redissolve the crystals.

(4) Sludge. As the developer is used, sludge gradually accumulates at the bottom of the tank. This sludge may consist of insoluble calcium and magnesium salts originally obtained from the water source; metallic silver reduced and removed from the emulsion by the developer, gelatin, and dirt particles. The sludge does not interfere with development unless it is present in large quantities. It can be easily siphoned from the bottom of the tank.

(5) Slime. Some kinds of bacteria grow on the accumulated gelatin in the developing solution despite its alkalinity. Evidence of this growth is slime on the walls of the tank. Sometimes the slime floats in the solution and adheres to the surfaces of films being developed. The remedy is to thoroughly clean the tank before making new solution. After scrubbing, use a solution of sodium hypochlorite, then rinse thoroughly.

b. **Effects on Radiographs.** These effects may be manifested in several ways:

(1) Uneven development. Evidence of uneven development may appear in the form of streaks. Probable causes may be the use of a very short developing time, insufficient agitation during development, incorrect high temperature processing procedures, use of exhausted acid rinse and fixing solutions, or failure to agitate films when first immersed in the fixing bath. The remedy lies in the use of correct processing methods.

(2) Chemical fog and stain. Chemical fog and stain are usually the result of using exhausted developer solution, contaminated fixing bath, or dirty developing hangers.

(3) Blisters and reticulation. The formation of blisters and reticulated emulsion is usually the fault of improper high temperature processing. Reticulation is usually the result of transferring a film between solutions possessing wide temperature difference. Physical distortion of the emulsion usually takes place under such conditions.

3-61. SECONDARY CHARACTERISTICS OF FIXER SOLUTIONS

a. **Sludging.** An excess of developer carried over into the fixer solution tends to participate some of the hardening agent. The result may be a white sludge in the solution or a white scum on the films. This sludging may be prevented if films are thoroughly rinsed in flowing water between developing and fixing. The films should then be adequately drained so that a minimum of developer-contaminated rinse water is transferred to the fixer.

b. **Streakiness.** Uneven density or streakiness in uniformly exposed areas may result if films are not rinsed before fixing and not agitated during fixing. This is due to the fact that one or two minutes may elapse before the alkali in the developer carried over by the films is neutralized by the acid in the fixer solution. During this time,

development of the film may continue unevenly in the fixer solution, resulting in streaks. The importance of adequate rinsing cannot be too strongly emphasized.

c. **Opalescence.** Sometimes a film viewed immediately after fixing in a fresh solution appears opalescent. This is a transient condition, disappearing when the film is washed and dried. It is caused by the reaction of the gelatin of the emulsion to the high concentration of sodium thiosulfate in the fixer. This condition frequently occurs when the solution has been freshly mixed.

Continue with Exercises

EXERCISES, LESSON 3

INSTRUCTIONS: The following exercises are to be answered by marking the lettered responses that best answers the question or best completes the statement or by writing the answer in the space provided.

After you have completed all the exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers.

1. The micro switch in an automatic processor, used to detect the presence of more than one film, also activates the:
 - a. Filtration system.
 - b. Transport system.
 - c. Replenisher system.
 - d. Dryer system.

2. If a breakdown occurs in the transport system, you should:
 - a. Consult the manual and repair it.
 - b. Call the radiologist.
 - c. Call a nurse.
 - d. Call medical maintenance.

3. Automatic processing is faster than manual processing because automatic processors circulate the solutions. Also, they use more active chemicals and:
 - a. Higher temperatures.
 - b. Lower temperatures.
 - c. Fast rollers.
 - d. Filtered solutions.

4. When the automatic processor has been idle long enough for drops of chemical solution to dry, you should not operate it until you wipe off the:
 - a. Crossovers.
 - b. Feed tray.
 - c. Main drive.
 - d. Cog wheels.

5. When clearing a film jam in an automatic processor, the power should be turned _____ if sheet film is involved and _____ if roll film is involved.
 - a. Off, also off.
 - b. On, also on.
 - c. Off, on.
 - d. On, off.

6. Insufficient rinsing of film may cause:
 - a. Image distortion.
 - b. Underdevelopment.
 - c. Discoloration of the image.
 - d. Excessive swelling of the emulsion.

7. The time needed to dry x-ray film is determined by the amount of emulsion swelling. Swelling can be controlled by using:
 - a. A stop bath.
 - b. Fresh developer.
 - c. A good fixing bath.
 - d. Adequate wash water.

8. In the course of manual processing, what is the recommended time for leaving film in the acid rinse bath?
 - a. 10 seconds.
 - b. 15 seconds.
 - c. 20 seconds.
 - d. 30 seconds.

9. When mixing x-ray film replenisher, the amount of fixer normally used for one gallon of fixer solution is mixed with _____ quarts of water.
 - a. One.
 - b. Two.
 - c. Two and one-half.
 - d. Three.

10. There may be times in the field when cold weather makes washing of films difficult. Under such conditions, it may be desirable to use:
 - a. Salt water.
 - b. Boiled water.
 - c. Gasoline.
 - d. Alcohol.

11. If the film dryer overheats, what effect can this have on the film?
 - a. Opalescence and deformation of the film base.
 - b. Diffusion of the water from the film base.
 - c. Softening of the emulsion and resultant distortion of the image.
 - d. A milky image.

12. After manually processing and washing x-ray film, what would be the fastest way to dry it?
- a. Use denatured alcohol.
 - b. Use a wetting agent.
 - c. Increase the heat of the dryer.
 - d. Increase the blower speed of the dryer.
13. What determines the amount of silver deposited on a processed x-ray film?
- a. Choices b and c below.
 - b. Development time.
 - c. Degree of exposure of silver bromide crystals to x-rays.
 - d. Washing time.
14. What results when a film is developed in solutions that have been idle for a time and are not stirred before use?
- a. The film receives a light brown stain.
 - b. The hanger clips release the film.
 - c. The film develops unevenly.
 - d. There will be a clear strip across the top of the film.
15. What chemicals should be used to control the bacterial growth that cause slime in developing tanks?
- a. Sodium sulfite.
 - b. Sodium carbonate.
 - c. Sodium thiosulfite.
 - d. Sodium hypochlorite.

16. What undesirable result is most likely to occur when films are processed in solutions with wide temperature differences?
- a. Blistering and reticulation.
 - b. Chemical fog.
 - c. Underdevelopment.
 - d. Crystallization.

Check Your Answers on Next Page

SOLUTIONS TO EXERCISES, LESSON 3

1. c (para 3-3a)
2. d (para 3-3d)
3. a (para 3-6a)
4. a (para 3-10a(4))
5. d (paras 3-10f(1)(a), (2)(a))
6. c (para 3-31)
7. c (para 3-37a)
8. d (para 3-26b)
9. c (para 3-29b)
10. a (para 3-35)
11. c (para 3-37d)
12. d (para 3-36)
13. a (para 3-40e)
14. c (para 3-58a)
15. d (para 3-60a(5))
16. a (para 3-60b(3))

End of Lesson 3

LESSON ASSIGNMENT

LESSON 4

Ray Film Processing under Adverse Film Conditions and Other Special Methods.

LESSON ASSIGNMENT

Paragraphs 4-1 through 4-20.

LESSON OBJECTIVES

After completing this lesson, you should be able to:

- 4-1. Select the proper procedures for the handling and storage of X-ray film.
- 4-2. Identify the various factors, which influence the processing of x-ray film.
- 4-3. Choose the appropriate procedures for manually for processing x-ray film.
- 4-4. Identify the various types of artifacts, which appear on finished radiographs.
- 4-5. Select measures for the prevention of artifacts.

SUGGESTION

After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

Section I. X-RAY FILM PROCESSING UNDER ADVERSE FIELD CONDITIONS AND OTHER SPECIAL METHODS

4-1. INTRODUCTION

a. Efficient processing of x-ray film under field conditions is often difficult. This is particularly true when, in amphibious or airborne operations, an x-ray laboratory is established in strange terrain proximate to combat operations. Under these conditions, casualties are awaiting medical attention and the hospital's surgical and radiographic functions should be established as soon as possible.

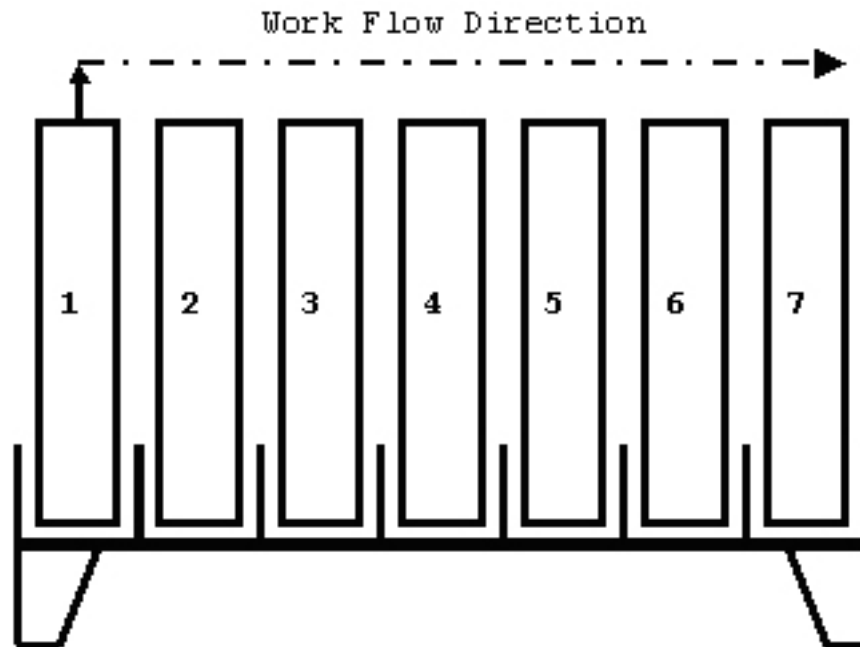
b. There may be no electric power to operate processing tank refrigeration units. Conventional x-ray processing requires water; frequently, however, water will have to be hand carried in large quantities for long distances. An inadequate water supply may necessitate the use of special processing techniques or a method of instantaneous dry processing, which requires special equipment. The following paragraph describes a method in which a completely processed, but wet, radiograph can be produced within 15 to 20 minutes following its initial immersion in the developing solution. If not required for inspection immediately, it may be hung in a drying rack to be air-dried.

4-2. FIELD PROCESSING PROCEDURE

Since electric power is not needed and a small quantity of fresh water can be included with the equipment, processing of radiography can begin as soon as the equipment is landed and assembled. The amount of water needed for the first 24 hours can be contained in a 50-gallon drum. This will be enough to mix solutions and accomplish the film washing process. After solutions are made, the water for washing purposes will average 15 gallons per 480 14 by 17-inch films or the equivalent. Treatment of the x-ray film during the processing procedure assures protection of the emulsion by good hardening characteristics and freedom from residual salts after the film is dry. The elimination of conventional processing apparatus is offset by using a processing system that chemically controls the processing procedure within a temperature range of the prevailing solution temperatures--one is used for the range 60° to 75°F and the other for 75° to 90°F. The method of developer replenishment requires the maintenance of the correct solution level by frequent additions of replenisher. The volume of replenisher needed to process 600 14 by 17-inch films, or their equivalent, is about equal to four times the original volume of the developer. This system makes possible the use of a constant development time for a given temperature.

4-3. EQUIPMENT

Seven stainless steel (Alloy number 316) tanks are needed for this method of processing. Each tank should be of approximately five gallons capacity. A frame upon which tanks may be grouped for convenient use by the x-ray specialist may be improvised (figure 4-1)



Tank 1--Developer.

Tank 4--Second fixing solution.

Tank 2--Acid or water rinse.

Tank 5--First wash.

Tank 3--First fixing solution.

Tank 6--Second wash.

Tank 7--Third wash plus detergent.

Figure 4-1. Diagram of tank (five gallon) arrangement in seven tank processing procedure.

4-4. PROCESSING AT 60° TO 75°F

The sequence of processing steps for temperatures 60° to 75°F is tabulated in Table 4-1.

TEMPERATURE (FAHRENHEIT)	60	62	64	66	68	70	72	74	75
DEVELOPMENT TIME (MIN)*	5	4½	4	3½	3	2½	2¼	2	1¾
* For use with rapid x-ray developer and x-ray replenisher.									

Table 4-1. Time and temperature development--60° to 75°F.

a. **Development.** Development is by time and temperature in tank one, according to table 4-2. After development, the film is removed quickly and drained to waste for 15 seconds (do not drain into the developer tank). The waste can be a trough in the back of the tanks leading to a drainage pit outside the processing room structure.

b. **Rinsing.** The film is next placed in tank two containing an acid rinse bath (stop bath) made by mixing 2-1/2 quarts of 28-percent acetic acid with five gallons of water. Exhaustion of this bath occurs when 200 14- by 17-inch films, or their equivalent, have been passed through the solution. If an acid rinse bath is not available, a fresh water rinse bath can be used, but it must be changed after 40 14- by 17-inch films have been rinsed. The film should be rinsed in tank two for one minute with active agitation or for two minutes without active agitation. After rinsing, it is removed and drained to tank two for 15 seconds and then immersed in tank three for fixing.

c. **Fixing.** Tanks three and four are used for fixing solution. The fixing solution should be mixed using a sodium thiosulfate formula. The film remains in tank three from one to two minutes until clear. It is then removed and drained to tank three for 15 seconds before being placed in tank four, where it remains two minutes for hardening. Be sure that the fixing solution from tank three does not drain into tank three. When 80 14- by 17-inch films have been passed through tank three, it is replaced with new solution and tank four is moved into number three position. The new solution in tank three then assumes the number four position.

d. **Washing.**

(1) Washing is a precise operation in this procedure and all the rules must be observed if a radiograph of quality and permanence is to result. For this operation, freely circulating water is not used. When the film is removed from tank four, it is drained for 15 seconds to tank four, or to waste, and then immersed in tank five where it is agitated for one minute (leave it in tank five for two minutes if it is not agitated). It is then removed and drained for 15 seconds to tank five, or to waste, before being placed in tank six. After agitation for one minute in this tank, it is removed to drain into tank 6, or to waste, for 15 seconds. The film is then immersed in tank seven for one minute while being agitated (or for two minutes if not agitated) and then removed to drain into tank seven, or to waste, for 15 seconds. Tank seven also contains a wetting agent (Table 4-2). In the process of transferring films between tanks five, six, and seven, if the films are drained to the waste, be sure that each water level is maintained by the frequent addition of fresh water to compensate for the water loss. The film may then be placed in the dryer or viewed by the radiologist or surgeon.

TANK NO.	PROCESSING SOLUTION	QUANTITY SOLUTION	IMMER-SION TIME	DRAIN TIME	EXHAUS-TION RATE 14 X 17 INCH FILM	REMARKS
1	Developer ¹ with replenisher	5 gal	3 minutes at 68°F	15 sec (to waste)	600	Replenishment procedure described on label of chemical container.
2	Acid rinse	5 gal	1 min active agitation or 2 min without agitation	15 sec (to tank 2)	200	If acid not available, use fresh water and change after each 40 14X17" films.
3	No 1 fixer ¹	5 gal	1 to 2 min or until clear	15 sec (to tank 3)	80	Discard; replace with tank 4.
4	No 2 fixer	5 gal	2 min	15 sec (to tank 4)	160	Move to tank 3. Replace with tank of fresh fixing bath.
5	No 1 stagnant wash	5 gal	1 min with agitation; 2 min without agitation	15 sec (to tank 5)	160	Discard; replace with tank 6. Maintain tank water level with fresh water
6	No 2 stagnant wash	5 gal	1 min with agitation; 2 min without agitation	15 sec (to tank 6)	320	Move to tank 5; replace with tank 7. Maintain tank water level with fresh water
7	No 3 stagnant wash with wetting solution ²	5 gal	1 min with agitation; 2 min without agitation	15 sec (to tank 7)	480	Move to tank 6; replace with fresh water plus wetting agent. Maintain tank water level with fresh water.
¹ Data based on use of solution made from rapid x-ray developer and its replenisher, and sodium thiosulfate x-ray fixer.						
² Mix 3 1/3 oz of wetting solution (if available) in tank 7 to eliminate drying marks and accelerate drying of the radiograph.						

Table 4-2. Special field processing procedure 60° to 75°F.

(2) The chief purpose of the washing done in tank five is to remove the bulk of the residual fixing solution and silver salts. Therefore, the water soon becomes charged with these chemicals and should be discarded when 160 14- by 17-inch films have been washed. Since the rotation of fixing and washing tanks is necessary to conserve water, tank five is removed, the old wash water is discarded, and tank five is filled with fresh water. Tank six is moved into the position of tank five and tank seven to the tank 6 position. The former tank 5 containing fresh water is put in the number 7 position. This system of rotation is repeated each time tank five washes 160 14- by 17-inch films in number five position.

4-5. PROCESSING AT 75° to 90°F

a. The sequence of processing steps is the same as the one just described except for the use of the specially treated developing and rinse bath solutions (Table 4-3). Time and temperature processing is accomplished by reference to Table 4-4. To ensure emulsion stability when processing at these higher temperatures, 50 ounces of sulfate is added to the developing solution. The rinse bath is replaced by a hardener solution made according to the following formula. Any quantity may be mixed, so long as the proportions are observed.

Water	5 gallons.
Potassium chrome alum	20 ounces.
Sodium sulfate (desiccated)	2 1/2 pounds.
<u>or</u> Sodium sulfate (crystalline)	5 pounds, 10 ounces.

b. Development of the film in the temperature range of 75° to 90°F ordinarily would proceed at too rapid a rate for adequate control. Sodium sulfate, therefore, is added to slow down the activity of the developer to more controllable limits. Be sure that any replenisher added to the developer contains sodium sulfate in the quantity of 50 ounces per five gallons of prepared replenisher solution. The hardener bath used after development serves to harden the emulsion so that the balance of the processing procedure can be carried out without the emulsion becoming too soft or melting before the final washing step.

TANK NO.	PROCESSING SOLUTION	QUANTITY SOLUTION	IMMERSION TIME	DRAIN TIME	EXHAUSTION RATE 14 X 17 INCH FILM	REMARKS
1	Developer ¹ with replenisher plus 50ozsodium sulfate	5 gal	See time temperature table	15 sec (to waste)	600	Replenishment procedure described on label of chemical container.
2	Hardner bath ²	5 gal	3 min active agitation	15 sec (to tank 2)	80	Discard daily whether used or not.
3	No 1 fixer ¹	5 gal	1 to 2 min or until clear	15 sec (to tank 3)	80	Discard; replace with tank 4.
4	No 2 fixer	5 gal	2 min	15 sec (to tank 4)	160	Move to tank 3. Replace with tank of fresh fixing bath.
5	No 1 stagnant wash	5 gal	1 min with agitation; 2 min without agitation	15 sec (to tank 5)	160	Discard; replace with tank 6. Maintain tank water level with fresh water
6	No 2 stagnant wash	5 gal	1 min with agitation; 2 min without agitation	15 sec (to tank 6)	320	Move to tank 5; replace with tank 7. Maintain tank water level with fresh water
7	No 3 stagnant wash with wetting solution ³	5 gal	1 min with agitation; 2 min without agitation	15 sec (to tank 7)	480	Move to tank 6; replace with fresh water plus wetting agent. Maintain tank water level with fresh water.
<p>¹ Data based on use of solution made from rapid x-ray developer and its replenisher, and sodium thirosulfate.</p> <p>² Above 90°F double strength.</p> <p>³ Mix 3 1/3 oz of wetting solution (if available) in tank 7 to eliminate drying marks and accelerate drying of the radiograph.</p>						

Table 4-3. Special field processing procedure 75° to 90°F.

TEMPERATURE (FAHRENHEIT)	75	76	78	80	82	84	86	88	90
DEVELOPMENT TIME (MIN)*	4	3½	3	2½	2¼	2	1¾	1½	1¼
* For use with rapid x-ray developer and x-ray replenisher.									

Table 4-4. Time and temperature development--75° to 90°F.

Section II. SPECIAL PROCESSING METHODS

4-6. INTRODUCTION

Most radiographers in their careers will be faced with processing many different types of film. Not all films are processed by placing the film into the automatic processor or placement on a film hanger. The following information outlines different types of film and the proper procedure for processing.

4-7. PHOTOFLUOROGRAPHIC FILM

a. Photofluorography is a complex, precise procedure. Processing of photofluorographic film differs from the manner in which conventional x-ray film is processed. Photofluorography is covered in SC 959. There are two basic types of single-emulsion films available for photofluorography--green-sensitive and blue-sensitive. They are produced in rolls 35 and 70 millimeters wide as well as in the form of single-coated x-ray film in 4 by 5-inch, 4 by 10-inch, and 2-11/16 by 6 1/2-inch sheets. The green-sensitive films are used with green-fluorescing DuPont-Patterson B, 52, and E fluorescent screens, while blue-sensitive films are used with the blue-fluorescing D or D2 screens.

b. Both green and blue-sensitive roll films are available in 70-millimeter width for use in the Fairchild Fluoro-Record Cameras, F-212. However, only the green-sensitive film has been found useful in the 35-millimeter width. Single-coated x-ray film is available in 2-11/16 by 6-1/2-inch sheet for use with both green and blue-fluorescing screens. The blue-sensitive type of this film, however, is also available in 4 by 5-inch and 4 by 10-inch sizes.

4-8. ACCESSORIES FOR PHOTOFLUOROGRAPHIC FILM PROCESSING

Safelight filters--Wratten Series 2--may be used with either blue or green-sensitive films, but the Wratten Series 68 may be utilized only with blue-sensitive films. Two processing hangers are available--the number 11 x-ray processing hanger and the adjustable processing hanger.

4-9. CHEMICALS FOR PHOTOFLUOROGRAPHIC FILM PROCESSING

Processing chemicals recommended for use with photofluorographic films are rapid x-ray developer and acid rinse bath, x-ray fixing solution, and wetting solution. Regular x-ray developer should not be used because of its relatively lower development activity. Solutions prepared for these chemicals may be stored in bottles prior to use. All used but unexhausted solutions should be stored in stopper bottles also.

4-10. PROCESSING ROLL FILM

a. In processing roll film, the leader and trailer should not be left attached to the ends of the roll while it is being processed. There are camera-activating perforations along the edges of the leader and the trailer. If the film is rolled on spools in the tank so that the first and last few frames will be in contact with the leader and trailer, the perforations can be the source of oval areas of increased density on these frames. The alternative to removing the leader and trailer prior to processing is not to make exposures on the first and last three of four frames on a roll.

b. In transferring the film from the magazine of the camera to the spool of the tank, great care must be exercised not to produce crimp marks or abrasions on the film. In addition, static electricity will occasionally be created during this operation if the humidity is low. This can lead to the creation of tree-like artifacts on the film. This can be prevented if the magazine itself is placed temporarily on one of the spindles of the tank cover assembly and the film threaded and started onto the processing spool. The entire assembly can then be immersed in water and the transfer of the film to the spool completed. The empty magazine reel is then removed and the other processing spool put into place.

4-11. PROCESSING FACILITIES FOR ROLL FILMS

a. A shallow sink, 30 inches long by 20 inches wide by 12 inches deep, equipped with a standpipe is very useful as a water jacket. The processing tank as well as the solution bottles can be placed in the sink for regulation of the temperature. The sink should be supplied with both hot and cold water and either a mixing faucet or a thermostatic mixing valve, the latter being the more satisfactory. A rubber hose connected to the faucet or the valve outlet is useful for filling or cleaning the processing tank and solution bottles as well as for filling the sink itself.

b. The motor-driven, rewind type tanks are designed with a spout so that if necessary only, one tank can be used and the processing solutions poured in and out as necessary. However, it is much more convenient to use two tanks so that the motor-driven reel assembly can be removed from one solution and immersed in the next solution in a second tank with a minimum loss of time.

4-12. SOLUTIONS FOR ROLL FILMS

a. **Temperature.** It is important that the entire processing cycle be carried out at 68°F. Above 70°F, the emulsion may be softened to such an extent that the edges of the film are damaged.

b. **Exhaustion Limits.** The maximum amount of film that may be processed in each of the processing solutions is as follows:

- (1) One gallon of rapid x-ray solution will develop 200 feet of film.
- (2) One gallon of acid rinse solution will stop development of about 100 feet of film.
- (3) One gallon of fixing solution will fix 300 feet of film. However, this capacity will be lessened when short lengths of film are processed.
- (4) One gallon of wetting solution should be sufficient for 100 feet of film. It should be discarded after each batch of 100 feet. For optimum results, these recommended limits should not be exceeded. When the recommended amount of film has been circulated through one of these solutions, the solution should be discarded.

4-13. PROCEDURES FOR PROCESSING ROLL FILMS

a. **Prewetting Roll Films.** Unless the film has been wound onto the processing tank spool under water, it should be wet with water at 68°F before being placed in the developer. This may be done by running the film through the water-filled tank for five minutes.

b. **Developing Time for Roll Films.** It is important that the developing time be measured from the time of immersion of the film in the developer to the time of immersion in the rinse bath. The developing time at 68°F for the first 100 feet of film in one gallon of developer solution varies with the length of the roll being processed. These times are listed in table 4-5. The developing time should be increased by one minute for the second 100 feet of film processed in one gallon of developer solution.

c. **Rinsing Roll Films.** The film should be removed from the developer solution and immersed in the stop bath as rapidly as possible. (To make the stop bath, add 16 ounces of 28-percent acetic acid to water to make one gallon of solution.) To stop development quickly over the entire length of film, wind the film by hand through two complete cycles in each direction.

d. **Fixing Time for Roll Films.** The fixing time for various lengths of roll film is listed in Table 4-6.

LENGTH OF FILM	DEVELOPMENT AT 68°F
6-1/2 feet	6 minutes
25 feet	8-1/2 minutes
50 feet	9 minutes
100 feet	10 minutes

Table 4-5. Developing time--roll film.

LENGTH OF FILM	FIXING TIME AT 68°F
First 100 feet	10 minutes
Second 100 feet	12-1/2 minutes
Third 100 feet	15 minutes

Table 4-6. Fixing time--roll film.

e. **Washing Roll Films.** To increase the flow of water through the motor-driven tank during the washing procedure, one end of the cover assembly should be propped up about one-quarter inch. The hose nozzle is inserted into the bottom of the solution trap and the film should be washed for at least 25 minutes in rapidly running water.

f. **Preventing Water Spots.** Following washing, the flow of water should be stopped and the motor turned off. The lid of the tank with the film pools attached should be removed and about a pint of water poured from the tank. Then, 1-1/4 ounce of wetting solution should be added to the remaining water. The lid and spools are replaced and the motor runs for five minutes.

g. **Drying Roll Films.** All photofluorographic film requires great care in drying. Drying should be done in a room as free as possible from dust. After film has been removed from the tank, excess water should be removed with a chamois, photographic sponge, or squeegee. This should be done regardless of whether the film is to be dried in loops or on a rack. If heat is used, the film should never be allowed to become bone dry since it will tend to become brittle. Allowing the film to remain several hours in a normal room atmosphere after drying will promote equilibrium between the moisture content of the film and that of the room. When the film is dry, any residual spots or fingerprints may be removed with film cleaner.

4-14. PROCESSING SHEET FILM AND SHORT LENGTHS OF ROLL FILM

a. Standard tanks for processing 14 by 17-inch radiographs may be used to process both sheet and short lengths of 35 millimeter and 70 millimeter roll film. An

adjustable processing hanger is especially designed for processing any length of 35 millimeter or 70 millimeter film up to 11 feet. Adjustable film guides accommodate strips of different widths, while sliding clips on the top and bottom bars hold the film smooth. The number 11 processing hanger is of the channel type and holds five sheets of 2-11/16 by 6-1/2-inch film. Other hangers are available for 4 by 5-inch and 4 by 10-inch films.

b. The processing procedure is the same as for conventional radiographs in tanks. Green-sensitive films are developed for seven minutes at 68°F in rapid x-ray developer while blue-sensitive films require eight minutes. This difference is caused by the fact that the films are coated with two entirely different emulsions. In all instances, an acid rinse bath should be used as a rinse between developing and fixing of the films.

Section III. SPECIAL PROCESSING METHODS

4-15. HIGH TEMPERATURE PROCESSING

If it is not possible to cool the solutions and wash water to 68°F, a number of general precautions may be exercised to lessen the difficulties of processing x-ray film at higher temperatures. For temperatures up to 75°F, the development time should be shortened as indicated in the development time-temperature table (see Table 4-1). The fixing solution should be renewed frequently. The film should be fixed for fully 15 minutes to ensure maximum hardening and the washing time should be limited to 15 minutes. A good practice is to use a fixing solution, which is twice the volume of the developer, and to change the fixer when the developer is changed. Short development, through fixing, and minimum washing all help to prevent excessive softening and swelling of the emulsion gelatin.

4-16. TEMPERATURE ABOVE 75°F

For processing at temperatures above 75°F, further precautions must be taken. It is not generally possible to work with solutions at temperatures above 95°F due to the likelihood of reticulation and blisters. The recommended processing times for development, hardening, and fixing of x-ray films are given in Table 4-7. Between development and fixing, the film should be rinsed in a solution made with the hardening bath formula. This solution hardens the emulsion.

TEMPERATURE	DEVELOPMENT--RAPID X-RAY DEVELOPER	HARDENING BATH	FIXATION
80°F	1 1/2 minutes	3 minutes	10 minutes
90°F	1 1/2 minutes	3 minutes	10 minutes
95°F	1 1/2 minutes	3 minutes	10 minutes

Table 4-7. High temperature and processing time.

4-17. TEMPERATURES ABOVE 90°F

a. **General.** When the temperature of the processing solutions is 90°F or above, sodium sulfate should be added to the developer solutions as indicated in table 4-8. When the temperature is 95°F, sodium sulfate should also be added to the hardening bath. Once the sodium sulfate has been added, the bath should not be allowed to cool; if its temperature falls 5° to 10°F, the sodium sulfate may crystallize. The hardening bath should be mixed fresh every 24 hours because, when partially used, the bath loses its hardening properties rapidly.

	TEMPERATURE (FAHRENHEIT)	OUNCES OF DESICCATED SODIUM SULFATE ADDED PER GALLON OF SOLUTION
Rapid X-Ray Developer	80°F	0
	90°F	10
	95°F	20
Hardening Bath	80°F	0
	90°F	0
	95°F	7

* No modification of fixer required in this temperature range.

Table 4-8. Modification of developer and hardener solutions For high temperature processing.*

b. **Hardening and Fixing at Temperature Above 90°F.** X-ray film should remain in the hardening bath for three minutes; during the first minute, they should be agitated frequently to prevent the formation of a precipitate on the film surface. Next, the film should be transferred to the fixing solution. In order to minimize exposure to the air, the film must be transferred quickly from solution to the other.

c. **Washing at Temperatures Above 90°F.** In washing the films, the flow of water should be sufficient to permit washing for a period not exceeding 10 minutes. Prolonged washing may cause the gelatin in the emulsion to swell excessively. In a single wash tank, the hourly flow of water should be at least 15 times the volume of the tank. In the two-compartment cascade washing system, the hourly flow of water should be at least eight times the volume of one compartment.

4-18. TRAY PROCESSING

a. **General.**

(1) When a tank is not available, films may be processed in trays, although this method is not as efficient as the others that have been discussed.

(2) At least four heavy, durable, white enamel trays are essential. They should be of adequate size to accommodate the largest film normally exposed. One tray each is used for developer solution, rinse water or stop bath, fixing solution, and wash water. The tray used for washing should be fitted with an automatic tray siphon so that the water will be kept in constant circulation.

(3) A quantity of developer and fixing solution should be mixed at regular intervals and kept in brown bottles. Enough solution to cover the film at least one inch is poured into the proper trays just before processing. The temperature of the solutions should be 68°F. Only one film should be developed at a time and care must be taken to ensure that the softened emulsion is not scratched during development, and it does not stick to the bottom of the tray. The method requires somewhat less time than tank processing because of the constant agitation of solutions in trays, which is essential in tray processing.

b. **Procedure.** Assuming that the solutions are ready and at a temperature of 68°F, the steps in the processing procedure are as follows:

(1) On removing the film from the cassette or exposure holder, attach a dental x-ray film clip to one corner to facilitate handling. Immerse the film in the developer solution with a quick sliding motion so that it is completely covered. Unduly slow and uneven immersion will result in a dark line on the radiograph.

(2) Start the timer for the proper interval as indicated by the temperature and activity of the solutions. Because of the more or less continuous agitation afforded by this procedure, it requires 20 percent less development time than the tank system. For example, using rapid developer and a basic three-minute development time at 68°F, normal contrast is provided in screen-type film with a 2-1/2-minute tray development. During development, the film must be moved about frequently so that the underside does not adhere to the tray and thereby retard the action of the developer on the emulsion. It is also advisable to turn the film over several times during development. The tray should be rocked to provide continuous redistribution of solution over both surfaces of the film. This agitation can be accomplished by raising and lowering alternate sides of the tray and must continue throughout the processing period.

(3) Rinse the film in fresh water or acid bath for 20 seconds and transfer it to the fixing solution for 15 minutes. When the film is first placed in the tray, and at intervals during fixation, the solution should be agitated by the method previously described. The film must not be allowed to rest on the bottom.

(4) After fixing, the film should be washed in running water for not less than 20 minutes. The rate of flow should be rapid enough to replace the water in the tray at least eight to 10 times an hour. If several films are developed in succession, the washing time must be calculated from the time the last film was placed in the wash water.

(5) The developer and fixer solution should be returned to their respective bottles promptly after use or discarded because of aerial oxidation of the developer solution and dust and other foreign matter collecting in uncovered trays.

4-19. RAPID PROCESSING OF SURGICAL RADIOGRAPHIC

a. **General.** Occasionally during surgical procedures, it is necessary for the surgeon or radiologist to view radiographs at the earliest possible moment. In such situations, normal processing time can be reduced by several minutes by adding sodium hydroxide to the developer solution according to the following formula:

SPECIAL RAPID PROCESSING DEVELOPER	
Water	96 ounces
Desiccated sodium sulfate	12 ounces
Hydroquinone	6 ounces
Sodium hydroxide (caustic soda)	5 ounces
Potassium bromide	4 ounces
Water to make	1 gallon

The chemical should be dissolved in the order listed.

b. **Procedure.**

(1) Two parts of stock solution are mixed with one part water, and the x-ray film is developed in it for about 60 seconds at 68°F. The development time may be reduced to 45 seconds by decreasing to one ounce the potassium bromide in the above formula. However, appreciable fog may result. The tray method of processing is preferred because the keeping quality of the developer is poor when diluted as recommended above. The solution should be discarded after it has been used. The stock solution, however, will retain its properties for about two months if kept in a well-stoppered brown bottle.

(2) Since caustic soda is one of the components of the developer, dental x-ray film clips should be used for handling the films to protect the hands. It is important that the films be rinsed well following development before being placed in the fixer. This step is necessary to prevent the formation of stains or diachronic fog.

(3) If fresh fixer solution is used, the radiograph should be ready for viewing after having been immersed, with frequent agitation, for approximately 10 minutes to ensure thorough hardening of the emulsion. It may then be washed in the usual manner.

4-20. EMERGENCY PROCESSING MEASURES

Whenever possible, the x-ray specialist should strictly adhere to the rules of good processing outlined in the preceding sections. However, emergencies may arise during which it may be impossible for the x-ray specialist to know all the facts about the developer and fixer. In such emergencies, the following rules of thumb may be helpful.

a. Sight Development.

(1) Except in cases of extreme emergency, proper time-temperature processing should be carried out at all times. However, in case the processing timer should stop working, or if an improperly exposed but badly needed emergency film is required, it may be necessary for the specialist to estimate visually (sight development) the appropriate time for terminating development.

(2) Sight development opens avenues of error through which the quality of the finished radiograph may be impaired. It is a characteristic of x-ray film emulsions that the silver bromide crystals are packed more closely together than in the usual photographic emulsion. Depending upon the type of exposure given, the visual appearance of the developing image may be comparatively different. In radiographs exposed with intensifying screens, the exposure effect occurs chiefly in the crystals at or near the surface of the emulsion because the exposure is made chiefly by the fluorescent light emitted by the intensifying screens. The image appears to flash up quickly in the developer and the developed crystals at the surface prevent estimation of the degree of overall development in the body of the emulsion. Therefore, it is largely a matter of guesswork as to the time that development may be judged complete. Frequently, the radiograph is removed from the developer before complete development of the entire image has taken place because the image appears to the eye to possess a very high density. This results in underdevelopment. In direct exposure of the x-ray film, the x-rays penetrate the entire emulsion layers fairly equally. Crystals at the emulsion's surface as well as throughout the layers develop slowly. The developing image is ill defined at first, gradually building up to the point where the well-accommodated eye sees what may be construed to be a well-defined image. Frequently, however, an error in judgment is made and full development is not given.

(3) Sight development requires much experience before proficiency is attained and, even then; there are physiological factors which hinder the efficiency of the method. The degree of fatigue of the x-ray specialist is a major factor that lessens eye acuity in sight development as well as producing poor inherent ocular adaptation. Passage from a brightly lighted exposure room to the dark processing room requires a period of adaptation--in some instances, 15 to 30 minutes. The frequent inspection of the developing radiograph in front of the safelight together with the action of aerial oxidation frequently fogs the film. To avoid these disadvantages, use a standardized time-temperature processing procedure and develop films by inspection only when absolutely necessary.

(4) To sight develop a film, you may place a finger behind the densest part of the film and then view it against a safelight. If the shadow of the finger cannot be seen through the film, development should be terminated. To avoid causing aerial fog, the x-ray specialist should be particularly careful not to keep the film out of the developing solution for too long a time.

b. Solutions of Unknown Temperature and Strength.

(1) It is not advisable to process films by the sight method if the temperature and/or the strength of solutions are unknown. For consistency in film quality, standardized processing times must be established for both the developer and the fixer. This may be done by using the following methods.

(2) A simple test for proper development time can be carried out within a few minutes. Using an eight by 10-inch, cassette, flash-expose half the film to x-rays while covering the other half with lead. Then, in the darkroom, cut the exposed film into strips so that each strip has one exposed and one unexposed end. Only one strip is used in making the test, so the remainder of them should be stored in a lightproof container. Using a stopwatch with a second hand, place the strip of film in the developer so that it can be easily observed by the safelight illumination. The instant that the exposed half of the film becomes different in appearance from the unexposed half, note the time elapsed in seconds. Then, divide the number of seconds elapsed by 10; the result gives a suitable development time in minutes. For example, if it took 35 seconds for a density to appear on the exposed half of the film, then the proper development time for that solution at that temperature would be 35 divided by 10, or 3-1/2 minutes.

(3) To estimate the proper fixing time, place a film in the fixer (the first film processed will do satisfactorily) and note the time it takes for the film to clear. Triple this time for the complete fixing of all films. For example, if it took six minutes to clear a film, then all films left in the fixer for 18 minutes would be satisfactorily hardened.

Continue with Exercises

EXERCISES, LESSON 4

INSTRUCTIONS: The following exercises are to be answered by marking the lettered responses that best answers the question or best completes the statement or by writing the answer in the space provided.

After you have completed all the exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers.

1. When working in the field, temperatures may have to be compensated by:
 - a. Using a large fan.
 - b. Keeping tanks covered with lids.
 - c. Developing film at only certain times of the day.
 - d. Using chemicals.

2. When processing manually at temperatures from 75° to 90°F, sodium sulfate is added to:
 - a. Slow development.
 - b. Speed development.
 - c. Harden the emulsion.
 - d. Soften the emulsion.

3. Photofluorographic film is classified as _____-sensitive and _____-sensitive, depending on the type screen with which it is to be used.
 - a. Green, yellow.
 - b. Red, green.
 - c. Green, blue.
 - d. Blue, red.

4. Suppose that a processed roll of photofluorographic film shows small oval areas at the beginning and end of the roll. What is the cause?
 - a. Loose lid on the processing tank.
 - b. Contact of leader and trailer ends with the film.
 - c. Film not wound completely on the spool and overlapping.
 - d. Processing chemicals below the proper developing level.

5. To avoid static electricity on roll film, it may be necessary to:
 - a. Immerse the roll in water.
 - b. Rub the roll with a piece of wool.
 - c. Trim the trailer from the film.
 - d. Install the roll in a tank of developer.

6. Hand processing of roll film should be carried out at what temperature?
 - a. 52°F.
 - b. 68°F.
 - c. 75°F.
 - d. 82°F.

7. A "stop bath" is made with water and:
 - a. Fixer.
 - b. Wetting solution.
 - c. Acetic acid.
 - d. Sodium sulfate.

8. While a regular x-ray film is developed at 68°F for three to five minutes, a segment of blue-sensitive film requires minutes.
- a. Two.
 - b. Six.
 - c. Eight.
 - d. Ten.
9. According to the subcourse, the absolute upper temperature limit at which x-ray film can be hand processed is:
- a. 65°F.
 - b. 70°F.
 - c. 80°F.
 - d. 95°F.
10. When processing in trays, sticking is prevented by:
- a. Adding chemicals.
 - b. Keeping the temperature low.
 - c. Rocking the tray from side to side.
 - d. Putting the film in very slowly.
11. Tray agitation requires _____ less development time than the tank system.
- a. Five percent more.
 - b. Ten percent more.
 - c. Fifteen percent less.
 - d. Twenty percent less.

12. When speed is quite important but manual procedures must be employed, _____ may be added to the developer to speed its action.
- Elon.
 - Sodium hydroxide.
 - Hydroquinone.
 - Potassium bromide.
13. In a time-strength solution test, the exposed filmstrip required forty seconds to show a density change. What is the developing time?
- Three minutes.
 - Three and one-half minutes.
 - Four minutes.
 - Six minutes.

Check Your Answers on Next Page

SOLUTIONS TO EXERCISES, LESSON 4

1. d (para 4-5b)
2. a (para 4-5b)
3. c (para 4-7)
4. b (para 4-10)
5. a (para 4-10b)
6. b (para 4-13a)
7. c (para 4-13c)
8. c (para 4-14b)
9. d (para 4-16)
10. c (para 4-18b(2))
11. d (para 4-18b(2))
12. b (para 4-19a)
13. c (para 4-20b(2))

End of Lesson 4