As a Navy photographer, you must realize that composing and exposing a scene on film does not guarantee top-quality photography. The quality of the finished print depends on the quality of your darkroom work. A perfectly exposed film is useless if it is fogged, scratched, or under- or overdeveloped. Therefore, each step of film processing is important and you must master each step.

During the discussion of basic film processing concepts, both black-and-white and color film processing are covered. The mechanics of black and white and color processing are very similar. The primary differences between processing color film and processing black-and-white film are there are more steps in a color film process, and the time and temperature requirements are more critical.

DEVELOPERS AND DEVELOPMENT

The purpose of development is to convert those parts of the light-sensitive material (film or paper) that has been affected by light to black metallic silver. This produces a visible image from the invisible latent image. Development is usually carried out by bringing the exposed film into contact with a solution that contains a developing agent, but no silver salt. The silver that forms the developed image comes from a reduction of the individual silver halide grains in the film emulsion. This process is called chemical or direct development.

In another process that is seldom used, the developed image is derived from a soluble silver salt contained in the developing solution itself. This process is called physical development. The physical development process can be difficult to use because there is a tendency for silver to be deposited where it is not wanted.

The process of chemical development is most commonly used for film development. Chemical development is the process with which you should be concerned. In chemical development, the individual silver halide grains in the film emulsion are reduced to a black metallic silver. Each grain in the emulsion acts as a unit, in the sense that a grain is either developable as a whole or is not developable. When film development is performed properly, only exposed grains containing a latent image are reduced to black metallic silver. You may ask, “Why doesn’t the developer develop the unexposed grains as well as the exposed grains?” Actually, the unexposed grains are developable. When development is carried out over a long enough period of time, all grains are developed or reduced to black metallic silver. The density that results from the development of unexposed silver halides is called fog. Thus development is a rate phenomenon and the development of the exposed grains takes place at a faster rate than the unexposed grains.

The individual grains of silver halide in an emulsion are protected against the action of the developer by a chemical layer. When light strikes the emulsion, it breaks down the protective layer at one or more points on each individual light-struck grain. When the exposed film is placed into the developer, the grains are acted upon at these points by the developing agent, and each grain that received more than minimum exposure is quickly reduced to black metallic silver. The amount of blackening (density) over the film surface depends primarily upon the number of grains that have been affected by the developer. Density is also influenced because some grains may not develop to completion in the time the developer is allowed to act on the film.

COMPOSITION OF A DEVELOPER

There are many different formulas used as developing solutions, but most developers contain the following four essential ingredients: developing agent, preservative, accelerator or activator, and restrainer.

DEVELOPING AGENT

The developing agent, commonly referred to as the reducing agent, is the most important chemical in a developing solution. It is the developing agent that actually converts the silver halide grains in the emulsion to metallic silver. Nevertheless, the other ingredients are necessary to make the solution function properly.

One of the properties of a developing agent is its reducing potential. This refers to its relative ability to develop or reduce the silver halides. An active developing agent attacks silver halides vigorously, whereas one of low potential is slower in its action. For
certain purposes, one agent may be preferred over another. The temperature of the solution affects the activity of some agents much more than others. Hydroquinone, Metol, paraphenylenediamine, and phenidone are some of the more commonly used developing agents.

**PRESERVATIVE**

All developing agents in an alkaline state are affected by oxygen. When the developing agent combines with the oxygen in the air, the efficiency of the developing agent is reduced. When elements combine with free oxygen from the air or water, oxidation occurs. Therefore, a preservative is added to developing solutions to prevent excessive oxidation. The preservative prolongs the useful life of the developing solution and prevents stains caused by the formation of colored oxidation products.

The preservative is a chemical with a great attraction for free oxygen and combines with it when mixed into a solution. A large amount of free oxygen is in the water used for solutions. When the free oxygen is left in the water, it oxidizes most of the developing agent and produces stains before the metallic silver image is developed completely. By adding enough preservative, you may remove practically all of the free oxygen from the solution, the developing agent works as intended, and no stains are produced. Sodium sulfite is the preservative most commonly used in developing solutions.

**ACCELERATOR**

All developing agents (not developing solutions) are either neutral or slightly acid. Most developing agents must be in an alkaline state to be effective reducing agents, thus solutions require an alkali to activate the developing agent. A developing solution contains an accelerator so the solution becomes alkaline.

The accelerator serves two functions. First, it speeds up the swelling of the gelatin in the emulsion. This swelling permits the solution to penetrate the entire emulsion more quickly. The effect of this action is physical. The second action is completely chemical. As the silver halide salts in the latent image are reduced by the developing agent, the halide elements freed from the silver are absorbed by the accelerator and combined into neutral salts. This prevents harmful effects in the solution.

Because the accelerator is a determining factor in the activity of a developing solution, it affects the degree of graininess produced in the negative. This graininess is dependent upon the clumping action of the silver grains during the development process. The more active the developer, the higher the pH, and the greater the clumping action. Therefore, the milder or less alkaline developers yield finer grain. Common accelerators used in developing solutions are sodium carbonate and potassium carbonate.

Without an accelerator, there is little or no action. With some accelerators there is too much action. By the addition of a bromide restrainer, you may slow down the action of the developing solution to a controllable degree.

**RESTRAINER**

Without a restrainer most developing solutions act too rapidly and develop unexposed silver halides near the surface of the emulsion. This causes chemical fog, developing streaks, and an image with low contrast. During development, some restrainer is released from the silver and has a restraining action on the reducing agent during development. However, its action is not enough to prevent fog. When a restrainer is added, development time is prolonged and fog is minimized. Contrast is increased because the activity of the developing agent is cut down in unexposed areas. However, too much restrainer greatly retards the amount of development. The chemical most commonly used as a restrainer is potassium bromide.

**TYPES OF BLACK-AND-WHITE DEVELOPERS**

As stated previously, when a photographic emulsion is exposed to light, there is an invisible change produced in the minute crystals of silver halides that results in a latent image. To make the image visible, you must treat the exposed emulsion in a solution known as a developer. This solution converts the halides affected by light to black metallic silver. These black metallic silver particles form the visible image on the negative.

At the beginning of development, there is little difference in density between the highlight and shadow areas of the film. However, during normal development, this difference increases because the highlight densities continue to increase after the shadow areas are completely developed. Development should stop when the contrast between the shadows and highlights reaches a desired difference. The activity of the developer, and to some extent the type of film, primarily determines this developing action.
One type of developer cannot cover all situations; for example, film exposed by poor lighting conditions may require an active developer to bring out as much of the image as possible, while a film exposed under normal conditions requires a normal working developer. There are many different developers, each provides different activity and quality of development. The actual choice of the developer to use depends on the type of film, conditions under which it was exposed, type of negative required, and the developing time that is best for your development method.

GENERAL-PURPOSE DEVELOPERS

A developer for general-purpose work should produce moderate grain, normal contrast images. Clear areas of the negative, as well as the image areas, should be basically fog free.

Some general-purpose developers are as follows:
- HC-110
- DK-50
- Microdol

FINE-GRAIN DEVELOPERS

All photographic emulsions have a grainy structure. Although this grainy structure is not normally visible to the naked eye, it becomes visible whenever high magnifications are used to make prints. The tendency to use small-format film and make large enlargements has resulted in the need for fine-grain developers.

When enlargements are made from small negatives developed in other than fine-grain developer, the grain of the film may be objectionable. Graininess in the film should be controlled in the development of the film. Keep in mind, however, that every film has its own grain structure or characteristics. For 35mm-roll film, it is normally best to use a fine-grain developer.

Fine-grain developers achieve the desired result in several ways:
- They are usually soft working and this tends to reduce clumping of the silver grains.
- Some fine-grain developers actually produce smaller individual grains of black metallic silver. This, however, tends to reduce the film speed.
- The grayish white images produced by some fine-grain developers help by providing for increased passage of light between individual grains. This results in less local variation in density.

- Most fine-grain developers produce relatively low-contrast negatives. A reduction in contrast in the negative tends to reduce the graininess of the negative. However, this may not contribute significantly to a reduction in the graininess of the final print. Any advantage achieved by lowering negative contrast may be offset by the need to use a higher contrast printing filter to print the negative.

Some fine-grain developers are as follows:
- ID-11 (Ilford)
- D-76 (Kodak)
- Atomal (Agfa)

HIGH-CONTRAST DEVELOPERS

To produce maximum contrast on process and line copy type of films, you must have a developer that produces density readily and is free from any tendency to produce fog within the time of development.

Some of the most popular high-contrast developers are as follows:
- Kodalith (Kodak)
- D-11 (Kodak)
- D-19 (Kodak)

To prevent staining when using a high-contrast developer, you should rinse the negative well between developing and fixing.

HIGH-DEFINITION DEVELOPERS

A high-definition, or compensating, developer adds increased sharpness to the image by enhancing contrast of image edges and fine detail in the negative. High-definition developers may increase film speed by one or two f/stops, but they also increase graininess. High-definition developers are recommended for use only with fine-grain (slow or medium speed) films.

Some of the high-definition developers are as follows:
- Acufine
- Ethol TEC
You should consult the film data sheets or the Photo-Lab-Index for the recommended developers for each particular type of film to be processed.

CHANGES IN DEVELOPER WITH USE

The function of a developer is to change chemically the sensitized material treated in it. It stands to reason then that a chemical change also takes place to the developer itself. Most developers are used more than once. Therefore, you must know what changes to the developer can be expected and what can be done to prevent them or at least compensate for them. The primary changes that occur to a developer as it is used are as follows:

- Some developer is removed or carried out with the film and on the film hangers or reels.

- The developing agents are used up by reduction of silver halides to black metallic silver and by aerial oxidation. When the developing agents are used up by the reduction of silver halides, the by-products of the reaction cause the pH of the solution to drop, thus becoming more acid. When the developer agents are used up by oxidation, the pH tends to rise.

- The preservative is used up, thus the developing agents oxidize faster.

- The bromide within the solution is increased because the bromide is released from the film emulsion itself.

The effects of these changes to a developer are as follows:

- The development time required to reach a given contrast index or gamma is increased. Therefore, when a developer is used over and over, development time must be increased as more film is developed.

- The effective film speed produced by the developer decreases because of the increased bromide (a restrainer) in solution. However, this speed loss may be partially offset by increasing development time to maintain image contrast.

Complete exhaustion of a developer occurs when the developing agents are all used up. The approach of exhaustion is characterized by a brown color of the solution. Since a developer in this state can stain sensitized materials, it should not be used.

In most Navy imaging facilities, it is not economical to use a developer to the practical exhaustion point and then discard it. The quality of the image usually suffers long before the exhaustion point of the developer is reached. Replenishers are usually used to prevent this from happening.

Replenishment of a developer involves replacing those chemicals in the used developer that are exhausted by a replenisher so that the developer remains consistent. The aim of replenishment is not to keep the composition of the developer constant but to keep its activity constant.

There are two commonly used methods of replenishment. The first or “topping off” method is used extensively in tank processing. When topping off is used, the developer solution is maintained at a constant level in the tank by adding replenisher, so the volume added is equal to the amount of developer carried out. When you are replenishing by this method, it is possible to maintain consistency in development for only a certain period of time. After a given volume of replenisher has been added to the developer, the developer must be discarded. This procedure is then repeated with new developer.

The second replenishment method is called the ”bleed” method. The bleed method is used primarily with machine processing where a circulating developer system is used. In the bleed method, used developer is drained off and replenisher (in proportion to the amount of film processed) is fed in, so the characteristics and the level of the developer in the machine remain constant.

FIXING, WASHING, AND DRYING

As soon as a light-sensitive material is developed, it contains a visible silver image, but the image is not ready to be exposed to light. Only a portion of the silver halides in the emulsion were reduced to black metallic silver by the developer. The silver halides that were not reduced restrict both the immediate usefulness and the permanence of the image. These undeveloped silver halides must be removed. This is the purpose of the fixing bath. Before treating the sensitized material in the fixer (as it is called), you must stop or at least slow down the action of the developer. When the light-sensitive material is removed from the developer solution, there is a small amount of developer both in the emulsion and on the surface that must be removed or neutralized. For this, you use either a water rinse bath or an acid stop bath.
WATER RINSE BATH

To slow down the action of development, you must immerse the film in a water rinse bath. A plain water rinse bath is commonly used between development and fixation to slow down the development by removing all the developer that is clinging to the film (or paper) surface. A rinse bath does not completely stop development but retards it. A rinse bath has little affect on the developer that is actually in the swollen emulsion.

Rinsing is accomplished by quickly immersing the film in plain, clean water. A water rinse bath should be changed often to ensure it does not become loaded with developer. It is better to use running water.

The rinse bath, then, serves two purposes: first, it slows down development and second, it reduces the work that has to be done by the acid in the fixer. Rinsing, therefore, protects or prolongs the useful life of the fixer.

Following rinsing in plain water, the material (that is still light sensitive) must be treated in an acid fixing bath to stop the development.

ACID STOP BATH

Although a plain water rinse bath is commonly used between development and fixation, a better procedure is to use an acid stop bath. The function of a stop bath is not only to remove the developer that is clinging to the surface of the material but to also neutralize the developer in the swollen emulsion to stop development completely.

The acid stop bath stops the action of the developer because developing agents cannot work in an acid solution. An acid stop bath also helps protect or prolong the life of the fixer by neutralizing developer carry-over.

An acid stop bath should meet the following requirements:

- The pH must be low enough to neutralize the action of the developer carried over.
- The acidity should be limited so the small amount carried over into the fixing bath does not increase the free-acid content of the fixing bath and cause sulfurization.
- It must not contain enough acid to produce blister formations in an emulsion.

You should use only a weak acid stop bath between development and fixation. Strong acid and the acid in the fixing bath have a tendency to form carbon dioxide gas bubbles in the emulsion. When the film is taken from the developer and placed directly into a strong acid or fixing bath, these bubbles may break and cause small, round holes in the emulsion. These bubbles are sometimes mistaken for pinholes like those caused by dust particles settling on the emulsion before camera exposure.

When you are using an acid stop bath, remember that some of the stop bath is carried into the fixer when materials pass through it. Therefore, you cannot use a strong acid (such as sulfuric acid) because it can cause precipitation of sulphur in the fixer. Acetic acid is the type of acid used for stop baths. In its pure form as glacial acetic acid (99.5 percent), it freezes at a temperature of about 61°F. Its freezing tendency gives it the name “glacial.” For use as a stop bath, 99.5 percent glacial acetic acid is diluted with water to make a 28 percent working solution. Approximately 1/2 ounce of 28 percent acetic (not glacial) acid is added to 32 ounces of water. The process of determining the concentration of a liquid is discussed in chapter 8.

FIXING

When a light-sensitive material is removed from the developing solution, the emulsion contains a large amount of silver salts (halides) that has not been affected (developed) by the developing agents. This silver salt is still sensitive to light, and if it remains in the emulsion, light ultimately darkens and discolors the salt which obscures the image. Obviously, when this action occurs, the negative (or print) is useless.

The fixing bath is used to prevent this discoloration and to make the developed image permanent. It accomplishes this by removing the undeveloped silver halides by making them water soluble. Therefore, to make an image permanent, you must “fix” the light-sensitive material by removing all of the unaffected silver salt from the emulsion.

The fixing bath contains five basic ingredients: the fixing agent, preservative, neutralizer or acidifier, hardening agent, and an antisludge agent.

Fixing Agent

All fixing baths must contain a silver halide (salt) solvent. This solvent is known as a fixer or fixing agent. The two most commonly used in photography are sodium and ammonium thiosulfate, commonly termed hypo (taken from their other chemical name hyposulfite). Ammonium thiosulfate is used in rapid fixers that are stronger and require less fixing time.
Sodium and ammonium thiosulfate changes undeveloped silver halide to soluble silver sodium thiosulfate. It removes this compound from the emulsion and refills the space it occupied with nonexhausted fixing solution. Therefore, the function of the fixing agent is to convert the silver salts remaining in the emulsion after development to soluble compounds and to remove these soluble compounds by constantly diluting and replacing them in the emulsion. The number of substances capable of functioning as fixing agents is small because a good fixer must meet the following requirements:

- It must dissolve silver salts without affecting the metallic silver image.
- The compounds it forms must be soluble so they can be removed from the emulsion.
- The fixer should neither swell excessively nor soften the gelatin.

**Preservative**

A preservative prevents oxidation of the developing agents that are carried over into the fixing bath by the film. It also prevents decomposition of the fixer. Oxidized developer in a fixing bath produces stains.

Strong acids may cause a fixing agent to decompose (sulfurize). You must add preservative (sodium sulfite) in the fixer to prevent sulfurization. The preservative prevents the acid from decomposing hypo into free sulfur, prevents discoloration of the solution because of oxidation, and aids in preventing stains.

**Neutralizer**

After development, the pores of the swollen emulsion retain a portion of the developer. If allowed to remain, the developer continues its activity. Even when the emulsion is thoroughly rinsed in a water bath before being placed in the fixer, some developer activity remains. This causes uneven stains in the gelatin of the emulsion and makes the negative unusable. To stop development and prevent stains, you must add an acid neutralizer to the fixer. The most frequently used neutralizer is acetic acid.

**Hardening Agent**

During development, the gelatin becomes softened and swells. Frilling, reticulation, scratches, and other undesirable effects may result when processing is continued without hardening the emulsion. A hardening agent is included in the fixer to harden the emulsion in the fixing bath. The most common hardening agent is potassium alum. The hardening and toughening of the gelatin by the alum stops the tendency of the emulsion to swell but leaves it expanded and rigid enough for the washing process.

**Antisludge Agent**

The pH range of the fixer is limited. It must be low enough to neutralize the activity of the developer and also be high enough to prevent sulfurization. The reduced acidity of the bath is gradually neutralized by the alkali of the developer carried into the fixer by the film. When the active acidity is neutralized too far, a sludge of aluminum sulfite forms that can make the fixer useless. An antisludge agent, such as boric acid, is added to the fixer. This agent is capable of absorbing a large quantity of the developer before sludge occurs, thus lengthening the useful life of the fixer.

**Time Required for Fixing**

The time required for film to fix depends on several factors:

- The type of emulsion and its thickness. All else being equal, fine-grain emulsions fix faster than coarse-grained ones. Thin emulsions require less time to fix than thick emulsions.
- The type of fixing bath and degree of exhaustion. When sodium thiosulfate is the fixing agent, a concentration of about 75 percent gives the fastest rate of fixation. However, because of the tendency of hypo to bleach out the image, most fixers for negatives have a concentration between 20 and 40 percent.
- The fixing bath temperature. An increase in the temperature increases the rate of fixation. (Do not interpret this to mean that you can raise the temperature of the fixer above the temperature called for by the particular process being used.) The temperature of the fixer is not as critical as the temperature of the developer. However, you should keep all processing solution temperatures constant to avoid an increase of graininess.
- The amount of agitation. The rate of fixation is affected by diffusion of the chemicals, so agitation reduces fixation time.
- The amount of exposure. The more exposure the film has to light, the less unused silver halide to be removed by the fixer, and hence the faster the rate of fixation.
As a general rule, a film is considered completely fixed after twice the time it takes to clear it. Clearing or fixation occurs when all visible traces of the silver halides (a milky appearance) have disappeared. The clearing time can be determined by taking an undeveloped piece of the same type of film and agitating the film in the fixer until it clears. This procedure can be performed under normal room lights. The tongue cut from the beginning of the 35mm film may be used for this purpose.

Life of a Fixing Bath

The useful life of a fixing bath depends on several factors. One of which is the amount of material treated in the fixing bath. You cannot state accurately the exact amount of film or paper that can be safely fixed in a given amount of fixer. It is common practice to consider the fixer exhausted when the clearing time for the film is double the time it was originally. For a fixer used solely for prints, this is not easy to determine; therefore, the life of the fixer is considered ended after a given amount of paper has passed through it. This is usually about 200 8x10 prints (or equivalent) per gallon of fixer.

Using an exhausted or near exhausted fixing bath may cause the staining of films and paper. To avoid such staining, use two fixing baths in succession is the best practice. Initially, two fresh fixing baths are used. The materials are treated in the first bath until they are just cleared; then they are transferred to the second fixing bath for an equal period of time. In time, clearing time in the first bath (which is doing most of the fixation) is doubled from the original time required when the bath was fresh. When this occurs, the first bath is removed from use and replaced by the second bath. The second fixing bath is replaced by a completely fresh solution. This process is repeated as required, so the second bath is always relatively fresh. Using this procedure ensures that all film (and photographic paper) leaves the second fixer in stable condition and does not fade with time. This method is also economical, because all fixer is used to a point beyond that at which a single bath could be used.

WASHING

An unwashed or improperly washed emulsion will stain, crystallize, and fade. Therefore, the washing of the photographic emulsion is as important as any other part of processing. Removing as much of the salt and fixer from the emulsion is essential. Only by good washing techniques can image permanence be assured.

The purpose of washing is to remove the soluble salts from the emulsion. Fixing converts silver salts into soluble salts that must be removed. If the fixing process is incomplete, even prolonged washing cannot make the image permanent. This is because the compounds of silver sodium thiosulfate remaining in the emulsion discolor in time and produce stains. Thorough washing is necessary to remove the fixing agent that, if allowed to remain, slowly combines with the silver image to produce brownish yellow stains of silver sulfide and causes the image to fade.

Water containing iron should not be used for washing. However, impurities, such as rust, dirt, or silt, can be removed by installing a 5 micron water filter in the supply line.

Seawater may be used to wash negatives if it is followed with a freshwater rinse. Salt water removes the hypo from film in about two thirds of the time required for a freshwater wash. However, a short rinse with fresh water is required to remove the salt from the film.

Temperature, chemical contamination, and rate of water change all affect the time required to wash film correctly.

Temperature

The wash should be kept within a range of 60°F to 75°F (15.6°C to 23.9°C). Within this range of wash temperatures, the warmer the water, the shorter the washing time required. However, for black-and-white film, a wash temperature of 75°F should not be exceeded. Water at temperatures above 75°F swells the gelatin and tends to inhibit diffusion. It also can damage the emulsion. Therefore, you should keep the temperature of the wash water constant with the processing solutions.

Chemical Contamination

Adding negatives fresh from the fixer into a tank of partially washed negatives nullifies the effects of previous washing, and you must start the washing procedure again. The reason for this is that the negatives with the higher concentration of fixer add enough chemicals to the washed negatives to contaminate the partially washed film. This situation can also occur if
your hands are contaminated by chemicals when you place them in the wash tank.

Rate of Water Change

The length of washing time also depends on the diffusion of the hypo from the emulsion of the material. The rate of diffusion depends on the amount of fresh water coming into contact with the emulsion. Hypo remaining in the emulsion is continually halved in equal periods of time as the washing proceeds; for example, the average negative gives up about one half of the hypo it contains in 1 minute when in direct contact with running water. After 2 minutes, one fourth of the hypo remains, and so on, until the amount of hypo remaining eventually becomes negligible. Thus the rate of washing depends upon the degree of agitation and the amount of fresh water that comes in contact with the emulsion. The minimum washing time for negatives in running water is 20 minutes when a complete change of water occurs every 3 minutes.

Rapid film washers are designed to provide a constant freshwater exchange across the film emulsion. When rapid film washers are used, such as a Hurricane type of film washer, the film can be washed satisfactorily in 5 minutes.

Wetting Agent

After washing, water often drains from film in an irregular manner, clinging to both emulsion and base sides in drops, streaks, and uneven patterns. When such partially drained or incompletely wiped films are subjected to hot air or radiant heat, the areas under these streaks and drops of water dry much more slowly than the surrounding film. The swollen gelatin at these points is subjected to stresses and shrinks unevenly, changing the density of the silver image. When surplus water is removed from the emulsion side and drops of water remain on the base side, drying of the emulsion immediately opposite the water spots is retarded and drying marks usually result. The use of a wetting agent helps to prevent the formation of these water spots.

Wetting agents are chemicals that “superwet” the film to promote faster and more even drying. Wetting agents are chemically different from soaps, but they perform a related function. They all lower surface tension of liquids so the film surfaces are wetted quickly and evenly. Kodak Photo-Flo is a wetting agent used in imaging facilities.

After washing, bathe the film in a 1- or 2 percent solution of wetting agent (prepared according to instructions provided by the manufacturer) for about 2 minutes. Then drain the film briefly for about 30 seconds. Squeegee the film between your index and middle finger to remove surface foam and excess wetting agent. Be sure your hands are clean and dampened with the wetting solution before squeegeeing the film.

Drying

The final step in processing is to dry the wet film. This step should be given special attention. Film drying has two distinct phases. The first is the removal of excess water from the film surfaces. The second is the drying of the film by evaporation.

When you are drying the film, the primary problems you must guard against are uneven drying, dust, scratches, and damage to the emulsion caused by overheating. Dry the film in a vertical position, hanging it from a line or beam by film clips. When you are drying roll film, curling can be avoided by hanging another film clip at the bottom of a strip of film. Sheet film should be hung from one corner of the film to prevent drying streaks. Film should not normally be dried in the hanger or reel in which it was processed, since uneven drying results.

Dust and water spots are the problems you encounter most frequently when drying films. When the dust is not embedded in the emulsion, you can remove it with a camel-hair brush. Embedded dust in the film requires the film to be rewashed and dried properly. Water spots are more serious, since uneven drying can cause not only white stains but also small craterlike formations in the film under each spot. The white stains can be removed with alcohol, but the craterlike spots become a permanent defect. The best cure is prevention. You can avoid these problems by keeping the film surface clean and by using a wetting agent before drying.

The photographic emulsion consists of one or more layers of gelatin with silver halides of varying sizes distributed through the layers. After exposure and development, the halides are changed to metallic silver that occupies space and does not absorb water. In an emulsion that is unexposed, the undeveloped silver salts are made soluble and are removed from the emulsion during the fixing and washing stages. Only the gelatin and the space occupied by the halides remain, and these do absorb water. Because of these conditions, dense
negatives, or negatives containing many heavily exposed areas, contain less water and dry faster than thin negatives. When you think about this for a moment, you can see that since the heavily exposed and lightly exposed areas are distributed randomly throughout the average negative, drying occurs rapidly in the dense areas, more slowly in the intermediate areas, and most slowly in the thin or unexposed areas. Obviously, then, film does not dry uniformly.

When gelatin dries, the water it contains must first migrate to the surface and then evaporate into the air. Ideally, these processes should take place simultaneously and at the same rate. However, when the surface moisture evaporates too rapidly, the surface becomes hard, and the internal moisture is unable to escape it. In addition, when drying is too rapid, the outer surface shrinks while the rest of the gelatin layer is in an expanded state. This causes strains that can have a harmful effect upon the emulsion.

For a negative to dry, it must be surrounded by dry air; that is, air that contains a lower relative percentage of moisture than the gelatin. When the heated air circulates, the damp air moves away from the surface of the wet film and replaces it with dry air that permits the drying process to continue. This is the principle behind the air impingement dryers currently in use. Heated air accepts more moisture than cool air. When the air does not move, air can become heated and rapidly reach a state of equilibrium with the moist film, and drying stops.

In an air impingement drying system, air is warmed and blown against (impinges upon) the surface of the wet film. The warm, dry air picks up moisture and moves on. It is immediately replaced by more warm, dry air, and the process continues until the film is dry. The rate of drying is controlled by adjusting the velocity, temperature, and humidity of the air in the drying chamber. In hot and humid climates where the air is saturated with moisture, the air must be passed through a dehumidifier before it enters the drying chamber. When this is not done, the film does not dry. In dry climates, you must reduce both the heat and the air velocity to prevent overdrying.

Photographic films begin drying at the corners and edges as well as in the areas of heaviest density. This introduces strains in the direction of the dry areas. As a film continues to dry, the strains gradually begin to equalize, and the film, when dried properly, ultimately lies flat. The surface is not moist to the touch, but it is firm and soft enough that flexing does not damage it. If overdried, the film curls toward the emulsion and can become brittle.

The rate of drying and the amount of curl also depend upon how thick the emulsion layer is and whether or not the film has a gelatin backing. Naturally, the thicker the layer, the longer the drying time. A gelatin backing takes time to dry, but it introduces an opposing curl and causes the dried negative to lie quite flat.

**FILM PROCESSING EQUIPMENT**

Hand processing of photographic film is best carried out in a darkroom that is properly equipped. Whether the darkroom is large or small, certain essentials are necessary for good quality processing.

The darkroom must be clean and well ventilated. Shelves, bottles, racks, processing equipment, walls, and floors that are spotted with dried chemicals are harmful to photographic images. Navy photo lab equipment, therefore, must always be spotlessly clean.

The arrangement of a darkroom should be convenient, “a place for everything and everything in its place.” There should be adequate and correct safelights placed at recommended working distances. Only necessary sensitized material should be in the darkroom. Temperatures in the lab should be maintained as closely as possible to the normal processing temperature—about 70°F to 75°F. The well-equipped darkroom should contain the following items: sink, graduates, required chemicals, waterproof aprons to protect clothing, clean towels, accurate thermometer and timer, and the necessary film hangers, trays, reels, and tanks. All darkrooms should be well stocked with prepared chemicals in containers that are labeled properly. In general, good photographic quality demands that all work must be conducted in a clean, orderly, and systematic manner.

**DARKROOM SINKS**

Sinks in the photographic darkroom should be sized adequately and constructed properly. Most sinks in Navy labs are factory-made and meet all the requirements for photographic work. Sinks should be big enough and built so they drain thoroughly. The sink should have *duckboards* to keep trays and tanks off the bottom and to permit water to circulate under and around the solution tanks to maintain correct and constant temperatures. Sinks, also, should have a mixing valve to control the temperature of the water in the sink and a
standpipe to hold water in the sink at the correct depth, yet still allow water to flow out (fig. 10-1).

SAFELIGHTS

The function of a safelight is to transmit the maximum amount of light that can be used safely without damaging the sensitized materials being processed. The color sensitivity of different sensitized materials varies. Therefore, the color and intensity of transmitted light must be varied accordingly. A darkroom safelight is the combination of a rated light source and a filter designated to protect a specific sensitized material.

The word safe, of course, is a relative term since no sensitized photographic materials are ever completely safe from the effects of safelight illumination. However, a filtered light is accepted as safe when the sensitized materials can be handled under the illumination with no evidence of fogging for at least twice as long as the normal processing time. No procedures must be followed precisely when safelights are used:

- Use only the size of incandescent bulb specified; for example, 7 1/2 watt, 15 watt, or 25 watt.
- Handle sensitized material at the distance recommended by the manufacturer. This is usually between 3 and 6 feet.

To determine whether a safelight is safe, you should follow these procedures:

1. In the dark, place a sheet of unexposed film, emulsion-side up, on the working area where the film is to be processed.
2. Place several coins on the emulsion and turn on the safelight. Leave the safelight on for twice the length of time the film will normally be processed.
3. Process the film normally and check to see whether there is less density in the areas covered by the coins. When there is less density, it indicates the film was fogged by the safelight and the safelight is not safe. A safelight that causes fogging may be corrected by replacing the filter, by installing a lower rated bulb, or...
by increasing the distance between the safelight and the material. Safelight filters are covered in chapter 3.

A safelight is most efficient when its output of illumination is indirect or reflected. When the safelight is not constructed on the indirect principle, it should never be pointed directly at the sensitized material; it should be placed so the light beam is away from or at an angle to the sensitized material. Figure 10-2 shows safelights used in photographic darkrooms.

**SHEET FILM HANGERS**

Sheet film hangers are made of stainless steel or plastic that resist corrosion in photographic solutions.
They are constructed of perforated metal or plastic and channeled to receive and suspend film in solution. This allows the solution to circulate freely over the film surface. Sheet film hangers are used in tank developing and their use is described later in this chapter.

ROLL FILM TANKS AND REELS

Hand processing of roll film is usually done on reels in roll film tanks. The center-feed reel and tanks used most commonly in the Navy are made of stainless steel. The film is wound onto a spiral reel. The reel is then placed into a tank for processing.

TRAYS

Trays used for processing photographic film (roll or sheet) are the same as those used for processing photographic prints. They may be made of any material that is not affected by, or cause contamination of, photographic solutions. Most trays used today are made of stainless steel or plastic.

SHEET FILM DEVELOPING TANKS

Tanks used for developing sheet film come in a variety of shapes and sizes. They are usually made of stainless steel.

To process sheet film in tanks, load the film into sheet film hangers and then place it into the developing tanks of solutions.

FILM WASHING EQUIPMENT

Film washing does not require special equipment. Sheet film can be washed in the same type of tank or tray that is used to process the film or in tanks designed for film washing.

When a tray is used, only one film at a time should be washed. When more than one piece of film is washed at a time, the films will probably rub together and be
scratched. Only line copy types of negatives are usually washed in a tray.

The most effective washing method in a tray is when a siphon device is attached to the edge of the tray. The device siphons water from the bottom of the tray, while fresh water enters at the top (fig. 10-6). Because fixer is heavier than water, it sinks to the bottom of the tray.

The best way to wash hand-processed sheet film (especially more than one sheet at a time) is in a sheet-film washing tank. Film hangers hold individual negatives suspended separately in the tank. Fresh water flows into the bottom of the tank and runs out around the sides at or near the top of the tank (fig. 10-7). When you place the film hangers into the tank, ensure the negatives are separated, so sufficient fresh water reaches all areas of each negative.

**WARNING**

Aboard ship, hoses attached to potable water spigots can back siphon chemicals or wash water from the trays or sink into the drinking water supply. These hoses must have a backflow preventer installed in the plumbing system.

A rapid roll-film washer is excellent for washing hand-processed roll film. It is a cylindrical tank, large enough to hold several spiral reels. The washers come in a variety of sizes that will wash from two 35mm reels to as many as six or eight 120 reels (fig. 10-8).

The rapid roll-film washer is constructed so the wash water enters the tank at the base and flows up
through the tank and around the film at a rapid rate. By discharging the water from the top of the tank, you can remove more hypo in a shorter time.

Roll film also can be washed in the roll-film tank in which it was processed. To wash roll film in a roll-film processing tank, simply push a small hose down into the center of the reel and have the faucet turned on, so the water overflows steadily from the tank (fig. 10-9).

**TIMERS**

Every darkroom should have a reliable timer. Ideally, the timer should have both a minute hand and a sweep second hand. The timer most commonly used in the Navy is a Gray Lab timer (fig. 10-10). Not only does this timer have a minute and sweep second hand but the numbers and hands are fluorescent so they can be seen in the dark. A Gray Lab timer also has an alarm (buzzer) that indicates when the time for processing is up.

**PROCESSING METHODS**

No matter how many rolls or sheets of film you develop, it helps when you carry out the processing in three distinct phases, beginning with preparation. First, your work area must be clean, and the equipment needed must be arranged so it is easy to locate in the dark. The second phase is processing. If you are not familiar with darkroom work, you should complete ALL the processing steps with dummy or practice film and water to substitute for processing solutions under white light and then practice a few times in the dark. The third phase is film drying.

To make the latent image visible and permanent, you must process the film in different chemical solutions. There are five steps in the black-and-white processing phase. The first step is development. In this step the film is placed in a developer that transforms the latent image into a visible black metallic silver image. In the second step the developing solvents are neutralized, and development is retarded or stopped by a rinse bath or acid stop bath, respectively. The third step involves placing the film into a fixing bath to remove the light sensitive, undeveloped silver halides. The fourth step is to wash the film to remove all the chemicals, and the last step is to dry the film. Each of these steps is explained further in this chapter, since there are certain controls that must be applied to each step.

Some of the processing steps may be carried out in white light, while others must be done under appropriate safelight conditions or in total darkness. The steps that must be done in darkness or under suitable safelight conditions begin when the film package, holder, or roll is opened and end when the film is removed from the fixer.

As discussed earlier, there are five steps in film processing. The steps and the lighting conditions under which they are carried out are as follows:

1. Development-dark or appropriate safelight
2. Rinse or stop bath-dark or appropriate safelight
3. Fix—dark or appropriate safelight
4. Wash—white light
5. Dry—white light

In addition to exposure, there are four factors in development that control image density, contrast, and, to a limited degree, the uniformity of individual densities in a negative. These four factors are the type of developer used, development time, temperature of the developer, and agitation as follows:

- Type of developer. One type of developer cannot cover all film exposure/processing situations. For example, film exposed under poor lighting conditions may require a vigorous developer to bring out as much image detail as possible, while film exposed under normal conditions requires a normal working developer. There are many different developers, each provides a different activity and quality of development. The actual choice of the developer to use depends on the following: the type of film, conditions under which it was exposed, type of negative required, developing time that is best for the method of development to be used, and the manufacturer’s recommendation.

- Time and temperature. Many factors must be considered if you want to ensure correct development during film processing. Two of these factors are the length of time the film is allowed to develop and the temperature of the developer solution. Both factors can have a significant impact on the quality of the processed film.

As explained earlier, the activity of a developer increases as its temperature increases. Film development carried out for a given time at a given temperature produces both predictable and desired results—assuming, of course, that the film has been exposed properly. When film is developed for a given time at a given temperature, it is called "time and temperature development."

In the time and temperature method of film processing, as in any method of film processing, if the film is developed for too short a time or at too low a temperature, a weak, low-contrast image results. Underdevelopment can result in insufficient highlight density. On the other hand, if the negative is developed for too long a period or at too high a temperature, the result is a negative having too much density. The developer solution overdevelops the exposed areas and may even develop some of the unexposed silver halides.

For correct development, both time and temperature must be accurately controlled. Within limits, time can be adjusted for a given temperature, or temperature can be adjusted for a given time.

There is a definite correlation between time and temperature. When it is impossible to maintain solution temperature at the desired level, time can be shortened or lengthened to compensate. As the temperature increases, developing time must be decreased to provide equivalent development. As the temperature decreases, development time must be increased.

The normal temperature for hand processing most black-and-white film is 68°F (T-Max film with T-Max developer is 75°F). There are several reasons for this standardization. At a temperature of 68°F, the gelatin swells sufficiently to allow adequate penetration of the developing solution without oversoftening to the point where it is easily damaged (which occurs at higher temperatures). Temperatures lower than 68°F slow development excessively. Only when time is of the utmost importance are accelerated temperatures used. In most instances when high temperatures are used, the film is treated in a hardening bath before processing, or the film is designed specifically for being processed at such temperatures. Since a rise of several degrees in temperature shortens development only a small amount, there is little to be gained by deviating from standard processing temperatures.

When you know the time and temperature relationship for a given film and developer combination, processing in total darkness becomes simple. You simply adjust solutions to the prescribed temperature and then process the film for the required time. Assuming proper exposure, time and temperature processing can produce a correctly developed negative without your having to see what is happening in the solution.

All solution temperatures (developer, rinse, fix, and wash) should be as close to each other as possible. When there is considerable difference in the temperature of the solutions, excessive graininess may result, or the emulsion may be subject to excessive expansion and contraction that causes it to wrinkle or crack. This effect is called reticulation. Since reticulation is not correctable, it causes the negative to be useless for printing.

The temperature of solutions may be adjusted by surrounding them with hot water, cold water, or ice. Never add water or ice directly to a solution because it dilutes the developer to an unknown degree. Ice may be placed in a container and suspended in the solution. An immersion heater may be used in the solution to raise its temperature.
Agitation. If a film is placed in a developer and allowed to develop without movement, the chemical action soon slows down because the developing agent in contact with the surface of the emulsion becomes exhausted and bromide (a restrainer) is released as a by-product. When the film is agitated, however, fresh solution is continually brought to the surfaces of the film, and the rate of development remains constant. Therefore, agitation also has an important effect on the degree of development. An even more important effect of agitation is it prevents uneven development. If there is no agitation, the exhausted solution that became saturated with bromide from the emulsion may flow slowly across the film from the dense highlight areas and produce streaks. Constant agitation is usually recommended for the first 30 seconds of tank development and for the entire developing time when the film is being processed in a tray. After the initial 30-second agitation cycle, the film should be agitated for 5 seconds, once every minute during the remaining time.

The time, temperature, and amount of agitation required for a film/developer combination are recommended by each manufacturer of film or developer. These recommendations are in the instructions that accompany the film or developer. Another reference source is the Photo-Lab-Index.

There are three different methods of processing film by hand. These are as follows: the tray, the sheet-film tank, and the roll-film tank. Each method is discussed here with an example of the darkroom arrangement used.

TRAY PROCESSING

The tray method is used primarily for processing only a few sheets of film. With a lot of experience, you can process as many as 6 to 12 sheets of film in a tray at one time. You will find it easier to work with only a few sheets of film at a time, and repeat the process, than to start all the sheets at the same time and damage them.

The tray processing method described here has proven satisfactory under most conditions for processing one sheet of film at a time. You should use this method as described and develop the necessary skill using this procedure before you attempt to use variations.

The trays should be considerably larger than the film being processed; for example, 4x5 film should be processed in 8x10 trays, 8x10 film in 11x14 trays, and 11x14 film in 16x20 trays. Ideally, the trays should be arranged in a shallow sink that contains temperature-controlled circulating water. The trays should be arranged with the developer to your left as you face the trays. The stop bath goes next to the developer, followed by the fixer and the wash tray.

In all Navy imaging facilities, it is standard procedure when processing film (or prints) by hand to work from left to right.

Rinse the trays with fresh water as a precaution against contamination, and prepare the solutions. When the solutions are ready, place the exposed film holder to be unloaded on a clean, dry area of the workbench near the developer. Set the timer for the correct developing time, and place it in a convenient location near the processing solutions. Then, if you are processing panchromatic film, turn out all the lights. If you are processing monochromatic or orthochromatic film, you can use a suitable safelight.

Remove one sheet of film from the holder and submerge it quickly, emulsion-side down, into the developer. Then immediately turn it over (emulsion-side up) and slide it back under the surface of the developer quickly, and agitate it vigorously to eliminate possible air bubbles. The surface of the film must be wetted quickly and evenly; otherwise, developing marks may result. Start the timer just before the film is placed into the developer.

During tray development, the tray should be rocked continuously to provide constant agitation. Be careful that the tray rocking is not too fast and that it is varied at intervals; for example, first front to back, and then side to side to avoid patterns of uneven development caused by regular waves.

CAUTION

Do not allow your fingernails to touch the film emulsion at any time.

Tray development involves constant agitation, and development time is usually about 20 percent less than if the same film were being developed with intermittent agitation. When tray agitation is done very slowly, the agitation should be considered intermittent and the developing time adjusted accordingly.

When the timer rings, remove the film from the developer, drain it from one corner, and submerge it in the stop bath. Agitate the film in the stop bath for about 5 seconds; then transfer it to the fixer. You must agitate
the film vigorously in the stop bath and initially in the
fixer because gases are released in these solutions and
there is danger of air bubbles forming on the film
surface. If you allow these air bells, or bubbles, to form,
they may cause dark spots. This is due to the continued
action of the developer beneath the bubbles. Agitate the
film in the fixing bath for a few seconds and then the
safelights or the white lights may be turned on. Continue
agitating the film until it loses the cloudy or creamy
appearance. Note the time required for this change to
occur because it is just half the total required fixing time.
Agitate the film several times during the second half of
the fixing time. After the film clears, continuous
agitation is not necessary.

After fixing is completed, transfer the negative to
the wash water and continue to agitate it unless a regular
film washing tank or tray is available. After washing is
complete, the film should be treated in a wetting agent
and dried.

As stated earlier, with experience you can process
several sheets of line copy film at a time in a tray. When
processing several sheets in a tray at once, there
is an added step. This is a predevelopment rinse in
clean water that should be at the same temperature as
the rest of the processing solutions. The predevelop-
ment rinse is located to the left of the developer. Its
purpose is to prevent the films from sticking together.
Its

The procedure for processing more than one sheet
of line copy film at a time is the following:

1. When the solutions are ready, place a dry,
dust-free paper or cardboard on the workbench near the
predevelopment rinse. Place the exposed film holders
near this clean working space.

2. Set the timer.

3. Turn out the lights.

4. Remove one film from its holder and place it,
emulsion-side down, on the clean paper. Remove the
second film and place it, emulsion-side down, on top of
the first. Continue until all the film is placed in a loose
pile on the space provided for them.

5. Pick up the film on top of the pile with your left
hand (keep it dry until all films have been placed in the
water), drop it, emulsion-side down, into the water, and
immerse it quickly with your right hand. Pick the film
up immediately, turn it over, emulsion-side up, and push
it back under the solution. Place the wet film,
emulsion-side up, at one end of the tray. Immerse the
next film in the same manner. Stack it on top of the first
film, and continue with this procedure until all the films
are stacked in a pile at one end of the tray. Your left hand
should follow the last film into the tray to assist in the
agitation of the films.

Wet film may be handled with wet fingers. However,
be extremely careful to KEEP WET FINGERS OFF DRY FILMS. Slight pressure with the
balls of the fingers is not harmful to a wet emulsion
unless it has swollen excessively.

The films should be agitated or shifted constantly to
prevent the individual sheets from sticking together.
Agitation is accomplished by moving the first film from
the bottom of the stack and placing it on top or by
starting a new stack at the other end of the tray. Continue
agitating the films from bottom to top until they become
completely saturated with water-about 1 or 2 minutes is
sufficient. After the emulsion is completely saturated,
the danger of films sticking together is no longer a
problem.

6. Remove the films, one at a time, from the
predevelopment rinse and immerse them in the
developer. Place the films in the developer,
emulsion-side up; slide them under the surface of the
solution quickly, and agitate them vigorously to
eliminate possible air bells. Start the timer just before
the first film is placed in the developer. Use your left
hand to remove all films from the water, and be careful
not to get the water contaminated with developer. Your
left hand should follow the last film transferred from the
water into the developer to help with the agitation.

It is important for you to locate the first sheet of film
placed in the developer quickly. To do this, align the long
dimension of all other films at a right angle to the first
sheet placed in the developer.

The films are immersed, emulsion-side up, in the
developer to reduce greater damage that would occur if
the emulsion, already softened by presoaking, were
allowed to come in contact with the bottom of the tray.
Be careful not to dig or drag the comer or edge of a film
into the emulsion surface of the film below it. Do not
allow your fingernails to touch the emulsion at any time.
Stacking films by aligning their edges against the sides
of the tray helps to reduce scratches and abrasions.

7. Agitate the films constantly, not by rocking the
tray, but by moving each film from the bottom of the
stack and placing it carefully on top, and pressing it
down gently to assure a flow of solution over its surface.
Continue this procedure until the developing time is up.
8. When the timer rings, remove all the films from the developer in the same order that they were placed in the developer, and submerge them in the stop bath. Your right hand should go into the stop bath with the first film and stay there to handle each film as it is transferred from the developer by your left hand. Use your left hand only for transferring the film to avoid contamination of the developer or spotting of the film. A few drops of developer will not affect the stop bath or the fixing bath, but a few drops of either of these solutions could ruin a developing solution.

9. After all the films have been shifted several times in the stop bath, they should be transferred individually to the fixing bath or hypo. Shift the films several times in the fixing bath, agitating them vigorously. Then safelights or the white lights may be turned on. Continue shifting the films until they lose the cloudy or creamy appearance. You must shift the films several times during the second half of the fixing time, but continuous agitation is not necessary.

10. After fixing is completed, transfer the negatives to the wash water and continue agitation unless a regular film washing tank or tray is used. The negatives also may be put in regular film hangers for washing.

11. Treat the film in a wetting agent and dry it.

TANK DEVELOPING SHEET FILM

Tank development is the recommended method for hand processing of orthochromatic and panchromatic sheet film. The solutions and the tanks are deep enough to cover the films in the vertical position completely. The films are supported individually in the tanks by the film hangers. Films supported in this way are much less subject to damage. The solutions last longer when used in tanks and can process more films than when they are used in trays.

Tank development for sheet film requires tanks to hold the solutions, and racks, reels, or hangers to support the films while in the solutions. The solutions used should have good-keeping qualities, and they should be the type that can be replenished by adding fresh solution or replenisher, so the volume in the tanks can be maintained at the proper working level.

The minimum number of tanks that can be used is three: one each for developer, stop, and fixing bath. However, when a predevelopment rinse is used, four tanks are needed.

The tanks are arranged in the processing sink submerged in enough water to maintain the solutions at the prescribed processing temperature. Again the process is arranged so you work from the left to right.
The film hangers are simply channeled frames suspended below a bar. The bar is long enough to reach across the tank and allow the frame to hang below the surface of the solutions. The frame has channel pieces on the bottom and both sides and a hinged channel across its top. Each hanger holds from one to four films. The hangers accommodate standard film sizes, such as 4x5, 8x10, and so forth. After the films are loaded into the hangers, they may be carried through the entire process without being touched by the hands.

The darkroom should be checked using the steps common to all film processing, as explained earlier in this chapter. After you check the solutions and their arrangement, check the temperature of the solutions, and check the safelights. Then arrange an adequate supply of clean, dry, empty film hangers on a rack, and an empty rack to hold the loaded film hangers (fig. 10-11). If the darkroom is not equipped with racks to hold the film hangers, clean, dry tanks can be used to hold both unloaded and loaded hangers. Set the timer, place the exposed film holders between the empty film hangers and the rack or tank that is used to hold the loaded hangers, and turn out the lights.

To load a sheet film hanger, remove one of the sheet films from its holder. Take a hanger in one hand and place the thumb at one end of the hinged channel. Bush the hinged channel up and back with the thumb until the film can be slid along the inside of the end channels to the bottom of the frame. HANDLE THE FILM BY THE EDGES ONLY. Make sure the film is seated properly in the three channels of the hanger. When the film is seated properly in the side and bottom channels, bring the top channel forward and down over its top edge (fig. 10-12). This encloses all four sides of the film in the channeled frame. The hanger should be given a slight shake to ensure that the film is in place. Set the loaded hanger on the rack or in the empty tank to hold it.

The film should be loaded onto the hangers with the emulsion side facing you. This prevents the top channel from scratching the emulsion as the film is slid into the frame. Load the other film in the same manner. However, do not load more hangers than can be handled conveniently in the tanks at one time.

When the hangers are loaded, lift all of them by their crossbars and lower them into the predevelopment water rinse, if one is being used. They should be lowered into the tank until the hanger crossbars rest on top of the tank. The predevelopment water rinse is optional when using the tank method of development, but the water rinse has the following advantages:
Figure 10-13.—Sheet film tank processing agitation.

- The air bubbles that usually occur when dry film is immersed in a solution can be removed without harmful effects in the predevelopment water rinse.

- When the water-softened emulsion is placed in the developer, the action of the solution begins uniformly over the entire emulsion. Thus uneven or streaky development is avoided.

- The predevelopment water rinse removes the antihalation backing dye that interferes with the action of some developers.

- The predevelopment water rinse brings the temperature of the film and the hangers to the processing temperature. Maintaining constant temperatures in all of the processing solutions is very important.

The predevelopment water rinse is given by immersing the loaded hangers in a tank of water and agitating them for about 2 minutes. The temperature of the water should be the same as that of the other processing solutions. The loaded hangers are then lifted out of the water, drained by one comer, and processed in the usual manner.

Immerse the hangers in the developer slowly and smoothly to avoid splashing or the formation of air bells. Air bubbles usually result when films are immersed rapidly, especially when a predevelopment water rinse was not used. All the hangers should be immersed simultaneously to assure uniform agitation and development.

Strike the hangers sharply against the sides of the tank several times to dislodge any air bubbles that may
With a film clip. Dry the hangers, after washing them in hot water, without film in them. With suitable racks designed to hold reels, roll film can also be processed in tanks (fig. 10-14).

**TANK DEVELOPING ROLL FILM**

The most convenient and reliable way to hand process roll film is in a small roll-film tank. The construction of tanks and reels differ somewhat among the various manufacturers’ models, resulting in differences in loading and use. Generally, the basic unit used in Navy imaging facilities consists of a stainless steel, center feed, spiraled reel to hold the film; a tank with a lighttight cover; and a filler cap. Each reel is constructed for a specific size roll of film; for example, 35mm, 120, and 220. The tank top permits pouring the chemicals in and out of the tank under white light conditions. The tanks come in sizes to hold from one 35mm reel to as many as eight 35mm reels or five 120 reels. Small roll-film tanks of all metal construction (tanks, lids, caps) should be numbered or marked in such a way that prevents mixing different tanks, lids, and caps.

The proper loading of a film reel in total darkness can be the most important steps and challenges in processing roll film.

When processing roll film with a paper backing, the paper tape sealing the exposed roll should not be broken until the lights have been turned out. Also, for 35mm film, the cassette should not be opened until the lights have been turned out. If a short length of film is left protruding from the 35mm cassette when the film is rewound, you do not have to open the cassette to remove the film. The leader or loading tab on 35mm film can be cut off square while in the light to ease loading of the spiral reel (fig. 10-15).
There are three ways of loading a center-feed spiral reel. You should practice each method (with a dummy roll), both in white light and in total darkness, and select the method that is most comfortable for you. Then perfect that method. Although the three methods are similar, there are differences that may make one method easier for you. However, before beginning one of these methods, make sure that both the reel and your hands are clean and dry.

- First method. Remove the film from the cassette (35mm) or separate it from the paper backing (120 or 220). The film must be handled only by the edges to prevent scratches and fingerprints. (When you work with 35mm film, the tongue of the leader must be cut off to make a square end before loading the reel.)

If you are right-handed, the ends of the wire spiral must be positioned on the top and pointing to the right (fig. 10-16, view A). For left-handed people, the ends of the wire spiral reel when positioned at the top must point to the left.

Next, bow the film slightly concave to clear the edges of the spiral and clip or hold the film to the core (center) of the reel (fig. 10-16, view B). The film emulsion must face in or toward the reel center. The tension on the film should be firm enough to prevent the film from skipping the spiral grooves, but not so firm it overlaps or falls into the same groove twice.

Turn the reel, apply gentle pressure, and keep your thumb and forefinger on the film edges. This pressure produces a slight curl in the film and allows it to pass onto the edges of the reel. As you continue to turn the reel, the film straightens out and fits into the grooved spaces in the reel (fig. 10-16, view C). Apply enough tension to the film so it does not skip grooves. However, too much tension may cause the film to overlap in the same grooves of the reel.

- Second method. Prepare the film as before. Hold the reel to be loaded on a clean working surface in your left hand with the ends of the wire spiral at the top, pointing toward the right (fig. 10-17, view A). If you are left-handed, hold the reel in your right hand with the ends of the spiral wires at the top, pointing toward the left.

Hold the film by its edges in your right hand and bow it between your thumb and forefinger. With your left index finger or thumb, depress the grip clip and gently push the end of the film into the core of the reel (fig. 10-17, view B). When the reel does not have a grip clip, insert the film end about 1/4 to 1/2 inch into the reel core and hold it there with your left thumb and index finger (if right-handed). Remember, always load the reel with the film emulsion facing in, or toward, the reel core. Be sure the film is held straight at the reel center (fig. 10-17, view C).

Now turn the reel smoothly in a counterclockwise direction with your left hand, and guide the film into the spiral grooves with the thumb and forefinger of your right hand (fig. 10-17, view D).

- Third method. Slowly unwind the paper backing from the film until you feel the film with your finger. Do not completely unwind the paper backing from the film.

Figure 10-16.—Leading 35mm film on wire reel.
For 35mm film, if the film was not completely rewound into the cassette, cut the tongue off and leave the film in the cassette.

Hold the reel to be loaded in your left hand with the spiral wire ends at the top, pointing toward the right. Allow about 3 more inches of the paper backing to unroll. Bow the film and place it straight into the reel core. Smoothly and slowly turn the reel counterclockwise, guiding the film onto the reel. Allow the paper backing to unwind as the film is wound onto the reel.

When all but about 3 inches of the film is on the reel, you will feel the end of the film taped to the paper backing. With 35mm film in a cassette, the film stops unrolling from the cassette when the end is reached.

When you feel the tape or the end of the film is about 3 inches from the reel, carefully separate the film from the paper backing or cut the 35mm film right next to the cassette, being careful not to pull the film from the reel. Finish loading the reel.

The paper backing on 220 roll film does not run the full length of the film as does 120 film. The paper backing on 220 film serves as a leader and trailer that are taped to the ends of the film. Therefore, when using the third method described above, you must remove the paper trailer from the film before loading the reel.

Before processing film using a reel, you must practice loading it by using a roll of practice film in white light, then repeating the procedure in total darkness until you feel comfortable and do not damage the film. Only after you have the reel(s) loaded properly, should you think seriously about processing.

When a roll-film tank is used to process fewer rolls of film than the tank can hold, you must take up the extra space in the tank with enough empty reels to fill the tank. The empty reels go into the tank on top of the reels holding the film. When you are pouring solutions into the tank, completely cover ALL the reels in the tank.

When processing with a roll-film tank that has a lighttight cap, you can add or dump the chemicals without removing the cover. Only one tank is needed because the required solutions are poured out of and into the tank through the tank cover during processing. This can be done in white light. The chemicals should be arranged in the darkroom sink from left to right (developer, stop bath, etc.) and be
brought to the correct processing temperature in a water bath (fig. 10-18).

A clean, dry area should be provided on the work counter for loading the film onto the reels. The following steps are used to process roll film in small tanks:

1. Load the reel or reels with the film to be processed.

2. Place the loaded reels into the tank. If the loaded reels do not come to the top of the tank, add empty reels to take up the space. Place the cover and cap on the tank. The lights may now be turned back on. Once the lights are on and before the film is fixed, be careful not to remove the tank cover or the film will be exposed to light and ruined.

3. Hold the tank in one hand and tilt it slightly; pour the developer directly from the graduate into the tank through the light trap pouring hole. Pour as fast as you can without spilling. As the developer nears the top of the tank, hold the tank level or set it in the sink. Fill the tank to just overflowing. This step should take about 10 to 20 seconds, depending on the tank size.

4. Once the tank is full, immediately start the timer, replace the cap, and strike the tank on the edge of the sink once or twice to dislodge any air bubbles. Now agitate the film by inverting the tank slowly end to end (fig. 10-19). The initial agitation should be 30 seconds. Place the tank in the sink on its bottom (cover up).

5. Once every minute, agitate the film for 5 seconds by slowly inverting the tank end to end. After each agitation cycle, place the tank back in the sink. If you are holding the tank during the entire developing period, the heat from your hands may heat the developer and produce unpredictable results.

6. When only 10 seconds of developing time remain, remove the cap from the tank cover. Immediately start pouring the developer out of the tank through the light trap pouring hole. Dump the chemicals according to local instructions of the imaging facility. This step should take about 10 seconds to complete.

7. When the developer has been emptied from the tank, fill the tank to overflowing with stop bath. The stop bath must be poured into the tank through the light trap pouring hole in the tank cover. Replace the cover cap. Agitate the film in the stop bath for about 30 seconds using the end-for-end method.

8. When the stop bath portion of the process is complete, pour the stop bath through the light trap pouring hole in the tank cover.

9. With the tank cover still in place, pour fixer into the tank and replace the cap. Dislodge the air bubbles and set the timer to the required fixing time. Start the timer and agitate the film using the same agitation as the developer.

10. When the prescribed fixing time has elapsed, remove the tank cover and pour the fixer from the tank back into the bottle from which it came. Never pour the
11. The film can be washed either in the tank or in a roll-film washer. When the tank is used, insert a hose down through the center of the reels until it is about 1/2 inch from the bottom of the tank. Adjust the water (at the same temperature the film was processed) so a steady overflow is created. Wash the film for about 20 minutes. When you use a rapid roll-film washer, again, adjust the water temperature and place the reels containing the processed film into the washer. Adjust the rate of water flow until the reels start to turn. When the reels start to turn, adjust the rate of water flow until the reels stop turning. Set the timer and wash the film for about 5 minutes.

12. While the film is washing, rinse the processing tank, tank cover, and cap with clean water. Fill the tank with water (check the temperature) and add the wetting agent. After the film has been washed, place the film, still on the reels, into the wetting agent solution. Replace the tank cover and cap and agitate the film in the wetting solution very S-L-O-W-L-Y for 1 minute.

13. After 1 minute in the wetting solution, remove the loaded film reels from the tank. (Do not save the wetting solution.)

14. To dry the film, attach the end of the film to a film clip in the drying cabinet. Let the film unwind from the reel as you slowly lower the reel.

When the film is unwound, depress the grip clip (if the reel has one) or remove the film from the core of the reel. Squeeze the film and attach a second film clip to the lower end of the film. Close the drying cabinet door and dry the film.

Photographer’s Data Sheets

Sometimes a photographer’s data sheet will accompany film that enters your imaging facility to be processed. The photographer's data sheet will provide you with information on how the film was shot, lighting conditions, and specific processing instructions. When a photographer's data sheet accompanies the film or job order, you should process the materials specified by the form.

Cleaning Up

After processing, the darkroom and all equipment must be cleaned up immediately. Rinse thoroughly all processing equipment: tanks, reels, hangers, thermometers, funnels, and so forth, in clean, warm water. Place the clean equipment where it can dry before it is needed for the next processing run. Always keep the processing room shipshape.

REVERSAL PROCESSING

Normal processing of black-and-white film produces a negative; from this negative, a positive is made. However, by using the reversal process, you can produce a positive image directly on the black-and-white film.

In the reversal process, a negative image is first obtained by developing the original latent image in a developer that contains a silver halide solvent. This developer dissolves some of the excess silver halides. After leaving the developer, the negative image is dissolved away in a bleach bath. The silver halides remaining are chemically “exposed” (fogged) and developed by a second developer that provides the positive image.

Not all black-and-white films reverse well. Films that reverse well are Kodak Direct Positive Panchromatic Film 5246 (35mm), T-max 100 Direct Positive Film, and Kodak Technical Pan Films (35mm). Instructions for reversal processing of these films can be found in the Photo-Lab-Index.
COLOR PROCESSING

Color adds realism to photographs. At one time color was difficult to work with. It required special cameras and specialized films that could be processed only by the manufacturer of the film. Now, color materials have been improved and are used extensively in the Navy. They are far more popular than black and white.

As discussed in chapter 2, color films have at least three emulsion layers. Primary colors affect one emulsion layer only, while complementary colors affect two emulsion layers; for example, the color cyan affects the blue and green sensitive layers. White light affects all three emulsion layers. Black has no effect on any layer. The type of process used depends on whether the film is a negative type of film or a reversal (slide) film. The most common processes used in the Navy are Kodak Flexicolor for color negatives and Kodak Process E-6 for color reversal films. The Eastman Kodak Company continually strives to improve their processes by making them more environmentally safe. Always consult the Photo-Lab-Index for the most current information concerning film and paper processes.

COLOR NEGATIVE PROCESSING

In negative color film, the dye couplers produced are complimentary to the primary colors of light; therefore, a blue light records as yellow, a green light records as magenta, and a red light records as cyan. All colors within a scene are recorded through varying combinations of these yellow, magenta, and cyan dyes. The color negative is a halfway stage to a color print.

The cyan and magenta dye image layers formed by color processing absorb some light wavelengths that should be transmitted. In negative color film, these absorbed wavelengths of light cause a color cast when printed. To prevent this color shift, the manufacturer has given the green and red sensitive emulsion layers a yellowish and pinkish tint, respectively, during manufacturing. These tints are what form the overall orange mask that you see in finished color negatives. Some color film used for aerial photography does not have this orange mask. This allows for a direct interpretation of the negative image. An orange-masking filter is added when these films are printed.

The Kodak Flexicolor process is used for processing color negative films and some monochrome film, such as Ilford XP2. There are four chemical steps and two wash cycles in the Flexicolor process. They are as follows: color developer, bleach, wash, fix, wash, and stabilizer.

Color Developer

The first step in color negative processing is color development. A color developer in color processes works nearly the same as a black-and-white developer. The exposed silver is developed by a developing agent and converted to metallic silver and by-products are released. As the color developer is working at developing the silver, it becomes oxidized and reacts with nearby dye couplers. Dye couplers are built into the emulsion around all of the metallic silver sites. The primary function of a color developer is to develop the exposed silver halide crystals to metallic silver and then form dye around the metallic silver, using the oxidized color developing agent.

Temperature of the color developer is the most critical of all the processing steps. The temperature of the color developer must be 100°F ±0.25°F (37.8°C ±0.15°C). All other wet steps in the process can be within the range of 75°F to 105°F (24°C to 41°C); however, it is best to maintain all solutions at constant temperatures.

Bleach

Bleach is found in all color processes. The purpose of the bleach is to take the metallic silver still in the color film (or paper) and convert it to a form that can be fixed. In color products, all of the silver must be removed. Only the color dyes form the image. The bleach chemically converts the silver metal back to a soluble silver halide.

Fixer

The function of fixer is the same in color processes as it is in black-and-white processes. A fixer converts the silver halide to a water soluble form. Most fixers use thiosulfate as the fixing agent in an acidic solution. When fixing is incomplete, unwanted silver remains in the image. This causes a loss in contrast, added density, and an unwanted color cast.

Stabilizer

The final wet step in color negative film processing is the stabilizer. The main purpose of this solution is to provide a wetting agent to prevent spotting of the film and to prevent unused magenta dye couplers from attacking the newly formed magenta dye.
Unlike black-and-white film processing, color negative film cannot be “push processed” successfully; therefore, you must choose a film with an appropriate film speed for the lighting conditions in which you photograph your subject.

COLOR REVERSAL FILM PROCESSING

Color transparency film forms dyes according to a reversed silver positive; for example, a yellow dye image forms in the top emulsion that corresponds to an absence of blue in the original scene. This yellow dye subtracts blue light. A blue image is formed by magenta dye (minus green) and cyan dye (minus red), thus leaving blue. In color transparency film, the dyes subtractively produce a correct color positive image of the scene photographed.

The Kodak E-6 Process is used in the Navy for processing color reversal film. There are seven chemical steps and two wash cycles in the Kodak E-6 Process. They are as follows: first developer, wash, reversal bath, color developer, prebleach, bleach, fixer, wash, and final rinse.

The first chemical step is the first developer. The first developer is a black-and-white developer that converts the exposed latent image in each emulsion layer to a metallic silver. Like black-and-white negative processing, after the film leaves the first developer, there are undeveloped areas where the silver halides are unaffected by camera exposure. It is these undeveloped areas that the final color positive images are formed in reversal film.

After the first developer, the film is chemically fogged or “re-exposed” in the reversal bath. The reversal bath exposes the silver halides that were not developed in the first developer. This re-exposure is what forms the positive image. After 1 minute in the reversal bath, the normal room lights can be turned on.

After fogging, the film is developed in a color developer. The color developer works the same way in color reversal processing as it does in color negative processing. It changes the fogged silver halides to black metallic silver and at the same time, cyan, magenta, and yellow dye couplers are formed by the exhausted developer.

At this stage the film looks completely black because the formed dyes are shielded by the developed silver. The film is then placed in a prebleach. The prebleach prepares the film for the bleach and also stabilizes the dye layers.

The metallic silver is removed by the bleach and fixer processes. The bleach and fixer work the same way as they do for color negative processing. After the silver is removed, only the dyes remain, forming the image.

The film is then washed to rinse away any remaining chemistry and soluble silver. The last chemical step in the E-6 process is the final rinse. Final rinse provides a wetting agent to aid in uniform drying.

It is possible to “push process” (underexpose and overdevelop) or “pull process” (overexpose and underdevelop) most color reversal film; however, some sacrifice in quality results in "push processing." Less detail in the shadow areas (weaker blacks), less exposure latitude, and noticeably increased grain occur when color reversal film is "push processed." When the film speed is altered, only the first developer time is changed. All other chemical steps remain the same. You should not exceed two f/stops when you intend on “push” or “pull” processing.

MACHINE PROCESSING

Today most film processing is performed by machine, especially in larger imaging facilities. Machine processing has many advantages compared to hand processing. Machines can process high-volume production more efficiently and more consistently compared to hand processing. When machines are used, the variables involved in processing can be controlled more easily. Time, temperature, and agitation can be kept constant if the machine is properly maintained and operated properly. With fully automatic processing machines, all you must do is feed the film or paper into the machine and retrieve the finished product.

When there are advantages, there are also disadvantages to machine processing. Machines require maintenance, can jam, occupy precious shipboard space, and may require special plumbing, ventilation, or power requirements. The need for proper maintenance is most critical. Poor equipment maintenance is probably the major cause of machine processing problems. Therefore, it is very important for scheduled preventive maintenance to be performed properly on all imaging equipment, especially automatic processors. The best images captured by a camera are not of any use if they are not processed correctly and without defects. You must be qualified completely in the Planned Maintenance System (PMS) to become a valuable member of an imaging facility.

In a high-volume production facility, the advantages of automation far outweigh the disadvantages. There are
numerous automatic processors available on the market today. Two types of machine processors are commonly used in Navy imaging facilities. They are the rotary drum and the roller transport type of processors.

**ROTARY DRUM PROCESSOR**

The semiautomatic processor most commonly used in Navy imaging facilities is the Image Maker, manufactured by the King Concept Corporation. When this type of processor is used, film and paper are processed in a lighttight canister. Before being processed, the material must first be loaded on stainless steel reels for roll film or in a plastic basket for sheet film or paper. Depending on the setup of the processor, the holding tanks are either filled with chemicals manually, or they may be filled automatically. The solutions are then automatically added to and dumped from the processing drum. The time, temperature, and solution steps are all controlled by a computer. After the material is processed, it is then removed from the drum, squeegeed, and dried.

The advantages of a rotary drum processor is it is of relatively low cost, small in size, and can run many different processes through the same machine. The major disadvantage is that the chemicals are dumped instead of replenished which is not environmentally sound and can be costly.

**ROLLER TRANSPORT PROCESSOR**

Automatic processors commonly use roller transport systems. When you are using these machines, the material being processed moves at a constant speed by friction. The materials are guided through the processing solutions by a series of rollers and rack assemblies. On many processors, a leader tab must be attached to the beginning of the roll to aid in pulling the film through the machine.

The size of the solution tanks and the length of the path through the solution determine how long the material must remain in each solution (processing time). On some automatic processors, the finished, dried, processed material leaves the processor and is then automatically cut and sorted.

Roller transport processors contain two major sections: the wet section and the dryer section. The wet section contains the developer, fixer, and wash tanks. The film is then transported through a squeegee assembly and enters the dryer.

Many different types of processors are used throughout the Navy. Each type has specific installation,
operation, and maintenance instructions supplied with it. Therefore, in this section only general information that applies basically to any machine processor is discussed.

**TRANSPORT SPEED**

Most black-and-white automatic film processors have a variable speed operation. Unlike hand processing where developing time is measured in minutes and seconds, machine processing developing times are measured in feet-per-minute (fpm). Both methods measure the length of time the material is affected by the developer and other solutions. Most color processors have a set machine speed that can only be adjusted slightly because color materials must be processed to specific parameters so processing cannot be manipulated.

The time the solutions are allowed to act on the film or paper is a result of the speed that the machine moves the sensitized material and the length of time the material is immersed in a particular tank. Most machines have an fpm indicator that shows the set speed of the processor. The temperatures of solutions and the specific number of feet in each section of the machine are usually constant factors. It is the rate the paper or film travels that determines the total processing time; for example, if the speed is set to 10 fpm and the total roller path in the developing tank is 30 feet, a certain point on the material being developed takes 3 minutes (30 ÷ 10).

Regardless of the machine speed, film or paper cannot be processed faster than the total required solution times. For example, you are processing film that requires a processing and drying time of 10 minutes and 20 seconds. When the machine is processing this film, it takes 10 minutes and 20 seconds before the first foot of film leaves the dryer. However, the total time to process the entire roll is related to the speed of the machine and the total length of the material. For example, if the machine speed is 10 fpm and the roll is 10 feet long, the film takes 10 minutes, 20 seconds, plus 1 minute (10 ÷ 10). With a 200-foot roll, access time is 10 minutes, plus 20 seconds, plus 20 minutes (200 ÷ 10), or a total of 30 minutes, 20 seconds. It is important for you to know the access time of the processor. When the material being processed does not exit the machine in the required time, a machine malfunction or jam is evident.

**WATER TEMPERATURE AND FLOW RATE**

Wash water is an important processing consideration. Not only is the water temperature important but also the flow rate of the water. Two factors that must be considered are as follows: sufficient flow to ensure
complete washing of the material and to control or eliminate waste.

If the wash-water temperature is allowed to drop to 65°F (18°C) or below, emulsion staining may result. As the temperature decreases, less emulsion swelling occurs, reducing the effective penetration of fresh water supplied to the emulsion. When the emulsion does not swell, the chemical-laden water does not get out through the emulsion surface. These retained chemicals can cause stains.

The wash water flow rate is another important factor to consider. This rate must be high enough to wash the material, but no more. When insufficient water flow is supplied to the machine, crystallized chemicals may be seen on the material, and additional staining can result. You must not adjust the water flow rate higher than is needed. A few extra gallons-per-minute flow rate may not seem important; however, over time this effect can be extremely costly, particularly aboard ship.

**SOLUTION TEMPERATURE**

In machine processing, the temperature may vary, depending on the machine and the kind of processing being performed. High-speed processing machines operate at higher solution temperatures. Temperature control is critical and must be maintained to produce correct results. Although this may be considered a variable factor, the temperature is controlled automatically by processing machines. In some machines, the solution tanks are immersed in a temperature-controlled water jacket. By controlling the water temperature within the water jacket, you can control the temperature of the solutions inside the tanks. In other machines, the solution temperature is directly controlled by separate heaters or heat exchange control units in the recirculation system. A temperature probe in the solution tank monitors and controls the temperature control unit.

**SOLUTION LEVELS**

The solution levels of a processor must be checked before processing material. If the solution level is too low, stains, improper tracking, and roller marks may affect the film or paper. When the machines are shut down for a period of time, some evaporation occurs. Since only the water from the solution evaporates, you must top off the solution tanks with water before processing material. There is a certain amount of carry-over of solution from one tank to another within the machine. Usually, chemical carry-over is minimized with roller squeegees. When the replenishment rate of the processor is set properly, this carry-over is compensated by supplying fresh chemistry to the solution tanks.

**REPLENISHMENT**

Most processing machines use relatively large quantities of solutions to carry out the process properly. However, even considering the large quantities involved, certain chemical components within a given solution are used up at varying rates. In addition, there are certain reactions that form by-products that build up in the tank of the processor; for example, bromide (a restrainer) gradually builds up in the developing solution. Also, there is a certain amount of carry-over of solutions from one tank to another. This causes a continuous change in solution strength and solution purity. The replenisher solution replaces the used chemicals, dilutes the excess chemicals or by-products that have built up, and replaces the solution lost by carry-over and evaporation.

The replenishment system used in machine processing is called the bleed method. When the bleed system is used, a calculated amount of replenisher solution is added and forces some of the used solution out through an overflow drain in the solution tank. You must check the established replenishment rates as well as the replenisher holding tanks before and during processing. Inconsistent results occur when the process is not replenished correctly.

**DRYER TEMPERATURE**

After the material is processed and washed, it continues through the machine into the drying cabinet where moisture is removed. The drying cabinet is more than a heated compartment for the processed material. In a majority of machines, both the temperature and the humidity of the cabinet are carefully controlled. Too little drying causes the emulsion to be tacky, whereas too much drying may produce excessive curl and brittleness. Brittleness, once it occurs, cannot be eliminated; so it must be prevented. Both the temperature and the relative humidity must be adjusted for the speed of the machine and the type of material being dried.

Under ideal conditions, the drying cycle should yield a stable 50 percent relative air humidity. To lower the relative humidity of air, you must heat the air; this accelerates the evaporation of moisture. The rate of evaporation and the relative humidity are directly
proportional to the temperature. When the temperature is too low, evaporation is slowed down. When it is too high, the emulsion may be damaged.

Roller transport processors provide very consistent processing results and can be converted easily to a new process. The disadvantages of roller transport processors are: they can leave scratches and scuffs from dirty rollers touching the film, they require a high amount of maintenance due to the large number of moving parts, and oxidation can be a problem due to the churning action of the rollers in the chemistry.

QUALITY PROCESSING

The processing required to produce a quality product of any particular film varies with different developer and film combinations, time and temperature of the process, agitation, the film exposure, and the skill of the darkroom worker. A good, high-quality image is one that is free from all processing faults, including scratches and dirt, and so forth.

When processing black-and-white film, your goal is to produce a “normal” negative that is as fault-free as possible. Normal is a rather vague term; however, a normal negative is one that yields a pleasing print or reproduction of the original scene when printed without a printing filter or with a No. 2 printing filter.

When film is exposed and processed properly, it is a normal negative. However, when a negative varies from normal, you should be able to determine what conditions caused the deviation.

A negative has several basic characteristics to consider when evaluating quality. These basic characteristics are as follows:

- General negative density or opacity to light.
- Image highlights or areas of greatest density.
- The shadows or areas of least density.
- Contrast or the differences between highlight and shadow densities.
- Tonal gradation or the range of grays between the highlights and the shadows.
- Graininess or the appearance of silver grains in a negative that have clumped together. The size of the clumps determines the degree of graininess in the processed material.

All the basic characteristics of a negative are affected to some extent by a combination of exposure and development. By studying these characteristics, you can usually determine the cause of an error or poor quality in a negative.

DENSITY

Density determines how much of the incident light falling upon a negative passes through the image. When a small amount of silver is present in the negative, the image appears thin (transparent), and it has low density. When there is a large amount of silver present, only a small amount of light passes through the image, and the negative is said to have high density.

A low density, thin negative can be caused by underexposure or underdevelopment or by a combination of the two. A heavy or dense negative is the result of either overexposure or overdevelopment or a combination of the two.

HIGHLIGHTS

The highlights, or dark areas, of a negative for most purposes should not lack detail. When detail is lacking because the highlights are too dark, the highlights are too dense or blocked up. Excessive highlight density is caused by overexposure and/or overdevelopment. When both the highlights and the shadow areas are too thin and lack detail, the negative is probably underexposed. Thin highlights are caused by underexposure and/or underdevelopment.

This may seem like a repetition of the previous discussion on density. However, a negative could and may have overall good density except in the highlight areas. This situation is a result of exposure latitude that is not great enough for the scene brightness range.

SHADOWS

The shadows, or the more clear areas of the negative, also should contain image detail. If these areas are so thin and weak that they are transparent or nearly so, the shadow areas are said to be lacking in detail. Loss of shadow detail is caused normally by underexposure.

The need for detail in both the highlights and the shadows for photographs of most subjects cannot be stressed too strongly. One is as important as the other in the production of good photographs.

CONTRAST

Contrast is the difference in density between the highlights and the shadows in a negative. When this
difference is great, the negative is said to be contrasty. When the density difference is small, the negative is said to be flat or lacking in contrast.

For a negative to have normal contrast, the density differences between the highlight and shadow areas of the negative must be proportional to the reflective brightness range of the subject photographed.

A contrasty negative usually is the result of overdevelopment but also may be caused by a high scene lighting ratio (a contrasty original scene). A flat negative, on the other hand, may be caused, primarily, by underdevelopment or a low-contrast original scene.

TONAL GRADATION

Photographers often concentrate on the density and detail of highlights and shadows when they should actually be considering the most important or middle tones of the negative. Middle tones are the various tones of gray between the highlights and the shadows; that is, the densities that are not highlights or shadows are termed middle tones or intermediate tones. The middle tones vary with the type of film and the subject contrast.

A negative should have a range of middle tone densities that correspond proportionally to the middle reflective brightness of the subject. A panchromatic negative that does not have proportionate midtones is contrasty or flat.

GRAININESS

Because photographic images made from film are made up of fine silver grains, the images may appear “grainy” or exhibit graininess.

All negatives show graininess to some extent. The most important factors affecting negative graininess are as follows:

- The composition of the emulsion or the inherent graininess of the emulsion. That is to say, the size of the grains used to produce the emulsion.
- The type of developer used. When fine grain is desired, a fine-grain developer with the appropriate film should be used.
- The extent of development. Overdevelopment is a major cause of excessive graininess.
- Exposure or negative density. Overexposure is another key contributor to graininess. As negative density increases, so does graininess.

Figure 10-22—Grain structures in emulsions.

- Image sharpness. The sharper the film image, the greater the image detail and the less apparent the graininess.

EFFECTS OF EXPOSURE AND DEVELOPMENT VARIATIONS

The nine negatives reproduced in figure 10-23 compare the effects of exposure and development variations. From the left, they show the effects of development; from the top, they show the effects of exposure. The center negative has been given both correct exposure and normal development and is a “normal” negative that will print without a filter or with a No. 2 filter.

Negatives 1, 4, and 7 have been underdeveloped, while 3, 6 and 9 have been overdeveloped.

The negatives across the top—1, 2, and 3—are underexposed and lack detail in the shadow areas. Increasing development (No. 3) had no appreciable effect on the lack of shadow detail. Little can be done to improve negative quality when exposure is insufficient. Underexposure is identified by lack of shadow detail.

The negatives across the center—4, 5, and 6—were given correct exposure and all have sufficient shadow detail. However, No. 4 was underdeveloped and is flat or lacks adequate contrast. Negative No. 5 received normal development, has good shadow detail, and good contrast. It is a “normal” negative. Negative No. 6, although having received correct exposure, was overdeveloped. This resulted in excessive highlight density with a loss of highlight detail and excessive contrast. The highlights in both 6 and 9 are too dense.

Negatives 3, 6, and 9 are all overdeveloped. The correctly exposed negative, No. 6, is so dense that almost no detail is visible in the highlights. The highlights of the overexposed and overdeveloped negative, No. 9, are completely blocked up.

When a correctly exposed film is given normal development as in negative No. 5, the negative has
Figure 10-23.—Exposure and processing affects.
clearly defined detail in all parts of the image from the strongest highlights to the weakest shadows. The contrast is satisfactory. It may not reproduce the contrast of the original scene exactly, but it has sufficient contrast to produce a pleasing reproduction.

When the film is overexposed and normally developed, as in No. 8, the highlights in the image show a loss of detail. Giving the overexposed film less than normal development may save some highlight detail, but it also reduces the contrast. When the overexposed film is overdeveloped, as No. 9 was, all highlight detail is destroyed and the contrast is also reduced.

Table 10-1 is a listing of defects that commonly occur in film processing. The appearance, the cause, and the remedy for each of the defects listed are also provided.

<table>
<thead>
<tr>
<th>Defect</th>
<th>Appearance</th>
<th>Cause</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrasion marks or</td>
<td>Fine black lines, usually resembling pencil scratches and running in the</td>
<td>Friction on emulsion caused by improper handling or storage. Dirt, or grime, in camera or</td>
<td>Great care should be taken in storage of film. Boxes containing film should be stored on end,</td>
</tr>
<tr>
<td>streaks.</td>
<td>same direction.</td>
<td>magazine.</td>
<td>so no pressure is exerted on the surface of the emulsion. Care, also, should be taken not to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>rub or drag sensitized material over a rough surface. Be sure camera back or magazine is clean</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>and free from dirt, or grime.</td>
</tr>
<tr>
<td>Air bubbles.</td>
<td>An air bubble occurring during development shows as a small, transparent</td>
<td>Transparent spots occurring in the developer are caused by bubbles of air on the surface</td>
<td>Immerse film carefully and thoroughly in developing and fixing solutions. Move film during</td>
</tr>
<tr>
<td></td>
<td>spot. Sometimes minute dark streaks lead from the spot. When the negative</td>
<td>of the emulsion. These prevent the developer from coming into contact with the emulsion.</td>
<td>development and fixation to break up and prevent air bells. Water always contains some air</td>
</tr>
<tr>
<td></td>
<td>is rocked in a tray, streaks project from each side of the spot in the</td>
<td>Darkened streaks are the result of excess oxidation of the developer, caused by air in a</td>
<td>and when there is a rise in temperature, air is expelled and gathers in the form of small</td>
</tr>
<tr>
<td></td>
<td>direction the tray was rocked. If the tray is rocked in two directions,</td>
<td>bubble. Dark spots that occur in the fixing bath are caused by a pocket of air holding the</td>
<td>bubbles on the inside of the tank and also on the surface of the film during preliminary</td>
</tr>
<tr>
<td></td>
<td>streaks form a cross with a transparent spot in the center. In tank</td>
<td>fixer away from the emulsion and allowing a slight continuation of development.</td>
<td>stages of development.</td>
</tr>
<tr>
<td></td>
<td>development, dark streaks usually form at the lower edge of the transparent</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>spot. In the fixing bath they show as small, round, dark spots.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defect</td>
<td>Appearance</td>
<td>Cause</td>
<td>Remedy</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Blisters.</td>
<td>They resemble the familiar ones that are caused by slight bums on human skin.</td>
<td>Liquid or gas formed between the emulsion and film support when the solution has become too warm and has loosened the gelatin from its support. Also, produced by developer and fixer being too strongly concentrated. Changing film from one bath to the next may cause the formation of gas between the emulsion and support. Frequently caused by taking the film from an alkali solution and placing it into a strong acid. Another common cause is allowing water from a faucet to flow directly on the emulsion.</td>
<td>Blisters can be avoided by eliminating their causes.</td>
</tr>
<tr>
<td>Brown spots.</td>
<td>Small brown- or sepia-colored areas or spots on the negative.</td>
<td>Produced by oxidized developer or by fine particles of chemicals settling on the film before development. May also occur during washing, from rust, and other impurities in the water.</td>
<td>Avoid exhausted or oxidized developer. Keep processing room clean and free from dry chemicals. Filter the wash water.</td>
</tr>
<tr>
<td>Crystalline surface.</td>
<td>Surface of the negative emulsion has a crystalline appearance, resembling frost on a windowpane.</td>
<td>Insufficient washing after fixing. Hypo remains in the film and crystallizes.</td>
<td>Increase the final wash time.</td>
</tr>
<tr>
<td>Dark lines.</td>
<td>These lines are divided into two distinct classes. The first class, those that run from dark areas to more transparent areas of the negative, and the second class, those that run from the more transparent areas to the darker areas. In both cases, lines are wider, not as clean cut, and not nearly as parallel as abrasion marks.</td>
<td>The first class is caused by insufficient agitation of the negative in tank development. Cause of the second class is thought to be of an electrolytic origin.</td>
<td>For the first class, more frequent agitation during development. The remedy for this class aggravates the defect in the second class. Only known remedy is to remove all film hangers from the tank four or five times during the developing period, holding the hangers in a bunch, and allowing the corners of the hangers to rest on the edge of the developing tank for 10 to 15 seconds.</td>
</tr>
<tr>
<td>Defect</td>
<td>Appearance</td>
<td>Cause</td>
<td>Remedy</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Fading tendency.</td>
<td>Sepia- or yellow-colored stains or areas in the negative.</td>
<td>Incomplete fixation or insufficient washing causes fading. Remnants of the fixing bath left in the emulsion continues its action, and in time, this defect appears.</td>
<td>Properly fix and wash negatives.</td>
</tr>
<tr>
<td>Fingermarks.</td>
<td>Imprint of fingers shows up on negative.</td>
<td>Impressing wet or greasy fingers on the emulsion of film before or during development and fixation. If mark is merely an outline of the finger, it was caused by water or grease on the finger; if dark, it was caused by developer; if transparent or light, it was caused by fixer.</td>
<td>Keep hands clean and dry when handling film. Sometimes natural oil on the fingertips causes grease marks. When fingers become wet with water or solutions, wash and dry thoroughly before attempting to handle film.</td>
</tr>
<tr>
<td>Fog (Aerial).</td>
<td>A slight veiling of the negative or parts of the negative.</td>
<td>Negative exposed to air during development. Occurs most frequently in freshly mixed developers.</td>
<td></td>
</tr>
<tr>
<td>Fog (Dichroic).</td>
<td>Usually a fog of little density, consisting of finely divided particles of silver. When viewed by transmitted light, it is pinkish; when viewed by reflected light, it appears reddish green.</td>
<td>Hypo or excessive amount of sulfite in the developer.</td>
<td>Removed by treating the negative in a weak solution of potassium permanganate. Further prevention through use of clean tanks for developer and fixer.</td>
</tr>
<tr>
<td>Frilling.</td>
<td>Edges of the gelatin become detached from the base. Detached edge of emulsion may either break off or fold over.</td>
<td>Careless handling; using solutions that are too warm; insufficient hardening of emulsion due to insufficient fixation; exhausted fixing bath or one containing insufficient amount of hardener; or excessive washing. Frilling is usually caused by a combination of careless handling and any other mistake that will render the emulsion or film soft.</td>
<td>Handle film carefully and sparingly; use working solutions that are mixed correctly and are at the proper temperature. Wash film sufficiently, but never excessively.</td>
</tr>
<tr>
<td>Defect</td>
<td>Appearance</td>
<td>Cause</td>
<td>Remedy</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Air bubbles.</td>
<td>Minute pimples or blisters.</td>
<td>Develop by transferring the negative from strongly concentrated developer to strongly acid fixing bath without thoroughly rinsing after removing it from the developer and before immersing it in the fixing bath. In warm weather, air bubbles may appear even when using solution of normal strength, if rinsing between development and fixation has been insufficient.</td>
<td>Use an acid stop bath.</td>
</tr>
<tr>
<td>Pitmarks.</td>
<td>Fine holes or pits in emulsion.</td>
<td>Excessive alum in fixing bath; sulfurous precipitation from fixing bath when negatives are fixed in a tray; and film being dried too rapidly.</td>
<td>Proper fixing and drying.</td>
</tr>
<tr>
<td>Reticulation.</td>
<td>Leatherlike graininess or wrinkling of the emulsion.</td>
<td>Too great of a difference in the temperature of baths or between final wash water and the air in which the negative is dried. Gelatin may become badly swollen due to the temperature of a solution or wash water, and upon shrinking, contracts irregularly due to the metallic silver incorporated in the emulsion. Excessive softening of the emulsion followed by a strong hardening bath, or an alkaline treatment followed by strong acid.</td>
<td>Keep all solutions at the same temperature. Reticulation effect may sometimes be removed by placing the negative in a 10-percent solution of formaldehyde for a few minutes and then drying it rapidly with heat. Use ample ventilation when drying negatives treated in formaldehyde.</td>
</tr>
</tbody>
</table>
Table 10-1.-Negative Defects: Their Appearance, Cause, and Remedy-Continued

<table>
<thead>
<tr>
<th>Defect</th>
<th>Appearance</th>
<th>Cause</th>
<th>Remedy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Streaks.</td>
<td>Streaks and patches. In the case of spots, may be dark, white, or transparent.</td>
<td>May be due to uneven development, caused by insufficient agitation. May also be due to developer splashed on the film before development, a dirty tank, fixer tray or tank used for developing, or a light fog. If the edges of the film are clear, trouble is in the camera; if the edges are fogged, it is due to a light leak in the film magazine or processing tank. Certain types of resinous woods and varnishes cause dark patches. White or transparent patches may be due to obstructions in the camera that prevented light from acting on the film; an oil or grease that prevented action of the developer; hypo on film before development. Drying marks in the form of teardrops or white patches are caused by splashes of water on a dry negative or by leaving spots of water on the film before drying, especially if the film is dried in warm air.</td>
<td>Trace the cause of the streaks. In many cases, they can be avoided in the operation and maintenance of equipment. When drying negatives, be sure to use wetting agent or stabilizer.</td>
</tr>
</tbody>
</table>

**PROCESS MONITORING**

To consistently produce the highest quality photographic products possible and to prevent chemical processing defects, you must monitor the photographic processes. From a hand-processing system to a sophisticated, computerized processing system, process monitoring is necessary to achieve high quality on a consistent basis. When it is performed routinely, process monitoring can detect minor problems before a major casualty to your imagery results as well as aid in the proper replenishment of your processing system.

The area of quality control and process monitoring can be very complex. Some Navy Photographer's Mates earn an NEC and specialize in the field of quality control for photographic processes. It is not the intention of this training manual to provide you with the information necessary to become a specialist in photographic quality control; however, you must learn the appropriate steps to monitor the process.

The production of high-quality photographic products requires control over all the factors that affect light-sensitive materials. Film exposure and processing are the most important of these factors. Negatives or positives that have not been uniformly and correctly exposed and processed may provide unusable results. By monitoring the process and providing high-quality products, you can save time and operating costs by reducing waste and retakes.

Any monitoring system for the photographic process requires a reference or standard, and comparison of daily production to this standard. Visual comparison of the reference to the standard is very subjective and limited in accuracy because of personal opinion. A more accurate method is to measure your production against the standard. Two means of making
these measurements are through sensitometry and densitometry. When sensitometry and densitometry are used, variations from the standard and the corrections recommended are expressed in numbers, not in terms of personal opinion.

SENSITOMETRY

Sensitometry is the science of determining the photographic characteristics of light-sensitive materials. In sensitometry, special test or control strips are prepared by accurately exposing the material with varying amounts of light. These test strips are then processed.

A sensitometer is an instrument used to produce the special test strips called sensitometric strips. A sensitometer is used to produce these sensitometric strips because it provides consistent and repeatable exposures of a known quantity and quality of light. The sensitometer is used to expose a strip of film with varying amounts of known exposure on the same strip of film. Since the sensitometer provides repeatable exposures each time, any changes in density indicates a change in processing. In Navy photography, the sensitometer is used to expose black-and-white materials only. There are several uses for sensitometric strips; but in this training manual, we are only concerned with monitoring a process. Here the sensitometric strips are used as control strips. Control strips are made and processed under the controlled conditions of time, temperature, and agitation. This is true for both black-and-white and color materials. Black-and-white control strips are usually made in the photo lab, while color control strips are obtained by the manufacturer of each material.

Ideally, a sensitometer should be designed so you can accomplish the following objectives:

1. Predetermine the total amount of exposure.
2. Determine the difference in exposures given to various areas.
3. Control the color quality of the light.
4. Consistently reproduce or duplicate the same lighting conditions.
5. Provide a wide range of exposures.

The sensitometer used most commonly in the Navy today is the Egerton, Gerkeshausen, and Grier (EG&G) sensitometer [fig. 10-24]. This sensitometer uses a
Step Tablets

A sensitometer is set up to make only one exposure. In order to provide a range of exposures, a step tablet is placed between the light source and the light-sensitive material. The step tablet is a strip of neutral-density filters in equal increments, ranging from 0.05 to 3.05. This range provides a 10 f/stop range. The most common step tablets are as follows [fig. 10-25]:

1. 21-step tablet-1/2 f/stop between each increment.
2. 11-step tablet-1 full f/stop between each increment.

Control Strips

A sensitometric control strip should be processed as a minimum—at the beginning of a production day (or shift), before any production is processed, and before shutdown. You should process a control strip just before an important mission, or a special-interest film is processed.

To expose and process a control strip, you should take the following steps:

1. Take the film (in a lighttight container) and place it next to the sensitometer.
2. Turn on the sensitometer and allow it to warm up for a minimum of 15 seconds.
3. Turn off the room lights.
4. Place the film emulsion-side down on the sensitometer and lower the platen to make your exposure.
5. When hand processing or using a rotary tube type of processor, load the control strip on the reel. When machine processing, replace the film in a lighttight container. Turn on the room lights and turn off the sensitometer.
6. When a roller transport processor is used, check the speed, temperatures, and the proper operation of all systems.
7. Stick the film into the processor so the lightly exposed end of the film enters the machine first. When hand processing or using a rotary tube type of processor, process normally.
DENSITOMETRY

A densitometer is an instrument used for measuring and reading the density of film and paper directly. Film is read on a transmission densitometer, and paper is read on a reflection densitometer. Most densitometers supplied by the Navy today have both transmission and reflection reading capabilities on the same meter [fig. 10-26].

A densitometer uses a photoelectric cell to measure the light transmitted through film or reflected from paper electronically. Before a densitometer can be used, it must be checked and calibrated against a reference standard. To use the meter, you must place the material to be measured, emulsion-side up, in the light beam between the source and the photocell. The density reading is then read directly from the meter.

There are several sets of filters incorporated in the head of the densitometer. When you are reading black-and-white materials, the yellow filter must be in place. When color materials are read, there are two different sets of filters that are used. They are Status A and Status M filters. Status A filters are used to read color transparencies and prints. Status M is used to read color negative film that has an orange mask.

Only certain steps of the control strip are read. The steps that you are required to read are established by the manufacturer of the material or are established by the quality control technician within your imaging facility. When you are reading the steps on your control strip, be sure that the emulsion side is facing up and take the reading from the center area of each step [fig. 10-27].

PROCESS CONTROL CHARTS

A process control chart provides a visual representation of a process. Control strips that are processed and read on a densitometer are then plotted on a control chart. The points plotted on the graph indicate what has occurred in the process at the time the control strip was processed. Through the use of control charts, a determination can be made whether the process is operating normally. As stated before, only selected steps of a control strip are monitored. For black-and-white film, the minimum steps monitored are as follows: base plus fog (B + F) or gross fog, high density, low density, speed point, and contrast.

For each step monitored on a control chart, there are three lines. The center line represents the mean (X) (pronounced ‘bar X”), or average, a top line that represents the upper control limit (UCL), and a bottom line that represents the lower control limit (LCL).
Refer to Figure 10-28. For example purposes only, the following steps are monitored and plotted on a control chart below. The steps being monitored are as follows:

- High density (HD) is step 17 and reads 1.20.
- Low density (LD) is step 6 and reads 0.60.
- Speed point (SP) is step 4 and reads 0.23.
- B+F is 0.12.

When plotting a control strip, you should always annotate the date and the time the control strip was processed. When all points plot within the upper and lower control limits, the film can be processed. When any point plots outside the upper control limit (UCL) or lower control limit (LCL), the process is out of control. You should notify your supervisor before processing any material through that particular process.