# TM 11-401-1

ARTMENT OF THE ARMY TECHNICAL MANUAL

# ARMY PICTORIAL TECHNIQUES, EQUIPMENTS, AND SYSTEMS

# PICTORIAL FUNDAMENTALS



HEADQUARTERS, DEPARTMENT OF THE ARMY

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# ARMY PICTORIAL TECHNIQUES, EQUIPMENTS AND SYSTEMS
# PICTORIAL FUNDAMENTALS



* This manual supersedes so much of TM 11-401, 10 December 1953, including C 1, 28 June 1961, as pertains to pictorial fundamentals.

# CHAPTER 1
# INTRODUCTION

## Section I. GENERAL

### 1–1. Purpose and Scope

*a.* This manual is a guide for training military personnel in pictorial fundamentals. It presents material on the theory of light and optics, the camera, the principles of photographic exposure, characteristics of sensitized photographic materials, photographic chemistry, photographic processing, and pictorial operations under extreme climatic conditions.

*b.* The material covered in this manual is applicable without modification to both nuclear and nonnuclear warfare.

*c.* Users of this manual are encouraged to submit recommended changes or comments to improve the publication. Comments should be keyed to the specific page, paragraph, and line of the text in which a change is recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. Comments should be forwarded direct to the United States Army Signal Center and School, Fort Monmouth, N. J., ATTN: SIGOAO-2.

### 1–2. The TM 11–401 ( ) Series

The manuals listed below, when published, will form a progressive series of educational, training, and reference texts. They present the theory and application of pictorial operations.

*a.* TM 11–401–1, Army Pictorial Techniques, Equipments, and Systems: Pictorial Fundamentals.

*b.* TM 11–401–2, Army Pictorial Techniques, Equipments, and Systems: Still Photography.

*c.* TM 11–401–3, Army Pictorial Techniques, Equipments, and Systems: Cinematography.

*d.* TM 11–401–4, Army Pictorial Techniques, Equipments, and Systems: Photographic Laboratory Operations.

*e.* TM 11–401–5, Army Pictorial Techniques, Equipments, and Systems: Photographic Instrumentation.

*f.* TM 11–401–6, Army Pictorial Techniques, Equipments, and Systems: Sound Recording and Reproduction.

### 1–3. References

*a.* Appendix I lists other publications that contain information relative to the material presented in this manual.

*b.* Appendix II contains a glossary of terms that are commonly used in pictorial operations.

*c.* Appendix II contains formulas that are commonly used in pictorial operations.

*d.* Appendix IV and V contain tables that are commonly used in pictorial operations.

## Section II. THE PHOTOGRAPHIC PROCESS

### 1–4. General

*a.* The photographic process is the step-by-step chemical procedure common to all pictorial systems employing a camera and film. Accordingly, it is important for photographic personnel to understand pictorial fundamentals ranging from image recording to the production of a final print. With adjustments, this knowledge applies to both still and motion picture photography and any other special recording process utilizing an optical system, light, and a sensitized recording material.

*b.* In photography, an image is produced on sensitized material by some form of radiant energy. Three forms of radiant energy—light rays, infrared rays, and X-rays—are used as recording mediums. Light, the most obvious form of radiant energy, is the most easily understood. Characteristics of light, as they relate to the basic photographic process, are explained in chapter 2. Other forms of radiant energy are also discussed, but not in as much detail.

*c.* Excluding other forms of radiant energy, photography can be defined simply as *drawing with light.* A photographic can also be defined as the story of light, captured by a lens and projected on a piece of sensitized material.

*d.* Photography is divided into two operational parts: camera work and laboratory processing. The camera is the tool used to record a selected view or object on film. This undeveloped film is processed in a laboratory and then becomes a negative from which positive prints are produced (fig. 1–1).

### 1–5. Source of Light

A source of light is the beginning of the photographic process. Light may be natural —such as sunlight—or artificial, or a combination of both.

### 1–6. Subject

A subject absorbs and reflects some of the light that strikes it. The amount of light reflected is determined by the size, shape, and color of the subject. White subjects reflect a great deal of light, while dark subjects reflect very little light.

### 1–7. Photographic Lens

The photographic lens (or objective) is molded of special types of glass, and is then finely polished. It collects rays of light reflected by a subject and redirects these rays so that they converge at the back of a camera to form a definite image. Usually, a variable diaphragm controls the amount of light passing through the lens.

### 1–8. Camera

A camera is an instrument with which images are recorded. It is a lighttight inclosure or box equipped with a lens, shutter, diaphragm, and a means of supporting the film.

### 1–9. Shutter

A shutter is a mechanism that can be opened and closed for predetermined lengths of time. It regulates the length of time light is allowed to pass through a lens and on to the light-sensitive material at the back of the camera.

### 1–10. Light-Sensitive Material

A light-sensitive emulsion, called film, is placed in a camera at the plane where the light rays converge to a focus after passing through the lens. A focus is the point where an image formed by the light rays is sharpest.

### 1–11. Exposure

Exposure occurs when light rays from a subject reach the sensitized emulsion, or film. Although the film, thus exposed, is not visibly altered, it is affected and an invisible image is formed. This invisible image, known as the latent image, is made visible through chemical processing.

### 1–12. Developing

Exposure by light makes the film ready to respond to the action of a chemical solution. By immersing the film in a developing solution, the latent image becomes visible. A rinse in clear water or a diluted acid removes excess developing solution and arrests the action of the developing agent.

### 1–13. Fixing

The film is then placed in a fixing bath, which dissolves the unexposed and undeveloped silver in parts of the film. These parts are left clear.

### 1–14. Washing and Drying

By washing the film in water, all chemicals and unwanted particles are removed. The film is then dried, and the result is a negative. Tones, shades, and contrasts in the subject photographed are reversed in a negative. Light

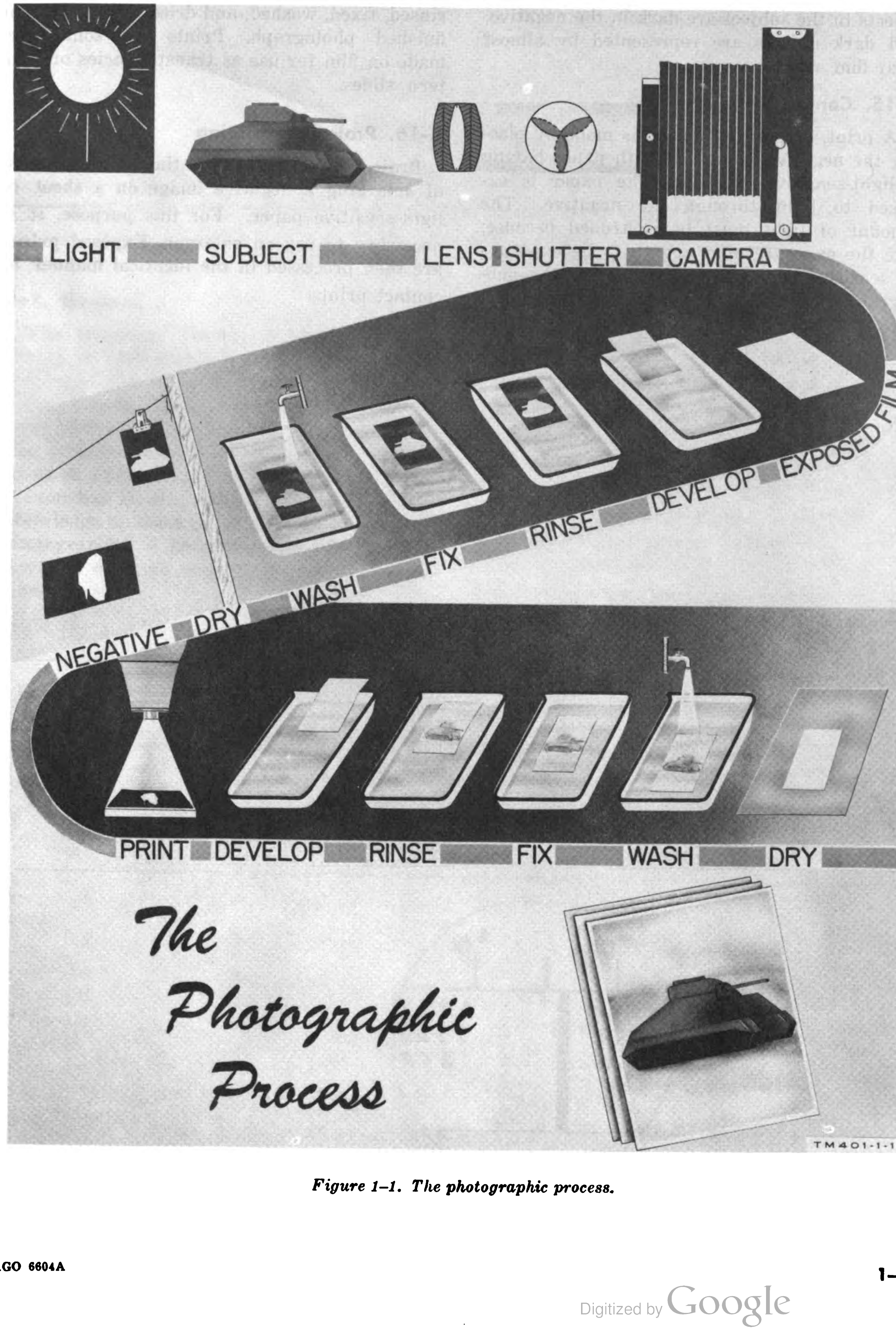


*Figure 1–1. The photographic process.*

objects in the subject are dark in the negative, and dark objects are represented by almost clear film areas.

### 1–15. Contact Printing

A print, or positive image, is made by placing the negative in contact with paper having a light-sensitive emulsion. The paper is exposed to light through the negative. The amount of light must be controlled because, like the exposure of a negative, the exposure of sensitive paper is a vital part of the photographic process. The paper is then developed, rinsed, fixed, washed, and dried to produce the finished photograph. Prints are sometimes made on film for use as transparencies or lantern slides.

### 1–16. Projection Printing

Projection or optical printing is the process of enlarging a negative image on a sheet of light-sensitive paper. For this purpose, it is necessary to use an enlarger. Exposed prints are then processed in the identical manner as contact prints.

# CHAPTER 2
# NATURE OF LIGHT

## Section I. CHARACTERISTICS OF LIGHT

### 2–1. General

The Quantum Theory, developed by Max Planck in 1900, stated that any ideal radiating body will give off energy in minute particles, called quanta. Later experimentation in this field resulted in the accurate measurement of the minute particles (now called photo-electrons or photons) and the revelation that each photon has kinetic energy and momentum. A knowledge of these properties of light aids the photographer in understanding why light behaves in different ways under different conditions.

### 2–2. Behavior of Light

Light energy travels in waves. These waves may differ in length, but their speed remains constant as long as they travel through a medium of constant density.

*a.* When light waves moving through one medium strike a second medium of greater density, the speed of the waves is decreased.

*b.* When light waves moving through one medium strike a second medium of less density, the speed of the waves is increased.

*c.* When light waves moving through one

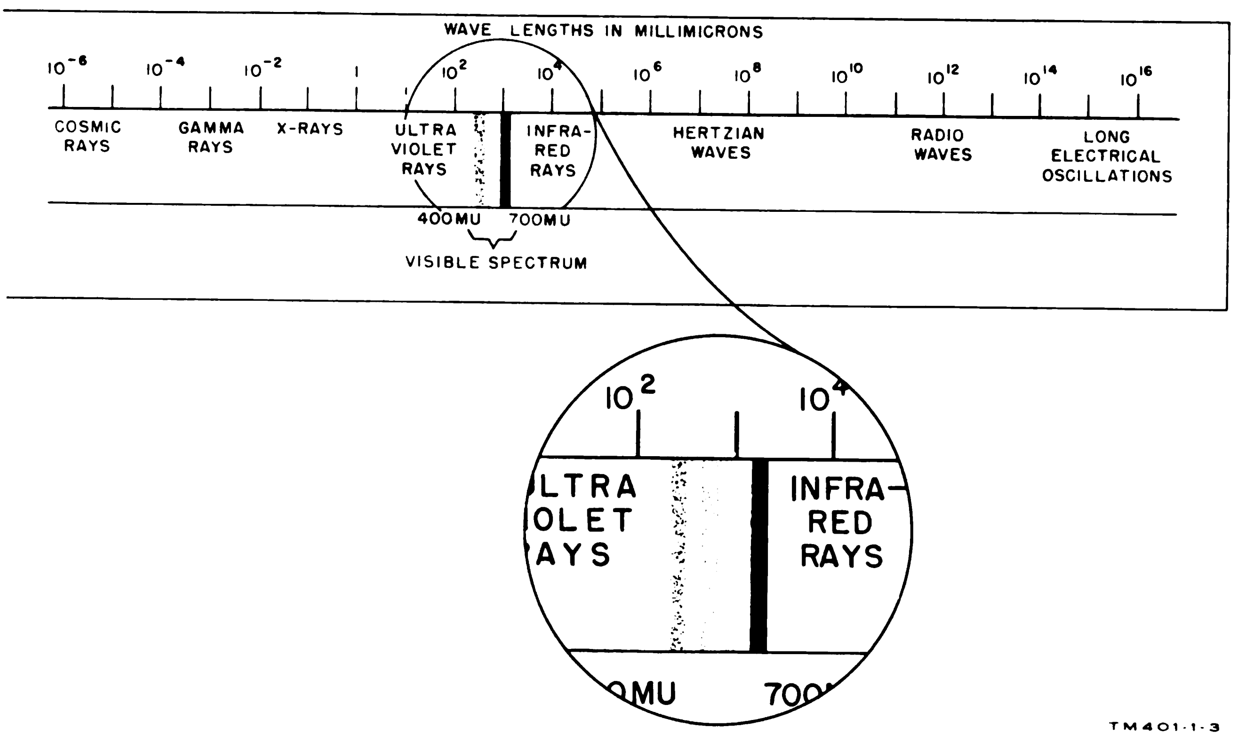


*Figure 2–1. The electromagnetic spectrum.*

medium strike a second medium at any angle other than 90 degrees, the light waves are bent (refracted).

## 2–3. Classification of Light Waves

All forms of radiant energy are classified according to their wavelengths and their frequencies.

*a.* Wavelength ($\lambda$) is the distance from the crest of one wave to the crest of the next wave. This distance is measured in microns (one-thousandth of a millimeter); in millimicrons (one thousandth of a micron) ($\mu$); in Angstrom units (one tenth of a millimicron); or in X-ray units (one thousandth of an Angstrom unit).

*b.* Frequency indicates the number of waves that pass a given point in each second.

## 2–4. Electromagnetic Spectrum

The electromagnetic spectrum is composed of various forms of radiant energy (fig. 2–1), such as heat and radio waves, light waves, ultraviolet and infrared rays, X-rays, and cosmic rays. The visible portion of the electromagnetic spectrum consists of light waves with wavelengths from 400 to 700 millimicrons. Those with wavelengths between 400 and 500 millimicrons are blue, those between 500 and 600 are green, and those between 600 and 700 are red.

## 2–5. Transmission of Wave Energy

The following is a simple experiment that can be used to illustrate how light waves carry energy. First, tie the end of a rope to some object; next, hold the other end of the rope in your hand, stretch it fairly taut, and shake

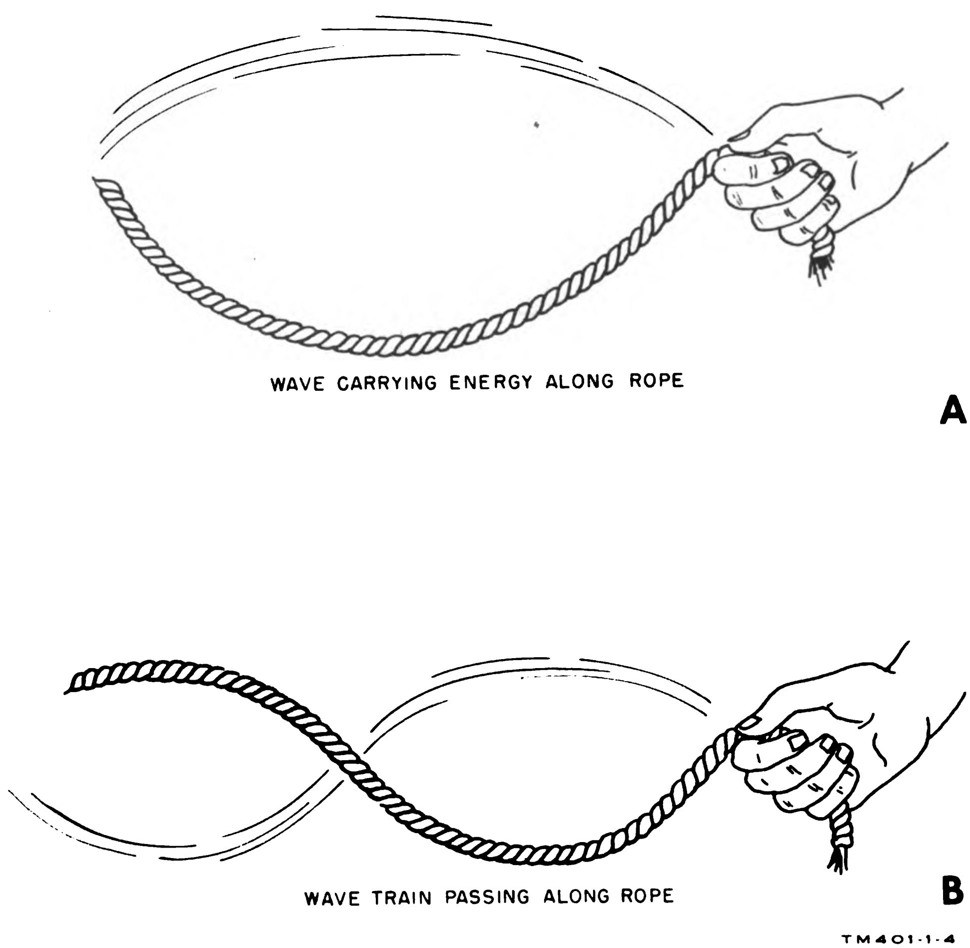


*Figure 2–2. Energy transmission.*

it. A wave motion, or wave pulse, passes along the rope to the end that is tied (fig. 2–2). Shake the rope continuously, so that a series of waves, or a wave train, passes along the rope. Note that different parts of the rope vibrate successively, and that each part bends back and forth in its own position. The disturbance travels, but the rope does not. Only energy is carried along the rope. This same principle applies to light waves, which are transmitted in the form of wave fronts composed of light rays.

*a. Light Rays.* Assume that the source of light is a luminous point and that light waves travel from this point in all directions to form a sphere around the luminous center (fig. 2–3). Light traveling along a radius of this sphere, and at right angles to the wave front, is called a light ray (fig. 2–4). These light rays move through space until they become virtually parallel.

*g. Wave Fronts.* A wave front radiating from a light source is curved when near its source (fig. 2–4) and becomes less and less curved as it moves away from its source. Eventually, it becomes almost straight. The radii of the wave diverge, or spread, as they leave the source and they eventually become almost parallel.

## 2–6. Composition of White Light

White light is composed of all wavelengths

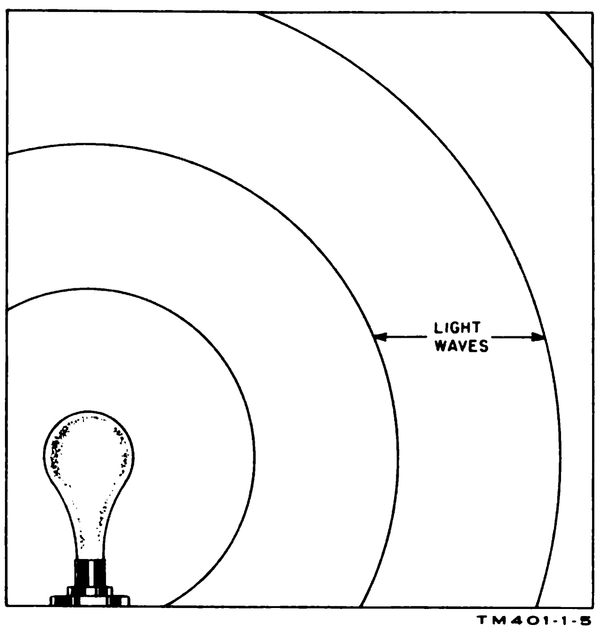


*Figure 2–3. Light sources send waves in all directions.*

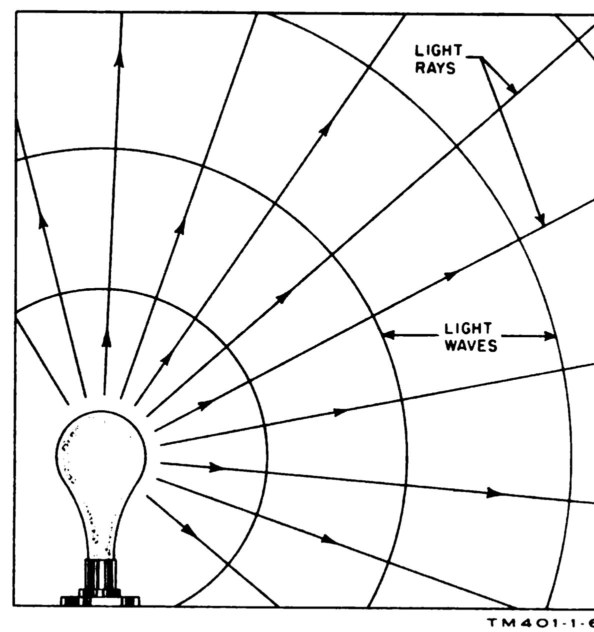


*Figure 2–4. Light travels in direction of radii of waves.*

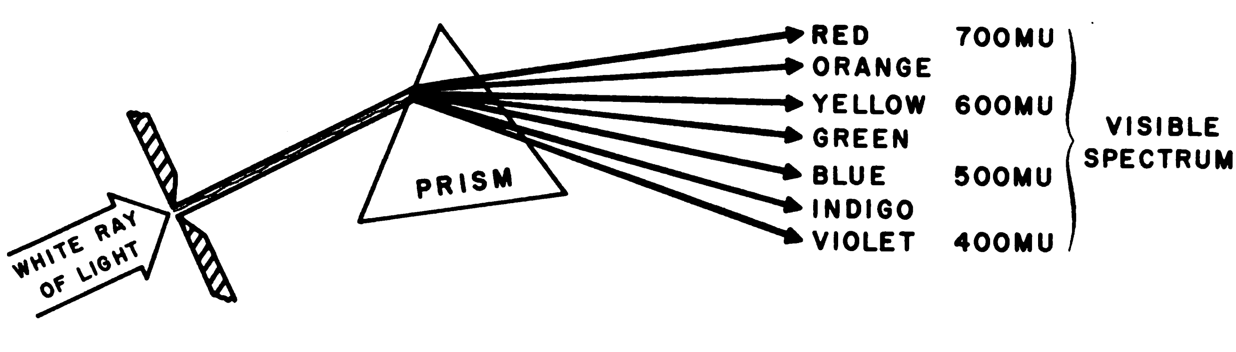


*Figure 2–5. Dispersion of light by a prism.*

in the visible spectrum. Thus, if an object reflects all wavelengths of light, the reflected light is white. To determine the composition of white light, pass sunlight through a slit and then through a glass prism. The light that emerges will be split into a band of colored light, called the light spectrum (fig. 2–5). The colors of the spectrum, in the order of their appearance, are red, orange, yellow, green, blue, indigo, and violet.

*a. Dispersion.* The process of passing white light through a prism to separate it into its component colors is called dispersion. The amount of dispersion will vary in accordance with the type of glass used. *For example,* a prism of dense flint glass will disperse light rays to a greater degree than a prism of less dense crown glass.

*b. Color Wavelength.* Each color of the spectrum represents light vibrating at a different frequency or wavelength. The shorter the wavelength, the more the rays are bent, or refracted, when passing through a transparent medium. Red light has the longest wavelength, and violet the shortest. Red rays are bent the least, and violet the most.

## Section II. REFLECTION

### 2–7. Specular and Diffuse Light

Light rays that are not transmitted through or absorbed by an object are said to be reflected, and this reflected light is either specular or diffuse. Specular light (fig. 2–6) travels in one direction; diffuse light is scattered and travels in many directions. Most objects will reflect both specular and diffuse light.

*a.* The reflection of light can be compared with the action of a rubber ball dropped on a smooth or rough surface. If a rubber ball is dropped perpendicularly on a smooth surface, it will bounce and return along its original path. Similarly, a beam of light falling perpendicularly on a smooth surface or mirror will be reflected back on its original path. This is called regular reflection, and the reflected light is said to be specular.

*b.* If a rubber ball is thrown against a smooth surface at any angle other than 90 degrees, it will rebound at an equal angle away from the point of impact. In the same manner, a beam of light that falls at an oblique angle on a smooth surface will be reflected at an equal angle away from the directoin of impact. Since this light is traveling in only one direction, it is also said to be specular.

*c.* If several rubber balls are dropped on a rough and irregular surface, it is impossible to determine in advance the direction in which they will bounce. When a beam of light falls on a rough surface, it also is thrown back in more than one direction. This is called an irregular reflection, and the light is said to be diffused.

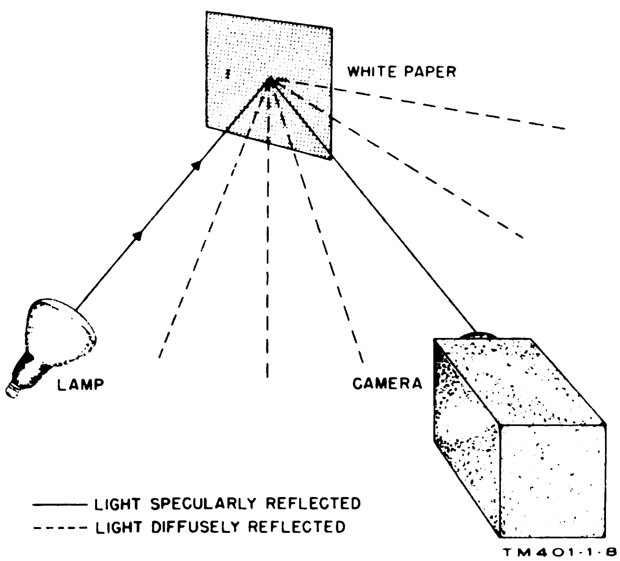

*Figure 2–6. Specular and diffuse light.*

*d.* The amount of light reflectde by any surface depends, to a great degree, on the color of the surface. Black or dark surfaces, for example, absorb much of the light and reflect very little. White or bright surfaces, on the other hand, reflect a great deal of light. This has a bearing on photography, since the lens of a camera picks up reflected light rays and projects them on the film in the camera.

### 2–8. Reflection From a Plane Mirror

A plane mirror is a flat polished surface used in photography to reflect specular light. In the

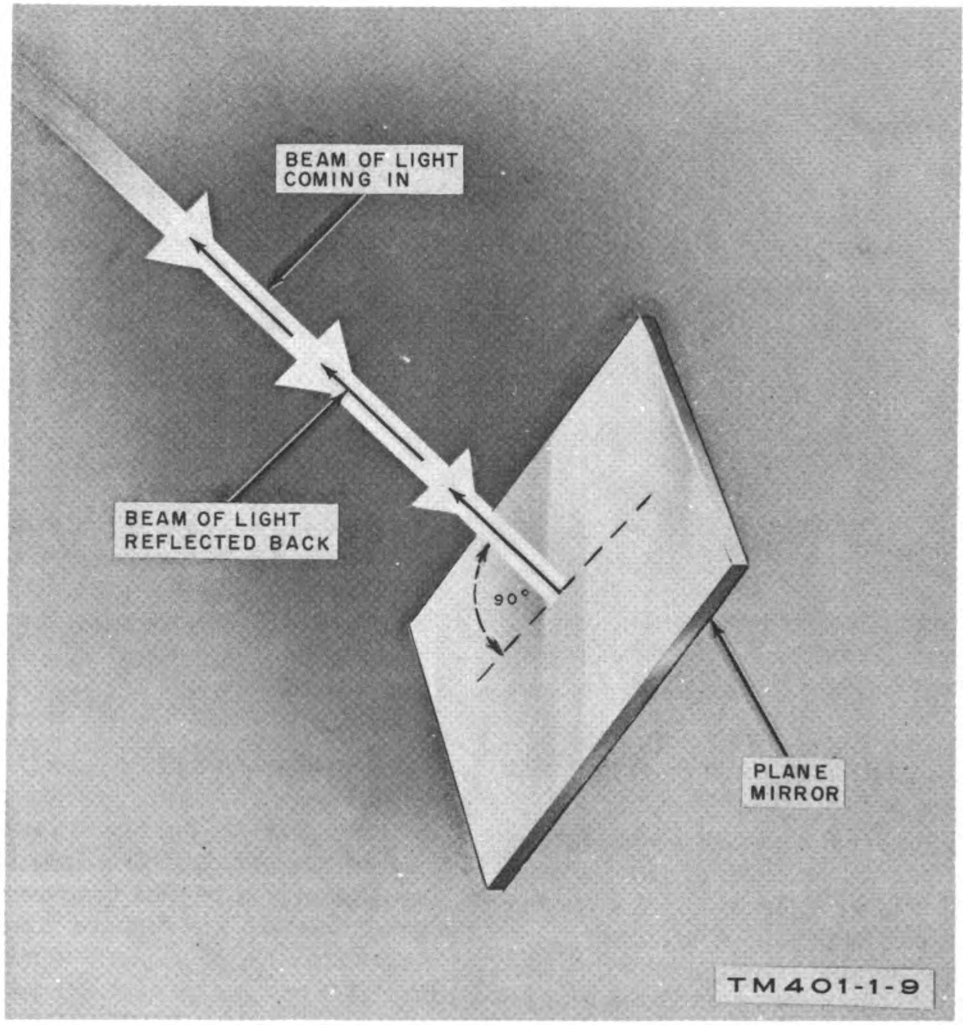


*Figure 2–7. Beam of light reflected back on its own path.*

examples below, the plane mirror is used to aid in explaining reflection terminology.

*a.* If a beam of light (*incident ray*) strikes a plane mirror perpendicularly, the reflected light (*reflected ray*) will be directed back along the path of the original beam (fig. 2–7). This path, which is an imaginary line perpendicular to the surface of the mirror, is called the *normal* or *perpendicular* (fig. 2–8).

*b.* If the incident ray strikes the mirror at an angle other than 90 degrees, the reflected ray will be reflected at an equal angle away from the direction of impact (fig. 2–8). In this case, the angle formed by the incident ray and the perpendicular (called the *angle of incidence*) is equal to the angle formed by the reflected ray and the perpendicular (called the *angle of reflection*).

*c.* Let us assume now that the incident ray is striking the mirror perpendicularly, and that we want the reflected ray to be at an angle. We cannot move the beam of light, so we shift the angle of the mirror to 45 degrees. In this case, the angle of reflection will be the same as the angle of incidence, i. e., 45 degrees.

## 2–9. Reflection From a Convex Mirror

*a.* The laws of reflection are the same, regardless of whether the surface is plane, convex, or concave. However, the degree of curvature of the reflecting surface and the light

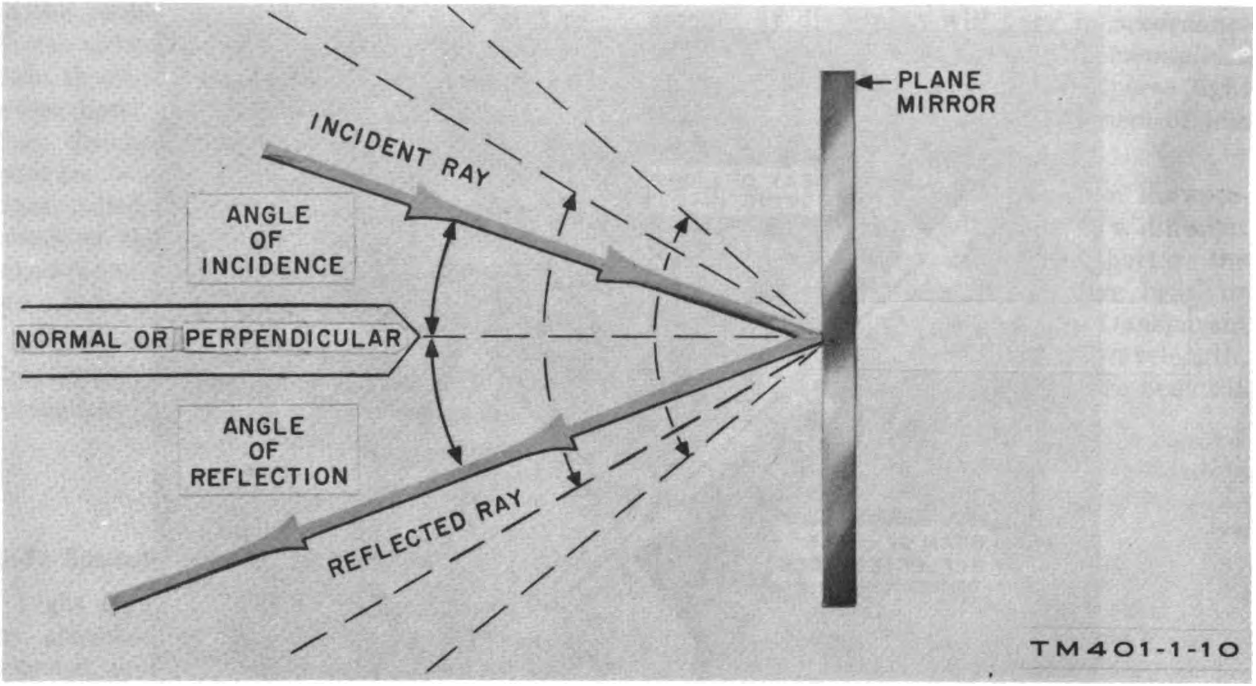


*Figure 2–8. Terms pertaining to reflected light.*

source distance will have an effect on the path taken by the reflected light.

*b.* When light from a distant source strikes a convex mirror in the form of parallel rays (fig. 2–9), it will be deflected in a divergent pattern. The perpendicular of each ray is an imaginary line running from the center of mirror curvature to the point of incidence of each ray. Therefore, the angle of reflection is equal to the angle of incidence of each ray.

*c.* Light from a close source will also be reflected in a divergent pattern; however, because the light does not reach the mirror surface in the form of parallel rays, the angle of reflection is slightly different than the angle of reflection from a distant light source.

## 2–10. Reflection From a Concave Mirror

*a.* When plotting the reflection from a concave mirror, it will be found that the principal focal point of the rays is in front of the mirror (fig. 2–10). By running imaginary lines from the center of curvature to the points of incidence of the incident rays, it is possible to indicate the normals of individual rays. Reflected rays can be plotted so that each forms an angle of reflection equal to the angle of incidence of the corresponding ray.

*b.* Rays converge after reflection and intersect at a point halfway between the center of curvature and the mirror surface. This point is called the principal focal point of the mirror. Assuming a perfect concave mirror, it is always one-half the distance from the center of curvature to the surface of a concave mirror. After passing through the focal point, the light rays diverge.

*c.* Concave mirrors with a nonspherical curvature are called parabolic mirrors. If a light source is placed at the principal point of focus, the reflected rays will be parallel. Mirrors of such design are used in projectors, studio lamps, and in long focal length optical systems.

## 2–11. Color of Objects

Color of objects is largely a matter of absorption and reflection. When white light falls on an object that absorbs some of the wavelengths and reflects or transmits others, the object appears to have color. The wavelength that is reflected or transmitted determines the color of the object. *For example,* a red object appears red because it reflects or transmits only the red wavelengths. Most of the other waves, which as a group produce green and

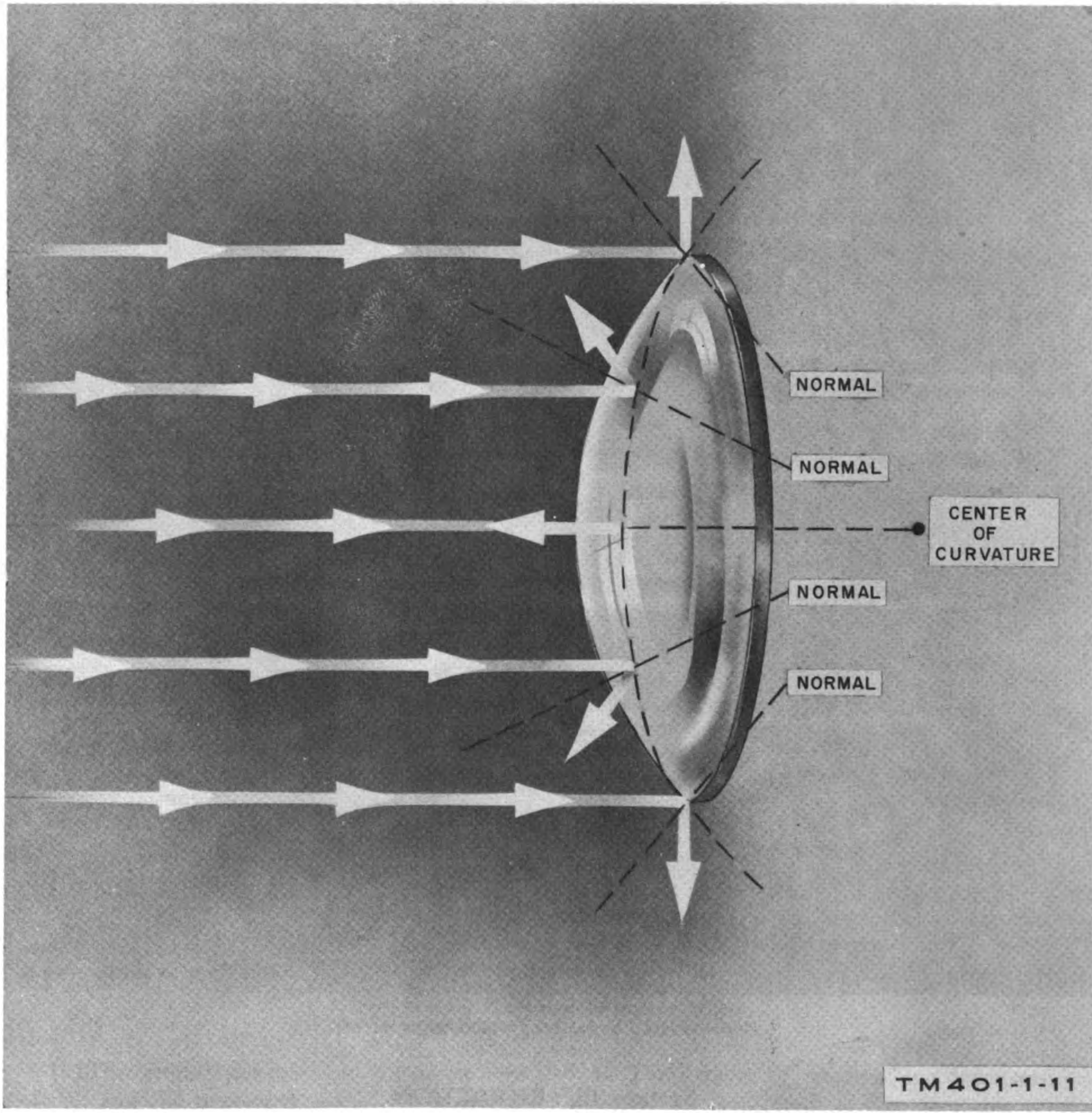


*Figure 2–9. Reflection from convex mirror, infinite source.*

blue, are absorbed. In the same manner, a green object absorbs more red and blue than green. A yellow object absorbs more blue than red and green, and the reflected or transmitted mixture of red and green appears to be yellow.

*a.* Light is not always white, and it does not always contain all wavelengths of the visible spectrum. If any one group of wavelengths is predominate, the light will be colored. If the light rays, for example, consist principally of waves ranging from about 400 to 500 millimicrons, the light will appear to be blue.

*b.* A colored object reflects or transmits light of its own color and absorbs all other colors. In the red light of a darkroom lamp, for example, all green objects appear colorless or black. In other words, an object appears colorless or black when the light striking it does not include its own color.

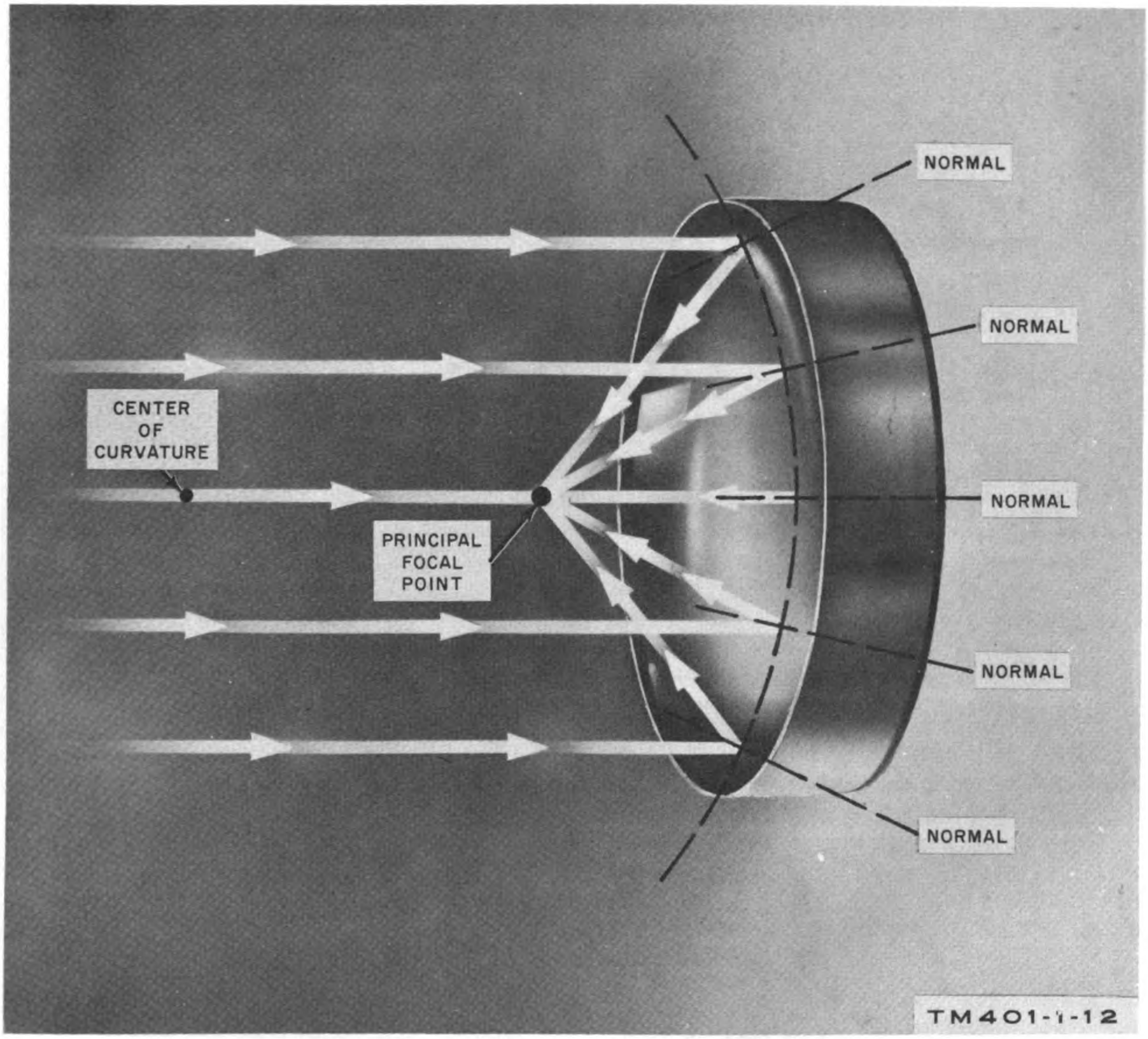


*Figure 2–10. Reflection from concave mirror.*

## Section III. REFRACTION

### 2–12. Definition and Terminology

*a. Definition.* Refraction is the bending, or deflection, of light rays when they pass obliquely from one transparent medium to a second transparent medium of different density.

*b. Terminology* (fig. 2–11).

(1) The light ray that strikes the surface of a transparent medium is called an *incident ray.*

(2) When the incident ray enters the second transparent medium, which is of different density than the first, it becomes a *refracted ray.*

(3) When the refracted ray passes from the second transparent medium to a medium of different density, it becomes an *emergent ray.*

(4) The imaginary line at a right angle to the surface of a medium is called the *normal* or *perpendicular.*

(5) The angle between the incident ray and the normal is called the angle of incidence.

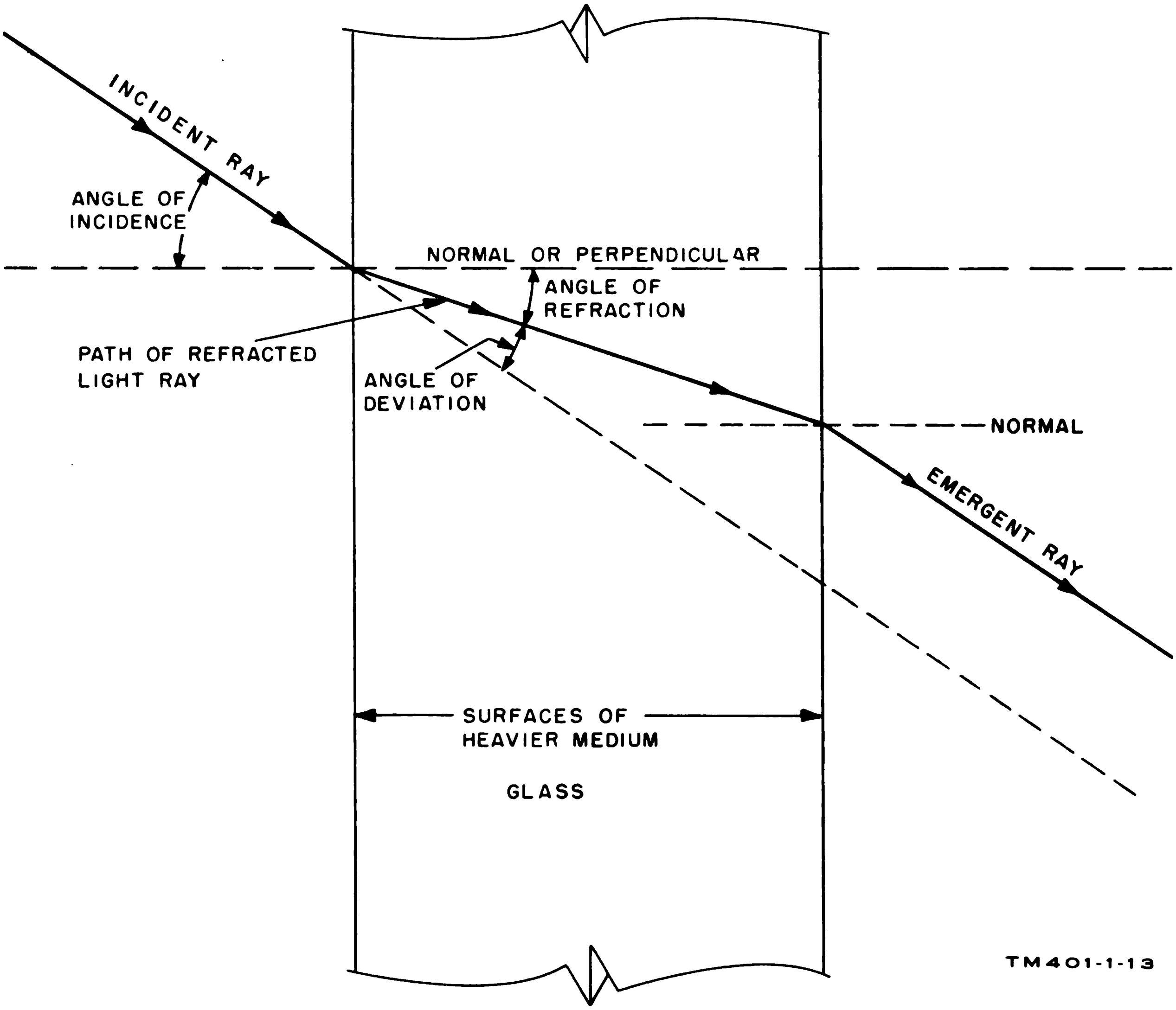


*Figure 2–11. Terminology in refraction.*

(6) The angle between the refracted ray and the normal is called the angle of refraction.

(7) The angle between the refracted ray and the extension of the incident ray is called the *angle of deviation.*

## 2–13. Law of Refraction

*a.* A light ray, in passing from a medium of lesser density to one of greater density, is bent *toward* the normal. In passing from a medium of greater density to a medium of lesser density, the light ray is bent *away* from the normal.

*b.* The greater the angle of incidence and the greater the difference in the densities of the two mediums, the greater the angle of refraction. If the two faces of the second medium are parallel, the bending at the two faces is always the same; thus, the beam that leaves the denser medium is parallel to the incident ray (fig. 2–11).

## 2–14. Refraction Through a Glass Plate

*a.* When a light ray strikes a glass plate perpendicularly (fig. 2–12), it is not bent or refracted. It continues through the glass in a straight line, but at a reduced speed. Light

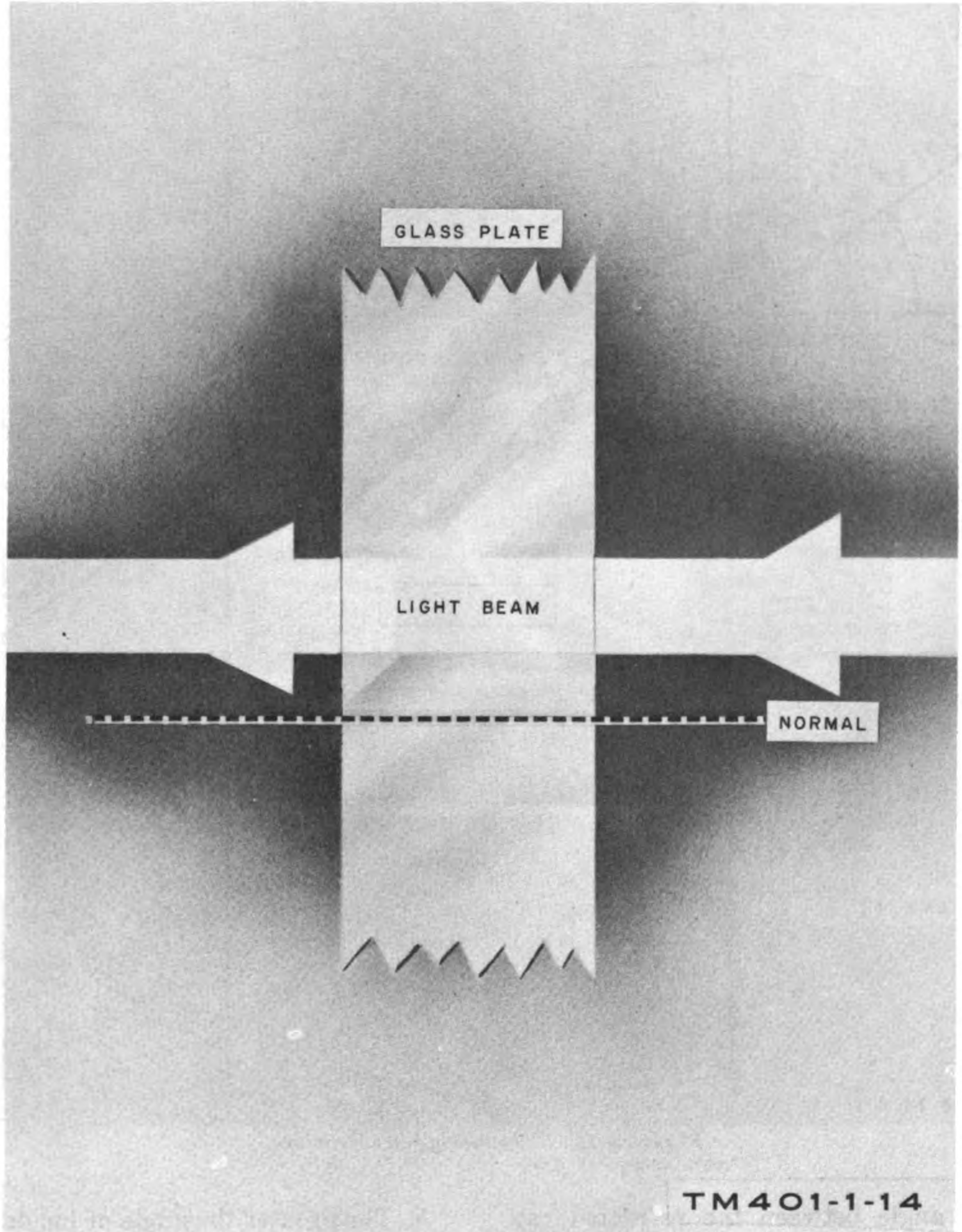


*Figure 2–12. Beam of light striking glass plate perpendicularly.*

travels approximately one-third slower in glass than in air. When the light ray emerges from the glass, it continues through the air in a straight line and at an increased speed.

*b.* When a light ray strikes a glass plate at any angle other than 90 degrees (fig. 2–13), it is bent toward the normal; when it emerges from the glass plate, it is bent away from the normal.

## 2–15. Refraction Through a Triangular Prism

A beam of light striking a triangular prism is bent toward the normal (fig. 2–14). When leaving the prism the refracted beam is bent away from the normal (fig. 2–15). Accordingly, the path of the beam of light deviates at the first prism surface and deviates again at the second surface. In both instances, the beam is bent toward the thickest part of the prism.

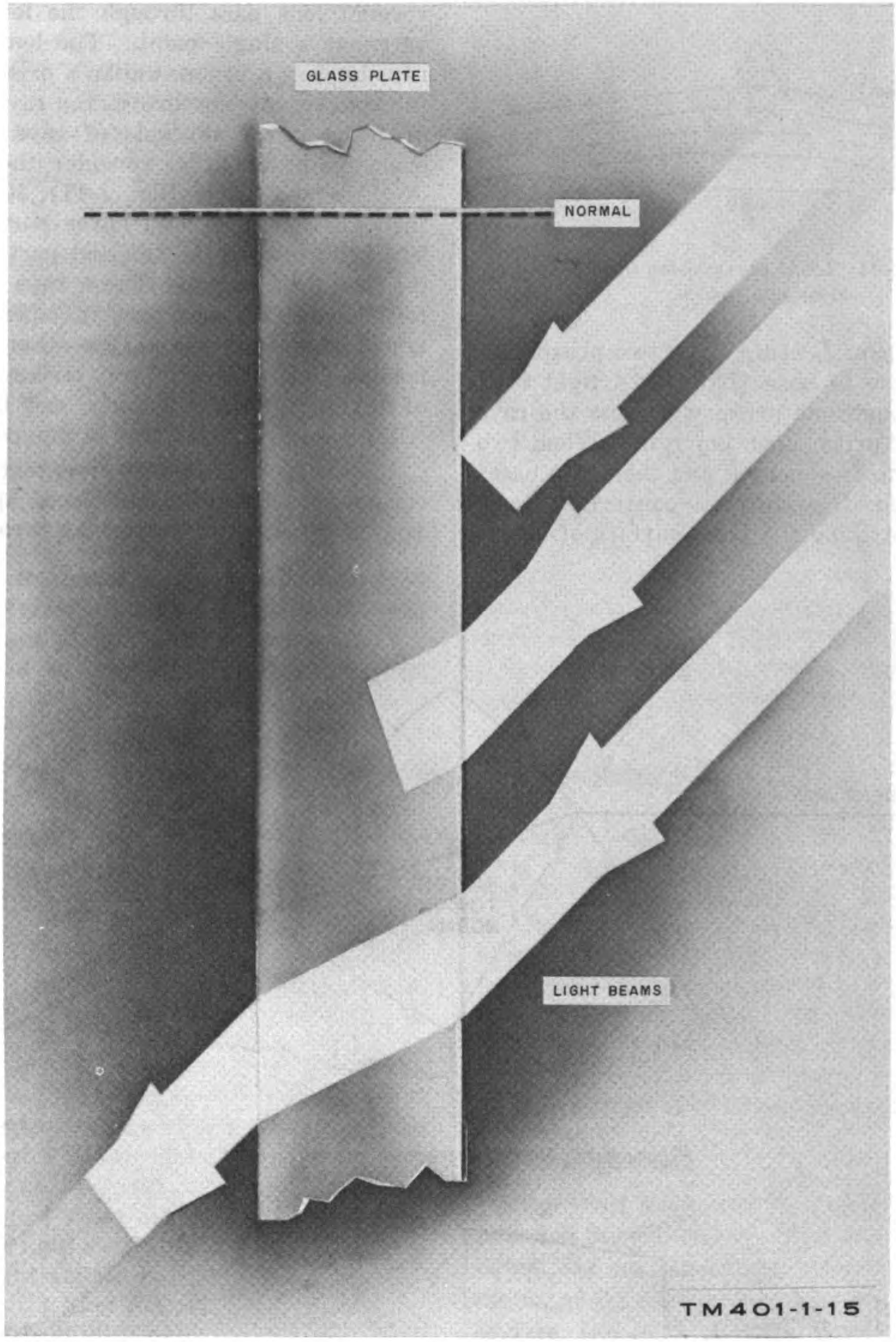


*Figure 2–13. Beam of light striking glass plate at an angle.*

## 2–16. Refraction Through Lenses

Since all lenses are a combination of prisms, the laws of refraction can be applied to all light rays passing through them. When a light ray strikes a lens, it is bent toward the normal of that lens (fig. 2–15). When the refracted ray emerges from the lens, it is bent away from the normal.

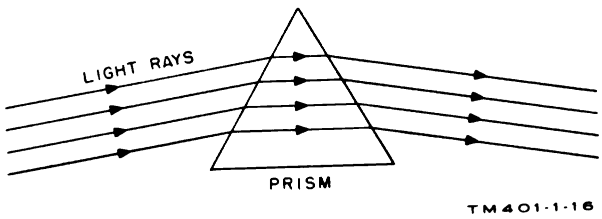


*Figure 2–14. Light rays passing through a triangular prism.*

*a. Convergent Lenses.* When two prisms are arranged base to base (fig. 2–16), light rays passing through one prism will cross the rays of the other prism upon emerging. When two prisms are made spherical and their two bases are cemented, they form a convergent lens. Light rays striking the front surface of a convergent lens pass through the lens and converge at a single point. The lens bends the rays as does a prism; unlike a prism, however, the convergent lens brings the rays to a point of focus. Since myriads of rays come from every point of light, consider the refraction of three such rays (fig. 2–17). Rays passing through the upper and lower portions of the lens bend toward the thickest part upon striking the first surface. These rays bend again toward the thickest part in emerging. As a result, they converge on the other side of the lens. A central, or axial, ray strikes the surface of the lens perpendicularly and is not bent. All of these rays converge at one point.

*b. Divergent Lenses.* A divergent lens can be considered as two prisms placed apex to apex (fig. 2–18). Light rays passing through the up-

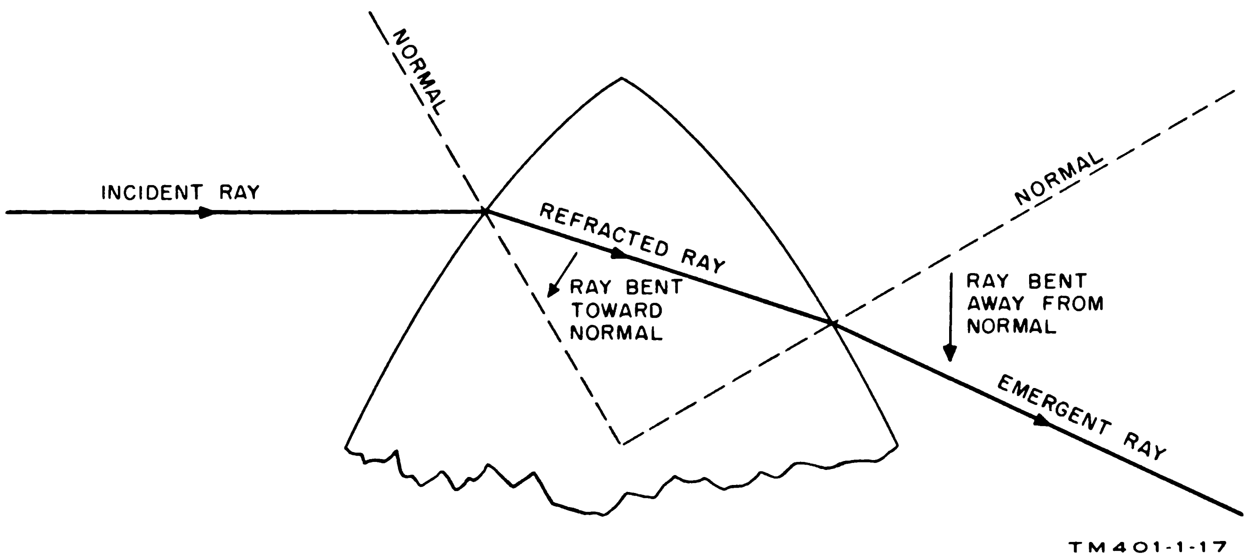


*Figure 2–15. Law of refraction applied to a lens.*

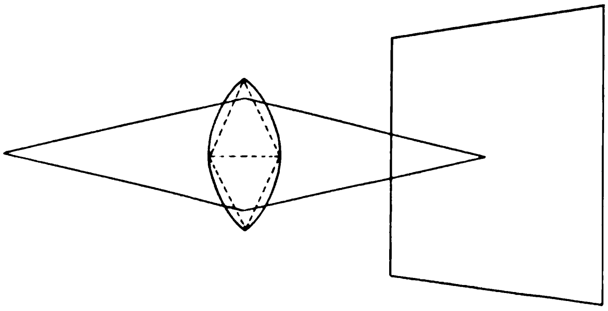


*Figure 2–16. Rays bent by a double prism.*

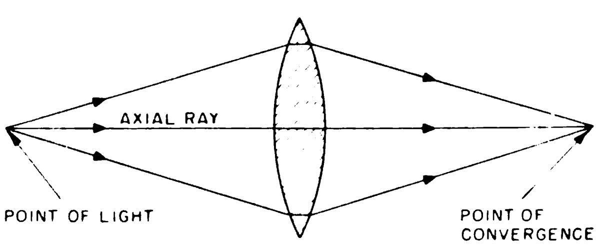


*Figure 2–17. Paths of light rays through a convergent lens.*

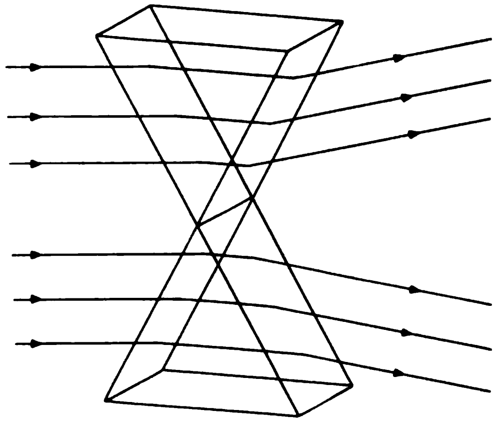

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*Figure 2–18. Deviation of rays by two prisms, apex to apex.*

per prism travel upward, and light rays passing through the lower prism travel downward. Figure 2–19 shows a spherical divergent lens, where all rays of light, except the axial ray, spread out or diverge after passing through the lens.

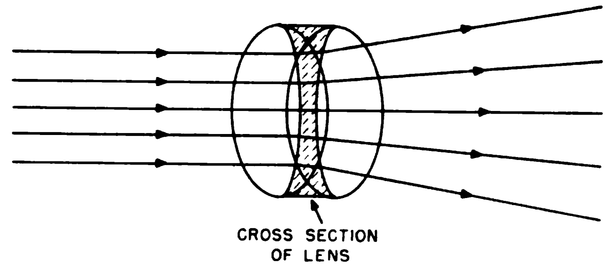


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*Figure 2–19. Deviation of rays by a divergent lens.*

## 2–17. Index of Refraction

Light travels through substances of different densities with varying velocities. *For example,* the speed of light through ordinary glass is approximately 120,000 miles per second. The ratio between the speed of light through air (186,000 miles per second) and the speed of light through a second medium is known as the *index of refraction.* The index of refraction is used to determine the angle of refraction of lenses made of various types of glass.

# Section IV. INTENSITY OF ILLUMINATION

## 2–18. General

Light emanating from a source of light is called incident light. When incident light strikes a surface and rebounds, it is called reflected light.

## 2–19. Illumination

The intensity of illumination on an object depends upon the strength of the light source in candlepower and the distance in feet from the light source to the object. In the formula for intensity of illumination ($I = C\ D^2$), I is the the intensity of illumination, C is the candlepower of the light source, and D is the distance from the light source to the object.

## 2–20. Inverse Square Law

Light intensity diminishes inversely with the square of the distance from a light source to an object. In figure 2–20, a card is placed 1 foot, 2 feet, 3 feet, and 4 feet from a light source. When the card is placed 1 foot from the light source, the intensity of illumination in foot candles is equal to the candlepower of the light source; when the card is moved to a point 2 feet from the light source, the intensity is $\frac{1}{4}$ (2 x 2) as bright; when the card is moved to a point 3 feet from the light source, the intensity is $\frac{1}{9}$ (3 x 3) as bright; and when the card is moved to a point 4 feet from the light source, the intensity is $\frac{1}{16}$ (4 x 4) as bright. As an object is moved closer to the light source, the phenomenon takes place in reverse; the object becomes brighter.

## 2–21. Brightness

Brightness represents the quantity of light reflected from a surface that has been illuminated. The amount of light reflected depends on the nature of the surface. The more glossy the surface, the more specular the reflection; the more matte (dull) the surface, the more diffuse the reflection. Tones, from white to black, also plays a part in the degree of reflectivity of the surface. Therefore, a very glossy white surface will approximate the effect of a mirror; a diffuse white surface, like a blotter, is not subject to specular reflection and gives a scattered

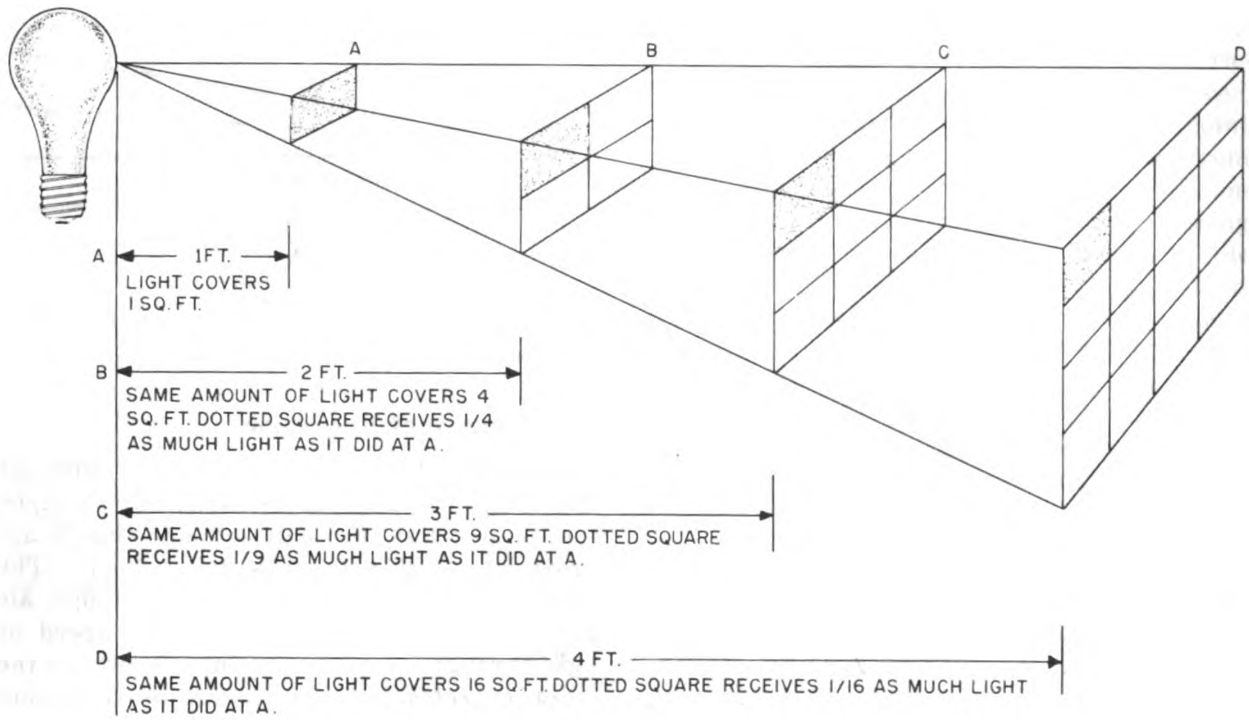


*Figure 2–20. Inverse square law.*

light. Normally, surfaces are a compromise between the two extremes.

*a. Distance.* Distance from the camera to the subject has no effect on brightness. If the camera is moved away from a surface to be photographed, apparent subject brightness will remain the same.

*b. Reflection Factor.* Any surface that is able to reflect light can be given a *reflection factor.* This factor is the ratio of the light reflected by the surface to the light falling on the surface.

## 2–22. Brightness Relationship of Photographic Subjects

In photography, light is the most important basic ingredient. The brightness of objects, the relationship of brightness extremes, and the relationship of brightness areas to shadow areas are some of the factors that must be considered, translated into values, and reproduced in a corresponding scale of shades on a light sensitive emulsion. Because photographic emulsions lack the extreme sensitivity of the human eye and the ability to be selective, the photographer must control the ratio of brightness extremes of a subject. He achieves this through judicious use of subject selection, control of light intensity, direction control of light, control of the direction of shadows, and control of the amount of reflected light. The photographer must aim for reduced brightness extremes, so that the light-sensitive emulsion can effectively reproduce conditions without sacrificing subject detail or reducing the range of monochromatic shades of the subject as it appears in the finished photographic print.

## 2–23. Ultimate Use of Light

Light emphasizes the shape, form dimension, and color of objects. Without this characteristic of light, photography would be impossible. Whenever it is necessary or advantageous, the photographer uses artifical light to supplement natural light or to emphasize, to change, or to adjust conditions as he finds them. The aim of this manipulation is to produce better photographs.

## 2–24. Summary

*a.* Light travels in waves that retain a constant speed as long as they pass through a medium with a constant density.

*b.* When light waves moving through one medium strike a second medium of less density, the speed of the waves is increased. However, when the second medium is of greater density, the speed of the waves is decreased.

*c.* The visible portion of the electromagnetic spectrum consists of light waves with wavelengths from 400 to 700 millimicrons.

*d.* White light is composed of red, orange, yellow, green, blue, indigo, and violet colored bands of light.

*e.* Light rays not absorbed by an object are either transmitted or reflected.

*f.* A beam of light falling perpendicularly on a smooth surface will be reflected back along its original path.

*g.* A beam of light striking a smooth surface at an oblique angle will be reflected at an equal angle away from the direction of impact.

*h.* The color of a subject's surface determines to a large degree the amount of light reflected by hte subject.

*i.* Parallel rays of light striking a convex mirror are reflected in a divergent pattern.

*j.* If parallel light rays strike a concave mirror, they will converge aftre being reflected and will intersect halfway between the center of curvature and the mirror surface.

*k.* The color of objects visible to the human eye is dependent to a large degree upon the absorption and reflection characteristics of the objects.

*l.* Whenever an oblique light ray passes from a transparent medium of one density to a transparent medium of another density, it is refracted or bent. The degree of refraction depends on the density difference of the two mediums and the angle of incidence.

*m.* The intensity of illumination falling on an object depends upon the strength of the source of light (in candlepower) and the distance from the source to the object (in feet).

*n.* The inverse square law states that light intensity diminishes inversely with the square of the distance from the light source to an object. When a card is placed 1 foot from the light source, the intensity of illumination in foot candles is equal to the candlepower of the light source; when the card is moved to a point 2 feet from the light source, the intensity is ¼ (2 x 2) as strong.

*o.* Camera distance has no effect on brightness of reflected light. Therefore, it must be handled judiciously in all types of photography.

## 2–25. Review Questions

*a.* What is a photon?

*b.* What decreases and what increases the speed at which light waves travel?

*c.* Describe the electromagnetic spectrum.

*d.* List the colors of the spectrum.

*e.* What are the two types of reflected light?

*f.* What effect does surface color of an object have on the reflection of light?

*g.* Define refraction.

*h.* Prepare a diagram to show the path of a light ray that strikes and passes through a sheet of glass at an angle; label the resulting angles of the ray along its path of refraction.

## 2–26. Review Answers

*a.* A photon is a minute particle constituting a portion of the energy given off by a radiating body. It has both energy and momentum and is also referred to as a photo-electron.

*b.* The speed at which light waves travel is affected by the degree of density of the media through which light passes.

*c.* The electromagnetic spectrum is a composite of various forms of radiant energy, such as heat and radio waves, light waves, ultraviolet and infrared rays, X-rays, and cosmic rays. The visible portion of the electromagnetic spectrum consists of light waves with wavelengths from 400 to 700 millimicrons.

*d.* The colors of the spectrum, in the order of their appearance, are red, orange, yellow, green, blue, indigo, and violet.

*e.* Reflected light is either specular or diffuse.

*f.* A colored object reflects light of its own color and absorbs all other colors. An object appears colorless or black when the light striking it does not include its own color.

*g.* Refraction is the manner in which light rays bend when they pass obliquely from one transparent medium to a second transparent medium of different density.

*h.* Refer to figure 2–11.

# CHAPTER 3
# OPTICS

## Section I. BASIC CHARACTERISTICS OF LENSES

### 3–1. Purpose of Camera Lenses

The purpose of a camera lens is to refract light rays in such a manner that a sharp, clear image is formed. Camera lenses are designed to function with the least amount of error and to reproduce objects in a practcal object-image size relationship.

### 3–2. The Pinhole Lens

The simplest type of lens is a pinhole in a piece of thin metal or black paper, but only an extremely small part of the light reflected by a subject passes through the pinhole to form an image in the camera. If the pinhole is made larger, more light passes through the opening and the image becomes blurred because of the overlapping of several images. The images produced by light passing through a small pinhole are sharper (fig. 3–1) than those passing through a large pinhole. However, no pinhole is capable of producing a critically sharp image. Because of this, and other limiting factors, pinhole lenses are not practical for general photography.

### 3–3. Camera Lenses

A camera lens is a piece of polished spherical and symmetrical glass that refracts light rays so that an image of a desired scene is projected on the rear wall of a camera. A lens transmits more light than a pinhole, and it increases the brightness and improves the sharpness of the image. The basic principle of a lens—any lens—is relatively simple.

*a.* First, consider an image formed with a single pinhole. Next, consider another pinhole above the first. This pinhole forms a second image. If these two images could be made to coincide, the result would be an image twice as bright as the original.

*b.* Now, consider a third pinhole on the side of the first, a fourth on the other side, and a fifth below the first. All four pinholes project separate images slightly removed from the first or center one (fig. 3–2). If these four images could be made to coincide with the center one, the result would be an image five times as bright as the image made by the one center pinhole.

*c.* Next, use the principle of refraction to make these four images coincide with the center one. In other words, place a prism behind each pinhole so that the light forming each of the four images is refracted to form a single image. This image is above five times as bright as the original image (fig. 3–3).

*d.* The theory discussed above indicates that the brightness and sharpness of the image depends upon the number of pinholes and prisms used. However, a lens consisting of numerous pinholes and prisms would be too cumbersome for practical use.

*e.* Therefore, the camera lens consists of a series of prisms incorporated in a single circular piece of glass, and the image is formed in the same manner as if two prisms were placed base to base (fig. 3–4). This eliminates the need for individual pinholes and prisms.

### 3–4. Types of Single Lenses

Single lenses are divided into two general classes: positive lenses (A, fig. 3–5) and negative lenses (B, fig. 3–5). Positive lenses form real images, because light rays passing through such lenses cross. Lenses in this class are also termed convex, convergent, or collective. Negative lenses form only virtual images, because light rays passing through them spread. These lenses are also called concave, divergent, or

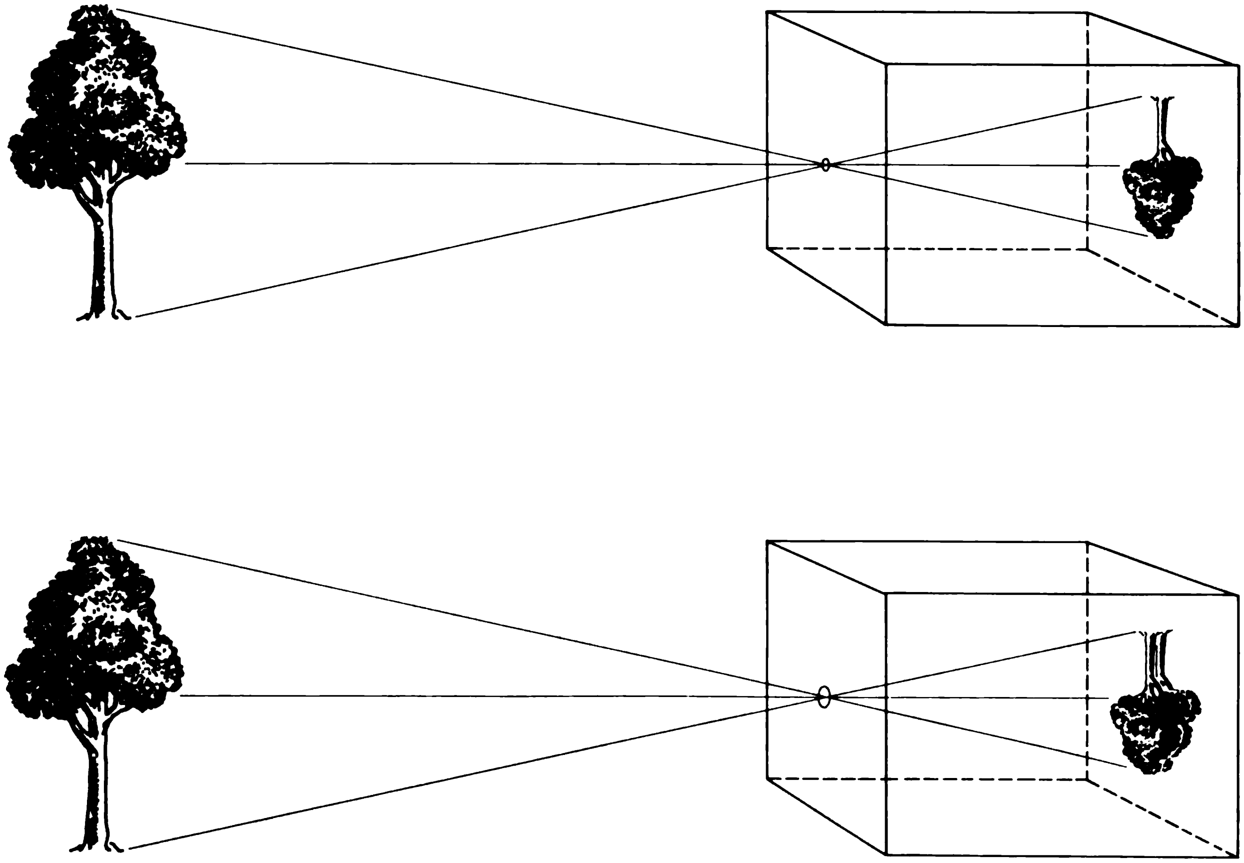

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*Figure 3–1. Images produced by large and small pinholes.*

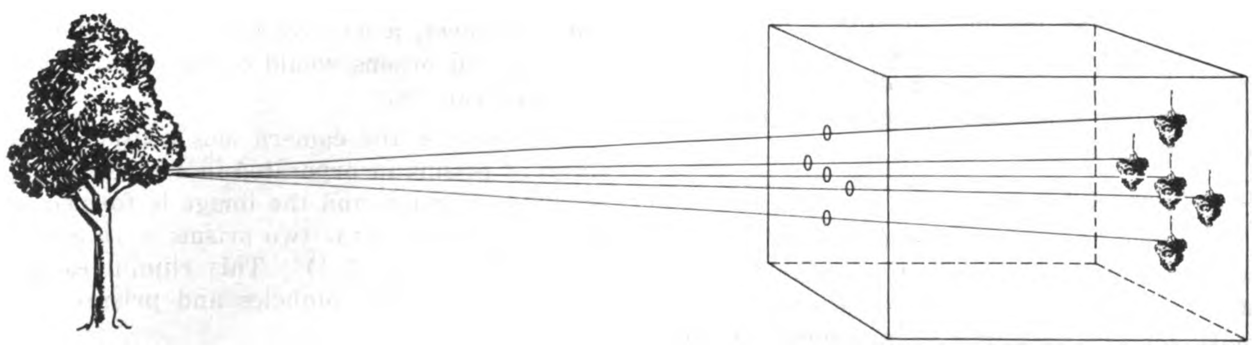

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*Figure 3–2. Separate images of the same object.*

dispersive. Negative lenses may be used as part of a compound lens to correct aberrations, but cannot be used individually as photographic lenses.

## 3–5. Positive Lenses

Positive lenses, which are convex lenses, are thicker in the center than at the edges and converge light rays. Both faces of a convex lens may be convergent. However, one surface may be convex while the other is flat, or one surface may be convex while the other is concave. (A, fig. 3–5).

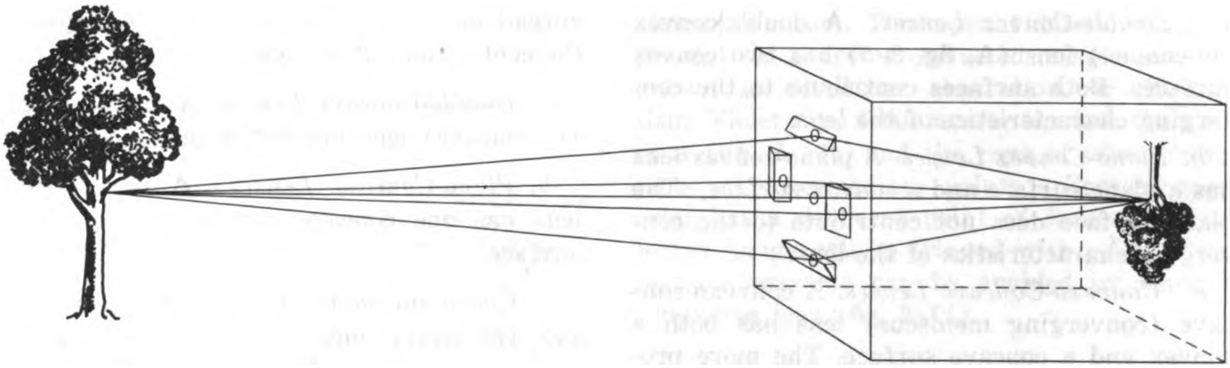

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*Figure 3–3. Separate images made to coincide.*

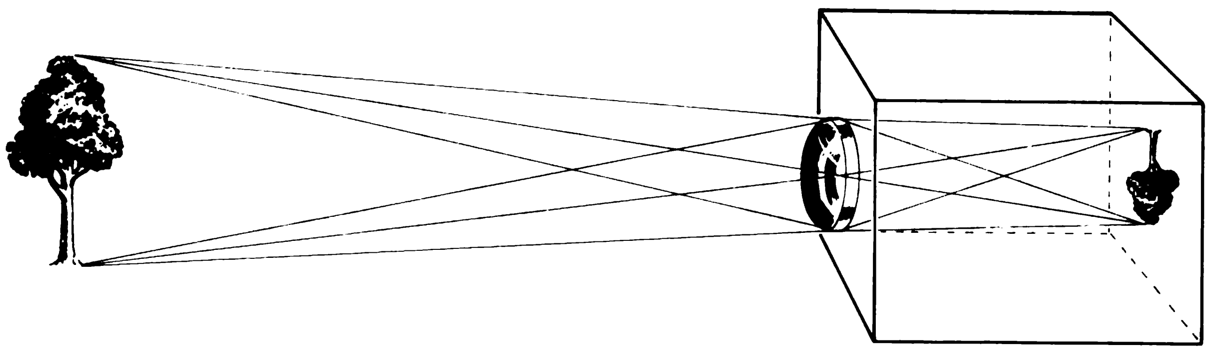

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*Figure 3–4. Formation of an image by a lens.*

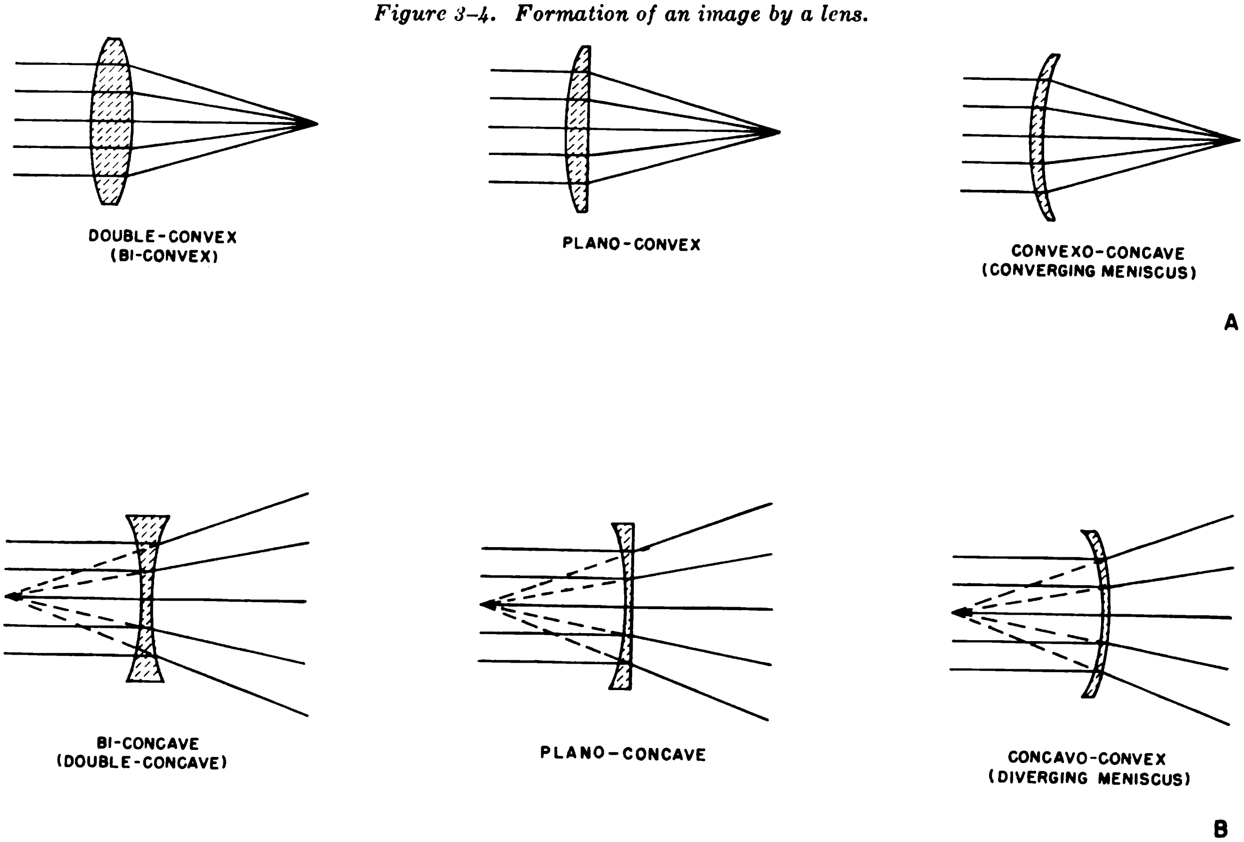


*Figure 3–5. Types of single lenses.*

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*a. Double-Convex Lenses.* A double-convex (bi-convex) lens (A, fig. 3–5) has two convex surfaces. Both surfaces contribute to the converging characteristics of the lens.

*b. Plano-Convex Lenses.* A plano-convex lens has a plane surface and a convex surface. The plane surface does not contribute to the converging characteristics of the lens.

*c. Convexo-Concave Lenses.* A convexo-concave (converging meniscus) lens has both a convex and a concave surface. The more pronounced convex curve makes this a positive lens, despite the fact that the concave surface spreads light and subtracts from the converging characteristics of the lens.

### 3–6. Negative Lenses

Negative lenses, which are concave lenses, spread light rays. These lenses are thinner in the center than at the edge (B, fig. 3–5).

*a. Double-Concave Lenses.* A double-concave (bi-concave) lens has two concave curvatures.

*b. Plano-Concave Lenses.* A plano-concave lens has one concave surface and one plano surface.

*c. Concavo-Convex Lenses.* A concavo-convex (diverging meniscus) lens has one face with a concave surface and one face with a convex surface. The concave surface is more strongly curved. The convex surface of either converging or diverging lenses of this type is often toward the light. The location of the more pronounced curve determines whether a lens is convergent or divergent.

## Section II. ABERRATIONS AND OTHER DEFECTS OF LENSES

### 3–7. General

*a.* A perfect lens is one that projects an image point for point in the exact form as the object. This is not always possible in the image formed by a simple lens, because there may be defects in the lens. A simple positive lens, such as a converging meniscus, will project an image, but it may have optical defects that will prevent critical sharpness and limit its use. These optical defects are called lens aberrations.

*b.* An aberration is an optical imperfection responsible for an image distortion. It can be avoided by combining several lenses and by eliminating marginal rays refracted through the outer edges of a lens. The six general types of aberrations are: spherical aberration, chromatic aberration, astigmatism, coma, curvature of field, and distortion.

*c.* Other optical defects in a lens, which are usually corrected during the designing process, include Newton's rings, light loss, air bubbles, and flare.

### 3–8. Spherical Aberration

Spherical aberration occurs in a convergent lens when light rays refracted through the center of a lens and those refracted through the outer margins do not intersect the lens axis at a single point. This causes a blurred image, since the other rays intersect the axis closer to the lens than do the more central ones (fig. 3–6). The opposite is true of a divergent lens (fig. 3–7). It should be noted that the thickness of a lens has a decided influence on the degree of spherical aberration, which is least in thin lenses. Spherical aberration can be reduced, and sometimes eliminated, by using either one of the following methods:

*a. Use of a Diaphragm.* Since the central portion of a lens is most free from spherical aberration, it is first necessary to perform lens tests to reveal how much of the area around the axis can be used to form a sharp image. This area is called the circle of least aberration. Then, to reduce spherical aberration, it is necessary to mask out all rays passing through a lens beyond this circle (fig. 3–8). The mask used for this purpose is called a lens stop, or diaphragm, which is a flat adjustable ring of opaque material. This lens stop, or diaphragm, will reduce spherical aberration, but it will also cut down the effective size of a lens by limiting the amount of light passing through the lens.

*b. Use of a Compound Lens.* Spherical aberration can also be eliminated by cementing together a convergent lens and divergent lens (fig. 3–9).

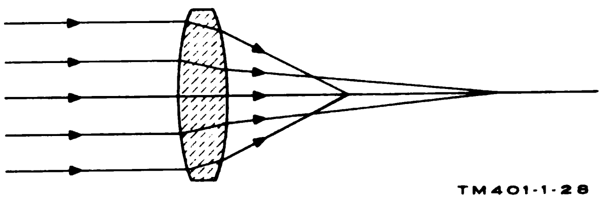


*Figure 3–6. Spherical aberration of a convergent lens.*

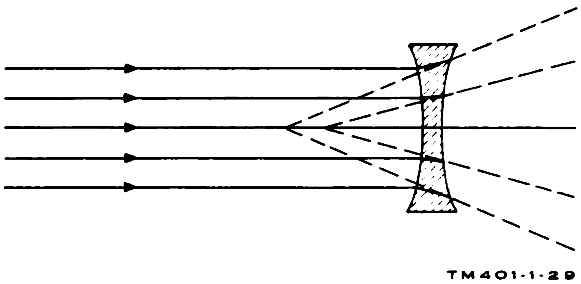


*Figure 3–7. Spherical aberration of a divergent lens.*

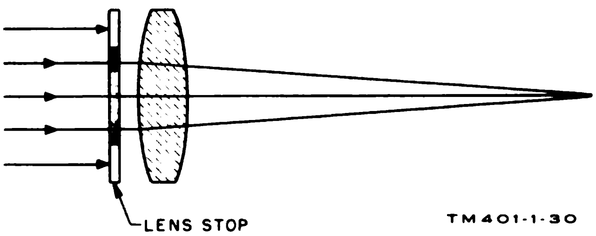


*Figure 3–8. Effect of a lens stop (diaphragm) on spherical aberration.*

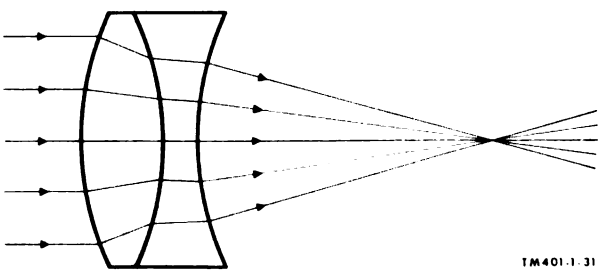


*Figure 3–9. Effect of a compound lens on spherical aberration.*

## 3–9. Chromatic Aberration

When light is refracted through a lens, light rays of different wavelengths are dispersed into bundles of rays of the same wavelength and form a spectrum of various colors. Rays of different colors are refracted to different degrees (red undergoes the least refraction, and violet the most). This optical defect, which is present in every uncorrected single lens, is known as chromatic aberration, or chromatism. Violet rays focus nearer the lens than red rays (fig. 3–10), and the rays of other colors focus at intermediate points. Because each color has a different point of focus, the projected image will be fringed with color. Chromatic aberration can be avoided by using a compound lens (fig. 3–11).

## 3–10. Astigmatism

Astigmatism (fig. 3–12) is the inability of a lens to focus both horizontal and vertical lines simultaneously sharp. This is quite evident in the areas at the margins and corners of the picture. If the focus in these areas is adjusted for the vertical lines, the horizontal lines will be light; conversely, if the focus is adjusted for the horizontal lines, the vertical lines will be light.

## 3–11. Coma

Coma (fig. 3–13) is a spherical aberration in which the image of a point source is a comet-shaped blur. This condition, in which images at the edges of the lens field are blurred, is caused by the unequal refracting power of the various concentric ring surfaces of a lens. Light rays from the lens focus at slightly different points and cause portions of points of light rays to overlap and produce blurred

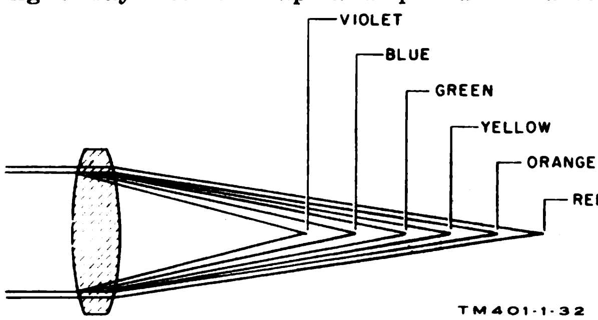


*Figure 3–10. Cause of chromatic aberration.*

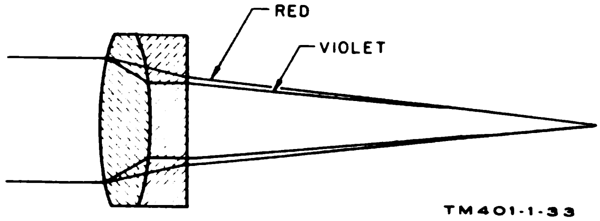


*Figure 3–11. Correction of chromatic aberration.*

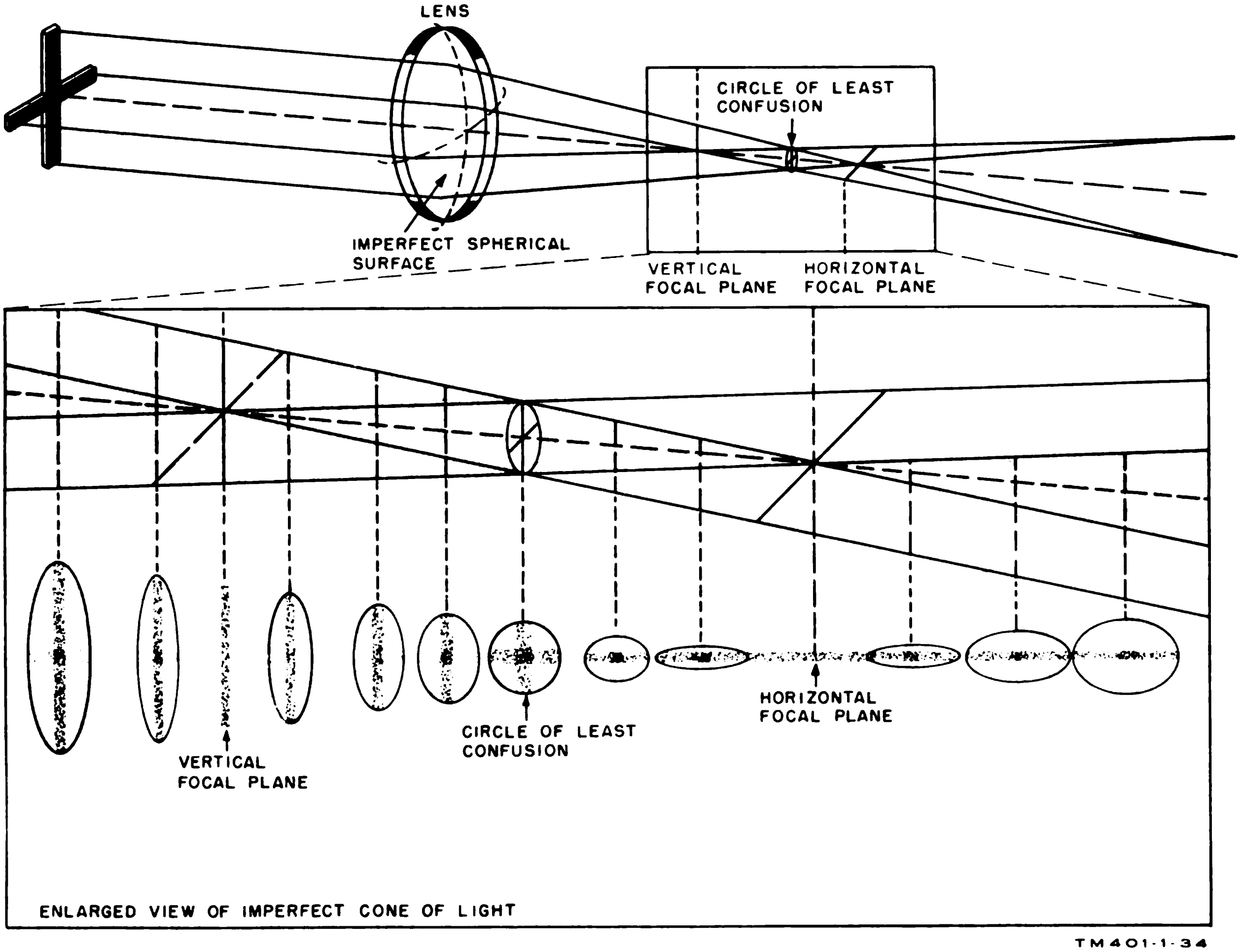


*Figure 3–12. Astigmatic refraction of a point of light.*

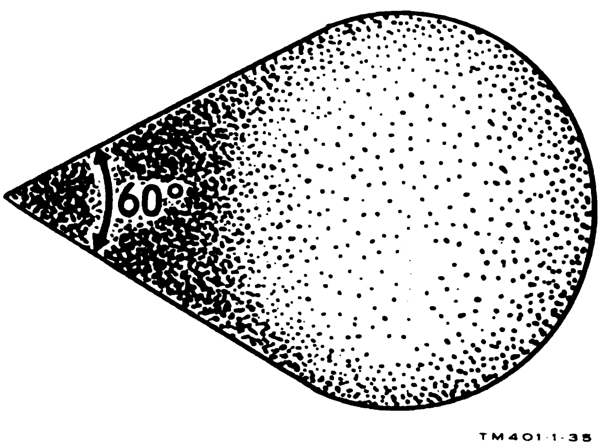


*Figure 3–13. Coma.*

images. To form a sharply defined point of light, the rays from each zone must come to focus at exactly the same plane.

## 3–12. Curvature of Field

The field of a lens is the area in which the real image produced by a lens is formed. If this area is flat, the image is not distorted; if it is concave or saucer-shaped, rather than flat, the condition is called curvature of field. To visualize curvature of field, think of an image of a cross made by a lens with this defect. (fig. 3–14). Light rays from the ends of the arm come to a focus nearer the lens than rays from the center of the cross. If the lens is focused on the center of the cross, the ends of the arms are not in sharp focus, and vice versa. To be in focus over the entire film, the image must be flat. Flatness of field is achieved by opposing the curvature of one lens surface with a lens of opposite curvature. A device that will limit use to only the center portion of the lens will aid in reducing the effects of this defect.

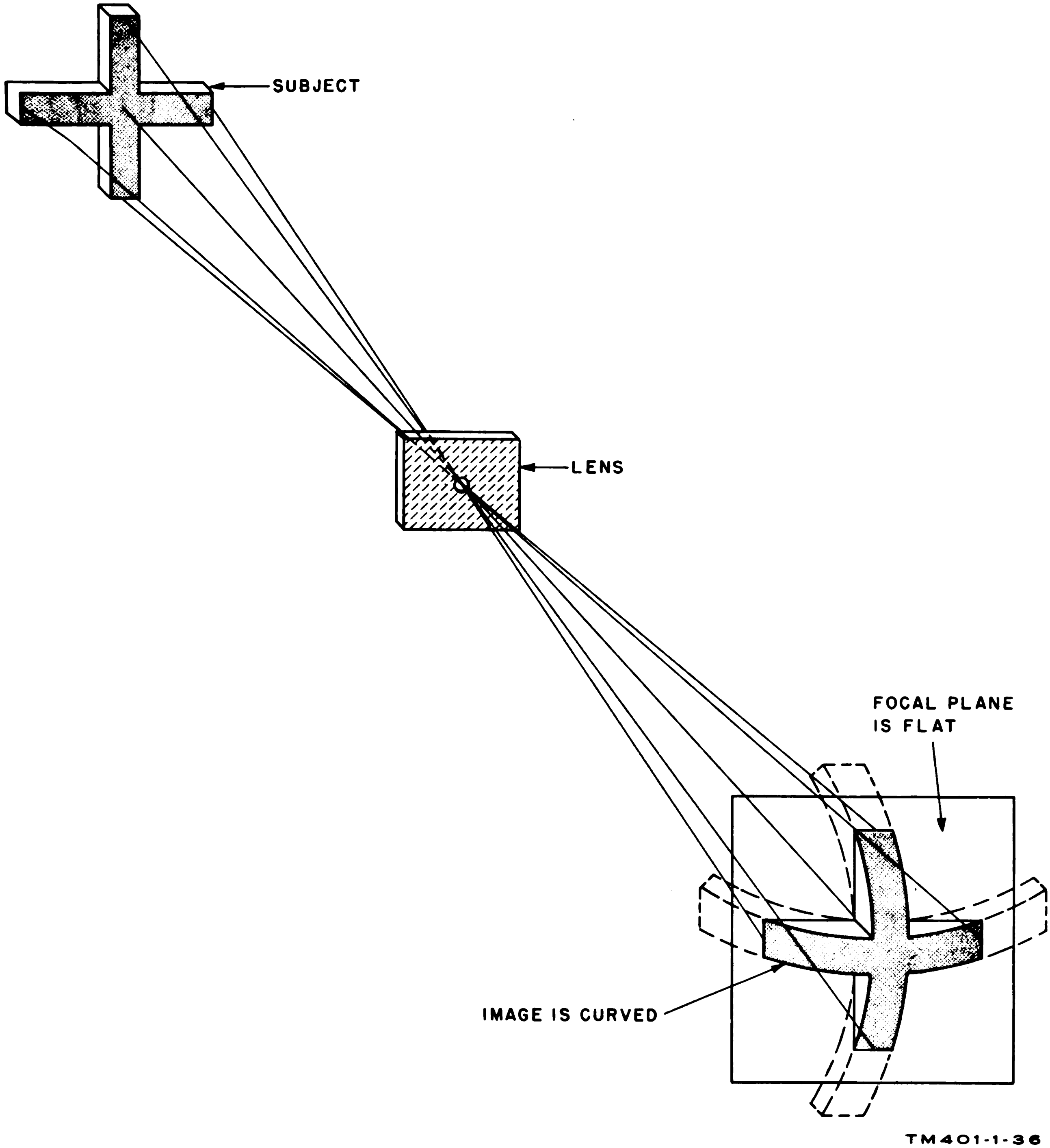


*Figure 3–14. Curvature of field.*

## 3–13. Radial Distortion

Distortion is a form of aberration that occurs when light rays from different points are refracted by dissimilar portions of a lens. When light rays are refracted by a lens with this defect, a straight line extending across the field is curved. Rays from the middle of the line strike closer to the center of a lens than rays from the ends of the line. Therefore, these rays are refracted at a different angle than

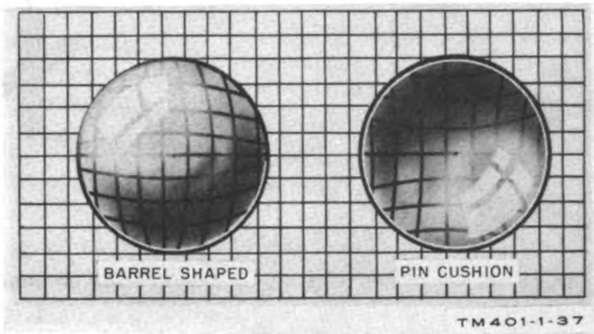


*Figure 3–15. Distortion.*

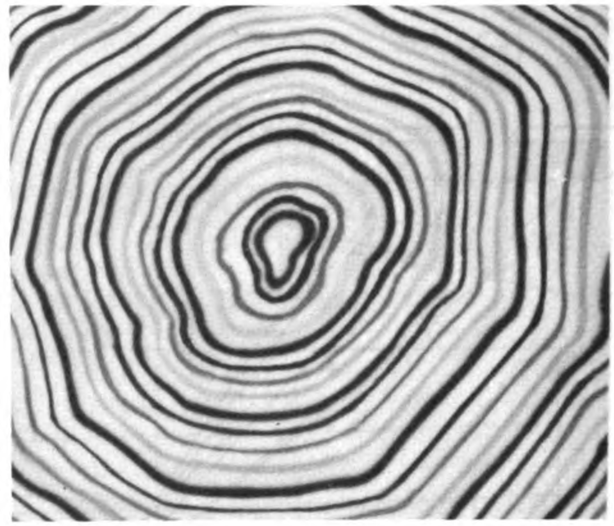

*Figure 3–16. Newton's rings—greatly magnified.*

rays striking near the margin of the lens. The projected image appears curved, rather than straight.

*a. Types of Distortion.* If the lines curve away from the center of a lens, the distortion is barrel shaped (fig. 3–15). If the lines curve toward the center, the distortion has the shape of an hourglass or pincushion. Distortion in a convergent lens produces the hourglass effect; distortion in a divergent lens produces the barrel-shaped effect.

*b. Removing Distortion.* Distortion in a lens is removed by grinding the lens properly or by placing a diaphragm between a pair of lenses. In the latter case, one form of distortion neutralizes the other, and the lens is called rectilinear. A diaphragm can be placed between or behind a properly ground lens without causing distortion. An anastigmatic lens, which is able to project an accurate image of an object, is used to correct astigmatism and other aberrations.

## 3–14. Newton's Rings

When positive and negative lenses of slightly unequal curvature are pressed together, irregular light and dark bands, or patches of color, appear between the surfaces. These patterns are called Newton's rings (fig. 3–16). This con-

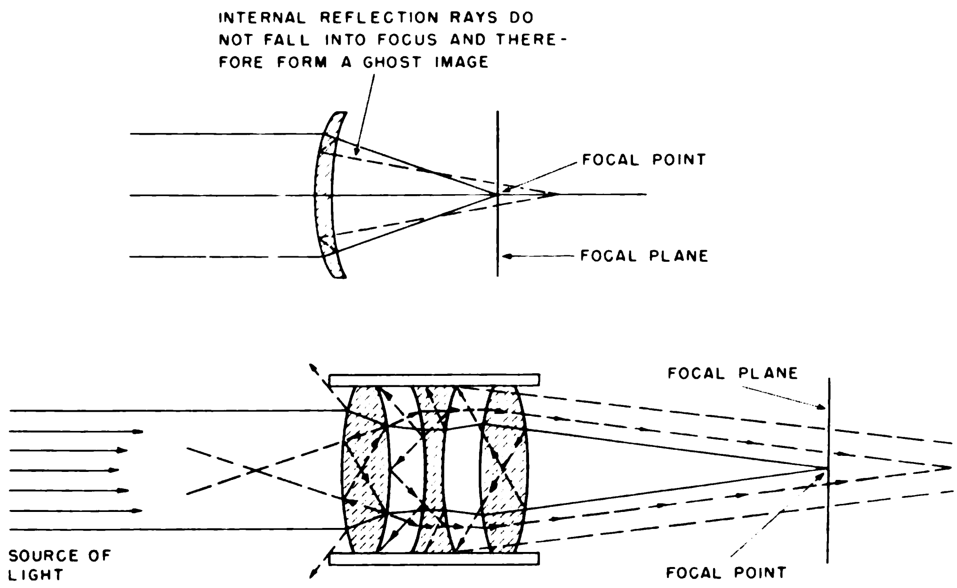


*Figure 3–17. Flare.*

dition, which is a defect found in some compound lenses, was first brought to the attention of the world by Sir Isaac Newton.

### 3–15. Light Loss

*a.* Whenever light rays strike the surface of any lens or prism, a certain amount of light is lost by reflection. In addition, light is absorbed by every element it travels through or strikes. Thus, the more elements combined in a lens system, the more light is lost by absorption and reflection.

*b.* Light loss can be greatly reduced by coating the surfaces of lens elements. The additional light transmitted by coated photographic lenses produces brighter images with improved tonal separation.

### 3–16. Air Bubbles in Lenses

Optical glass usually contains small air bubbles, which form during the heating process in production. These bubbles could be removed by further heating, but this would be accomplished only at a sacrifice in the quality of the glass. Since these bubbles neither benefit nor interfere with the performance of a lens, the actual loss of light as a result of them is negligible.

### 3–17. Flare

This condition causes patches of light or ghost images to appear within the projected image.

*a.* Mechanical flare occurs when light is reflected from some bright spot within a lens mounting or a faulty lens shade. The use of correct lens shades will shield lenses from stray light and reduce mechanical flare.

*b.* Optical flare occurs when light is reflected as it strikes individual lens surfaces (fig. 3–17). Optical flare tends to form in every lens, but complex lenses are subject to more optical flare than simple lenses because they are composed of more elements. Optical flare can be reduced by coating the lens surfaces with magnesium fluoride. This coating should be applied only by a qualified lens technician.

## Section III. FOCAL PLANE AND FOCAL LENGTH

### 3–18. General

*a.* When a lens projects an image, the plane in which the image is sharply formed is called the focal plane.

*b.* The distance from the optical center of a lens to its focal plane, when the lens is focused at infinity, is called focal length (fig. 3–18). This distance can be changed in some lenses by merely separating the lens elements; however, very few lens have movable and removable elements.

*c.* Focal length controls image brightness, lens speed, and image size.

### 3–19. Speed of Lens

The speed of a lens refers to the intensity of the light that forms the image on the film plane.

*a. Light Intensity.* The intensity of the light transmitted by a lens depends upon the diameter of the aperture (diaphragm opening) (fig. 3–19), the number of lens elements, the number of reflecting surfaces, and the focal length of the lens (fig. 3–20). With other factors remaining constant, a large aperture admits more light, or is faster, and a longer focal length decreases the light intensity, or is slower. In the same way that a card gets dimmer as a flashlight is moved farther away from it (fig. 3–21), a photographic image becomes dimmer as the focal length is increased. This is because light must travel a longer distance to reach the focal plane (para 2–20).

*b. Lens Aperture.* The aperture of a lens, expressed as an f/number (fig. 3–22), represents the ratio of the focal length to the diameter of the lens opening, as follows:

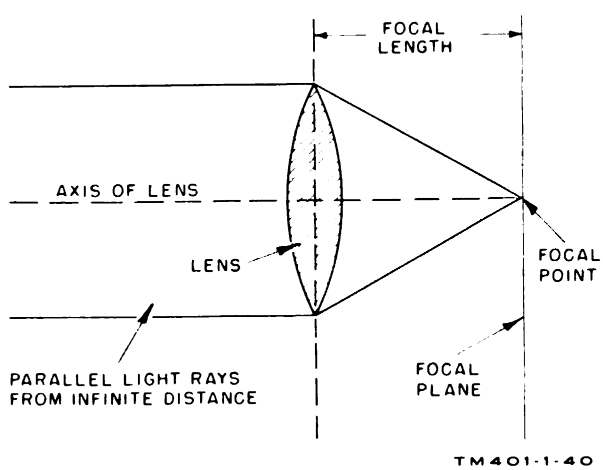


*Figure 3–18. Focal length.*

$$\frac{\text{Focal length}}{\text{Diameter of a lens opening}} = \text{f/number}$$

*For example,* if a lens has an 8-inch focal length and the diameter of the lens opening is 2 inches, the aperture is f/4.

*c. Relationship of Apertures.* The maximum opening of a lens can be reduced by adjusting the camera diaphragm. This will change the size of the aperture and, consequently, its light transmitting ability. If the diaphragm of the f/4 lens, discussed above is closed down to 1 inch, the effective lens aperture is 8 (8 ÷ 1 = 8). This is expressed as f/8.

*d. Full Stops.* Full stops are a series of f/numbers, each of which admits exactly one-half as much light as the preceding f/number. The table below indicates the amount of light passed by a lens when set at various stops. *For example,* a lens set at f/5.6 passes one-sixteenth as much light as a lens with an aperture of f/1.4. Conversely, a lens at f/1.4 passes sixteen times as much light as a lens with an aperture of f/5.6.

*Table 3–1. Full Stops*

| f/number, or diaphragmn scale sequence | Units of light passed by the lens in a given time (as the lens is closed down) | Units of light passed by the lens in a given time (as the lens is opened wider) |
|---|---|---|
| 1.4 | 1 | 2048 |
| 2 | 1/2 | 1024 |
| 2.8 | 1/4 | 512 |
| 4 | 1/8 | 256 |
| 5.6 | 1/16 | 128 |
| 8 | 1/32 | 64 |
| 11 | 1/64 | 32 |
| 16 | 1/128 | 16 |
| 22 | 1/256 | 8 |
| 32 | 1/512 | 4 |
| 45 | 1/1024 | 2 |
| 64 | 1/2048 | 1 |

*e. Intermediate Stops.* A continuously variable diaphragm makes possible settings between full stops.

## 3–20. The English and the Continental f/Number Systems

The following table shows the relationship of

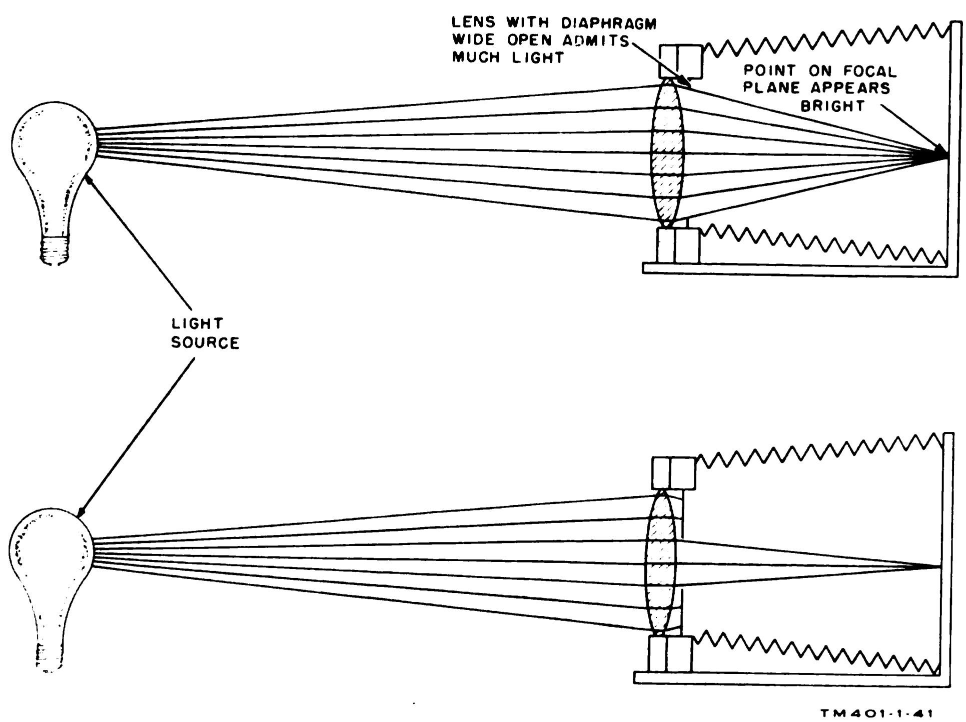


*Figure 3–19. Effect of diaphragm opening.*

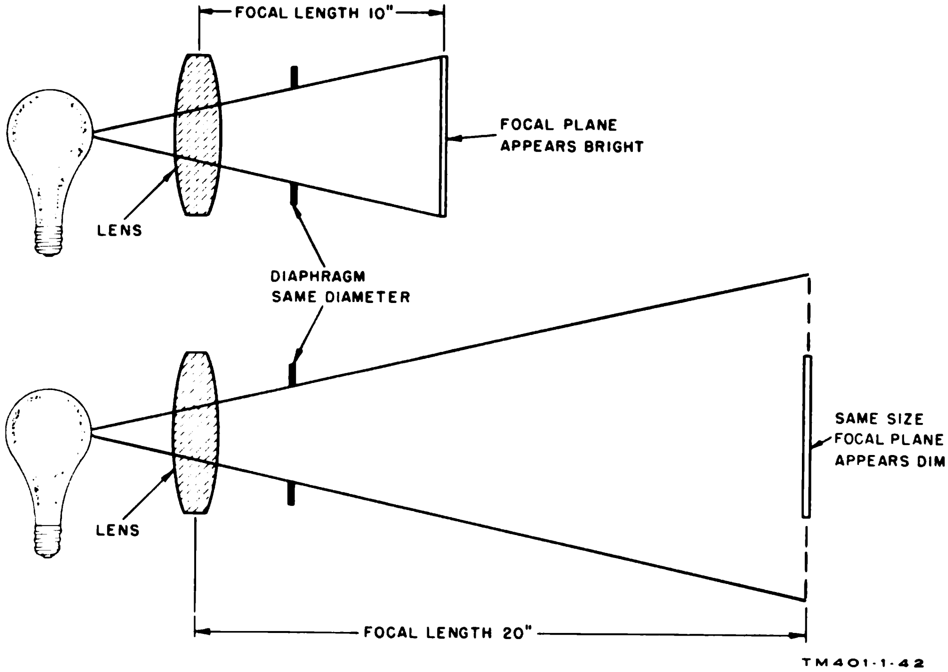


*Figure 3–20. Relationship of focal length and light source.*

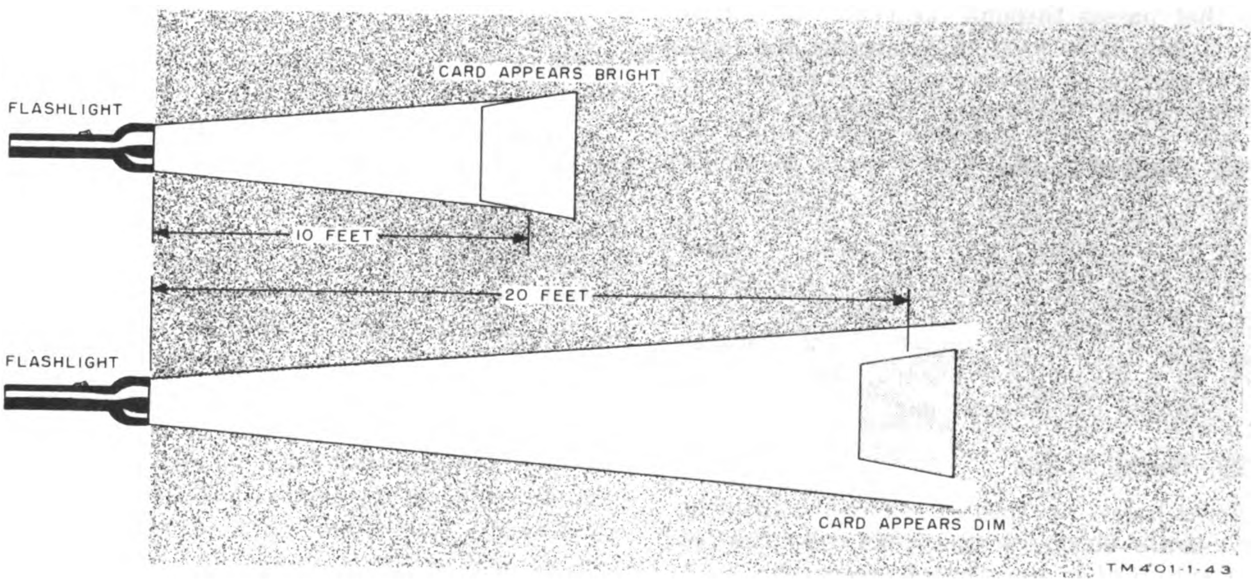


*Figure 3–21. Effect of distance on brightness.*

numerical settings used in the English and Continental systems. In both systems, each indicated numerical value passes twice the amount of light as the next higher number and, conversely, one-half the amount of light as the next lower number.

*Table 3–II. Lens Aperture Settings*

| English system of lens aperture setting | | | | Continental system of lens aperture setting | | | |
|---|---|---|---|---|---|---|---|
| f/1.4 | f/4 | f/11 | f/32 | f/1.6 | f/4.5 | f/12.5 | f/36 |
| f/2 | f/5.6 | f/16 | f/45 | f/2.3 | f/6.3 | f/18 | f/50 |
| f/2.8 | f/8 | f/22 | f/64 | f/3.2 | f/9 | f/25 | f/72 |

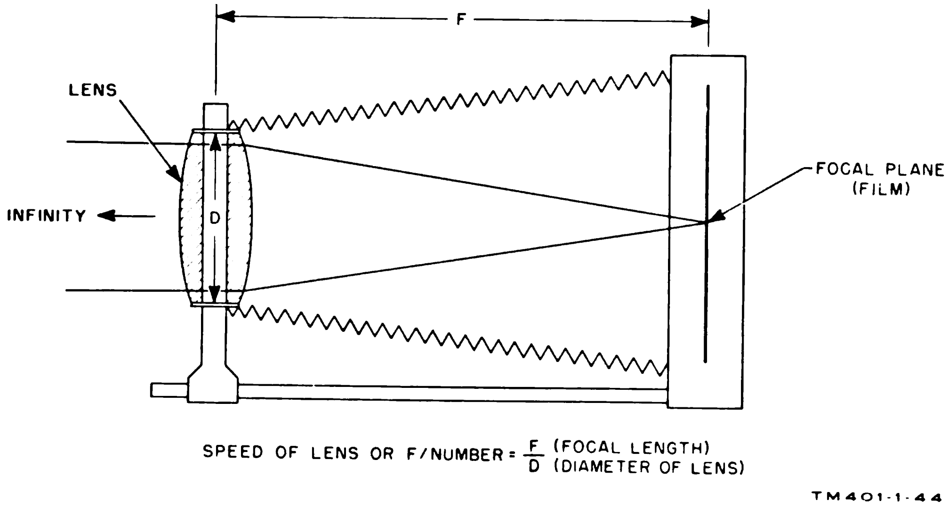


*Figure 3–22. Speed (aperture) of a lens.*

## Section IV. PERFORMANCE FACTORS OF LENSES

### 3–21. Optical Axis

The optical axis of a lens is an imaginary line that passes through the center of a lens (fig. 3–23). It is used to determine the location of specific points necessary in comprehending the optical performance of lenses.

### 3–22. Optical Center

The optical center of a lens is located at a point on the optical axis, generally of equal distance from the outer surfaces of a symmetrical lens (fig. 3–23). In a converging (convex) lens it is at the center of the thickest part. In a diverging (concave) lens it is at the center of the thinnest part.

### 3–23. Nodal Points

Nodal points are located where the incident ray and the emergent ray would cross the optical axis if they were unrefracted. The point at which the unrefracted incident ray would cross the optical axis is termed node of admission. The point at which the unrefracted emergent ray would cross the optical axis is indicated as the node of emergence. In figure 3–23, a ray of light AB enters the lens and is refracted. As it passes through the glass, it crosses the optical axis at the optical center C. The light ray contniues to D and is refracted again.

*a. Node of Admission ($N_1$).* By extending AB in its original direction and disregarding the effect of refraction, the extended line will intersect the optical axis, before reaching the optical center, and establish the node of admission ($N_1$).

*b. Node of Emergence ($N_2$).* By disregarding the effect of refraction and extending DE toward the optical axis, the node of emergence ($N_2$) is established. Normally, nodal points are located within a lens, but with some optical systems, such as telephoto lenses, the points may be located outside the lens.

*c. Use of Optical Center and Nodal Points.* In most photographic lenses, the diaphragm is consdiered to be at the optical center. For exacting purposes the focal length of a lens is measured from the node of emergence, while the subject-lens distance is measured from the node of admission. However, for most practical purposes, it is sufficient to take both measurements from the front lens surface.

### 3–24. Focal Length of Convergent Lens

The focal length of a convergent lens, when focused at infinity, is the distance from the node of emergence of the lens to the focal plane. To determine the approximate focal length of a convergent lens, focus the lens so

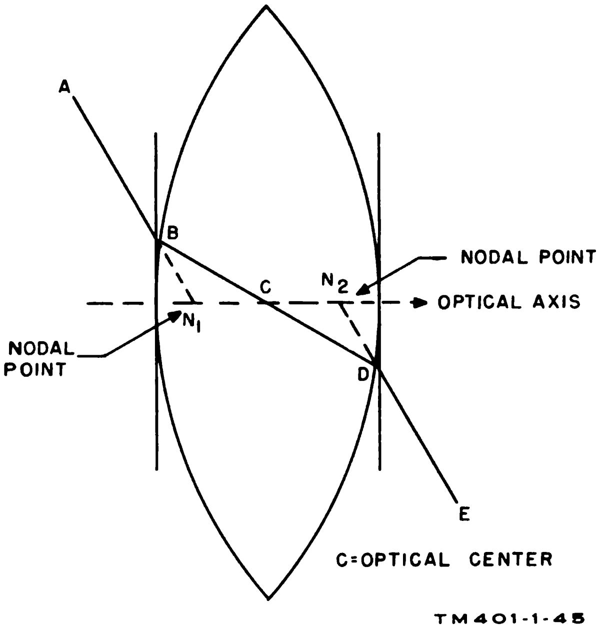


*Figure 3-23. Optical center, optical axis, and nodal points of a lens.*

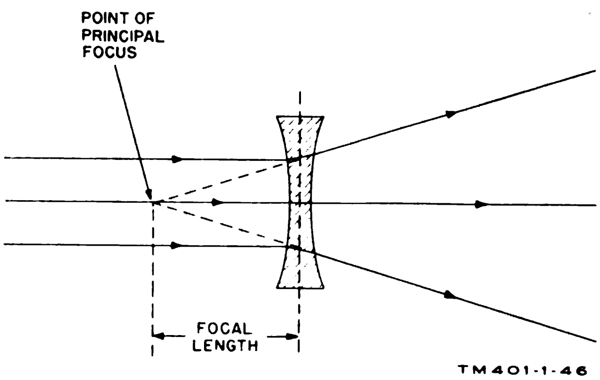


*Figure 3-24. Focal length of a divergent lens.*

that an image of some distant object falls on a sheet of paper or ground glass. Then, measure the distance from the image to the optical center. Determine the point of principal focus by finding the place where the image projected by the lens is sharpest. Figure 3–19 indicates that the principal point of focus and the fcoal plane of a convergent lens are behind the lens.

## 3–25. Focal Lengths of Divergent Lens

The focal length of a divergent lens, when focused at infinity, it the distance from the node of emergence of the lens to the focal plane. The point of principal focus and other focal points are located where the emergent rays intersect the axis between the object and the lens (fig. 3–24). When an object is near a divergent lens, the point of principal focus, the frontal plane, and other focal points are located in front of the lens.

## 3–26. Angle of Field

The angle of field (fig. 3–25) is the widest angle at which light entering a lens will produce, at its focal plane, a circle of good definition. This is the usable portion of the circle of illumination.

*a.* A normal (standard) lens has, approximately, the same angle of field as the human eye (about 45° to 55°); a wide-angle lens has a wider angle of field; and long focal length and telephoto lenses have a narrower angle of field.

*b.* The angle of field has a definite effect on the size of the negative that can be used with a given lens, since any part of the film extending beyond the circle of good definition will yield an indistinct image.

## 3–27. Angle of View

The angle of view of a photographic lens determines actual coverage when used with a camera of a particular film (negative) size. It is the angle (fig. 3–26) that has its vertex at the lens and is subtended by the diagonal of the negative. To determine the angle of view, draw a line AB (fig. 3–27) equal to the focal length of the lens. Construct BC perpendicular to AB and locate point C so that BC is equal to one-half of the diagonal of the negative. Draw the line AC and measure the angle at A. Multiply the size of the angle by two to determine the angle of view.

## 3–28. Factors Affecting Angle of View

While angle of field is an unalterable optical characteristic of a lens, angle of view is a variable depending on focal length of the lens, film size of the camera with which the lens is used, and subject distance.

*a.* With a normal lens, the focal length is equal to the diagonal of the negative size used. When a normal focal length lens is used with a negative having a shorter diagonal than the

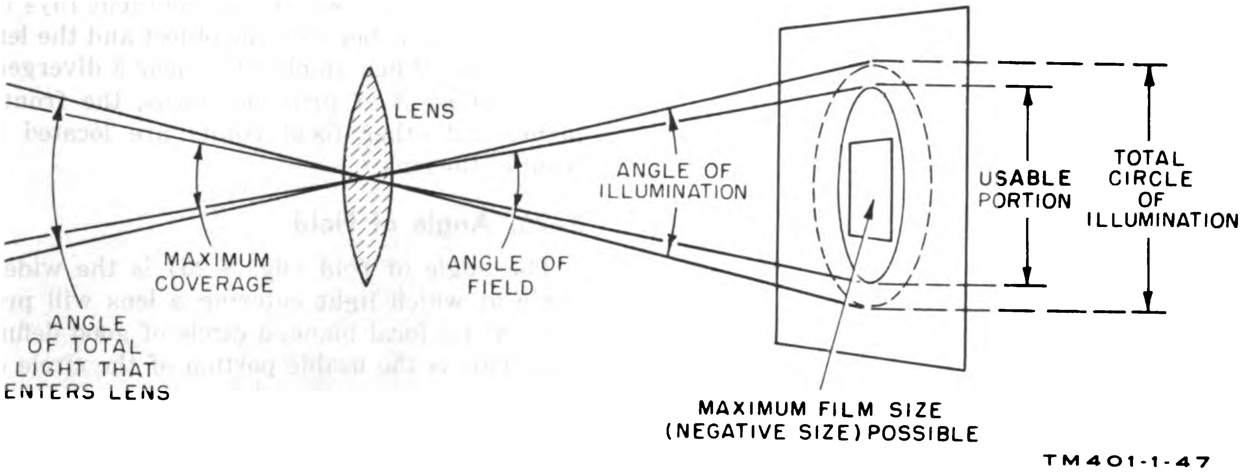


*Figure 3–25. Angle of field.*

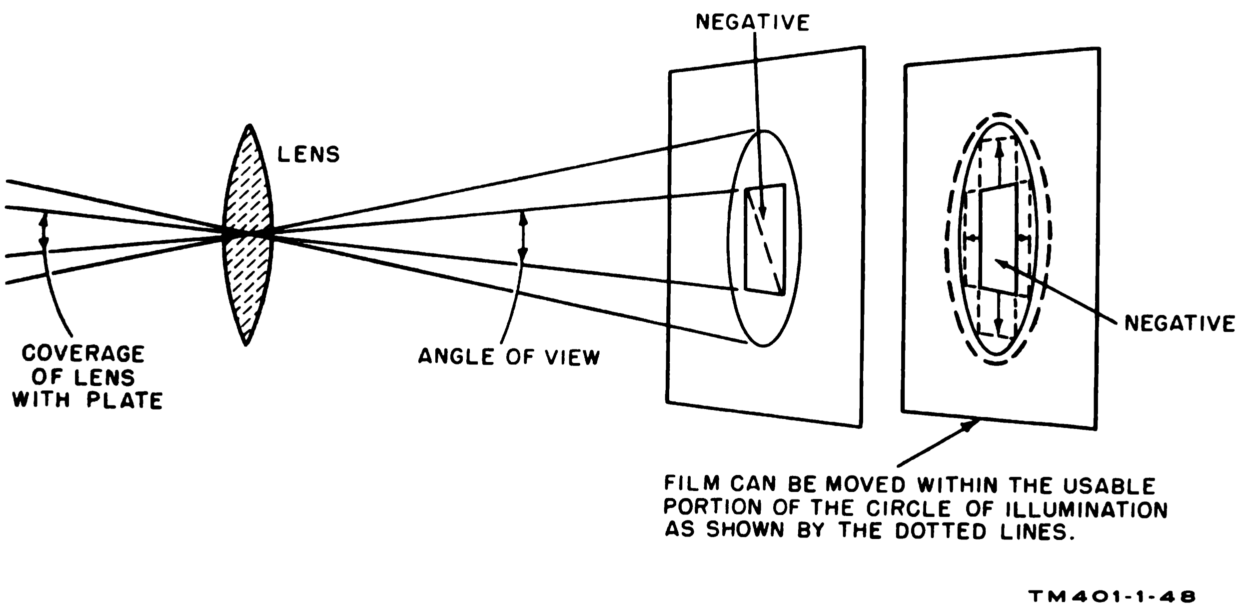


*Figure 3–26. Angle of view.*

focal length of the lens, the result is a narrow angle of view. If the same lens is used with a larger negative, the angle of view is greater. The larger the negative to be covered by a lens of a given focal length, the greater the angle of view.

*b*. If the focal length is equal to the diagonal of the negative, the angle of view decreases as the subject distance is shortened.

*c*. Since manufacturers usually produce lenses for specific negative sizes, they also prepare tables giving angles of view of commonly used lenses. Some manufacturers also list angle of view for vertical and horizontal measurements of film. *For example*, the readings for a 5-inch focal length lens are diagonal 65°, horizontal 53°, and vertical 44°.

*d*. Figure 3–28 illustrates the angles of view for wide-angle, normal, and long focal length lenses.

## 3–29. Tables of Angles of View of Lenses

*a*. *Angles of View of Still Camera Lenses*. The following table applies to still camera lenses focused at infinity.

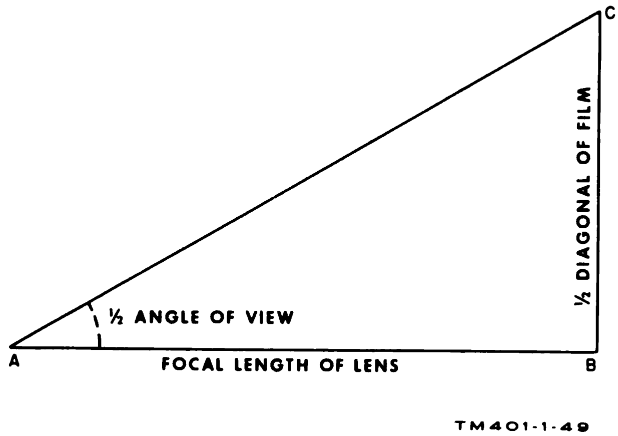


*Figure 3–27. Determining angle of view.*

*Table 3–III. Angles of View of Still Camera Lenses*

| Negative size | Focal length of lens | Angle of view |
|---|---|---|
| *Inches* | *Inches* | *Degrees* |
| 1x1.5 | 1⅔ | 63 |
| 1x1.5 | 2 | 46 |
| 1x1.5 | 3⅗ | 27 |
| 2¼x2¾ | 2⅘ | 64 |
| 2¼x2¾ | 4 | 46 |
| 2¼x2¾ | 9 | 22 |
| 4x5 | 5 | 65 |
| 4x5 | 6 | 56 |
| 4x5 | 7 | 49 |
| 4x5 | 10 | 35 |

*b. Angles of View of Motion Picture Camera Lenses.* The following table applies to 35-mm and 16-mm motion picture camera lenses focused at infinity.

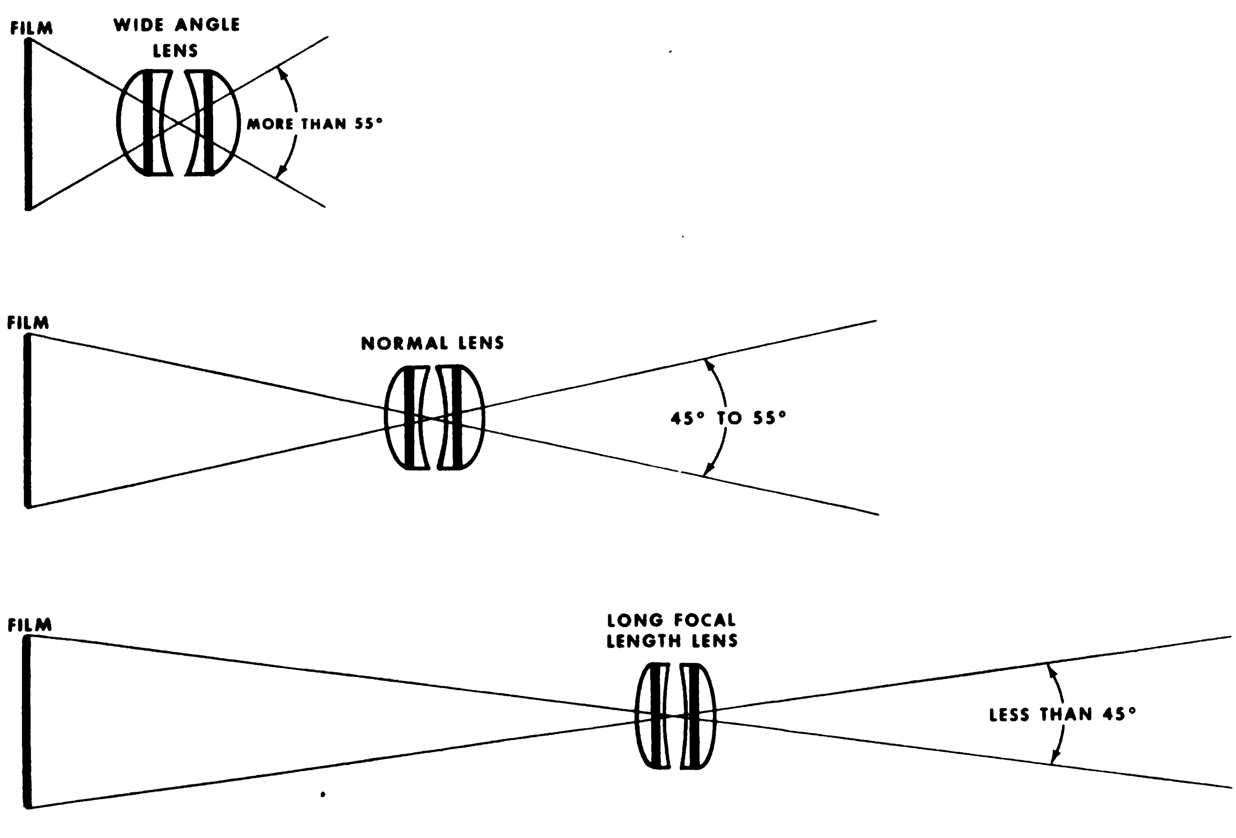


*Figure 3–28. Angle of view for various focal length lenses.*

*Table 3–IV. Angles of View of Motion Picture Camera Lenses*

| 35-mm Motion picture lens angle | | | | 16-mm Motion picture lens angles | | | |
|---|---|---|---|---|---|---|---|
| Lens size | | Angle | | Lens size | | Angle | |
| Inches | Milli-meters | Vertical | Horizon-tal | Inches | Milli-meters | Vertical | Horizon-tal |
| | 24 | 36.9° | 49.3° | ⅝ | 15 | 27.6° | 36.6° |
| 1 | 25 | 35.5° | 47.5° | ¾ | 20 | 20.5° | 27.1° |
| 1⅛ | 28 | 31.9° | 42.9° | 1 | 25 | 16.9° | 21.2° |
| 1¼ | 32 | 28.1° | 37.9° | 1⅜ | 35 | 11.1° | 15.7° |
| 1⅜ | 35 | 25.7° | 35.0° | 2 | 50 | 8.1° | 11.4° |
| 1⅝ | 40 | 22.7° | 30.8° | 3 | 75 | 5.2° | 7.2° |
| 2 | 50 | 18.3° | 25.0° | 4 | 100 | 4.5° | 5.3° |
| 2⅜ | 60 | 15.2° | 20.8° | 6 | 150 | 2.4° | 3.4° |
| 3 | 75 | 12.2° | 16.7° | | | | |
| 4 | 100 | 9.1° | 12.6° | | | | |
| 4⅜ | 110 | 8.3° | 11.4° | | | | |
| 4¾ | 120 | 7.6° | 10.5° | | | | |
| 5 | 125 | 7.2° | 10.1° | | | | |
| 5¼ | 135 | 6.8° | 9.3° | | | | |
| 6 | 150 | 6.1° | 8.4° | | | | |
| 7 | 175 | 5.2° | 7.2° | | | | |
| 8 | 200 | 4.6° | 6.3° | | | | |

## 3–30. Illumination of Negative

To be uniform, a negative must receive even illumination from a lens. If the margins receive less light than the center, a vignetting effect results. Actually, this effect is so insignificant that it is not obvious at ordinary angles of view. Nevertheless, the vignetting effect is produced by all lenses. When a lens with an angle of view of 90° or more is used, the vignetting effect becomes noticeable.

## 3–31. Image Size

*a.* If the subject distance remains constant, the focal length of a lens controls the size of an image on the film. A short focal length lens has a wide angle of view and produces, without changing the negative size, a smaller image than a long focal-length lens. When two lenses of different focal lengths are used with the same film size, the lens with the longer focal length includes less of the subject area. However, any subject detail in that area appears larger than it would if photographed with a shorter focal length lens (fig. 3–29).

*b.* The local length of the lens most frequently used with a particular camera should be approximately the same length as the diagonal measurement of the negative size. Use of the correct lens causes the proportions of objects to be recorded as normal. The following table indicates the diagonal measurement of the more common negative sizes:

*Table 3–V. Diagonals of Negatives*

| Negative sizes | | Diagonals | |
|---|---|---|---|
| Millimeters | Inches | Millimeters | Inches |
| 24x36 | 1x1½ | 43 | 1.8 |
| 60x60 | 2¼x2¼ | 85 | 3.4 |
| 60x90 | 2¼x3¼ | 108 | 4.3 |
| 100x125 | 4x5 | 160 | 6.4 |
| 130x180 | 5x7 | 220 | 8.7 |
| 200x250 | 8x10 | 288 | 12.8 |
| 264x336 | 11x14 | 426 | 17.75 |

## 3–32. Circle of Confusion

*a.* Basically, a photograph is an accumulation of many points that are exact images of points composing a subject. *For example,* light rays striking a subject are reflected from points on a subject, are refracted by a lens, and are reproduced on film or ground glass as circles.

*b.* Light rays seem to produce a "cone" of light. The apex of the cone originates at a point on the subject; the base of the cone is at the

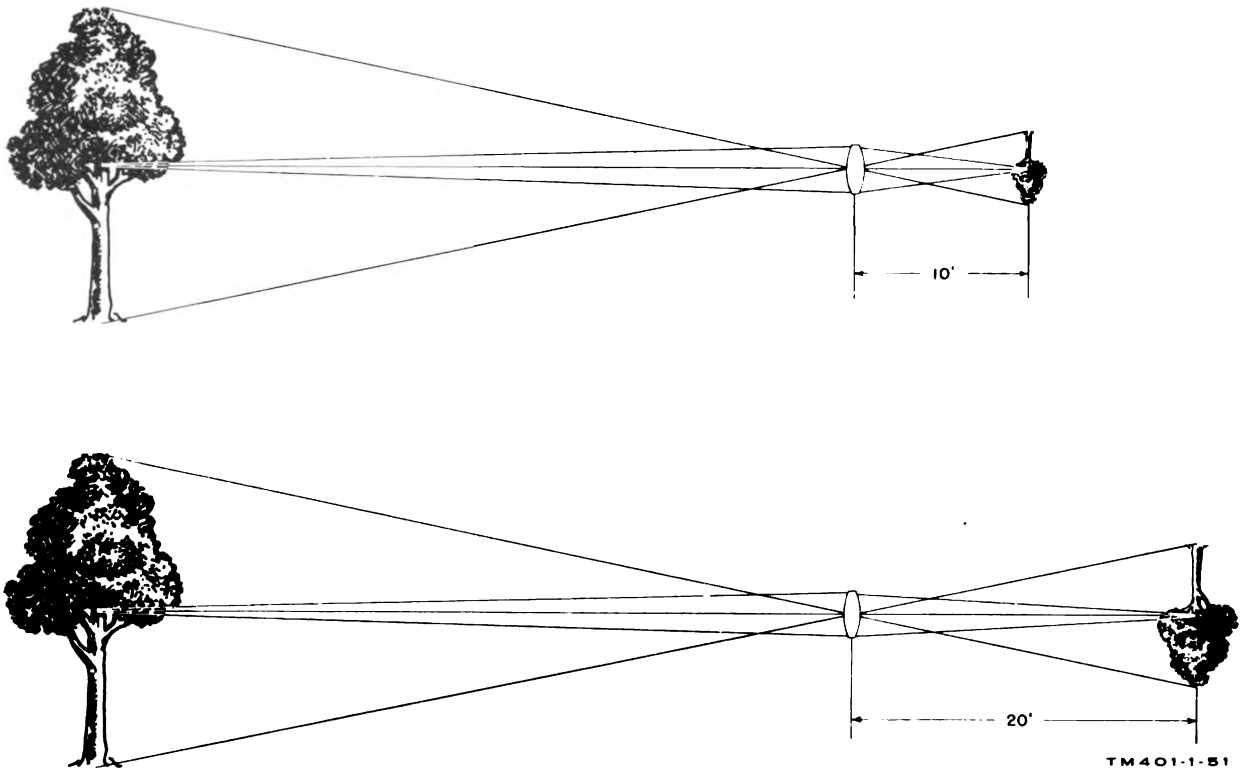


*Figure 3–29. Size of image in relation to focal length.*

lens. When the light rays pass through the lens, the cone of light is reversed. The base is still at the lens, but the apex now lies in the focal plane. An infinite number of these cones combine to produce a photographic image.

*c.* If the cone of light is intersected either in front or behind the focal plane, the light rays form circles rather than points. These are called circles of confusion.

*d.* If the circles of confusion are small enough, they rae "acceptably" sharp to the eye and are said to be in focus. If the circles are larger than 1/100 inch, they appear as circles and the image, now consisting of many circles, is blurred and out of focus. It should be noted, however, that a circle if confusion may be acceptable for one photograph and unacceptable for a second type photograph.

## 3–33. Factors Controlling Circles of Confusion

*a. Focusing.* Light rays from sharp points on ground glass or film if the subject is at a correct distance from the lens in relation to the distance between the lens and the film. At this point, the image is sharp and the lens is focused properly. If the ground glass or film is then moved nearer to or farther from the lens (fig. 3–30), the light rays intersect in front of or behind the ground glass or film and the image is blurred. This blur, caused by overlappping circles of confusion, can be overcome by changing the distance between the lens and the focal plane to give a minimum circle of confusion. This is called focusing.

*b. Lens Speed.* Another factor controlling circles of confusion is the speed or aperture of a lens. The smaller a lens opening, the less light reaches the film and the narrower the light rays falling on the lens. The narrower these rays, the smaller the circles of confusion. In practice, this means that a small lens opening permits the recording of several objects at varying distances. Even if the rays from some objects do not intersect perfectly at the film plane, the circles of confusion intersecting before or behind the film are negligible and still appear sharp.

*c. Photographic Prints.* Another factor to consider when dealing with circles of confusion

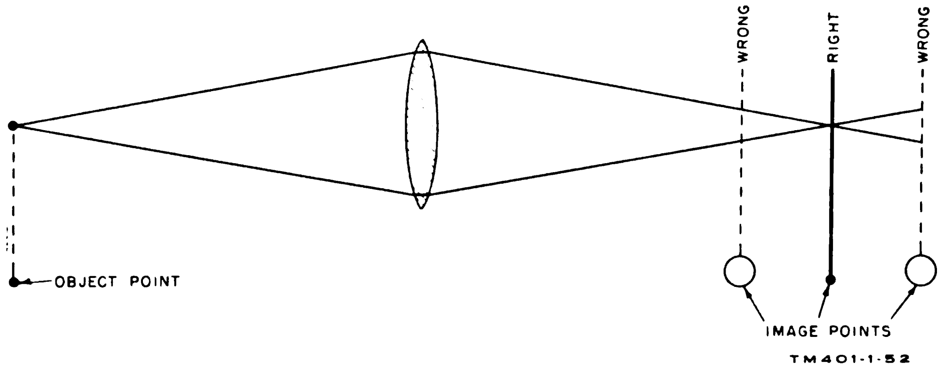


*Figure 3–30. Image points nearer to and farther from focal point.*

is the manner in which the negative is to be printed. Negatives used primarily for contact printing do not require as small a circle of confusion as negatives from which enlargements are to be made. A 1/250-inch circle of confusion is generally critical enough for negatives made with 4- by 5-inch cameras, and 1/1,000-inch circle for negatives made with miniature cameras. A uniform standard of definition in enlarging is automatically obtained by establishing the value of the circle of confusion as 1/1,000 of the focal length of the photographic recording lens of larger cameras and 1/2,000 of the focal length for miniature cameras. This is better than using arbitrary figures that vary with different focal length lenses.

## 3–34. Circle of Confusion Formulas

For most lenses, divide the effective focal length by 1,000. Miniature camera lenses require a more critical standard and, therefore, their effective focal length should be divided by 2,000. The formula is as follows:

$$\text{Circle of confusion} = \frac{\text{focal length}}{1{,}000}$$

*Table 3–VI. Diameter of Disc of Circle of Confusion With Given Formula*

| Focal length of lens | | Circle of confusion | |
|---|---|---|---|
| Inches | Millimeters | Inch | Millimeter |
| 2 | 50 | 1/500 | 0.05 |
| 4 | 100 | 1/250 | .1 |
| 5 | 125 | 1/200 | .125 |
| 6 | 150 | 1/167 | .15 |
| 8 | 200 | 1/125 | .2 |
| 10 | 250 | 1/100 | .25 |

*Table 3–VII. Circle of Confusion for Various Types of Camera Lenses*

| Type of lens | Focal length in millimeters | Applicable constant—part of effective focal length of lens | Circle of confusion in inches |
|---|---|---|---|
| Motion picture | 15 to 50 | 1/1,000 | 1/500 |
| Miniature | 50 and up | 1/2,000 | 1/1,000 |
| General photography | 75, 100 and 150 | 1/1,000 | 1/200 |
| View camera | 150 and plus | 1/1,000 | 1/100 |

## 3–35. Conjugate Distance (Foci)

The distance between a subject and a photographic lens varies inversely with the distance from the lens to the focal plane. These distances are called conjugate distances or foci (fig. 3–31). When we say that these distances vary inversely, we mean that one distance increases as the other decreases, and vice versa. In other words, when the lens-to-subject distance changes, the lens-to-film distance must change. When the lens-to-subject distance increases, the lens-to-film distance decreases (fig. 3–32). Similarly, if the lens-to-subject distance decreases, the lens-to-film distance will increase (fig. 3–32).

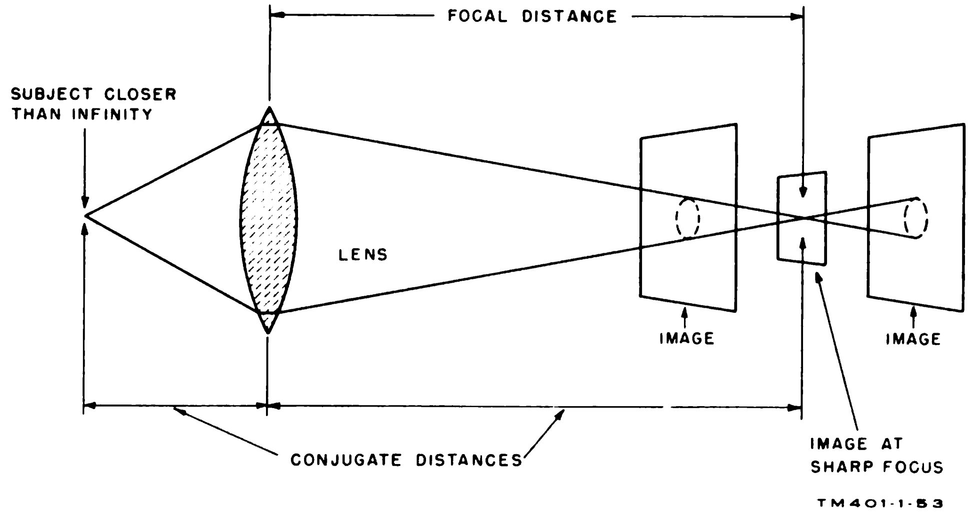


*Figure 3–31. Conjugate distances.*

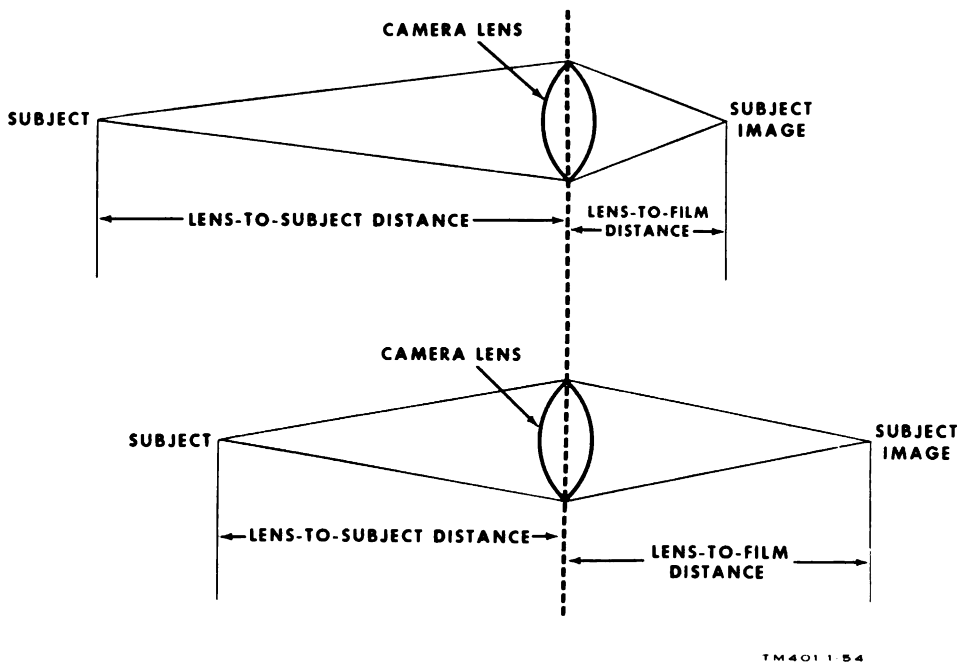


*Figure 3–32. Effect of lens-to-subject distance on lens-to-film distance.*

## 3–36. Use of Conjugate Distances

Let us assume that your are to photograph a tool that is 12 inches long. The image is to be 6 inches long, and you are to use a camera with 12-inch lens to accomplish your work.

*a.* The first step is to determine the scale of the photograph by using the formula below:

$$\text{Scale} = \frac{\text{image length}}{\text{object length}} = \frac{6}{12} = \frac{1}{2},$$

*b.* The next step is to use the formula below to determine the image distance.

$$\begin{aligned}\text{Image distance} &= \text{focal length x (scale plus 1)}\\ &= 12 \text{ x } (1 + \tfrac{1}{2})\\ &= 12 \text{ x } 1\tfrac{1}{2} = 18\end{aligned}$$

In other words, the lens should be 18 inches from the film.

*c.* The last step is to use the formula below to determine the object distance.

$$\text{Object distance} = \frac{\text{image distance}}{\text{scale}} = \frac{18}{1/2} = 36$$

In other words, the lens should be 36 inches from the object.

## 3–37. Focusing Lens for One Object

*a.* When light rays from a far object pass through a lens, they form a sharp image close to the lens. When light rays from a near object pass through a lens, they form a sharp image farther from the lens. This means that the lens must be focused on either the far or the near object, depending on which one the photographer wants to be sharp. If a sharp image of the near object is desired, the lens should be focused by moving it farther away from the ground glass or film. If a sharp image of the far object is desired, the lens must be moved closer to the ground glass or film.

*b.* Figure 3–33 illustrates this process. Light coming from far object A passes through the lens to form a sharp object at $A_1$, and light coming from the nearer object C passes through the lens to form a sharp image at $C_1$. To obtain a sharp image of object A, move the film to $A_1$. To obtain a sharp image of object C, move the film to $C_1$. This process of moving the focal or film plane of a camera to the point of intersection of a given ray is called focusing.

## 3–38. Resolving Power of Definition

*a.* The resolving power of a lens, also called the definition of a lens, is its ability to reproduce fine lines. Resolving power is usually measured in lines per millimeter. Thus, if the resolving power of a lens is 100 lines per millimeter, the lens records 100 definitely separated lines per millimeter. Most high quality lenses have a resolving power that far exceeds the resolving power of the film.

*b.* Two factors that influence the definition of a lens are the quality of the lens and diffraction. The maximum definition of any lens depends on the minimum circle of confusion. This, in turn, is controlled by the quality of the lens. Geometric limitations in lens design make it impossible to create a lens of uniform quality from center to edge. The edges retain aberrations that greatly affect definition. Accordingly, most manufacturers recommend use of the optimum aperture of a particular lens. This refers to the aperture at which the lens operates best. The optimum aperture is normally 2 to 2½ stops above the maximum aperture of the lens.

## 3–39. Depth of Field

*a.* Depth of field is the distance from the nearest point of acceptably sharp focus to the farthest point of acceptably sharp focus of a subject being photographed (fig. 3–34). Because most subjects exist in more than one plane and have depth, it is important in photog-

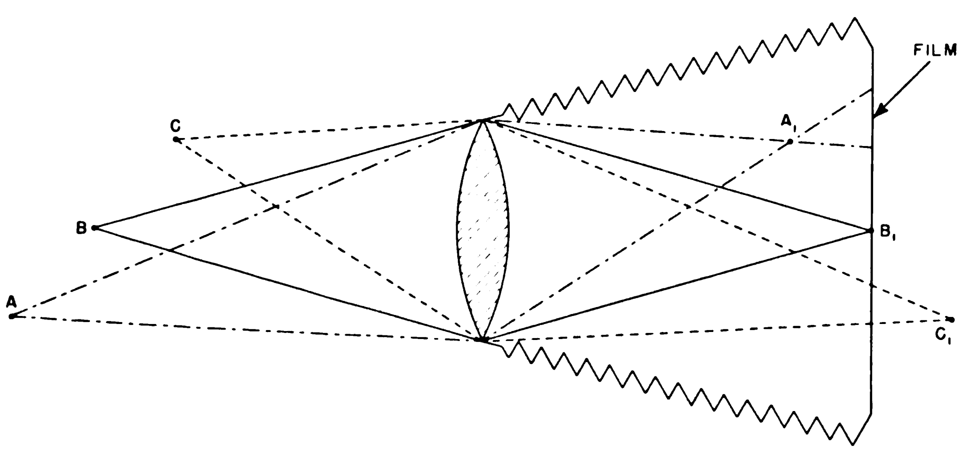


*Figure 3–33. Focusing for one object.*

raphy to have an area in which more than just a narrow vertical plane will appear sharp. Depth of field depends on the focal length of a lens, the lens stop, the distance from the point in focus to the lens, and the size of the circle of confusion.

*b.* Assume that a camera with a long focal length lens and a camera with a short focal length lens are placed at equal distances from a subject. In this case, the depth of field is greater with the short focal length lens than with the long focal length lens.

*c.* Depth of field also increases as the lens opening or aperture is decreased, because the size of each cone of light decreases in proportion to the aperture. The top and center sections of figure 3–35 show that a lens with a large aperture reproduces sharply only those objects located between B and D. In the lower sections, the sharpness range of the depth of field is increased to the distance A to E, because the diaphragm has been closed down to a small aperture.

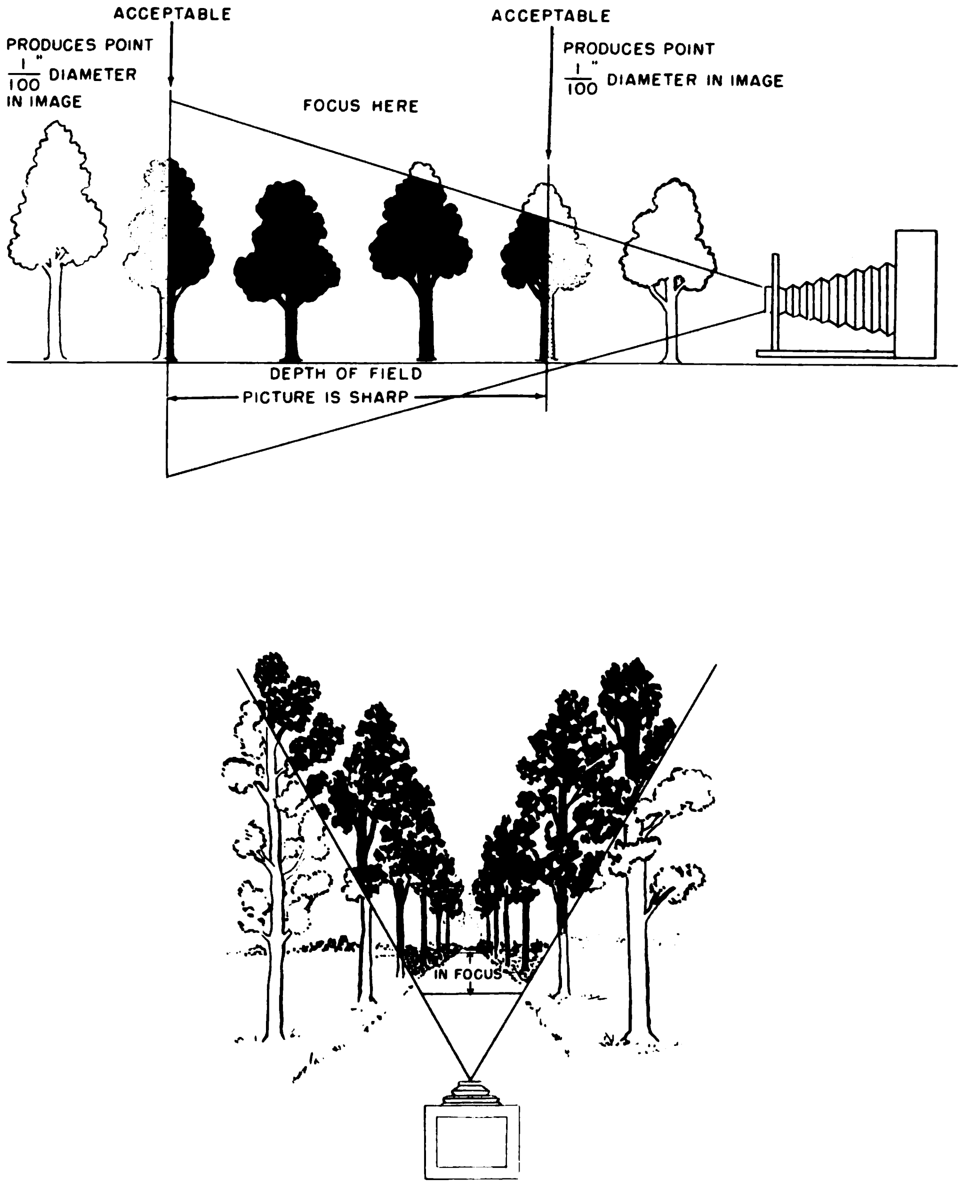


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*Figure 3–34. Depth of field.*

*d.* If a lens is focused on a nearby object (short distance setting), the depth of field is also short. If the distance setting is increased (lens is focused on a more distant object), the depth of field increases (fig. 3–36). For this reason, it is important to focus more accurately for pictures of nearby objects than for distant objects.

*e.* Accurate focus is also essential when using a large lens opening. A small f/stop compensates for minor inaccuracies. If enlargements are to be made from a negative, focusing must be extremely accurate.

## 3–40. Focusing Lens on Several Objects

When you are focusing a lens on several

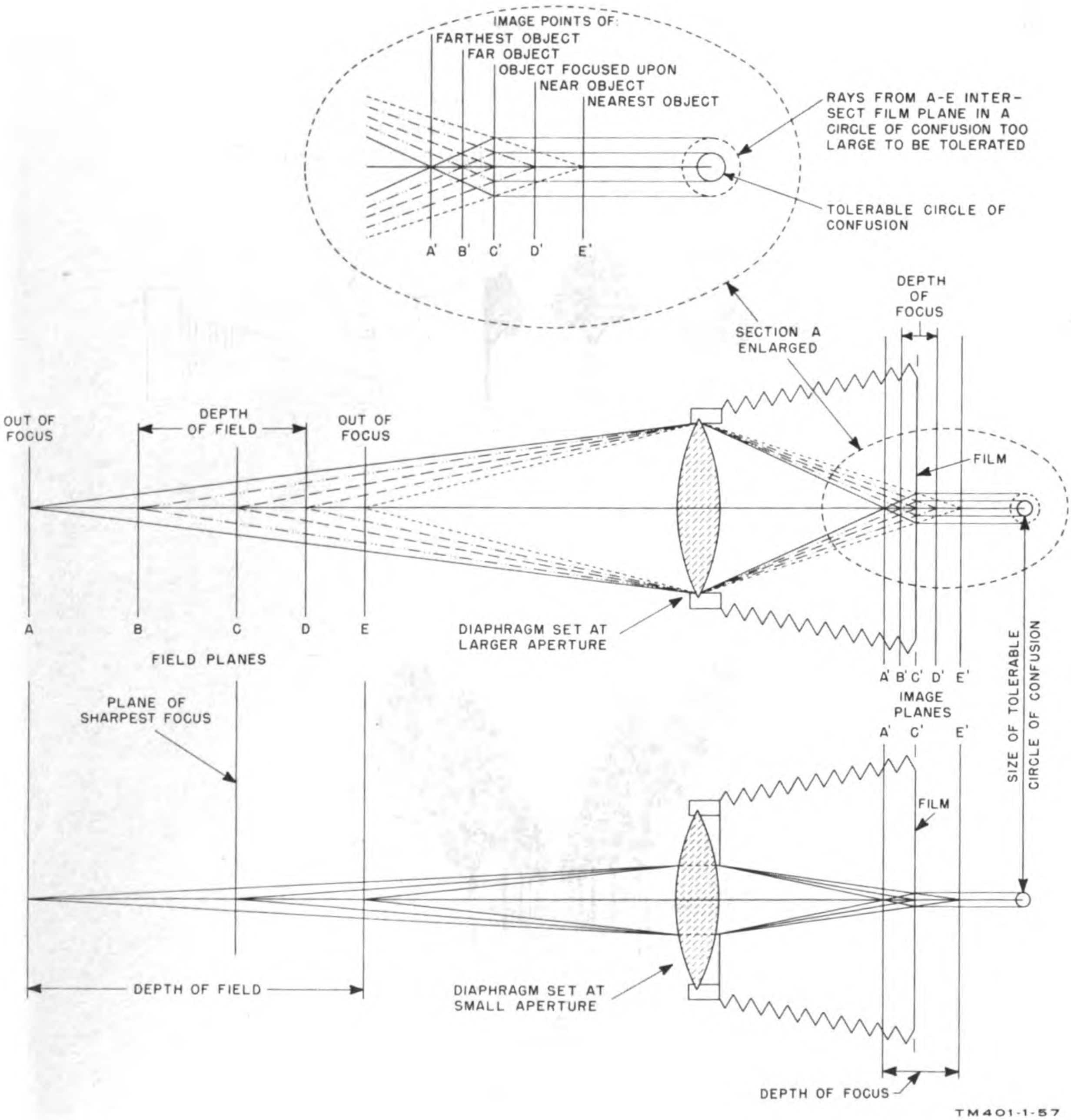


*Figure 3–35. Effect of diaphragm opening on depth of field.*

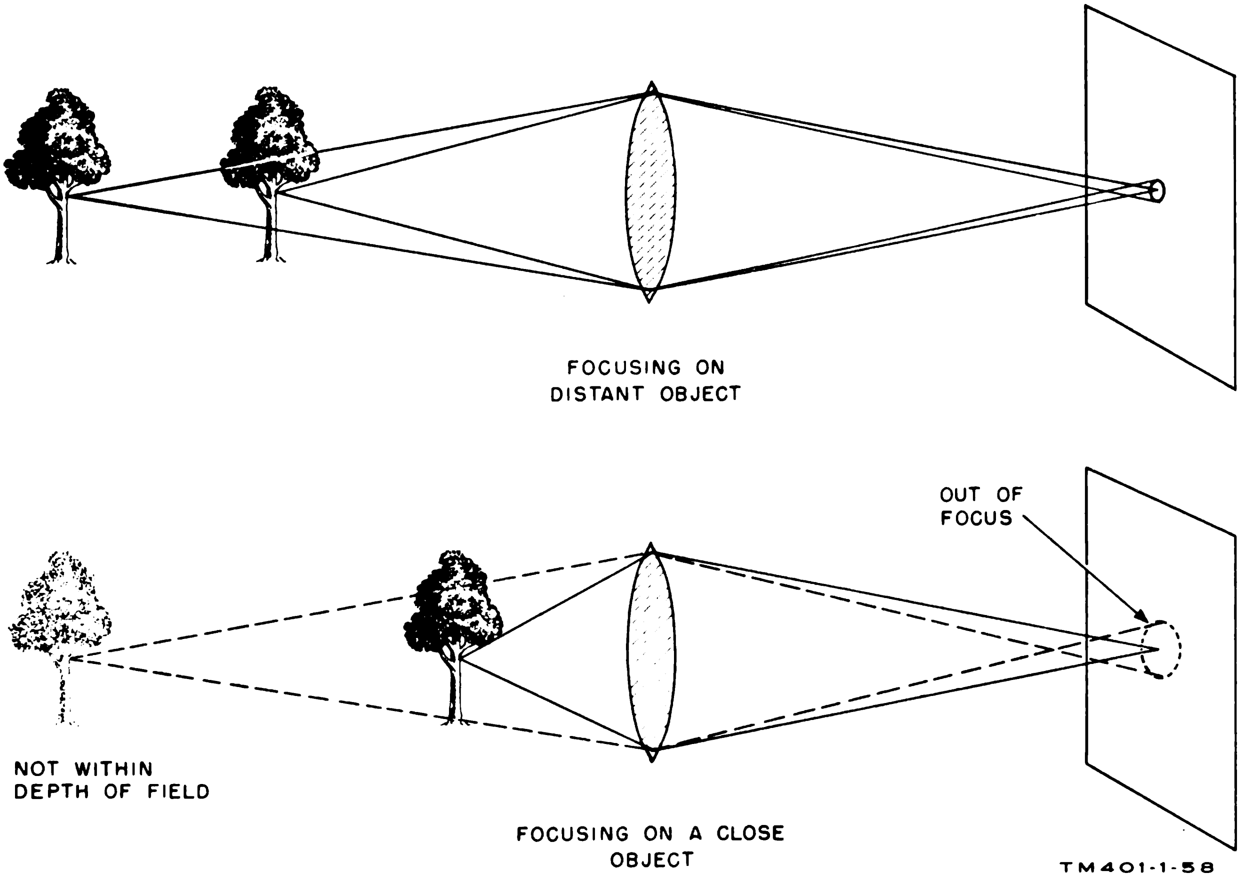


*Figure 3–36. Effect of distance on depth of field.*

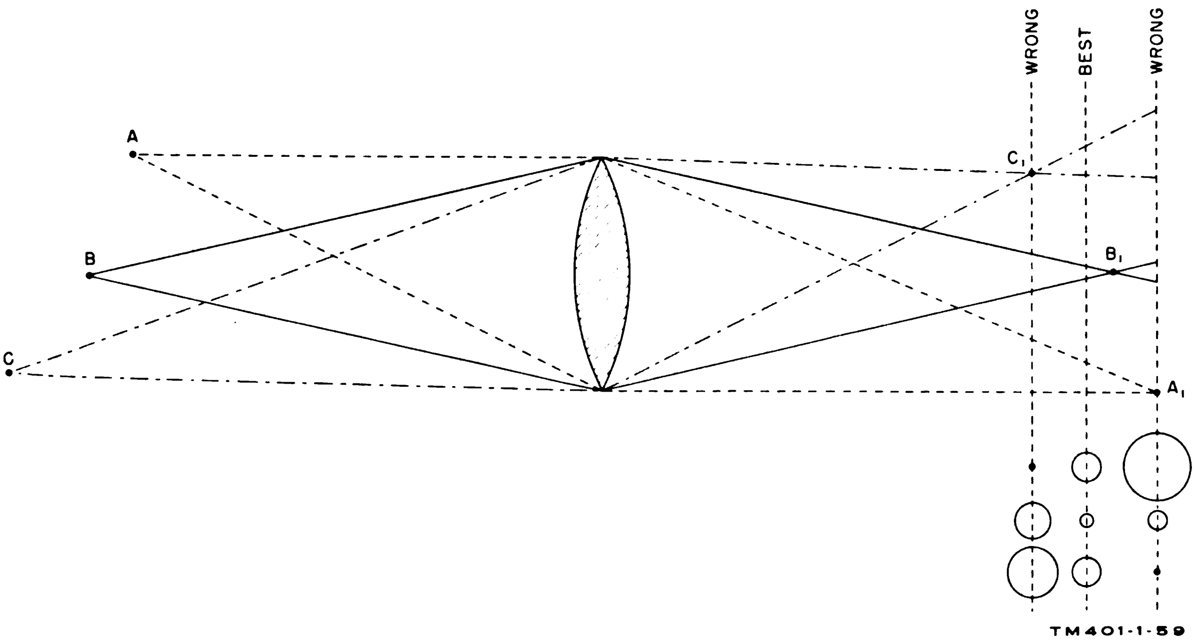


*Figure 3–37. Focusing one-third of the distance.*

objects that are at different distances from the lens, you must effect a compromise. You usually obtain the best results by focusing on a point one-third of the distance between the nearest ($C_1$) and farthest ($A_1$) point of focus (fig. 3–37).

## 3–41. Depth of Focus

Depth of focus (fig. 3–38) is the distance the focal plane can be moved forward and backward from the point of exact focus and still retain an image of acceptable sharpness. Figure 3–38 shows the area within which movement is possible.

## 3–42. Hyperfocal Distance

When a lens is focused on an object at infinity, the nearest point in usable focus is called the *hyperfocal point*. The distance between this point and the lens is the *hyperfocal distance* for the lens at that aperture.

*a.* When a lens is focused on its hyperfocal point, the depth of field extends from one-half of the hyperfocal distance to infinity. This setting provides maximum depth of field at any given f/number.

*b.* Hyperfocal distance is dependent upon the focal length of the lens, the lens stop, and the allowable circle of confusion.

*c.* If the aperature and circle of confusion are the same for two lenses, the longer focal length lens will have a greater hyperfocal distance than the shorter focal length lens. *For example,* the hyperfocal distance for an 8-inch lens might be 133 feet, whereas the hyperfocal distance for a 5-inch lens might be 84 feet at the same f/number.

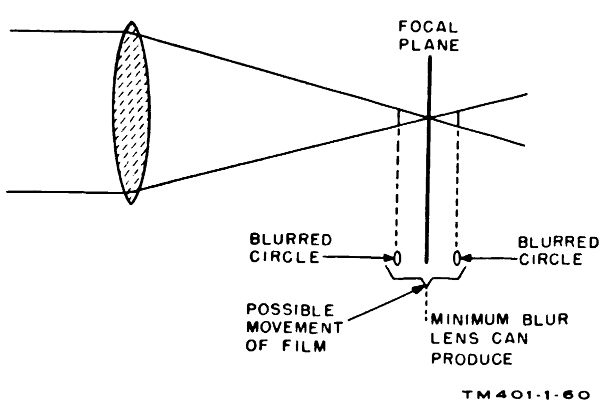


*Figure 3–38. Depth of focus.*

*d.* As the aperture or lens stop is closed down, the hyperfocal distance decreases. *For example,* assume that a lens stop of f/4.5 is used with a 5-inch lens. In this case, the hyperfocal distance will be 93 feet. If the lens stop is changed to f/16, the hyperfocal distance will become 26 feet (fig. 3–39).

*e.* If the circle of confusion for a given lens is decreased, the hyperfocal distance will be increased. *For example,* a 5-inch lens with a lens stop of f/8 and a circle of confusion of 1/000 will provide a hyperfocal distance of 26 feet. If the same lens and f/stop are used with a smaller circle of confusion (1/250 of an inch), the hyperfocal distance will be 65 feet.

## 3–43. Computation of Hyperfocal Distance

The following formula is used to compute hyperfocal distance.

$$H = \frac{F^2 \times \frac{1}{cc}}{12 \times f}$$

Where:

H = Hyperfocal distance in feet
F = Focal length of lens in inches
cc = Circle of confusion (para 3–34)
f = Aperture (f/number)

With camera lenses having a focal length to 4 inches, the formula is:

$$H = \frac{F^2 \times \frac{2000}{F}}{12f} = \frac{167F}{f}$$

Compute the hyperfocal distance of a 4-inch lens at stop f/4.5.

$$H = \frac{167 \times 4}{4.5} = \frac{668}{4.5} = 148.44 \text{ feet, for practical purposes} = 150 \text{ feet}$$

## 3–44. Determining Depth of Field

To determine depth of field, the hyperfocal distance must first be established. Using the hyperfocal distance, one can calculate the near and far distance. Depth of field is equal to the far point minus the near point in focus.

## 3–45. Computation of Depth of Field

The following formulas are used to compute depth of field:

Near point =

$$\frac{\text{hyperfocal distance} \times \text{distance focused on}}{\text{hyperfocal distance} + \text{distance focused on}} = \frac{HD}{H + D}$$

Far point =

$$\frac{\text{hyperfocal distance} \times \text{distance focused on}}{\text{hyperfocal distance} - \text{distance focused on}} = \frac{HD}{H - D}$$

Depth of field = far point − near point

Compute the depth of filed of a 5-inch lens at f/11 if the lens is focused on a point 10 feet from the lens and the allowable circle of confusion is 1/250.

$$H = \frac{F^2}{fc} = \frac{5 \times 5}{11 \times 1/250} = \frac{25 \times 250}{11} = \frac{6250}{11} = 568 \text{ inches} = 47 \text{ feet}$$

$$\text{Near point} = \frac{47 \times 10}{47 + 10} = \frac{470}{57} = 8.24 \text{ feet}$$

$$\text{Far point} = \frac{47 \times 10}{47 - 10} = \frac{470}{37} = 12.7 \text{ feet}$$

Depth of field = 12.7 − 8.24 = 4.46 feet or 4½ feet.

## 3–46. Depth of Field Indicator

Some cameras have depth of field indicators to show the approximate depth of field at various distances when using different lens stops. Figure 3–40 illustrates two settings, one when the lens is focused at 6 feet (on the left) and one when the lens is focused at 25 feet (on the right).

*a.* In the setting on the left in figure 3–40, the lens is focused at 6 feet. The depth is 5¾ to 6¼ feet with a lens stop of f/4.5; 5½ to 6½ feet with a lens stop of f/5.6; 5¼ to 6¾ feet with a lens stop of f/8; 5 to 7 feet with a lens stop of 5/11; 5 to 7½ feet with a lens stop of f/16; 4¾ to 8 feet with a lens stop of f/22; and 4¼ to 10 feet with a lens stop of f/32.

*b.* In the setting on the right in figure 3–40, the lens is focused at 25 feet. The depth of field, at the various lens stops ranges from 9 feet to infinity.

*c.* The depth of field scale is especially useful when you must know the exact sharpness range of the camera lens at various distance and aperture settings. This enables you to include objects at various distances within the area of focus.

## 3–47. Light Transmission

Light transmission capabilities of a lens are not determined by the transparency of glass alone, since any surface separating air from a medium reflects a portion of the light falling on it. Most of this reflected light is directed back through the front of a lens to produce a double internal reflection. This unwanted light,

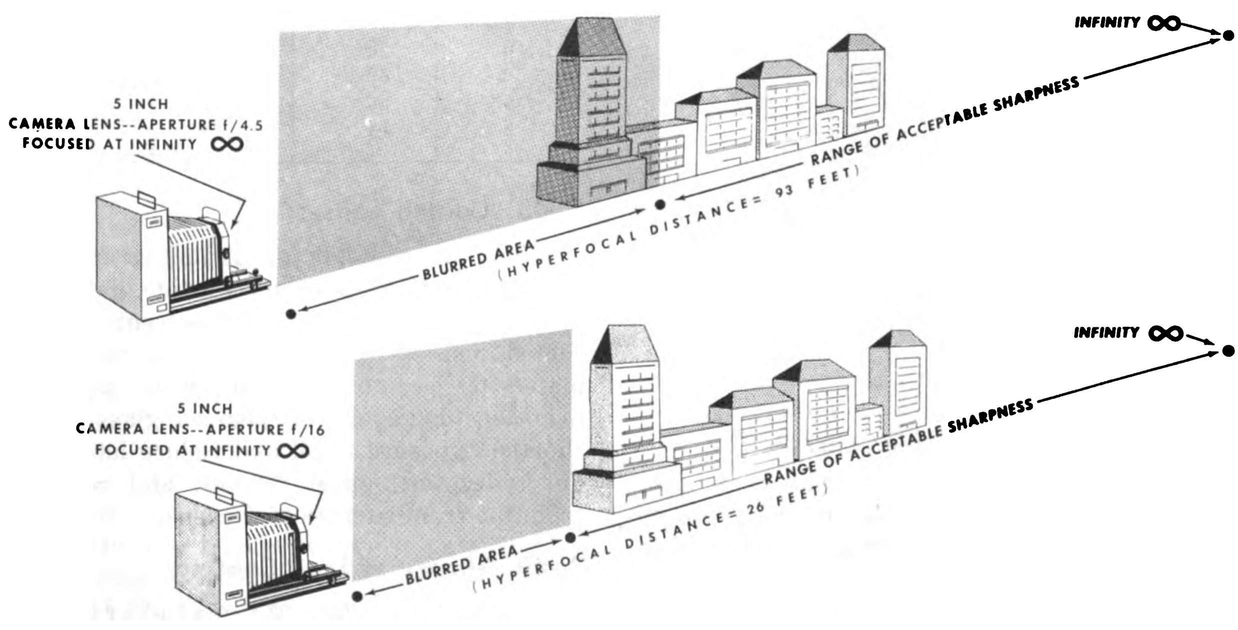


*Figure 3–39. Hyperfocal distance.*

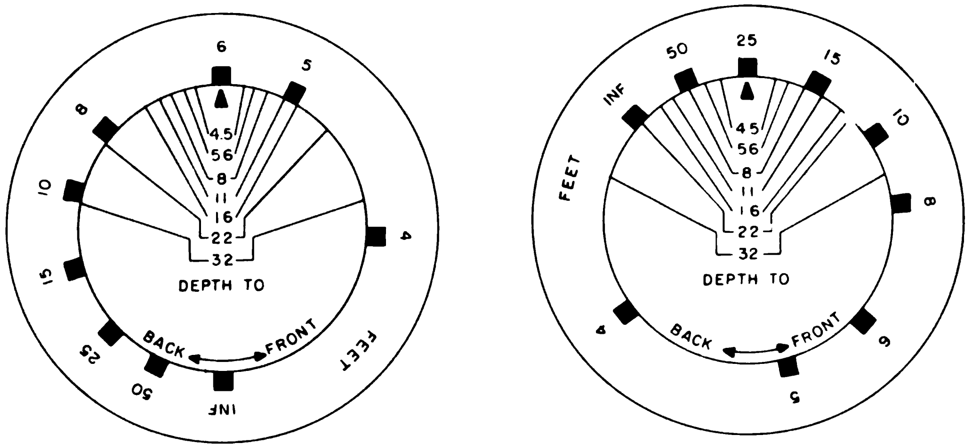


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*Figure 3–40. Depth of field indicator.*

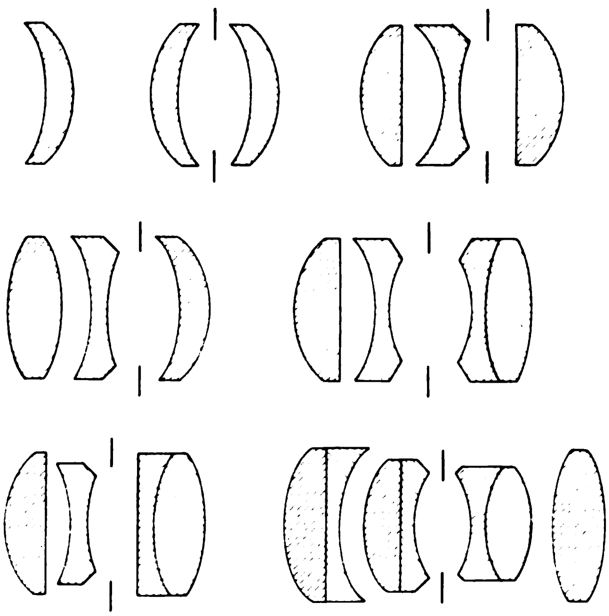

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*Figure 3–41. Photographic lens combinations (coated and uncoated).*

which is directed back to the camera, causes ghost images, which are double images of bright objects on a film. (See para 3–17.)

*a.* To correct aberrations common in individual lenses, photographic lenses are made up of several lens elements (fig. 3–41). It should be noted, however, that the use of several lens elements will result in extensive absorption of light, and that this, in turn, will cut down the speed of a lens. Lens coatings, commonly used on modern lenses, will prevent excessive light absorption.

*b.* The following chart indicates the transmission of light through the various lens components illustrated in figure 3–41.

*Table 3–VIII. Transmission of Light*

| Number of lens components | Uncoated (percent) | Coated (percent) | Relative increase (percent) |
|---|---|---|---|
| 1 | 91 | 98 | 8 |
| 2 | 84 | 97 | 16 |
| 3 | 77 | 96 | 24 |
| 4 | 70 | 95 | 35 |
| 5 | 65 | 94 | 45 |
| 6 | 60 | 93 | 55 |
| 7 | 56 | 92 | 66 |
| 8 | 51 | 91 | 80 |

## 3–48. Coated Lenses

When all elements of a photographic lens are coaed with magnesium flouride, light transmission is approximately 90 percent; with uncoated lenses, light transmission is approximated 60 percent. Coated lenses produce a brighter image on the general glass or film, shorten exposure time, and reduce haze, internal reflections, ghost images, and reflections from the front surface of the lens.

## 3–49. Theory of Lens Coating

*a. Uncoated Surface.* When a light ray strikes an uncoated glass surface as shown in figure 3–42.

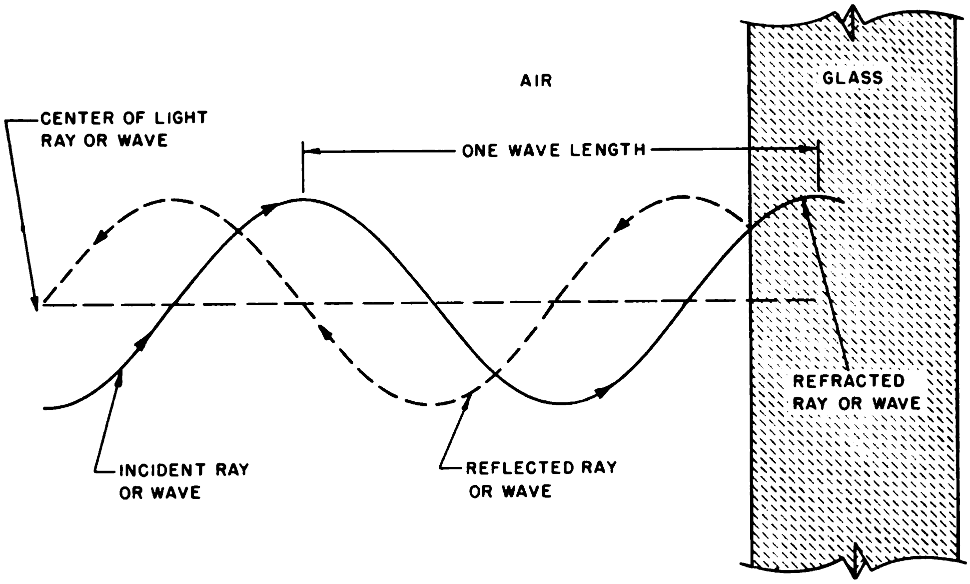


*Figure 3–42. Light ray striking an uncoated surface.*

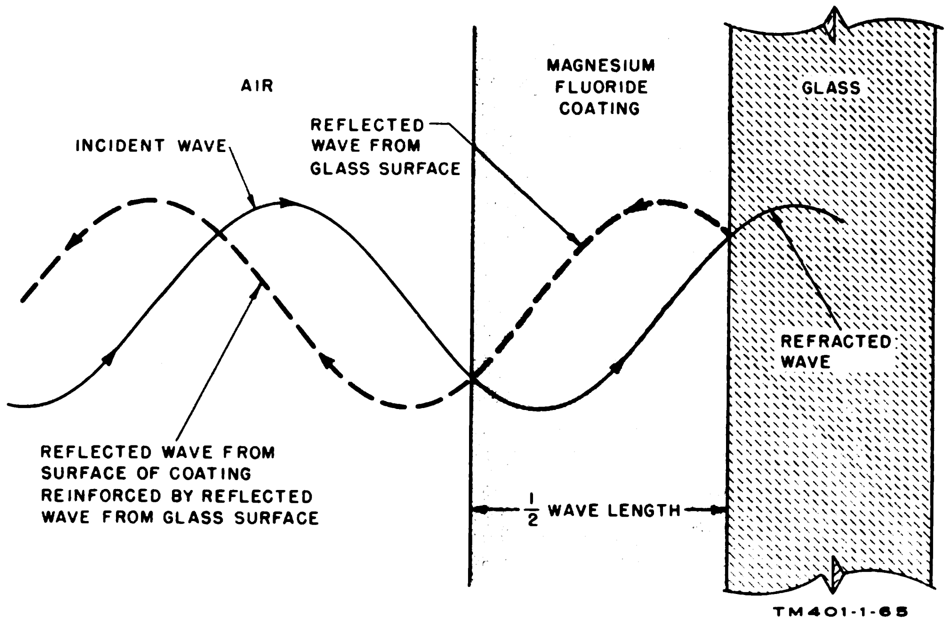


*Figure 3–43. Light ray striking a coated surface (coating is one-half the wavelength in thickness).*

*b. Coated Surface.* If a thin film of a transparent substance is placed on the lens, there are two surfaces from which the wave can be reflected. If this film is one-half as thick as the light wavelength, the reflected waves from the two surfaces follow the same paths (fig. 3–43) and reinforce each other. This action, which causes a maximum amount of light to be transmitted through the surface of the lens, is desirable in a reflector, but not in a lens. If the film is only one-fourth as thick as the light wavelength, the reflected waves follow paths

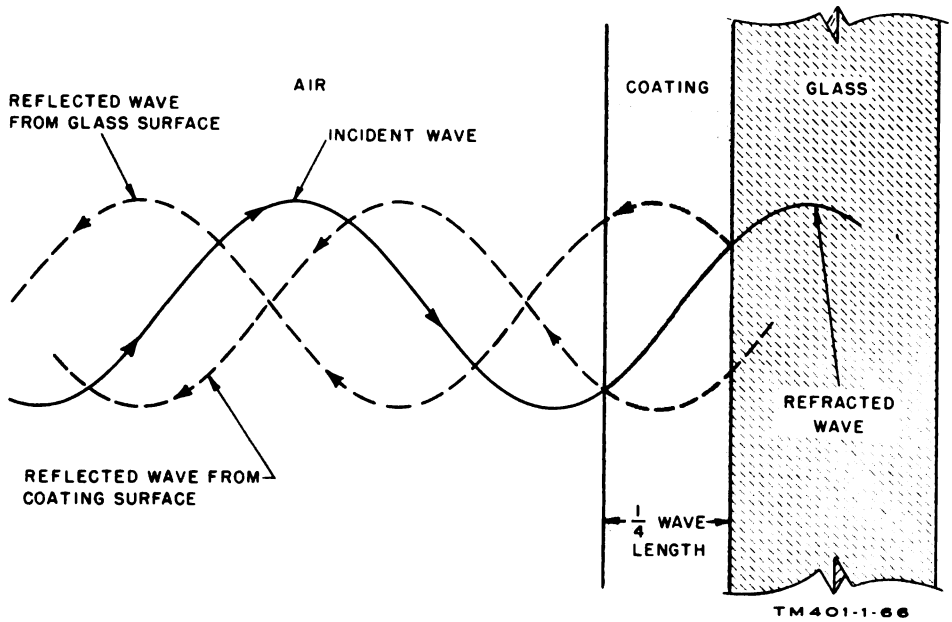


*Figure 3–44. Light ray striking a coated surface (coating is one-fourth the wavelength in thickness).*

(fig. 3–44) that cause them to cancel each other. In this case there is no light loss, and the energy is added to the refracted light. As cancellation is possible for only one wavelength, green has been selected for the greatest cancellation. The resulting slight reflection of blue and red causes the purplish color of most camera lenses.

## 3–50. Types of Photographic Lenses

Camera lenses have identifying information that indicate the focal length, f/number, type designation, and manufacturer's name. The type designation is of primary importance, because it indicates the basic optical design of the lens. Of the various references to types of camera lenses, the following terms are of particular interest: compound, anastigmat, apochromat, telephoto, mirror optics, and variable focus.

*a. Compound*. A compound lens has several elements that are combined to cancel the aberations common to a single lens. *For example,* if a double convex lens of crown glass is combined with a concavo-plano lens of flint glass, the combination has sufficient power to neutralize dispersion. Therefore, the light rays passing through this compound lens are brought to focus at a point about double the distance of the crown glass alone (fig. 3–45).

(1) In a compound lens, each element may be mounted separately (fig. 3–46), or two or three elements may be cemented together as doublets or triplets.

(2) Canada balsam, which does not affect the refractive index of the glass, is generally used to cement lens elements together. When lens elements are cemented together, their optical axes must be in alinement.

(3) When contact surfaces are cemented together, the loss of light through reflection at the two surfaces in contact is decreased. Cementing also aids in keeping the lenses clean and in keeping the lenses in alinement when the camera is jarred. Some of the better known camera lenses are illustrated in figure 3–47.

*b. Anastigmat.* An anastigmat is a compound lens that produces an evenly illuminated and well-defined image. It is corrected for astigmatism and other aberrations, and consists of two lens cells (each consisting of one or more lens elements) separated by a diaphragm. Figure 3–47 shows a number of well known anastigmats found in many modern cameras. Ana-

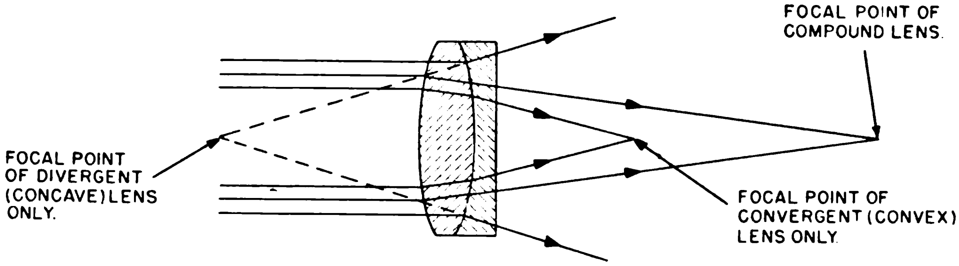


*Figure 3–45. Comparing focal lengths of elements in compound lens.*

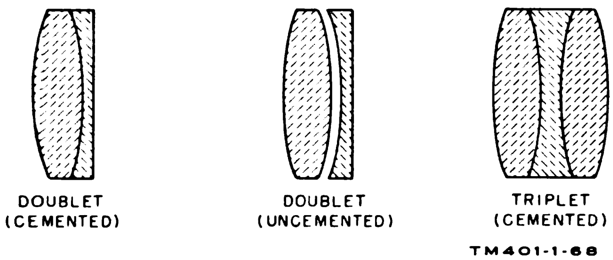


*Figure 3–46. Types of objectives.*

stigmats are commonly used in wide-angle, standard, medium long focal length, and long focal length lens designs. They are applicable to all kinds of cameras in still photography, motion picture photography, and television production work.

*c. Apochromat.* An apochromat is an anastigmat made up of lens components of different kinds of glass corrected for chromatic aberration with respect to three selected colors, or wavelength of light. Because of this high degree of correction, apochromats are used primarily for color reproduction camera work. The degree of correction is so extensive that objects of identical size are reproduced in exact comparative sizes regardless of their color. This lens characteristic is particularly important in three-color photography. The focal length of apochromats is usually quite long and the aperature is relatively small. These lenses are normally used for critical color copy work in studios where there is no requirement for a high speed lens.

*d. Convertible.* A convertible lens (fig. 3–47) is a compound lens that can be easily converted to provide different focal length lenses. This is accomplished by using each lens components separately, or by using various combinations of the lens components. A convertible may be a double or a triple convertible, depending upon the number of focal lengths provided. This type of lens was once quite popular, since it provided two or three different focal lengths in one lens system. However, it should be noted that the system has certain limiting factors, Although each element of a convertible lens is corrected for independent photographic use (fig. 3–48), the correction of a single component is not as high as that achieved by the combination of all elements. The fact that the focal length of each element is different results in a far less favorable aperature than that of the complete system. Since convertible lenses are limited to use with bellows-type cameras, a sturdy tripod is essential.

*e. Telephoto.* A telephoto lens is one in which the distance from the front lens surface to the focal plane is less than the indicated focal length. This type of lens is more useful than a normal long focal length anastigmat lens, because it does not require a long bellows extension, or long lens cylinder, and is relatively light.

(1) Telephoto lenses are used primarily to record distant action or to reproduce, in greater detail, small objects at medium distances. They may also be used when speed of the optical system is a vital factor.

(2) It is a common error in photography to associate image size with camera film size. When employing a telephoto lens, it is the image size rather than the film size that is important. *For example*, an object 200 feet high and 2,400 feet away measures ½ inch when photographed with a 6-inch lens

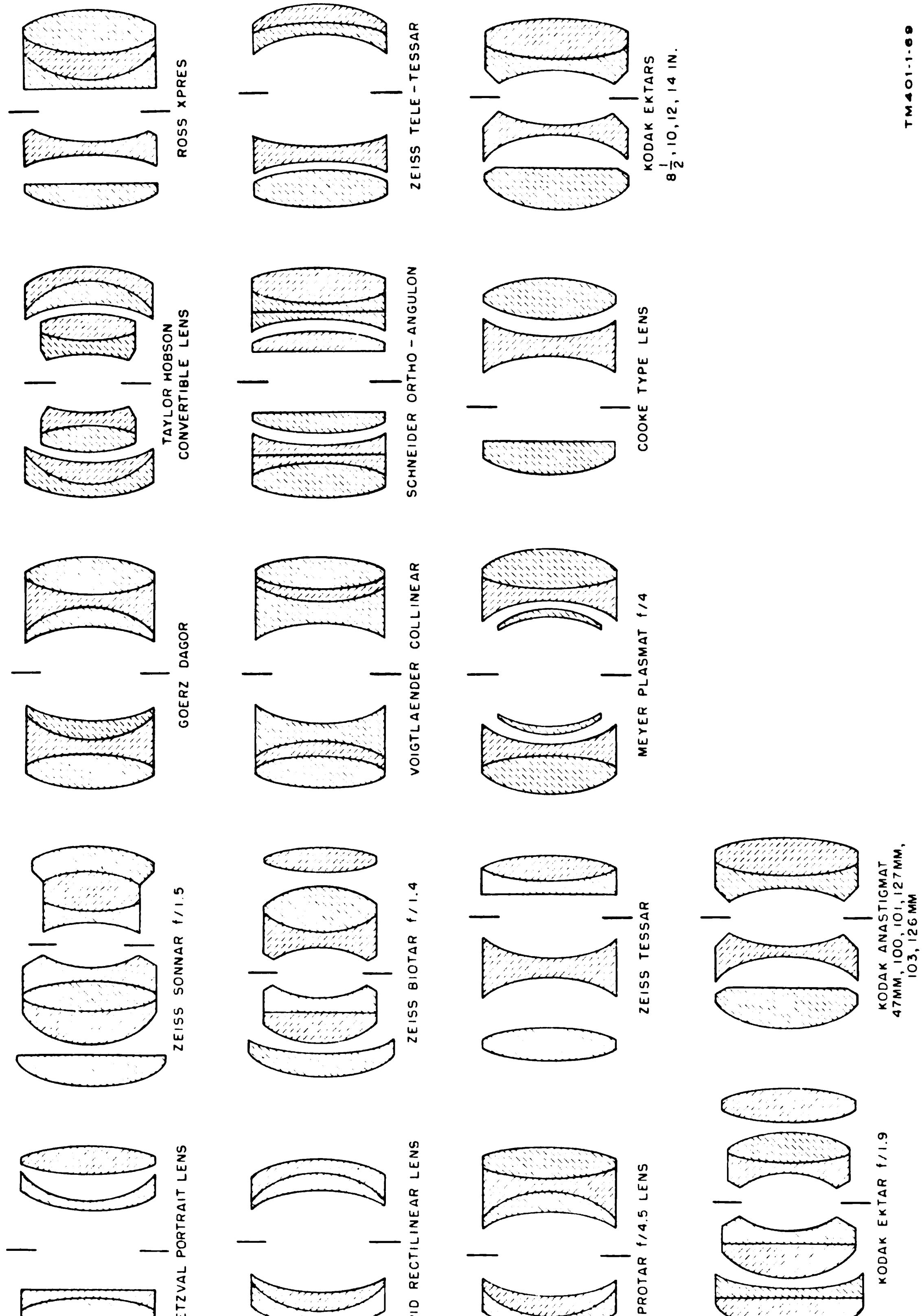


*Figure 3–47. Camera lens combinations.*

on either 35-mm or 4- by 5-inch film. Accordingly, when specific details of distant objects are to be recorded, it is wise to determine first the eventual size of the particular detail as it will appear on the film. With this determined, it is usually easier to use a 35-mm camera equipped with a high quality telephoto lens than a larger film size camera.

*f. Mirror Optics.* Mirror optics (fig. 3–49) are special camera lens designs consisting in part of optically perfect mirrors, or combinations of mirrors, arranged to shorten the length of large telephoto lenses. Spherical and parabolic mirrors, when used with standard optical designs, achieve compactness and greater effective focal length. This combination produces a long focal length optical system that is easily transportable.

(1) *Front element.* The front element of the mirror optical device has a corrector lens and a mirror (fig. 3–49). The intermediate annulus is silvered to form a convex mirror, and the outer zone acts as a corrector of the image

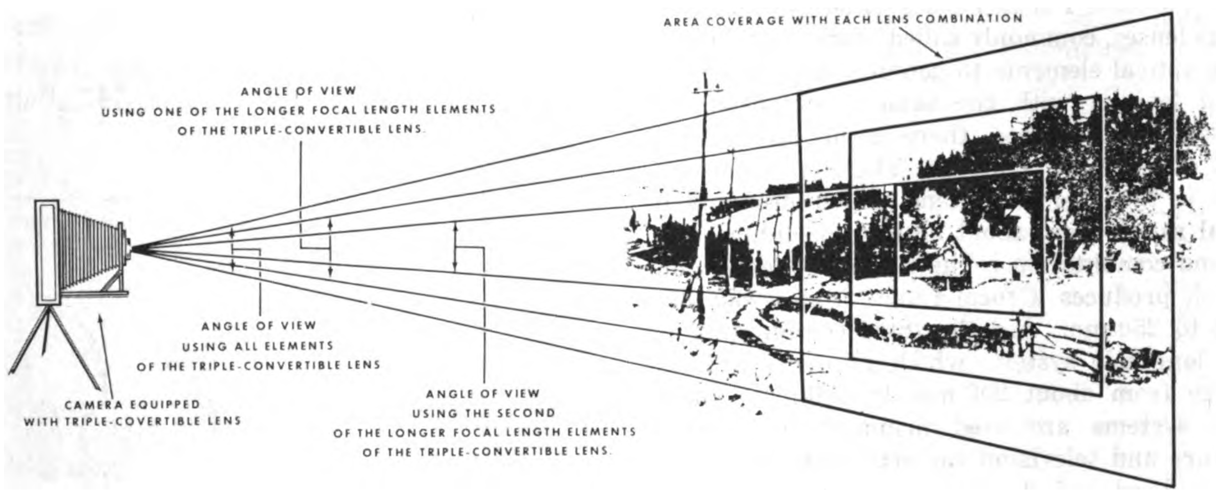


*Figure 3–48. Pictorial coverage pattern with triple-convertible lens.*

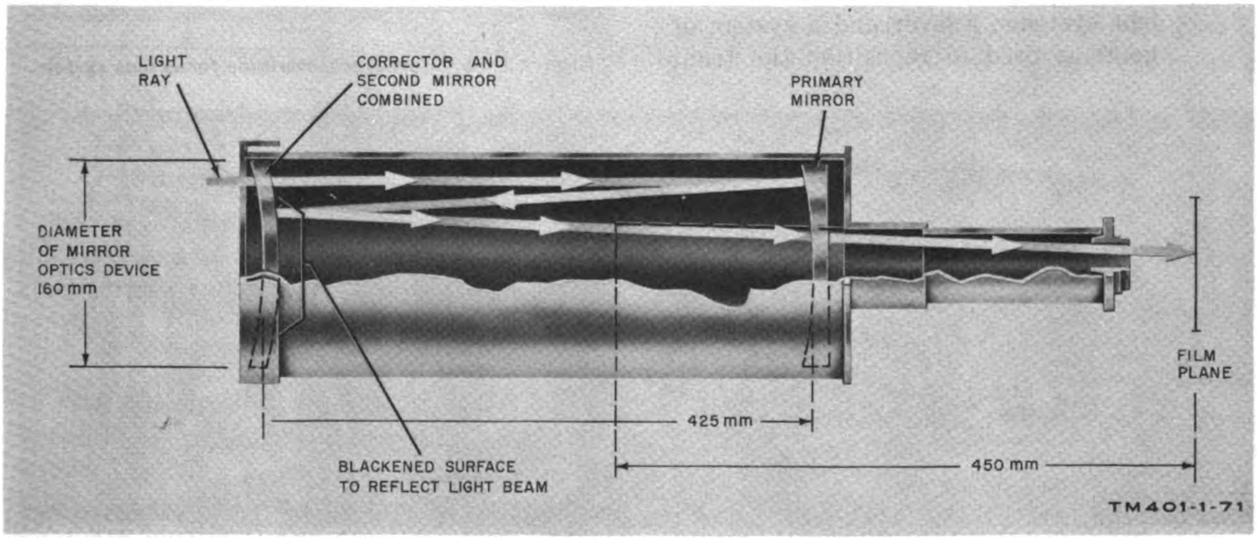


*Figure 3–49. Mirror optical device, f/8, 40 inches.*

projected by the primary mirror. The center part is black and reflects the light.

(2) *Primary mirror.* The primary mirror, which is a concave reflector, reflects the light beam emanting from the object to be photographed. After the light beam is first reflected to the convex mirror of the front element, it is reflected through a final aperture to the camera film plane.

(3) *Lens speed.* The lens speed of this typical mirror optical device is f/8; the focal length is 40 inches.

*g. Variable Focus Lenses (Zoom).* Variable ocus lenses, commonly called zoom lenses, comine optical elements to achieve three different ocal lengths with the same combination of enses. In each case, there is no appreciable oss of effective aperture. The first combinaion is the normal system, which produces a ocal range from about 35-mm to 90-mm; the econd combination is the medium tele system, hich produces a focal range from about 85-nm to 250-mm; and the third combination is he long tele system, which produces a focal ange from about 200-mm to 600-mm. These ens systems are used primarily in motion icture and television cameras, but some have een developed for use in miniature still ameras.

(1) *Mechanical variable focus lens systems.* In mechanical variable focus lens systems, a lever and a system of gears is used to reposition the front

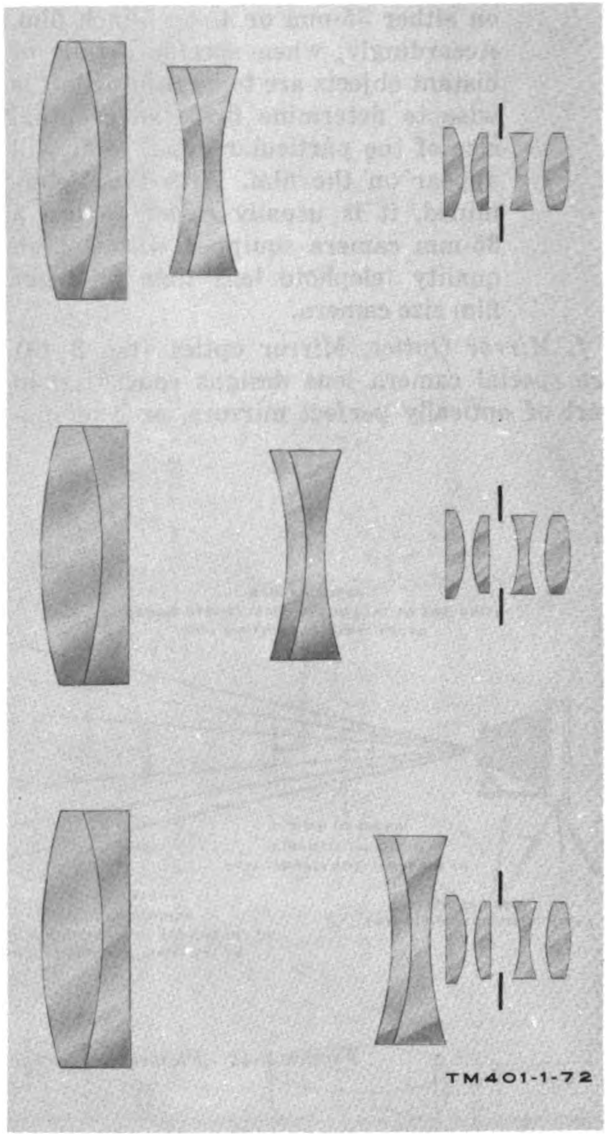


*Figure 3–50. Mechanical variable focus lens system.*

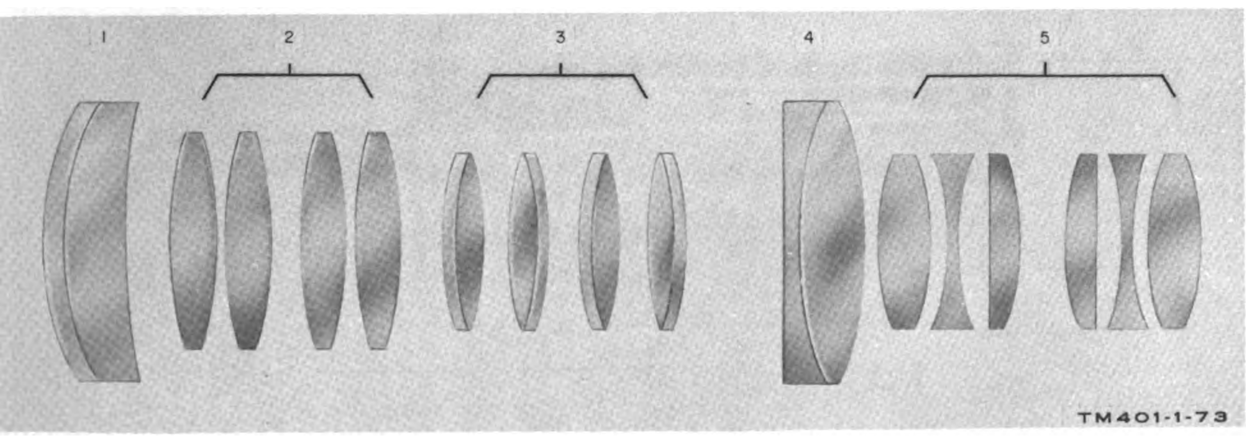


*Figure 3–51. Optical variable focus lens system.*

and rear elements. Figure 3–50 shows the interrelationship of the respective positions of the different lens elements to achieve a change in the focal length of the optical system.

(2) *Optical variable focus lens systems.* In optical variable focus lens systems, some lens elements move and the others remain fixed. Figure 3–51 shows a system composed of five groups of lenses. The second and fourth groups are coupled and move at an identical rate; the other groups do not move.

## Section V. PRACTICAL CAMERA LENS DATA

### 3–51. General

Photographers often require conversion tables and simple formulas to work out camera lens settings and reproduction ratios. This section contains information to solve some of these common problems in photography.

### 3–52. Camera Lens Size Conversion Table

When working with photographic lenses, the photographer will often be faced with the problem of converting relatively small measurements from inches into millimeters or from millimeters into inches. The table below greatly simplifies conversion of such measurements.

*Table 3–IX. Camera Lens Size Conversion Table*

| Millimeters | Inches | Millimeters | Inches | Millimeters | Inches | Millimeters | Inches |
|---|---|---|---|---|---|---|---|
| 15 | ⅗ | 105 | 4⅕ | 240 | 9⅗ | 340 | 13⅗ |
| 20 | ⅘ | 110 | 4⅖ | 250 | 10 | 350 | 14 |
| 25 | 1 | 120 | 4⅘ | 255 | 10⅕ | 360 | 14⅖ |
| 30 | 1⅕ | 125 | 5 | 260 | 10⅖ | 365 | 14⅗ |
| 35 | 1⅖ | 135 | 5⅖ | 275 | 11 | 375 | 15 |
| 40 | 1⅝ | 150 | 6 | 280 | 11⅕ | 385 | 12⅖ |
| 45 | 1⅘ | 165 | 6⅗ | 285 | 11⅖ | 400 | 16 |
| 50 | 2 | 170 | 6⅘ | 290 | 11⅗ | 415 | 16⅗ |
| 70 | 2⅘ | 175 | 7 | 300 | 12 | 425 | 17 |
| 75 | 3 | 180 | 7⅕ | 310 | 12⅖ | 435 | 17⅖ |
| 80 | 3⅕ | 200 | 8 | 315 | 12⅗ | 450 | 18 |
| 85 | 3⅖ | 205 | 8⅕ | 320 | 12⅘ | 475 | 19 |
| 90 | 3⅗ | 225 | 9 | 325 | 13 | 485 | 19⅖ |
| 100 | 4 | 235 | 9⅖ | 330 | 13⅕ | 500 | 20 |

### 3–53. Relationships Among Object Distance, Image Distance, and Focal Length

The relationship among focal length, object distance, and image distance is expressed in the following formula:

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}.$$

In this formula, *f* is the focal length, *o* is the object distance, and *i* is the image distance (fig. 3–52). Insolving problems, make sure that the units of measure used (inches, feet, millimeters, etc.) are identical. *For example,* if the object distance is in feet and the image distance is in inches, convert both to inches before solving problem.

*a. Determining Focal Length.* The lens of a camera is focused on an object 20 feet from the camera lens. If the image distance is 10 inches, what is the focal length?

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}.$$

$$\frac{1}{f} = \frac{1}{240} + \frac{1}{10}$$

$$240 = f + 24f$$

$$25f = 240 \text{ or } f = 9.6 \text{ inches}$$

*b. Determining Object Distance.* A camera has a 10-inch focal length lens and a maximum bellows extension of 12 inches. What is the closest point at which the lens can be focused?

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$$

$$\frac{1}{10} = \frac{1}{o} + \frac{1}{12}$$

$$12\ o = 120 + 10\ o$$

$$2\ o = 120$$

$$o = 60 \text{ inches or } 5 \text{ feet}$$

*c. Determining Image Distance.* A camera with a 12-inch camera lens is used to copy an object at a distance of 4 feet.
What is the correct bellows extension?

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$$

$$\frac{1}{12} = \frac{1}{48} + \frac{1}{i}$$

$$4\ i = i + 48$$

$$3\ i = 48$$

$$i = 16 \text{ inches}$$

## 3–54. Reproduction Ratio

Reproduction ratio, which is the ratio of object size to image size, is equal to the ratio of object distance to image distance (fig. 3–52).

$$\text{Reproduction ratio} = \frac{\text{object size}}{\text{image size}} = \frac{o}{i}$$

*a.* A camera is used to copy an object at a distance of 3 feet. The image distance, when the lens is in sharp focus, is 1 foot. What is the reproduction ratio?

$$\text{Reproduction ration} = \frac{o}{i} = \frac{3}{i} = 3$$

*b.* An enlarger has a lens-to-easel distance of 15 inches and a lens-to-negative distance of 5 inches. What is the largest print that can be made from a negative that is 2¼ inches square?

$$\text{Reproduction ratio} = \frac{o}{i} = \frac{15}{5} = 3$$

$$\text{Largest Print} = 3 \times 2\tfrac{1}{4} = 6\tfrac{3}{4} \text{ inches square}$$

## 3–55. Camera Bellows Extension

Normally a camera lens can be focused from 6 feet to infinity and retain its f/number value. However at close lens-to-subject distances the distance between the lens and focal plane becomes so great that the film does not receive the amount of light indicated by the marked f/number. When the camera is moved to a point closer than ten times the focal length from the subject, compensation must be made for light lost due to the bellows extension. This compensation is made by application of a multiplying factor.

*a. Multiplying Factor.* The multiplying factor for a critical exposure is determined in the following manner:

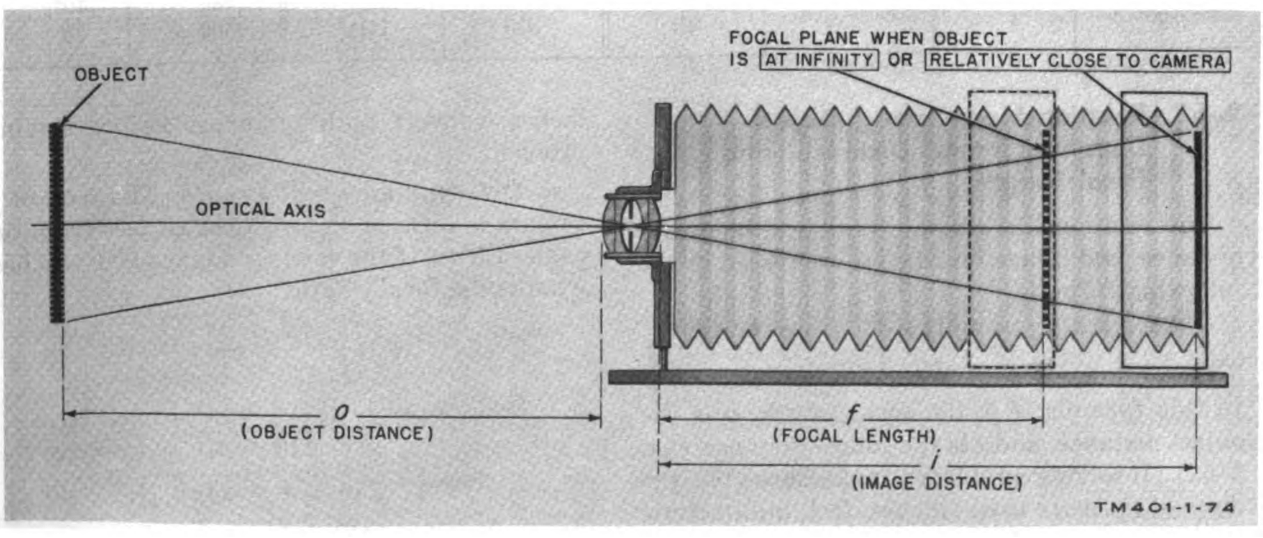


*Figure 3–52. Object distance, image distance, and focal length.*

$$\text{Multiplying Factor} = \left(\frac{\text{bellows extension}}{\text{focal length}}\right)^2$$

*Example:* If a 6-inch lens is used with a 12-inch bellows, the multiplying factor is—

$$\text{Multiplying Factor} = \left(\frac{12}{6}\right)^2 = 2^2 = 4$$

*b. Use of Multiplying Factor.*

(1) As explained previously each lens stop passes twice as much light as the lens stop above it. *For example,* f/4 passes twice as much light as f/5.6, four (2 x 2) times as much light as f/8, eight (2 x 2 x 2) times as much light as f/11, sixteen (2 x 2 x 2 x 2) times as much light as f/16, etc.

(2) The multiplying factor indicates the number of times that exposure must be increased. *For example,* a multiplying factor of 4 (2 x 2) indicates that the lens must be opened two lens stops beyond the exposure setting for an object at a normal 6-foot distance; a multiplying factor of 8 (2 x 2 x 2) indicates that the lens must be opened three stops beyond the normal exposure setting; and a multiplying factor of 16 (2 x 2 x 2 x 2) indicates a need for opening the lens four stops beyond the exposure setting normally used at the 6-foot distance.

## 3–56. Summary

*a.* A camera lens refracts light rays in such a manner that a sharp image is formed at the focal plane of the camera.

*b.* Positive lenses can be of double-convex, plano-conevx, or convexo-concave design.

*c.* Negative lenses can be of double-concave, plano-concave,or concavo-convex design.

*d.* To avoid optical imperfections inherent in single lenses, a camera lens may consist of a combination of positive and negative elements.

*e.* Optical aberrations are imperfections that are responsible for image distortions of one type or another.

*f.* The six general types of aberration are: spherical aberration, chromatic aberration, astigmatism, coma, curvature of field and distortion.

*g.* The plane at which a camera lens projects a sharp image is called the focal plane.

*h.* The distance from the optical center of the camera lens to the focal plane—the lens focused at infinity—is called focal length.

*i.* Focal length controls image brightness, lens speed, and image size.

*j.* The angle of field of a camera lens is the total angle of coverage of the particular lens.

*k.* The angle of view of a camera lens is the angle of coverage of the lens in terms of the film size of the camera with which it is used.

*l.* If a photographic image is in sharpe focus, the light rays that form the images visually appear as minute points. These points, actually cones of light of varying diameter, are called circles of confusion. With improper focusing, these cones of light are larger and the image appears to be blurred and out of focus.

*m.* The resolving power of a lens is its ability to reproduce fine lines.

*n.* Depth of field is the distance from the nearest point of acceptable sharp focus to the farthest point of acceptable shape focus of a subject being photographed.

*o.* Depth of focus is the distance the focal plane of the camera can be moved forward or backward from the point of exact focus without losing acceptable image sharpness.

*p.* Hyperfocal distance is the distance between the camera and the nearest point in usable focus when the camera lens is set at infinity. It differs with every change of the lens aperture.

*q.* An anastigmat is a compound lens that produces an evenly illuminated and well-defined photographic image.

## 3–57. Review Questions

*a.* Explain the function of a camera lens.

*b.* List optical defects of camera lenses other than the six general types of aberrations.

*c.* What are the causes of light loss in a camera lens?

*d.* How is normal light loss of a camera lens reduced?

*e.* What is the focal length of a camera lens?

*f*. Explain the relationship between the camera lens focal length and the aperture.

*g*. Prepare a diagram of a simple lens to indicate the optical axis, the optical center, and the nodal points.

*h*. What are conjugate distances?

*i*. Name six types of photographic lenses.

## 3–58. Review Answers

*a*. Camera lenses are designed to function with the least amount of error and to reproduce objects in a practical object-image size relationship.

*b*. Optical defects of camera lenses other than the six general types of aberrations include: Newton's rings, light loss, air bubbles, and flare.

*c*. The main cause of light loss in a camera lens is due to surface reflection of each separate element surface of the camera lens. Further, a certain percentage of light is absorbed by every element of the lens the light travels through.

*d*. Normal light loss of a camera lens can be greatly reduced by coating the surfaces of lens elements with magnesium fluoride.

*e*. The focal length of a lens is the distance from the optical center of a lens to its focal plane, when the lens is focused at infinity.

*f*. The focal length of a camera lens is the main factor in determining the lens aperture, or the speed of a given lens. Having determined the focal length you measure the front diameter of the lens. You then divide the focal length by the diameter of the lens and arrive at the relative aperture.

*g*. Refer to figure 3–23.

*h*. Conjugate distances are the distances between a subject and a photographic lens and from the lens to the focal plane of the camera. As one of these distances increases the other decreases, and vice versa.

*i*. Six types of photographic lenses are: compound, anastigmat, apochromat, telephoto, mirror optics, and variable focus.

# CHAPTER 4
# CAMERAS

## Section I. GENERAL

### 4–1. Camera Obscura

The forerunner of the modern camera was the camera obscura, meaning dark box, thought to have been originated about 350 B.C. by Aristotle, the Greek philospher. Camera obscura was a darkened room compartment, or portable box with a small hole in one wall. Light rays, reflected from objects in front of the hole, passed through the hole and projected an image on the opposite wall (fig. 4–1). The image had one peculiar characteristic—it was inverted, as are the images produced by lenses.

### 4–2. Pinhole Camera

The pinhole camera, in principle, is the same as the camera obscura. Although there was no permanent recording of an image with sensitized materials until the nineteenth century, camera obscura was used by medieval scientists studying eclipses of the sun and by early artists studying perspective for their drawings.

*a. Drawbacks of Pinhole Camera.* Camera obscura produces too faint an image, because very little light passes through the small hole. If the hole is made larger, the image becomes too blurred. Another fault with the image formed by the small hole is its lack of sharpness.

*b. Advantages of Pinhole Camera.* A pinhole has certain advantages over the finest modern lenses. It is not affected by distortion; it has unlimited depth of field; and its field of coverage is exceptionally wide. Most modern wide-angle lenses have an angle of field of 75° to 90°, but a pinhole can cover a 125° angle. Although resulting photographs require long exposure and are not wire sharp, they have plasticity and produce a feeling of depth that is often compared with the results of a stereoscope camera. Today, a pinhole camera is applicable only from an academic standpoint.

### 4–3. First Camera Lenses

It was not until the sixteenth century that a lens was used in a camera. In the early part of that century, Leonardo da Vinci wrote about a pinhole camera, but he did not men-

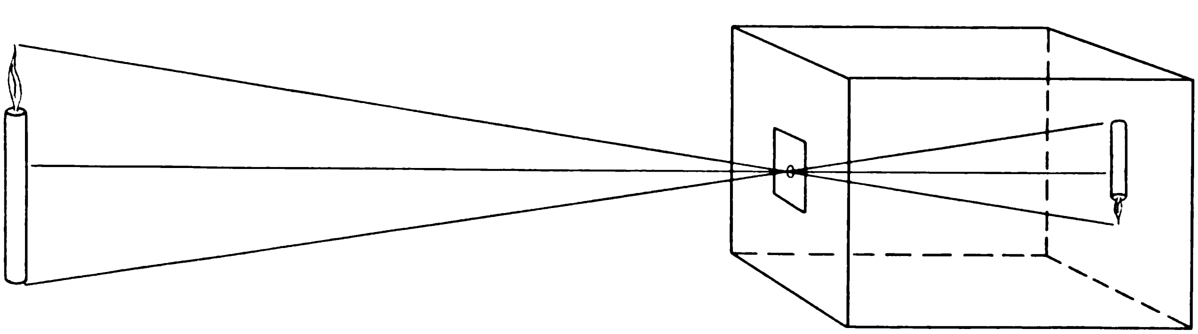


*Figure 4–1. Image formed by a pinhole camera.*

tion a lens. Danielo Barbaro, an artist, first wrote of using a lens with a camera in the latter part of the sixteenth century. The first really portable camera with a lens and a viewing glass was reported by Zahn, an oculist, in 1665.

### 4–4. Box Cameras

A box camera consists of a housing with a lens at one end and a film-winding mechanism at the other end. The lens position and aperture are arranged so that all objects from approximately 8 or 10 feet to infinity are in reasonable focus. It has a fixed aperture of f/11 or f/16, a simple viewfinder, and a spring shutter mechanism that provides usually only one speed ($\frac{1}{25}$ second). It does not have the potentials of more complex cameras, but it is a good tool for beginners. Figure 4–2A, illustrates an early type of box camera; part B illustrates a more up to date type of box camera.

### 4–5. Folding Cameras

Folding cameras (fig. 4–3A, B) have a bellows and are so constructed that the lens snaps into a fixed position when the camera is opened. Focusing, shutter speeds, and aperture are adjustable. Part A of the illustration shows an early type of folding camera; part B shows a more recent type.

### 4–6. Press and Hand Cameras

*a.* Press and hand cameras, using cut film and film packs, are used extensively in commercial and news photography. They are sturdy and practical, and they can handle a wide range of pictorial work.

*b.* As a general rule, the bellows of these cameras have either a double or a triple extension. This means that the photographer can increase the distance between the lens and the film to record very small objects. Therefore, this type of camera is ideally suited for reproduction and small parts photography.

*c.* Press and hand cameras have a between-the-lens shutter, a curtain shutter, or both. Their lenses, which are usually of high quality, have apertures from f/2.8 to f/4.5. Film sies range from $2\frac{1}{4}$ by $3\frac{1}{4}$ inches to 4 by 5 inches. The front, or lens standard, can be lowered, raised, or moved sideways.

*d.* The press-type camera (fig 4–4) which is equipped with a coupled rangefinder and synchronized flash attachments, has handled the bulk of Army still photography since World War I.

### 4–7. View and Studio Cameras

View and studio cameras (fig. 4–5) are, essentially, larger versions of press and hand cameras. They have removable lenses, can be focused from either the front or the rear, and are equipped with long bellows. The back of these cameras can be swung and set horizontally or vertically. Studio cameras are used primarily for portraiture, copy work, small parts photography, and interior recording. View cameras are used primarily for architectural photography, group photography, and general recording of large outside areas that must be reproduced in considerable detail. Both types of cameras are used widely throughout the Army.

### 4–8. Miniature Cameras

*a.* Miniature cameras are precision instruments designed for small film sizes. One of the best known miniature cameras (fig. 4–6) uses 35-mm perforated motion picture film. A second type (fig. 4–7) uses 70-mm perforated film.

*b.* Quality miniature cameras have optical and mechanical standards far in excess of those applicable for large cameras. Minute pictorial inaccuracies, not noticeable on large negative prints, would make a miniature negative worthless.

*c.* Many types of miniature cameras are designed for use with interchangeable lenses. In addition, each is equipped with a coupled rangefinder, a direct vision optical viewfinder, and a curtain shutter with speeds up to and beyond 1/1,000 second. These characteristics permit use of the miniature camera in a wide range of photographic missions.

*d.* Miniature cameras were designed to provide lightweight instruments for difficult forms of pictorial coverage. Such types of photography require fine-grain film, special processing and temperature control, a very clean darkroom, and careful enlarging of the negative with a high quality optical printer.

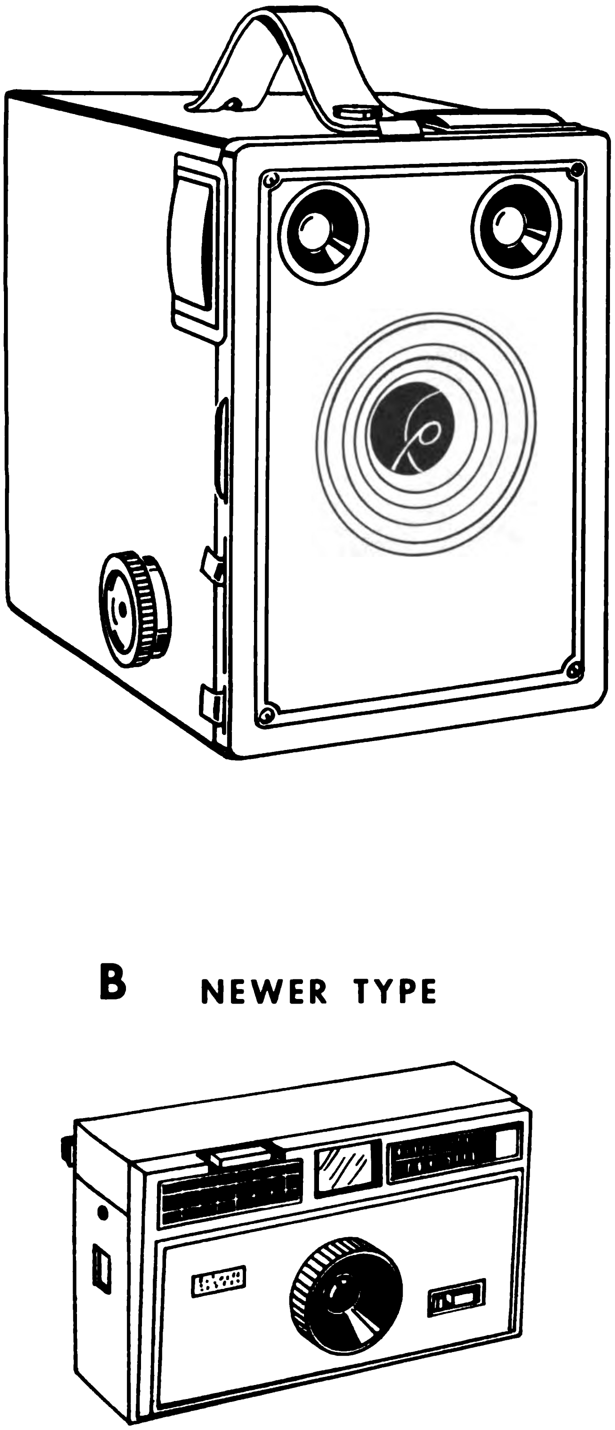


*Figure 4–2. Box cameras.*

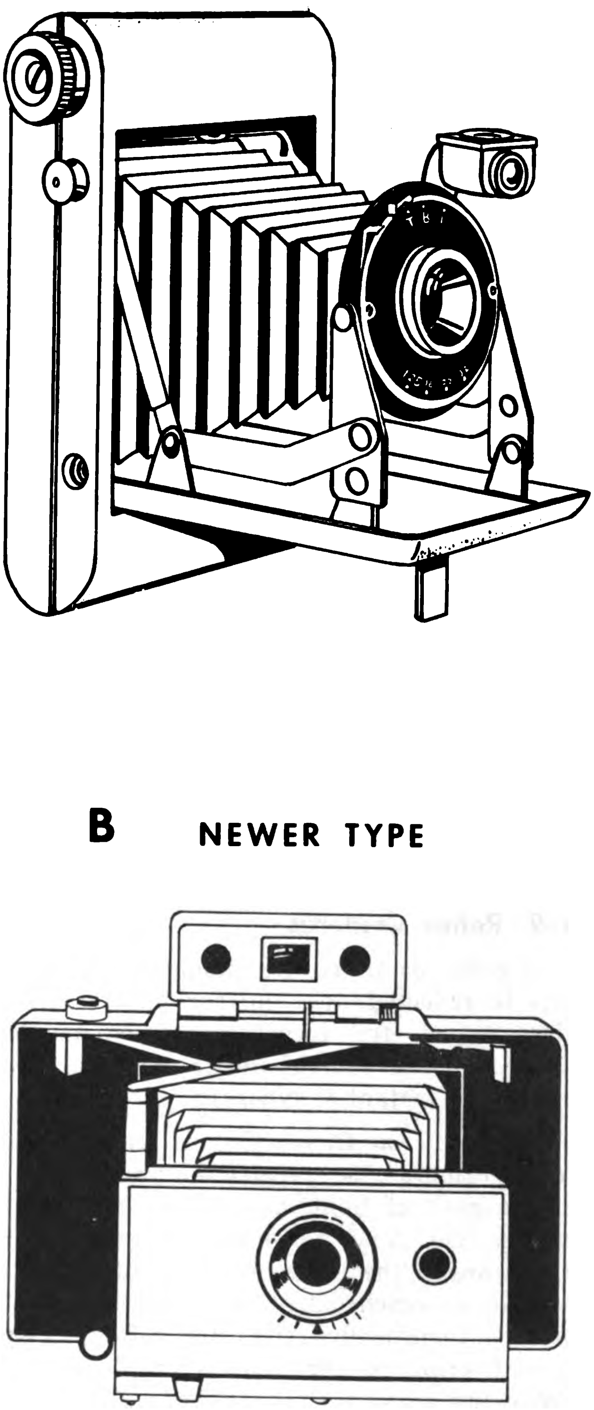


*Figure 4–3. Folding cameras.*

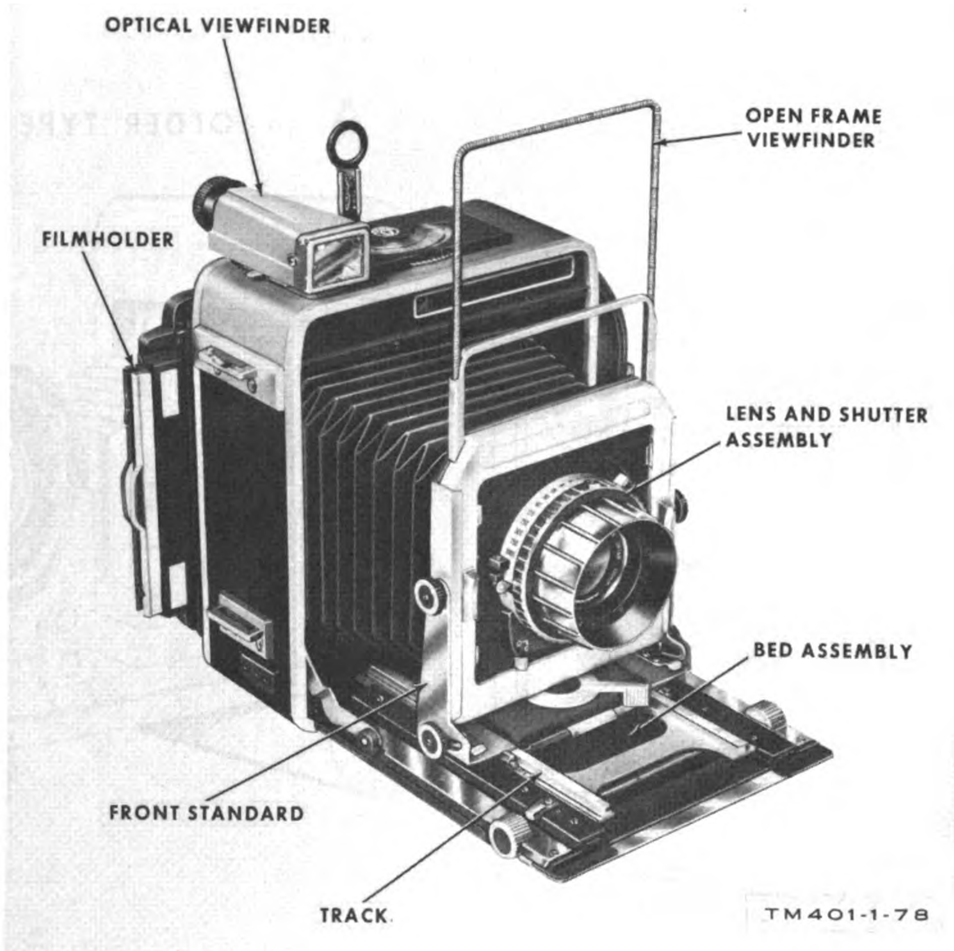


*Figure 4–4. Press-type camera.*

## 4–9. Reflex Cameras

In reflex cameras, the image formed by the lens is reflected by a mirror onto a ground glass screen for focusing and composition. Thus, one can control image sharpness until the precise instant of exposure.

*a. Single Lens Reflex Camera.* In single lens reflex cameras, a movable mirror is located in the path of light rays transmitted by the camera lens. Since the mirror is positioned at a 45° angle, the image is reflected. Upon exposure, a synchronized mechanical arrangement automatically raises the mirror a split second prior to the release of the shutter. Following exposure, the mirror drops again and the photographer is ready for another pictorial opportunity. One of the advantages of this type of camera is that what ever one sees on the ground glass will appear on the eventual picture. This is particularly important when different focal length lenses are used. In addition, this camera simplifies focusing and prevents parallax.

*b. Twin Lens Reflex Camera.* In twin lens reflex cameras, one lens, permanently fixed, is used for focusing, composing, and framing, while a second lens, below the first, actually records the image on the film. Normally, the second lens is also fixed and not interchangeable with lenses of different focal lengths. Since the mirror is permanently positioned behind the upper lens, the camera is always ready for recording. The typical twin lens reflex camera in figure 4–8 produces a 2¼-

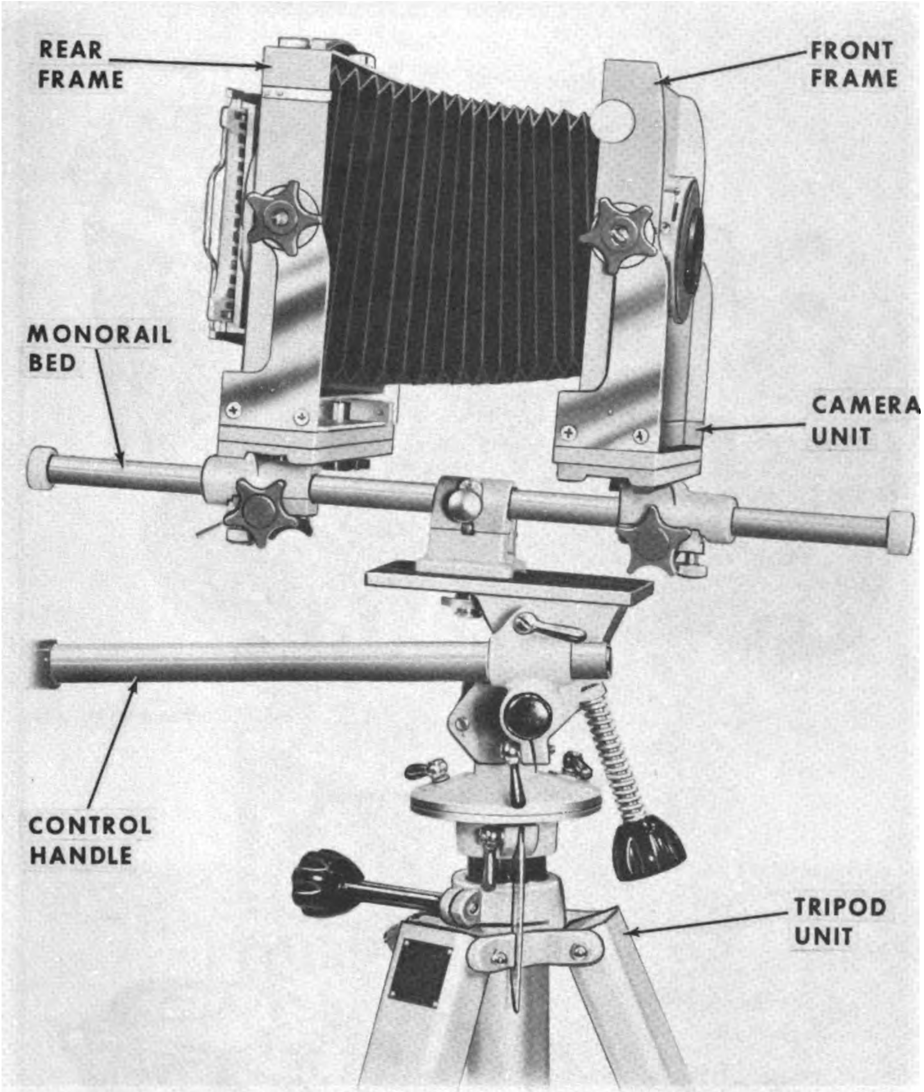


*Figure 4–5. View camera.*

by 2¼-inch negative. It has an f/3.5, 7.5-cm anastigmat, a high speed Compur shutter, and an automatic parallax adjustment.

## 4–10. Other Types of Cameras

There are numerous other types of cameras; however, almost all of them follow, in some way, the basic design features of the instruments explained in the above paragraphs. Some cameras, such as aerial equipments, are highly specialized items constructed for specific purposes and capable of performing only selected pictorial requirements. Where the nature of the task dictates it, the Army makes use of the type of camera best suited to satisfy a particular need.


*Figure 4–6. 35-mm miniature camera.*

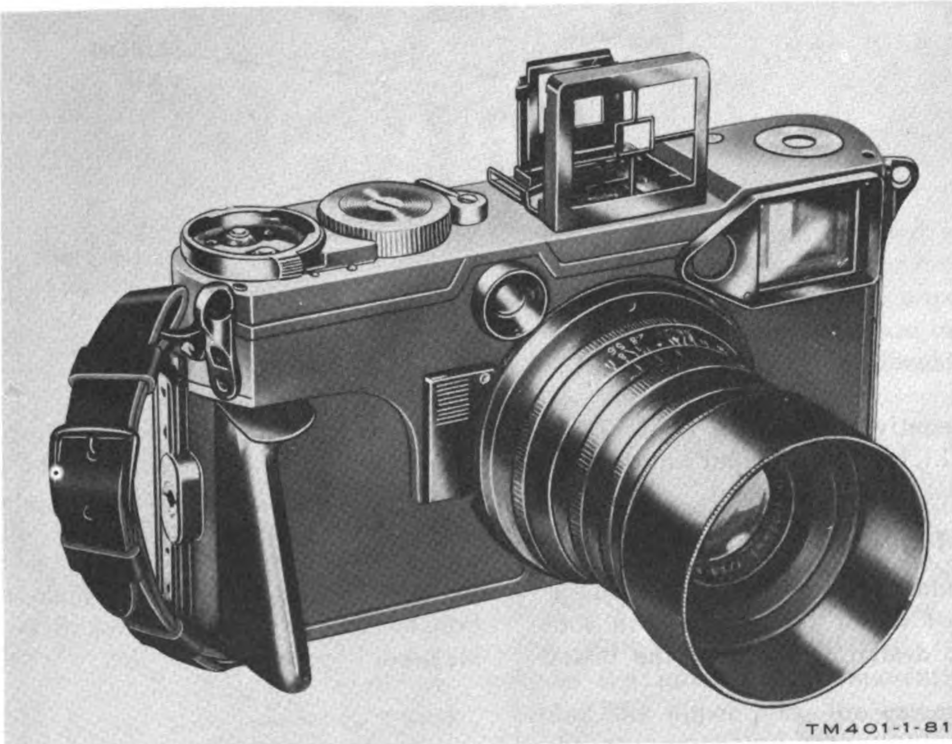


*Figure 4–7. 70-mm camera.*

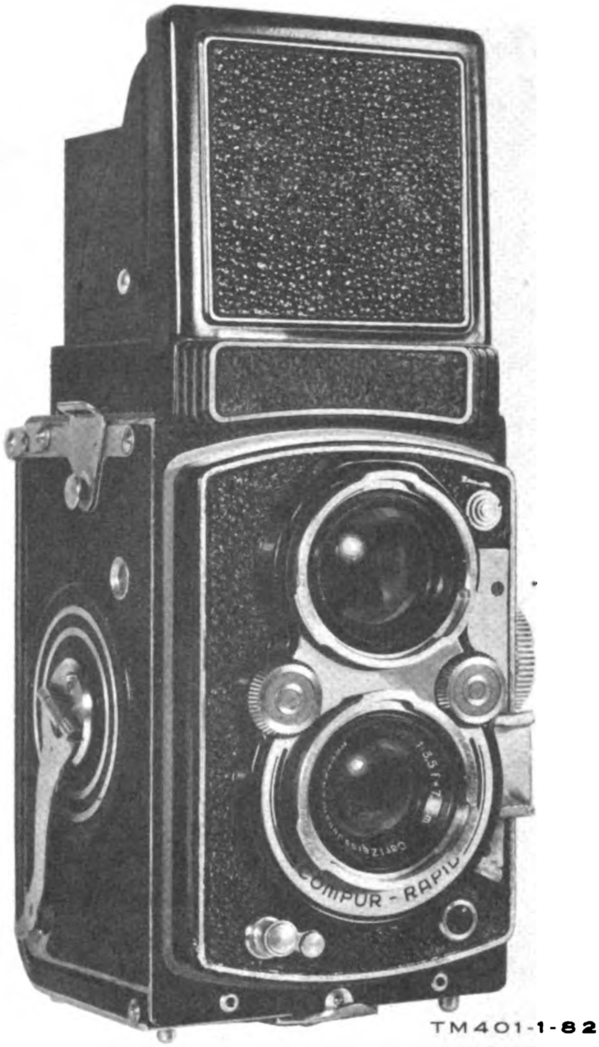


*Figure 4–8. Twin lens reflex camera.*

## Section II. CAMERA FOCUSING

### 4–11. General

A camera is focused by moving the lens nearer to or farther from the film plane. To accomplish this, the lens is mounted on a standard that is separated from the camera housing by a collapsible bellows, or on a threaded mount that permits precision movement of the lens. Focusing can also be facilitated through the use of distance scales, depth of field tables, rangefinders, and ground glass.

### 4–12. Distance Scale

Cameras that do not have fixed focus lenses are provided with a simple distance scale. This scale is located on the camera bed or is engraved directly on the lens mount.

*a.* The vernier scale (fig. 4–9, A) is a typical distance scale. One part of the scale is attached to the camera bed, and the other is on the sliding track. To focus for a given distance, the focusing knob is turned until the lines cor-

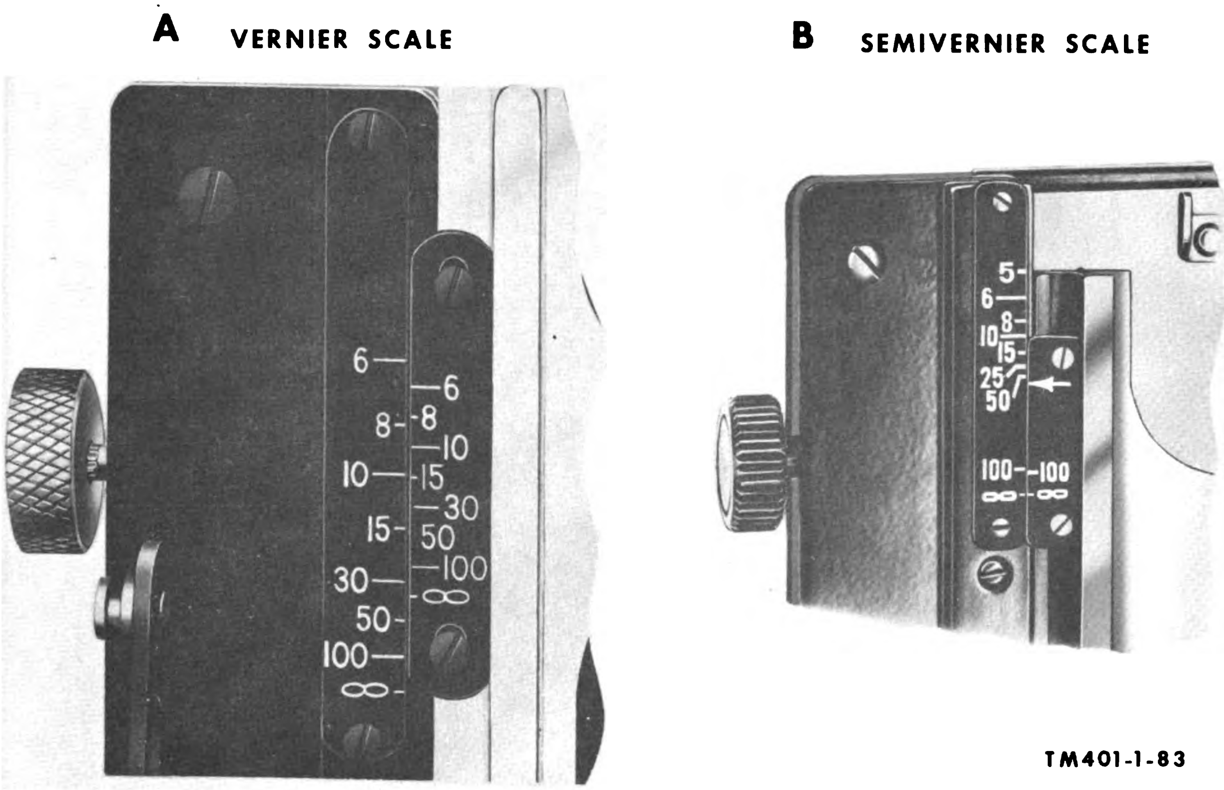


*Figure 4–9. Vernier and semivernier distance scales.*

responding to that distance lie exactly opposite each other on the two parts of the scale.

*b.* When the semivernier focusing scale (fig. 4–9, B) is used, distances are lined up opposite an arrow engraved on the scale.

*c.* When engraved directly on the lens mount, as is the case with 35-mm and 70-mm miniature cameras, the scale consists of a distance scale and an adjoining depth of field scale. Figure 4–10 shows the related scales on the 4-inch lens of a 70-mm camera. These scales permit you to determine the depth of field of the lens for any given aperture at any given focal distance. By referring to the scale of duplicated lens apertures you establish the range of focus by adjusting the adjacent scale of distances. *For example*, if you match the f/16 setting at one end of the scale with the infinity mark on the adjacent distance setting, the f/16 setting at the other end of the scale will indicate that the depth of field extends from approximately 16 feet to infinity.

## 4–13. Judging Distances

*a.* Scale focusing depends on the ability of the photographer to estimate distances correctly. A photographer can learn to judge distances correctly by estimating the distances of everyday objects and then actually measuring the distances to check his estimates. With practice, a photographer will become quite adept in this simple process.

*b.* Estimating distances of near objects is particularly difficult. To produce a sharp picture of a near object, his estimate must be correct within a matter of inches; for an object at medium or far distances, his estimate must be correct within several feet.

*c.* A photographer must learn to think of distances as dimensions with depth (fig. 4–11). By comparing distances of objects in a plane perpendicular to the line of sight with distances parallel to the line of sight, a photographer is better equipped to visualize the effect of depth on distances. Practice helps the photographer

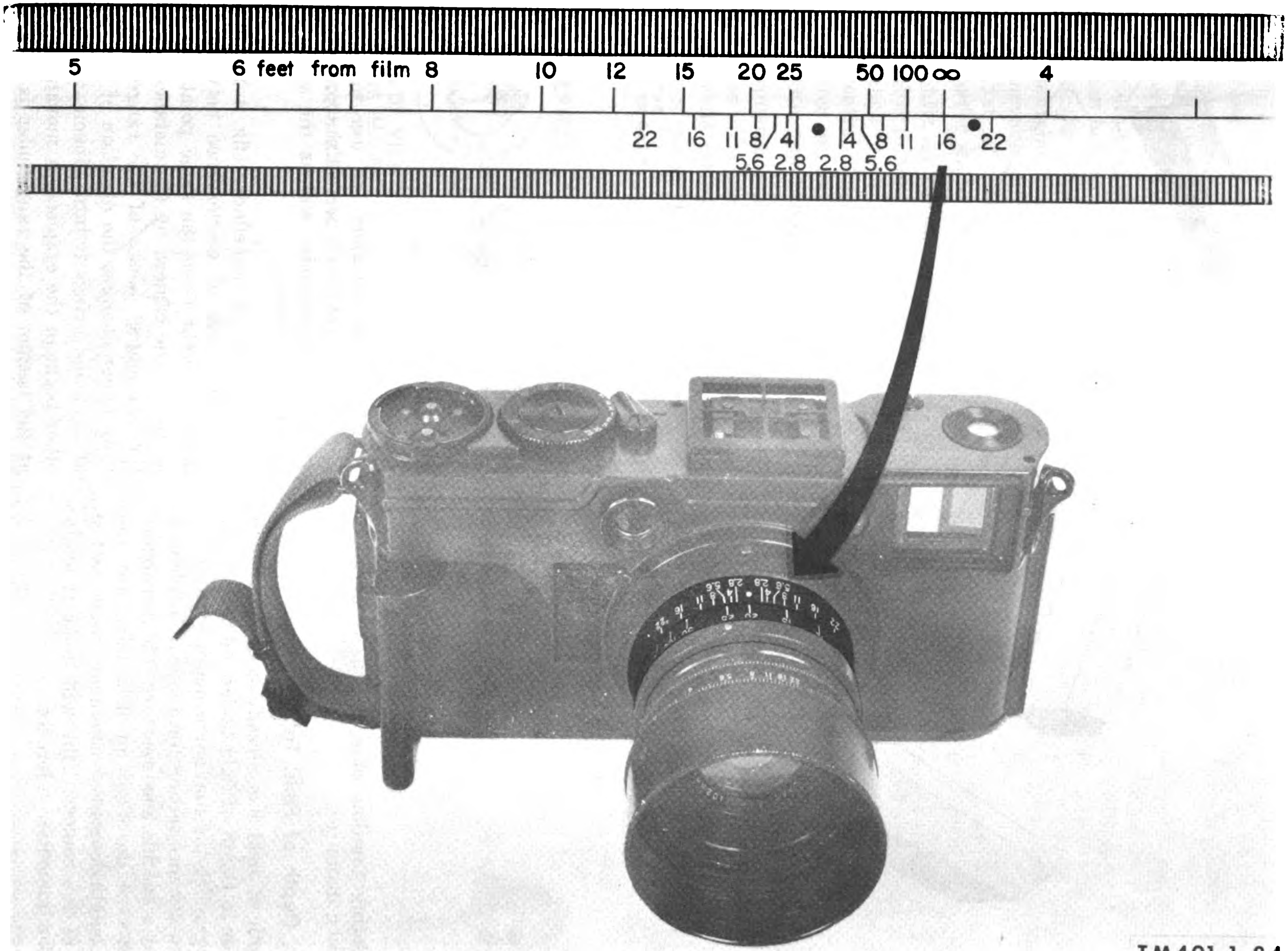


*Figure 4–10. Distance and depth of field scale on 70-mm camera lens.*

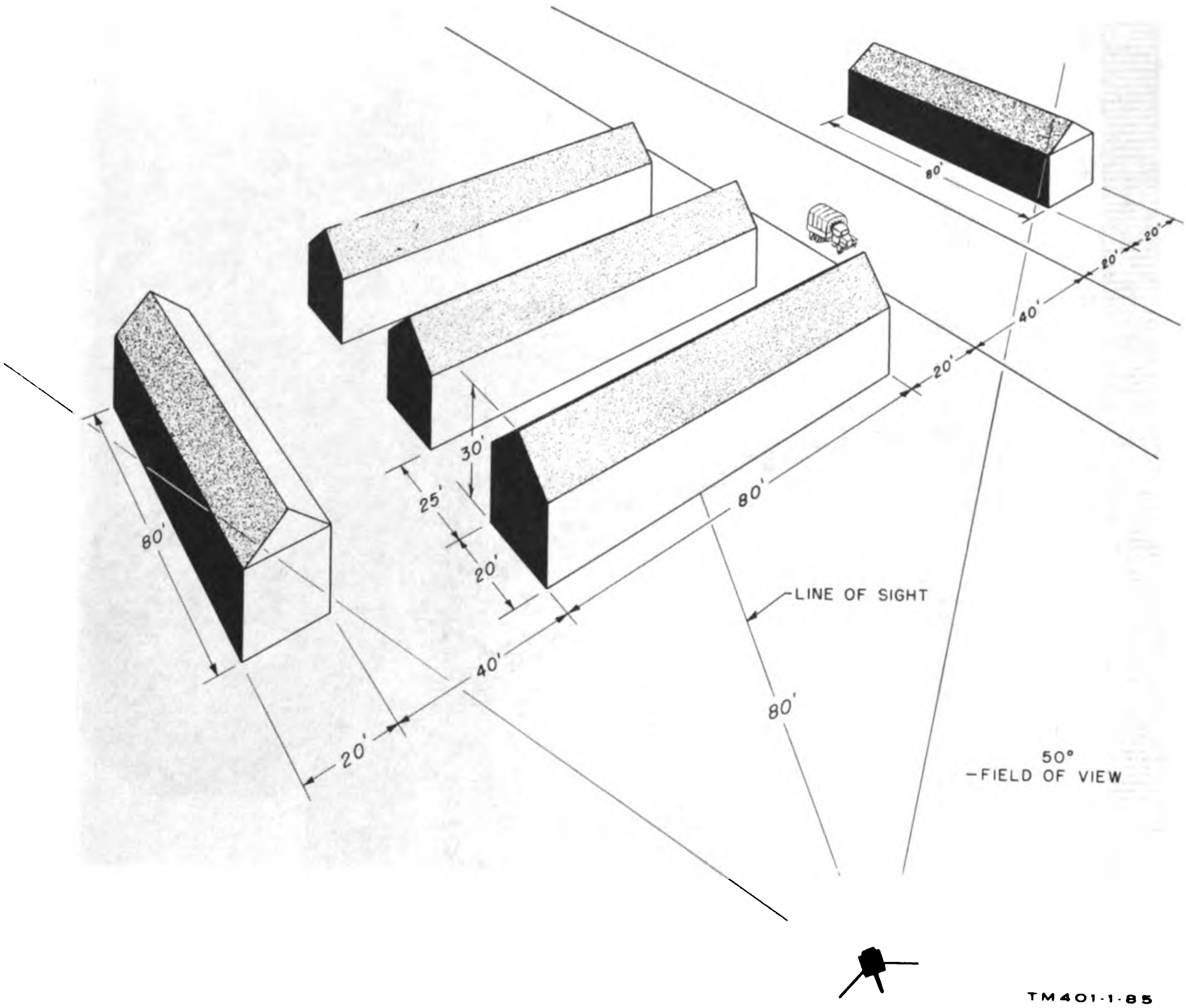


*Figure 4–11. Estimating distance.*

in relating familiar objects and distances to unknown distances.

## 4–14. Depth of Field Tables

Depth of field has already been covered in chapter 3. Depth of field tables indicate to the photographer the maximum depth of field for a given distance setting for a given focal length lens at a specific lens aperture. Photographers should tape the depth of field table, for the focal length lens most commonly used, to the back of the camera. This will make it available for immediate reference.

## 4–15. Rangefinders

A modern rangefinder, coupled with a camera lens, serves one primary purpose. It allows the photographer to use the largest aperture and yet retain perfect sharpness of the subject. A rangefinder widens the scope of a camera considerably.

*a.* Basically, a rangefinder (fig. 4–12) measures the angle of convergence between two beams of light from the same point and separated at the camera by the distance between the two object lenses of the rangefinder. A rangefinder changes the direction of one beam of light and brings it into alinement with the other beam in the eyepiece. A movable mirror at the bottom of the rangefinder is mechanically linked to the sliding track so that the lens is focused when the two beams are brought together in the rangefinder.

*b.* The operation of a rangefinder (fig. 4–12) is simple—

(1) Look through the eyepiece of the rangefinder, and move the camera until the desired object is in the center of the visible field.

(2) Note that a smaller and brighter field can be seen in the approximate center of the larger one. This smaller field contains the image reflected by the movable mirror as well as the image that is passed directly through the upper stationary mirror.

(3) Shift the image reflected by the movable mirror by turning the focusing knob until the two images in the central field coincide. The object is then in focus. A double image indicates that the object is out of focus.

*c.* Fundamentally, all rangefinders are based on the same principle. Some are equipped with mirrors, while others have prisms of various shapes. Even though they differ in construction, each performs the same basic service. Not that—

(1) Mirrors can be replaced by triangula prisms and rotating circular or re tangular wedges.

(2) Coupling arrangements are more pr cise in miniature cameras than in be lows-type press cameras.

(3) Interchangeable lenses can be aut matically coupled with the sam rangefinder without necessitating o tical adjustment.

*d.* Medium-size and small cameras ar equipped with coupled rangefinders. A couple rangefinder is an optical instrument that meas ures the distance between the subject and th camera, and then mechanically fixes the prope separation between lens and film.

*e.* The most advanced type of rangefinder i a viewfinder-rangefinder combination. This ar rangement permits a photographer to view focus, and compose a picture through one opti cal window. When the rangefinder and view finder are separate, the photographer mus

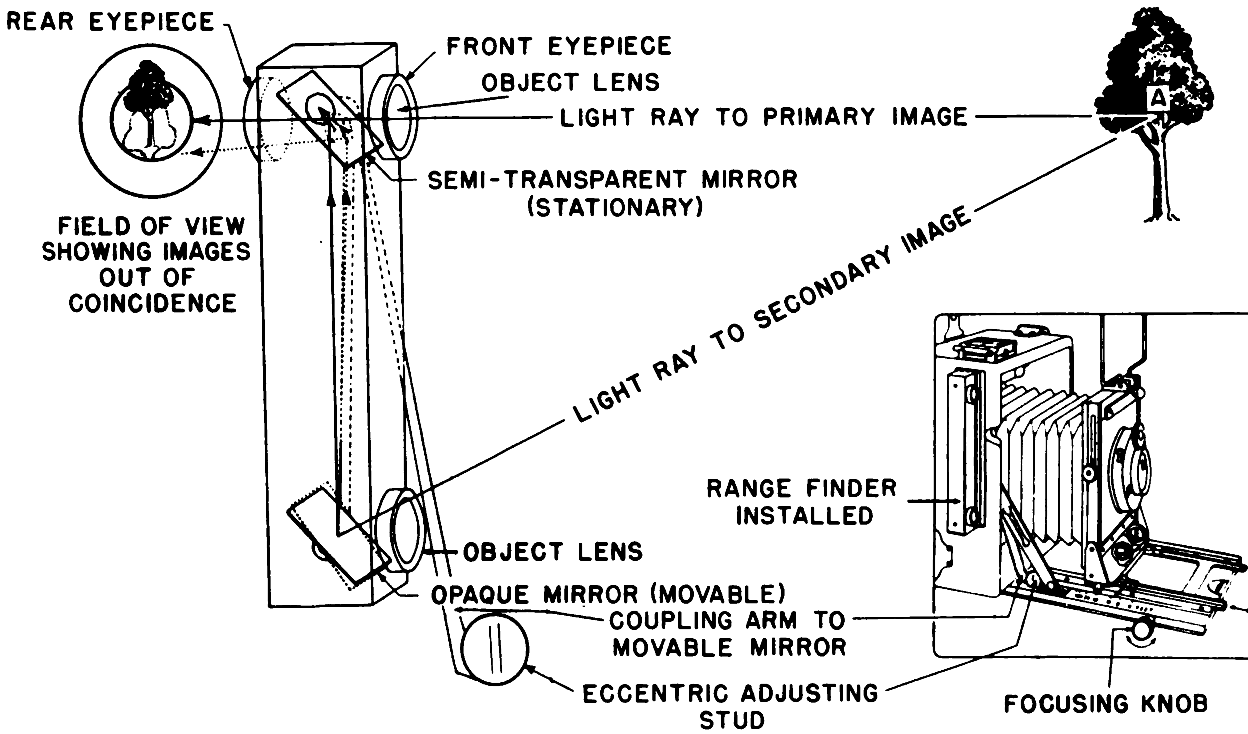


*Figure 4–12. A typical rangefinder.*

first focus on the object through the rangefinder, and then shift to the viewfinder. When recording rapid action, this time loss in shifting from one finder to the other may be the difference between pictorial success or failure.

### 4–16. Ground Glass

*a.* Cameras that use cut film and film packs are equipped with a ground glass to determine accurately the correct focus for any lens. If the camera is equipped with a front shutter and a rear shutter, ground glass focusing must be done with both shutters open.

*b.* In ground glass focusing, the preferable procedure is to place the camera on a tripod. The lens is set at its maximum aperture and the process of focusing begins. When the lens is stopped down to the opening at which the exposure will be made, the photographer can determine the depth of field and the composition of the picture.

*c.* It is quite obvious that ground glass focusing is impractical for use in operations where speed is essential and the action will not wait for elaborate procedure. However, it is practical for testing the focal length of a new telephoto lens, and it is absolutely essential for certain phases of closeup, reproduction, and macrophotography.

## Section III. SHUTTERS

### 4–17. General

The camera shutter is an adjustable mechanism that can be opened and closed for predetermined lengths of time to regulate the amount of light that is permitted to pass through the lens. Some cameras are equipped with between-the-lens shutters; others have curtain shutters; and some have both types of shutters.

### 4–18. Shutter Speed

Shutter speed is the period of time during which the shutter is open to permit light rays to reach the film. If a subject moves slowly, the shutter speed may also be slow. If subject movement is fast, the shutter speed must also be fast to record the object sharply.

*a.* Under normal conditions, hand-held photography of stationary objects requires a speed of about 1/50 second. If the camera is mounted on a tripod or a steady support, speeds of less than the recommended 1/50 second can be used.

*b.* To photograph moving objects, a shutter speed in excess of 1/100 second is ordinarily required. Direction of moving action is also a factor in determining correct shutter speeds.

*c.* Tables in appendix IV list average shutter speeds for use under varying conditions.

### 4–19. Between-the-lens Shutters

A between-the-lens shutter (fig. 4–13), located between the elements of a lens, consists of thin blades activated by springs. When the shutter is set for a given speed, the springs are set automatically; when the shutter is released, the blades spread evenly to the maximum aperture size and then close again. This entire operation occurs within a split second. The fastest between-the-lens shutters have speeds up to 1/1,000 second.

*a.* Some between-the-lens shutters also provide for time, bulb, and synchronized flash exposures. The time and bulb settings are used when an exposure of more than 1 second is desired. When a shutter is set at T and released, the exposure lasts until the shutter is released a second time. When a shutter is set for B, the downward pressure against the shutter release opens the shutter and keeps it open until the pressure is withdrawn. The camera should be placed on a rigid support when time and bulb settings are used.

*b.* Between-the-lens shutters assure images free from distortion when moving objects are photographed, because fast moving objects are recorded in their entirety at the moment of exposure. This is not true with curtain shutters.

### 4–20. Curtain Shutters

*a.* A curtain shutter, also known as a focal-plane shutter, consists of a curtain with different size rectangular slits. One of these slits passes in front of the film at a given speed while the exposure is being made. The slits,

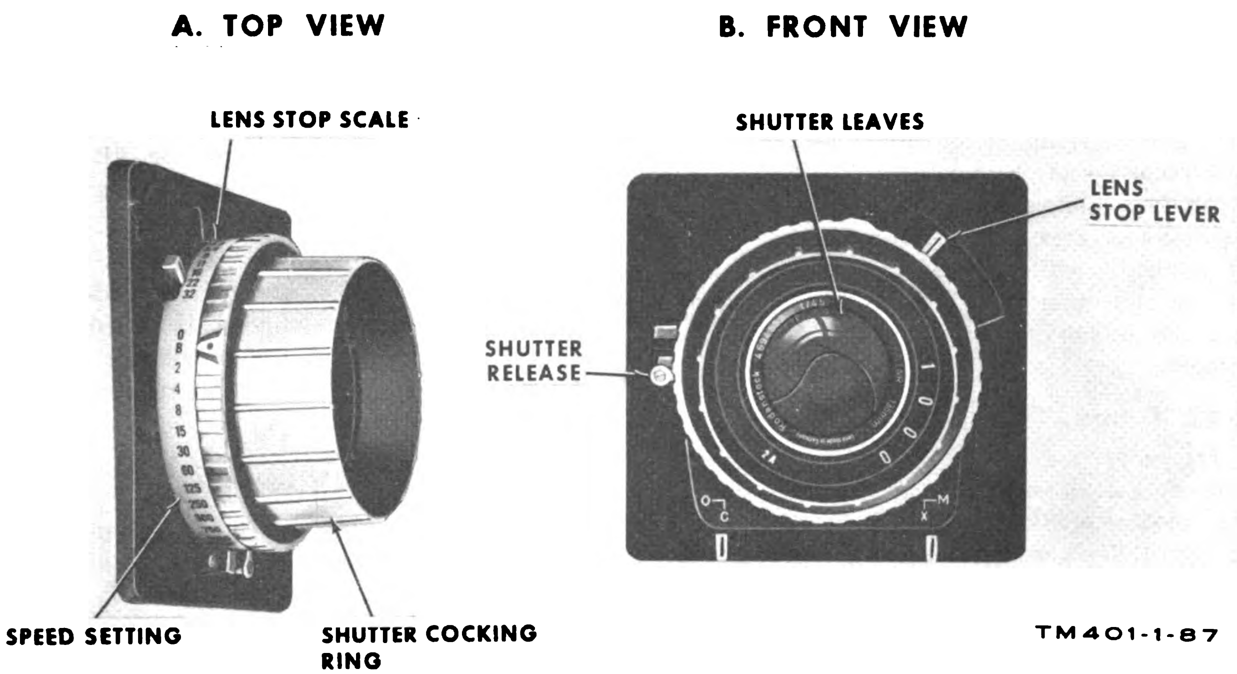


*Figure 4–13. Between-the-lens shutter.*

or curtain apertures, vary in width (fig. 4–14). Most precision miniature cameras, equipped with curtain shutters, have one rectangular slit that can be adjusted.

*b*. Unlike a between-the-lens shutter, a curtain shutter does not expose the entire film area in one instantaneous movement. The film is exposed section by section as the slit passes over the film plane. Although a curtain shutter exposes the image area of the film section by section in an insignificant part of a second, distortion cannot be completely avoided. Distortion results from image movement occurring while the curtain slit is traveling across the image area at the focal plane. Distortion is usually negligible and is seldom noticed, particularly if the fast-moving objects are irregularly shaped and are not too close, if they are properly panned.

*c*. Distortion caused by curtain shutters is most pronounced with large shutters. Theoretically, a given shutter speed is the same with a large or small curtain shutter. In practice, however, a small curtain shutter, such as that in a 35-mm camera, is superior to that of a curtain shutter designed for a camera that uses 4- x 5-inch film, because the curtain need not travel the same distance when making the exposure. Accordingly, a smaller curtain shutter records the photograph in less time, even though the shutter speed is the same.

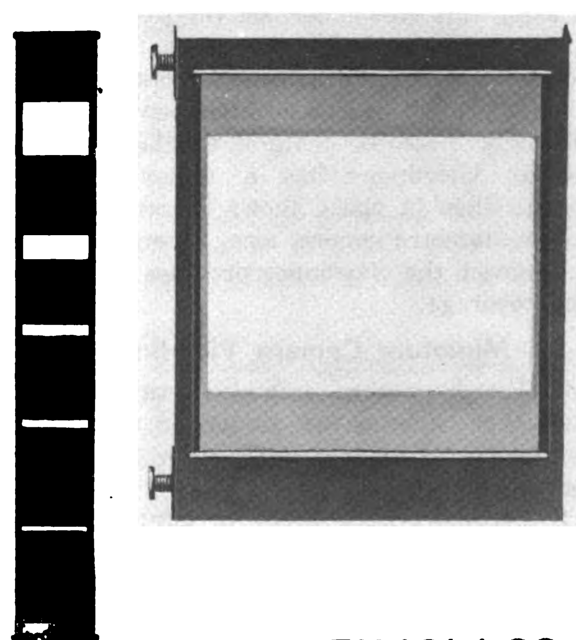


*Figure 4–14. Apertures of curtain shutter.*

## 4–21. General

The primary purpose of camera viewfinders is to give a visual image of what the camera will record and to permit the photographer to analyze the composition of the particular view. Some types of viewfinders require no adjustment, while others must be adjusted so that the image seen through the viewfinder and the image recorded by the camera lens coincide.

## 4–22. Ground Glass

The camera ground glass is the most accurate means of focusing an image, and also the most dependable viewfinder. What the photographer sees on the ground glass is the identical image that will be recorded on the film.

## 4–23. Tubular Optical Viewfinder

*a*. A tubular viewfinder is a small optical instrument that is mounted either on top of a hand camera near the rangefinder or built into the body of a miniature camera.

*b*. The tubular viewfinder provides a means for determining the field of view and for locating the center of the field at close distances. In using this viewfinder, set the revolving dial at the marking that corresponds to the subject distance. If the subject is centered when the eye is on the axis of the viewfinder, the subject will also be centered on the film. This tubular viewfinder has a removable mask which, when in place, shows the area covered by the standard camera lens. When this mask is removed, the viewfinder provides wide-angle lens coverage.

## 4–24. Miniature Camera Viewfinders

*a*. Viewfinders of miniature cameras and press-type cameras are similar in design, but the former is usually inclosed in the camera body.

*b*. Parallax (para 4–28) in miniature cameras is much less a problem than in larger cameras, because viewfinders in miniature cameras are much closer to the axis of the photographic lens than in large cameras.

*c*. A special type of optical finder is the universal viewfinder (fig. 4–15), which is positioned in a clamp as part of the camera housing. This precision instrument indicates the exact field of coverage of the camera's various interchangeable lenses for all subject distances. Parallax in this viewfinder is corrected by turning a distance lever.

*d*. The built-in optical viewfinder in one camera incorporates a coupled coincident-type rangefinder. This viewfinder is adjusted to accommodate the field of coverage of the two lenses (4 inch and 8 inch) normally supplied with the camera.

## 4–25. Wire Frame Viewfinder

Press-type cameras are also equipped with a wire frame (sports) finder (fig. 4–4) that consists of a peepsight and a wire frame. When the peepsight is brought close to the eye, the photographer has a full-sized view of consists of a peepsight and a wire frame. forming a border around the subject. This finder is particularly well suited to following moving subjects.

## 4–26. Reflecting Viewfinders

*a*. The reflecting type viewfinder, which is used in a simple box camera, consists of a lens, a mirror, and ground glass. The lens projects an image on the mirror, which is set at a 45° angle. The mirror, in turn, reflects the image onto the ground glass. The image is right side up, but it is reversed from left to right.

*b*. A more advanced reflecting viewfinder is the brilliant finder, which is used on simple folding cameras. Instead of ground glass, this finder has a collecting lens that increases the brilliancy of the image.

## 4–27. Reflex Viewfinders

Reflex viewfinders are used in cameras of the Rolleiflex (reflex camera) type. This finder, which acts in the dual capacity of rangefinder and viewfinder, permits the photographer to view the subject on a ground glass that is exactly the same size as the negative produced by the camera. When the viewfinder is in focus, the recording lens is also in focus, since these lenses are mechanically coupled. Thus, the

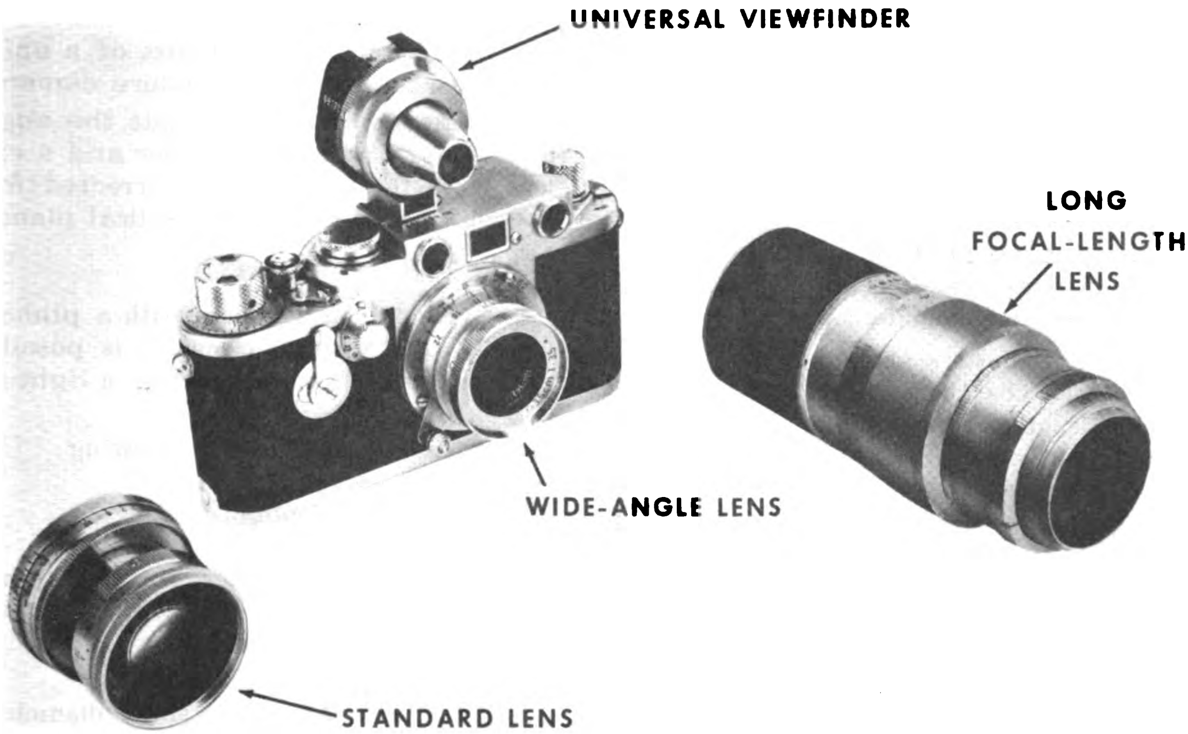


*Figure 4–15. Camera set, showing interchangeable wide-angle, standard, and long focal length lens, as well as the universal viewfinder.*

photographer can compose and focus in one large finder. A magnifying lens permits more detailed study of the image to determine maximum sharpness.

## 4–28. Parallax
(fig. 4–16)

Parallax, in simple terms, is the difference between what the camera lens projects on the film and what the photographer sees through the viewfinder. It occurs when the line of sight from a lens and that from a viewfinder are slightly apart.

*a.* If a viewfinder is directly above the lens, only vertical parallax correction is necessary. If the viewfinder is not in either the same horizontal or vertical plane as the camera lens, correction for both directions is necessary.

*b.* Some cameras automatically correct for parallax. Others have devices that can be adjusted mechanically to make corrections.

## 4–29. Summary

*a.* Basically a camera consists of a light-tight box, a lens, a shutter, and a back designed to hold a light-sensitive material at the focal plane.

*b.* Press or hand cameras are designed for the widest range of pictorial work, but are primarily used in public information photography.

*c.* View and studio cameras handle larger film sizes than most other camera types, permit extensive adjustment of the camera lens and camera back positions, but are too large and unwieldy for field use. Principal use of these cameras is for studio, laboratory, and special types of outdoor coverage.

*d.* Miniature cameras are relatively compact and light, and handle a small film size. They are particularly useful for types of field coverage when operational speed is essential.

*e.* Reflex cameras permit image control until the precise moment of exposure; both single-lens and double-lens types are available in a wide range of film sizes.

*f.* To focus a camera—projection of a sharp image unto the focal plane of the camera—the lens is moved nearer to or farther from the camera back through mechanical means.

*g.* Devices designed to facilitate focusing include distance scales, depth of field tables, rangefinders, and ground glass.

*h.* Camera shutters are adjustable mechanisms that can be opened or closed for predetermined lengths of time to regulate the amount of light that is permitted to pass through the lens.

*i.* Photography of stationary objects with hand-held cameras generally requires a shutter speed of about 1/50 second.

*j.* Photography of moving objects call for a shutter speed in excess of 1/100 second.

*k.* Camera viewfinders frame the portion of the subject to be recorded and permit the photographer to analyze the composition of the particular view.

*l.* Parallax is the difference between what the camera lens projects on the film and what the photographer sees in the camera viewfinder. It poses a problem only when the line of sight from the camera lens and the viewfinder have not been adjusted and, accordingly, do not exactly overlap.

## 4–30. Review Questions

*a.* Is it possible to produce a photographic image without a camera lens?

*b.* What are the advantages and disadvantages of a pinhole lens?

*c.* List the various types of cameras.

*d.* For what types of military photography would you use a view camera?

*e.* Describe the operation of a camera rangefinder.

*f.* How can a photographer learn to judge distances correctly?

*g.* What are the advantages and disadvantages of ground glass focusing?

*h.* Explain the operation and function of a between-the-lens camera shutter.

*i.* What is the main disadvantage of a curtain shutter?

*j.* Describe the characteristics of a universal viewfinder designed for miniature cameras.

*k.* Draw a diagram to indicate the angles of coverage of a camera viewfinder and a camera lens when the viewfinder is corrected for the horizontal plane but not the vertical plane.

## 4–31. Review Answers

*a.* By equipping a camera with a pinhole, in place of a photographic lens, it is possible to produce a photographic image on a light-sensitive emulsion.

*b.* A pinhole lens has the following:

(1) *Advantages.*

(*a*) Great depth of field.

(*b*) Wide angle of view.

(*c*) Pleasing image softness particularly suited for various types of artistic photography.

(2) *Disadvantages.*

(*a*) Because of the small diameter of the pinhole aperture only a fraction of the light reflected by the subject passes through the pinhole.

(*b*) No pinhole is capable of producing a critically sharp image.

*c.* Generally, the various types of cameras are box, folding, press, view, miniature, and reflex cameras.

*d.* View cameras are used primarily for architectural photography, group photography, and general recording of large outside areas that must be reproduced in considerable detail.

*e.* Basically, a cameras rangefinder measures the angle of convergence between two beams of light from the same point and separated at the camera by the distance between the two rangefinder lenses.

*f.* A photographer can learn to judge distances correctly by estimating the distances of everyday objects and then actually measuring the distance to check his estimates.

*g.* Ground glass focusing is time consuming and must be done from a camera tripod. However, it simplifies subject composition, clearly indicates the depth of field of the camera lens at various apertures, and accurately shows the coverage of the camera lens used.

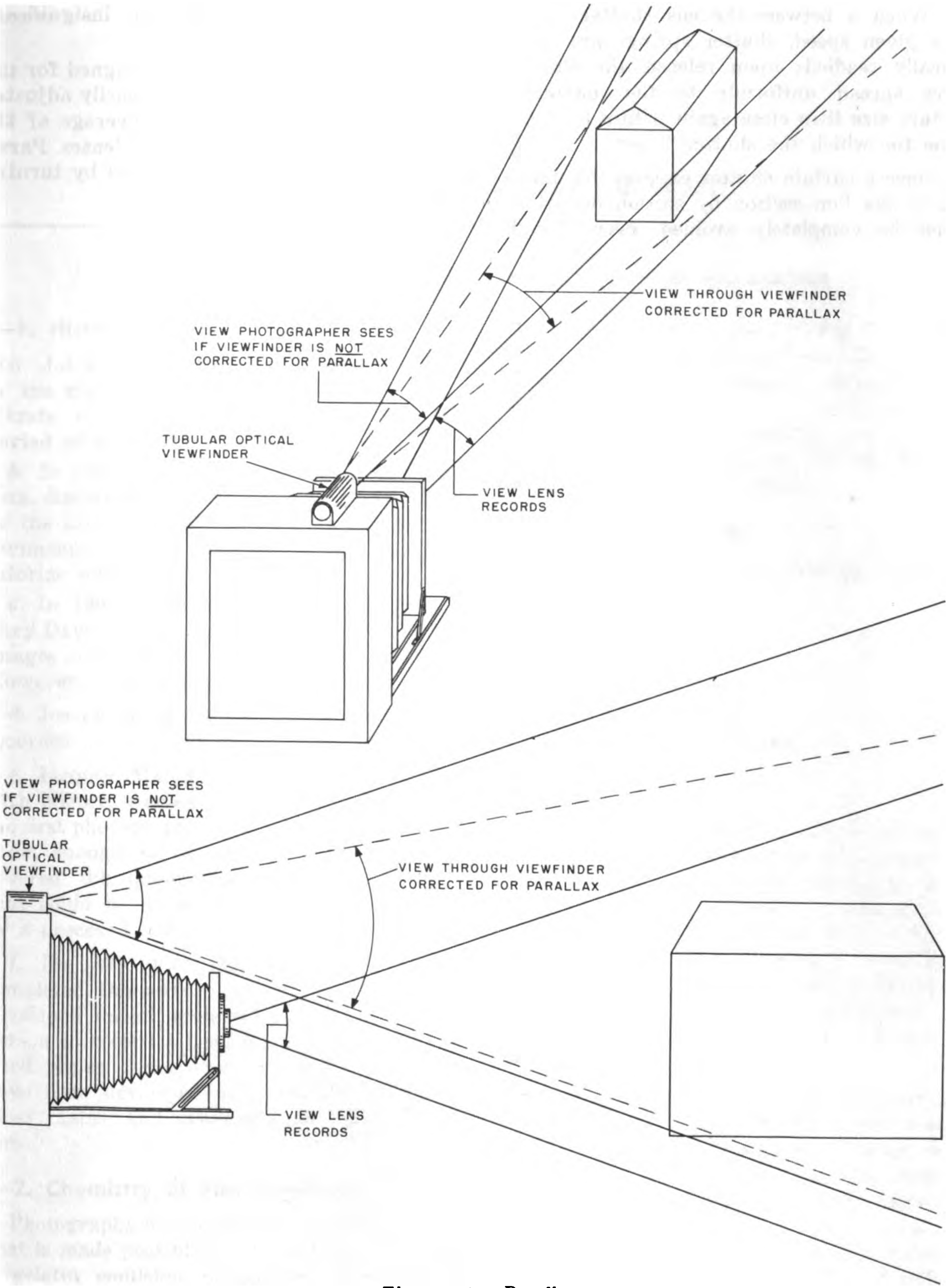


*Figure 4–16. Parallax.*

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*h*. When a between-the-lens shutter is set for a given speed, shutter springs are automatically readied; upon release, the shutter blades spread uniformly to the maximum aperture size then close again within the time frame for which the shutter is set.

*i*. Since a curtain shutter exposes the image area of the film section by section distortion cannot be completely avoided, even though exposure may occur within an insignificant part of a second.

*j*. The universal viewfinder designed for use with miniature cameras can be easily adjusted to indicate the exact field of coverage of the camera's various interchangeable lenses. Parallax in this viewfinder is corrected by turning a distance lever.

*k*. Refer to figure 4–16.

# CHAPTER 5

# SENSITIZED PHOTOGRAPHIC MATERIALS

## Section I. PHYSICAL CHARACTERISTICS OF FILM EMULSIONS

### 5–1. History

*a.* Jabir Ibn Hayyam, an Arab who lived in the eighth century, first noted that silver nitrate darkens considerably over a given period of time.

*b.* In 1727, Johann Heinrich Schultz, a German, discovered that this darkening was caused by the action of light. Schultz, in his first experiments, formed stenciled images on silver chloride surfaces without a camera.

*c.* In 1800, Thomas Wedgewood and Humphry Davy of England used a camera to record images on paper sensitized with silver chloride. However, these images were not permanent.

d. Joseph Nicèphore Nièpce, a Frenchman, recorded the first permanent image in 1826.

*e.* Jacques Mandè Daguerre, who worked with Nièpce, started investigations that led to the first photographic process with an exposure short enough to be practical. Daguerre discovered the latent image (invisible image) that could be made visible and strengthened by a process known as development.

*f.* In 1839, Fox Talbot, an Englishman, completed Daguerre's process by making the developed image permanent. He was the first person to record a permanent image on sensitized paper. Since then, sensitized materials have been developed as a coating on paper, glass plates, and eventually on photographic films.

### 5–2. Chemistry of Film Emulsions

Photography is essentially a chemical process that is made possible by the action of light on a gelatin emulsion containing light-sensitive silver halides. The light, focused by a photographic lens, strikes the minute particles embedded in the gelatin layer of the film, causing a permanent physical change. This change known as a latent image is invisible to the human eye. However, this latent image can be made visible by the catalytic action of the developer. Development of the photographic material produces a negative.

### 5–3. Anatomy of Film

A photographic film is made up of the following layers (fig. 5–1):

*a.* A base support.

*b.* An emulsion.

*c.* A protective covering.

*d.* A noncurl backing.

*e.* An antihalation backing.

### 5–4. Base

The material selected as a base or support for a film emulsion must possess two qualities. First, it must be photographically inert—unable to cause any harmful action in the emulsion, either to the latent image or to the silver grains of the developed image. Second, it must remain unaffected by the solutions used in processing. Many materials meet these qualifications, but those most commonly used are cellulose acetate and glass.

*a. Cellulose Acetate.* Cellulose acetate is commonly used as a support for negative emulsions because it is transparent, strong, lightweight, and flexible. In addition, cellulose acetate is not inflammable. It is known as safety base film. This material is gradually being replaced by polyester plastic materials.

*b. Glass.* Since the introduction of cellulose acetate, the use of glass as a base has been greatly reduced. Its main disadvantages are

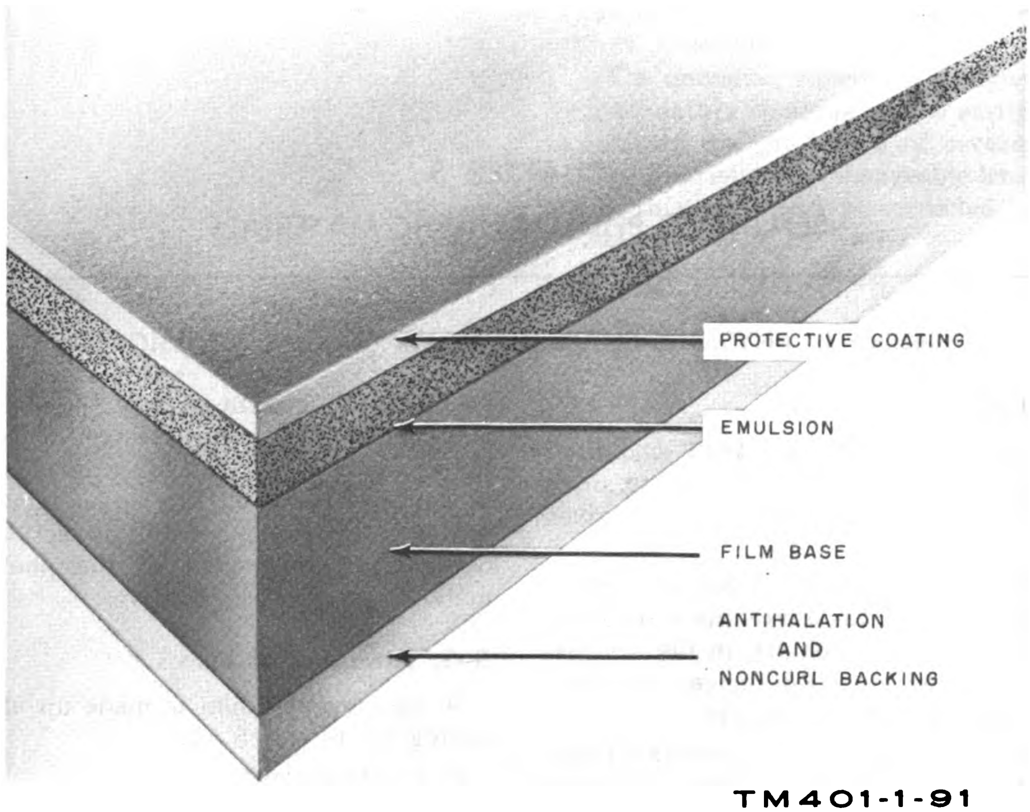


*Figure 5–1. Cross section of a photographic film.*

weight, bulk, fragility, and inflexibility. Glass is still used when rigidity and freedom from expansion and contraction of the base are important.

## 5–5. Emulsion

The emulsion is a thin layer of gelatin containing minute crystals of light-sensitive silver halides. Gelatin, which swells when wet and is easily penetrated by the processing solutions, is the best support for silver halide grains. When dry, the gelatin contracts to its original shape. Gelatin may be handled safely in solutions at temperatures up to 85° Fahrenheit, which is about 43° Fahrenheit below the melting point of gelatin. When desired, it can be chemically hardened and subjected to higher processing temperatures.

## 5–6. Protective Coating

An overcoating of clear hard gelatin is applied to some emulsions to prevent scratches and abrasions. This is a protective coating.

## 5–7. Noncurl Backing

A film emulsion swells when wet and shrinks when dry. This produces a strain that causes the film to curl. To counteract this curling, another layer of clear gelatin (noncurl backing) is often applied to the back of the base.

## 5–8. Antihalation Backing

When light passing through an emulsion is reflected from the back of the film base, it produces a halo of light on the image. Halation is minimized by adding a light-absorbing dye to the base or noncurl backing. Such a dye may be either neutral gray or the color to which the emulsion is least sensitive.

## 5–9. Photographic Characteristics

The primary characteristics of a photographic emulsion are—

*a.* Color sensitivity.

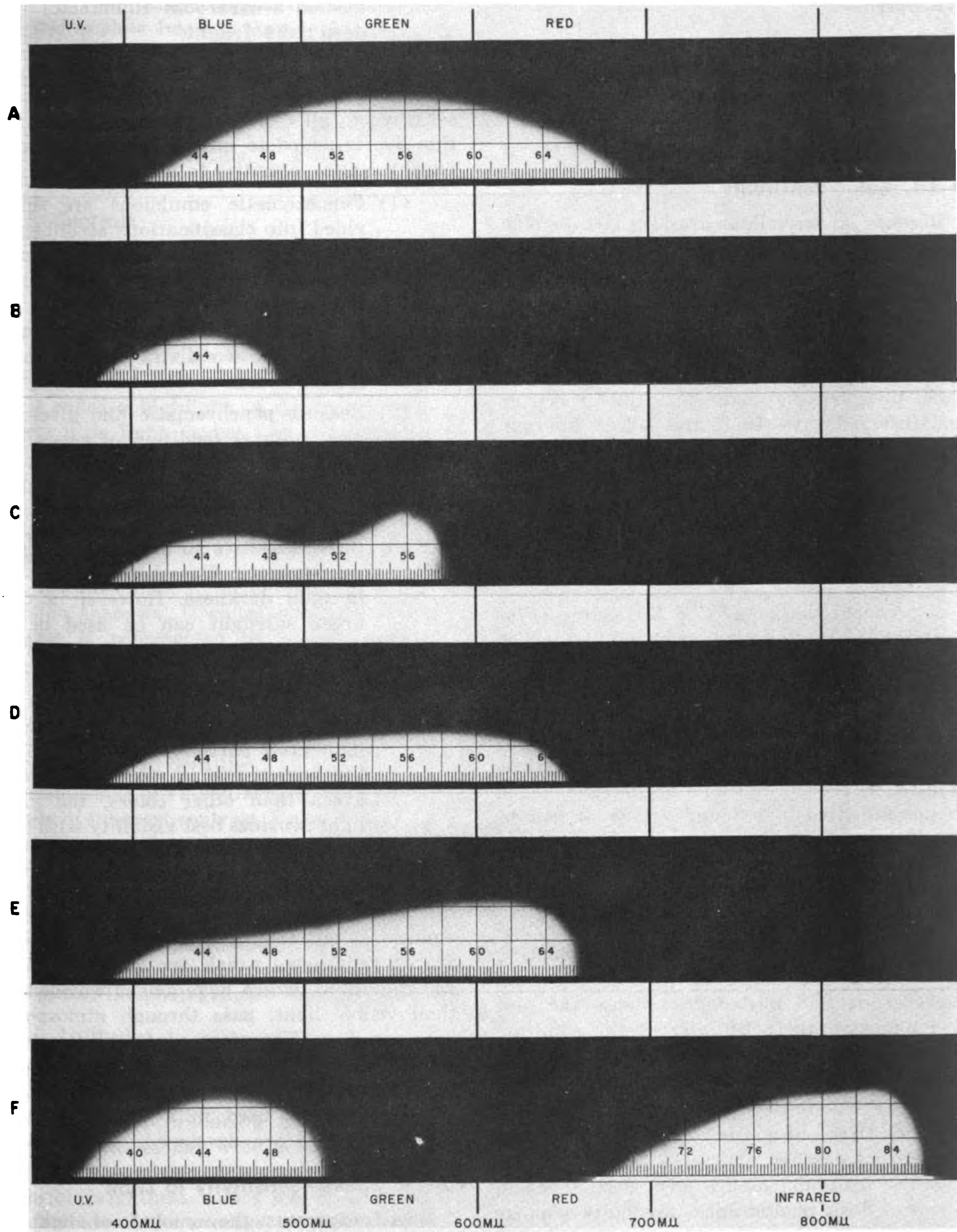


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*Figure 5–2. Spectrograms showing color sensitivity of various films.*

*b*. Speed.

*c*. Contrast.

*d*. Latitude.

*e*. Grain

*f*. Resolving power.

## 5–10. Color Sensitivity

Because silver halides are sensitive to blue, violet, and ultraviolet light, all photographic emulsions are inherently sensitive to these colors. Sensitivity to other colors is obtained by adding various dyes to the emulsion during manufacture. The discovery of new dyes has increased the color sensitivity range of emulsions to cover the complete visible spectrum and infrared rays. In figure 5–2, A approximates the sensitivity of the normal eye, B represents noncolor sensitized emulsions, C represents orthochromatic emulsions, D represents panchromatic type B emulsion, E represents panchromatic type C emulsions, and F represents infrared emulsions.

*a. Nonchromatic (NC) Emulsion (Blue Sensitive)*. This noncolor sensitized film, which has only ultraviolet and blue-violet sensitivity, is used when natural color rendition is not important. *For example*, a nonchromatic emulsion is used to copy black and white originals and to photograph colorless items when extreme contrast is needed. Since an ordinary emulsion is not sensitive to red and yellow, it can be handled safely in a darkroom with a bright red safelight.

*b. Orthochromatic Emulsions*. The first emulsion manufactured with a dye was called orthochromatic, which literally means a rendering of true colors in shades of gray. In this case, however, it is a misnomer, because the first dye increased the sensitivity of the emulsion to green but not to red. Red reproduced as a dark tone, while green and blue registered as light tones on a print.

(1) Orthochromatic emulsions, which strengthen character lines in a portrait and assure good flesh tones in flash photographs, are quite popular for portraiture.

(2) Because an orthochromatic emulsion is not sensitive to red, it can be handled in a darkroom illuminated by a deep red safelight.

*c. Panchromatic Emulsions*. A dye has been developed to make photographic emulsions sensitive to all colors of the spectrum. When this dye is added to an emulsion, it becomes panchromatic—sensitive to all colors.

(1) Panchromatic emulsions are subdivided into classifications according to their color sensitivity. Films having a fairly even balance of color sensitivity to red, green, and blue are known as type B. Those having a higher red sensitivity are known as type C.

(2) Because panchromatic film gives the most natural rendition of colors and brightness in shades of gray, it is the film most generally used in photography.

(3) Being sensitive to all colors of light, panchromatic film should be handled in total darkness. However, a dark green safelight can be used in the darkroom for periods of time after development is at least 50 percent complete. This is possible because the emulsion becomes less sensitive to light after partial development. Since the human eye is more sensitive to green than other colors, the green light provides best visibility with least illumination.

*d. Infrared Emulsions*. These emulsions have the same sensitivity as noncolor sensitized emulsions, but they are also sensitive to infrared radiations, which are invisible. Infrared radiations, which have longer wavelengths than visible light, pass through atmospheric haze readily. Therefore, infrared sensitive emulsions are vital to the aerial photographer when he is recording at high altitudes. A green safelight can be used in a darkroom when these emulsions are developed.

## 5–11. Speed—Sensitivity to Light

Speed expresses the amount of light required to produce a satisfactory negative with a given emulsion. Although most fast films are panchromatic, color sensitivity is not a definite indication of emulsion speed. Some emulsions are rated as slow because they require a great amount of light to produce a satisfactory image; other emulsions are rated as fast because a relatively small amount of light produces a satisfactory image. An exposure guide with the film speed rating is usually included in the film package.

## 5–12. Contrast

Contrast, which is the difference between the bright, dark, and intermediate tonal areas of a photograph, depends on the difference in the density of metallic silver in an emulsion. A bright area, which reflects a great amount of light, causes heavy density in a negative and is called a highlight. A dark area, which reflects little light, leaves only a slight tonal mark on the negative and is called a shadow. Various brightnesses between the light and dark areas also register on the negative as corresponding densities, called intermediate tones.

*a.* The difference in brightness, from highlights to shadows, is called contrast. Normal contrast is represented by a full range of densities, including highlights, intermediate tones, and shadows. High contrast records only highlights and shadows, with little or no intermediate gradation. Low contrast shows very little difference in densities.

*b.* Emulsions are manufactured with varying degress of inherent contrast. Process (high contrast) film records a short range of tones, such as black and white, and is used to copy line drawings. Normal contrast film is used to record a wider range of tones, as found in a portrait or landscape. In other words, the selection of film is governed by the contrast of the subject and the photographic rendition desired.

## 5–13. Latitude

The ability of an emulsion to record a range of brightness values is called *latitude*. An emulsion capable of producing a long range of brightness values has wide latitude, and, conversely, an emulsion producing only a short range of brightness values has little latitude. The latitude of the average panchromatic film of normal contrast is about 1 to 130. This means that a highlight 130 times as bright as a shadow can be recorded without impairing any intermediate gradations. The brightness range of an average scene, however, is about 1 to 32. Consequently, variations of exposure above and below normal will still produce normal negatives. The extent to which exposure can deviate from the normal, and still produce an acceptable image, is called exposure latitude.

## 5–14. Grain

Ordinarily, microscopic silver grains that make up the negative image are not visible in the negative or contact print. However, a granular or speckled effect usually appears when a negative is viewed under a microscope or when a big enlargement is made. With further magnification, graininess increases.

*a.* Grain in an emulsion depends on the size of the silver halide crystals before development and on the clumping of the silver grains during development.

*b.* To achieve the necessary degree of sensitivity to light, silver halide crystals in high speed films are larger than those in low speed emulsions. The tendency of silver crystals to clump during development can be minimized by using a fine-grain developer.

*c.* When a photographer plans to make large projection prints, the negative should be produced on a fine-grain emulsion and developed in an appropriate fine-grain developer.

*d.* Correct exposure, precise processing and uniform solution temperatures are important in preventing excessive graininess in negatives.

## 5–15. Resolving Power and Acutance

Resolving power is the capability of an emulsion to reproduce fine subject details. Acutance is the degree to which an emulsion can record a sharp division between image area details of differing contrast.

*a. Resolving Power.* Resolving power, which increases with the fineness of grain of the emulsion, is expressed in terms of the number of lines per millimeter a film is capable of recording separately and distinctly. However, since the test patterns used to determine response are normally of high contrast, they fail to indicate emulsion performance with respect to less contrasty objects.

(1) Experience has shown that resolving power is of practical value in those types of specialized photography where individual fine lines or details

must be faithfully recorded. In general photography, however, the acutance or definition of an emulsion is of greater importance, because it is responsible for the visual impression of image sharpness.

(2) Table 5–I shows the relative ability of various types of film to resolve details.

*Table 5–I. Resolving Power*

| Type of sensitive material | Lines per millimeter resolved |
|---|---|
| Extra high speed film emulsions | 40 |
| High speed film emulsions | 50 |
| Positive motion picture stock | 60 |
| Medium speed panchromatic film emulsions | 70 to 100 |
| Lantern slide plates | 75 |
| Copy-type 35-mm film emulsions | 135 to 150 |
| Special film emulsions for microradiography | 600 |
| Extra fine-grain film emulsions for specialized work | 1,000 |

*b. Acutance.* Acutance is the emulsion characteristic that is responsible for producing clear and sharp photographic images. It is achieved most satisfactorily by thin emulsions that have a specific silver halide concentration suspended within the emulsion layer.

(1) Image sharpness is limited by irradiation, which is the degree to which light (during exposure) is scattered sideways through reflection and refraction by the crystals. Irradiation, in turn, governs the extent to which diffusion occurs beyond any sharply defined image details projected onto the emulsion by the camera lens.

(2) Acutance, which is an inherent emulsion characteristic present in the latent image, is only slightly altered by later film processing.

*c. Application.* Photographers, in selecting a fine-grain film, must consider both resolving power and acutance. Since both of these characteristics are not inherent in all films, the photographer must study his results to find the type of emulsion that meets his particular requirements.

## Section II. PHYSICAL CHARACTERISTICS OF PAPER EMULSIONS

### 5–16. General

Paper is an ideal support for sensitized emulsions, because it reflects light and is flexible, economical, and durable.

*a.* The requirement for negative paper emulsions in military photography is limited; most paper emulsions are used to produce positive prints from photographic negatives.

*b.* Printing paper emulsion is particularly thin to increase the reflectivity of the finished print and to make it extremely flexible.

*c.* There are three types of printing paper emulsions: bromide, chloride, and chlorobromide. The main difference among these types is speed and latitude. Surfaces are either matte or glossy.

### 5–17. The Chemistry of Paper Emulsions

When light strikes the minute silver halides embedded in the gelatin layer of a paper emulsion, a physical change takes place, creating the latent image. Subsequent chemical development makes the invisible latent image visible.

### 5–18. The Anatomy of Photographic Paper

Photographic positive papers (fig. 5–3) are composed of the following layers:

*a.* A paper base.

*b.* A baryta layer.

*c.* An emulsion.

### 5–19. Base

The base must be chemically pure to insure that it will not interfere with the chemical processes to which the emulsion is subjected. Accordingly, the paper base must meet the highest standards with respect to quality and purity. Paper is available with either a single or double weight base.

### 5–20. Baryta Layer

Although paper has a high degree of natural reflectivity, the quality of a photographic print can be increased if the reflectivity is increased.

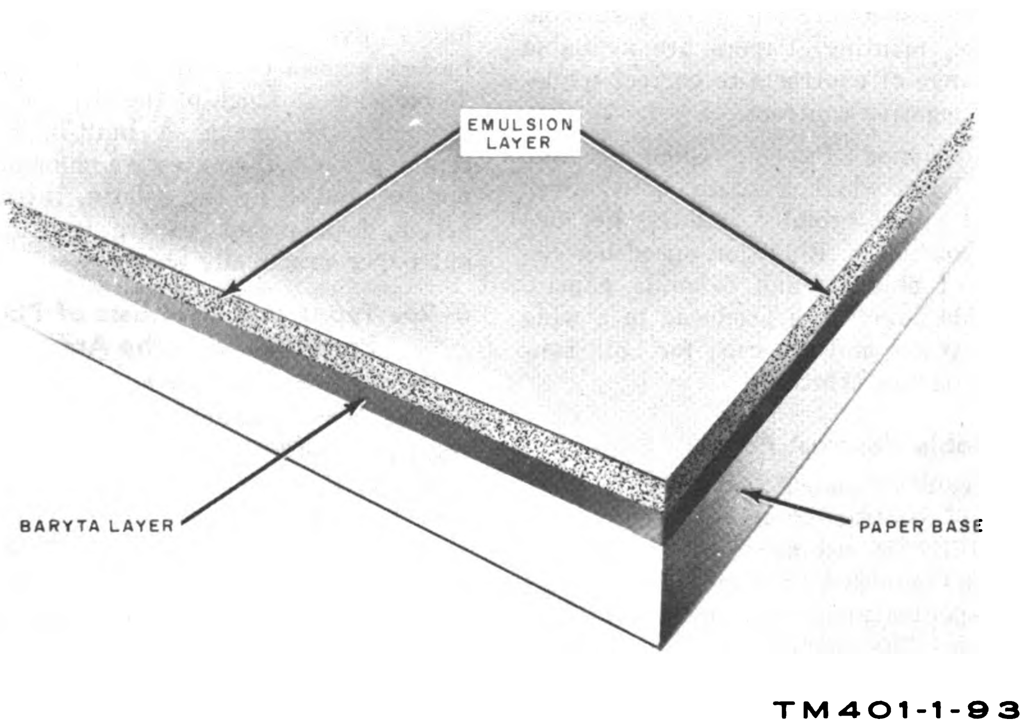


*Figure 5–3. Cross section of a sheet of photographic printing paper.*

This is accomplished by adding, to the paper, a gelatin layer containing baryta crystals (fig. 5–3).

## 5–21. Emulsion

The emulsion layer, which contains minute silver halides suspended within a gelatin medium is thin. Printing paper emulsions need only reproduce the tonal range of a negative, while film emulsions must have the capability of interpreting brightness, shadows, colors and related details of a given scene or subject Accordingly, printing paper emulsions are o a much simpler structure than film emulsions

## 5–22. Development Papers

Development papers (photographic printin papers) have a gelatin surface that contain light-sensitive silver halides. Following expo sure, the papers are subjected to a precise chemical development process.

*a. Chloride Papers.* Chloride papers, which have a slow speed emulsion containing silver chloride, are fine grain and produce deep blacks. Because of low sensitivity to light, they are used for contract printing. Chloride papers are made in different contrasts, ranging from soft (low contrast)ı to hard (high contrast).

*b. Bromide Papers.* Bromide papers, which have a faster emulsion speed than chloride papers, achieve sensitivity through the use of silver bromide halides. They produce blacks that are warmer than those of chloride papers. Because of the relatively high sensitivity to light, these emulsions are particularly suitable for projection printing. Papers are available in a great range of contrasts to correct inadequancies in negative contrast.

*c. Chlorobromide Papers.* Chlorobromide paper emulsions, which contain both silver chloride and silver bromide halides, produce pleasing warm blacks. Emulsion speed lies between that of chloride and bromide papers. Chlorobromide papers are produced in a wide range of contrasts and are used for both contact and projection printing.

## 5–23. Variable Contrast Paper

Variable contrast paper combines the complete scale of contrast ranges in one paper. This versatility is achieved with a special chlorobromide emulsion that produces varying contrast responses upon exposure to different colored lights. The photographer, instead of using different grades of paper, places one of a series of colored filters over the projection printer lens to achieve a specific contrast response. Up to ten filters are available to permit the widest possible contrast. They range from light yellow, for low contrast, to deep blue, for high contrast.

## 5–24. Special Emulsions

*a. Nonsilver Printing Papers.* Nonsilver printing papers, which are sensitized with iron salts, are printed in daylight or exposed by arc lamps or mercury-vapor lamps. They are much less expensive than papers sensitized by silver halides, are simple in operation, and prodce a direct positive image. These papers are used when quality is not primary consideration.

(1) *Blueprint Paper.* Blueprint paper has a ferro-prussiate emulsion.

(2) *Diazo paper.* Diazo paper has a coating of organic compounds that are destroyed by light and are combined with a phenol or an aromatic amine to produce azo dyes. This paper is superior to blueprint paper, but it is greatly inferior to standard silver image papers. Diazo paper is generally used when low quality prints are satisfactory and the cost factor is important.

*b. Printing-Out Papers.* Printing-out paper has a silver chloride emulsion. Basically, extended exposure by a powerful light source decomposes so much of the silver chloride that it forms the image. A built-in halogen acceptor absorbs the excessive chlorine that cannot be handled by the gelatin. Introduction of better development papers has made printout paper practically obsolete.

## 5–25. Types and Contrasts of Photographic Papers Used in the Army

Photographic papers used in the military service are designated by type, subtype, and contrast. The type (table 5–II) specifies if the emulsion is designated for contact or projection printing, and whether the paper is in graded contrasts or variable contrast. The subtype (table 5–III) refers to the thickness of the base stock, the surface finish, and whether or not the base is water resistant.

*Table 5–II. Types of Photographic Papers*

| Type | Description |
|---|---|
| I | Contact, graded contrast |
| II | Projection, graded contrast |
| III | Contact, variable contrast |
| IV | Projection, variable contrast |

*Table 5–III. Subtypes of Photographic Papers*

| Subtype | Description |
|---|---|
| A | Single weight, glossy |
| B | Double weight, glossy |
| C | Single weight, semimatte |
| D | Double weight, semimatte |
| E | Single weight,semiglossy, water-resistant base. |
| F | Lightweight, semimatte, flexible. |

*a. Photographic Recording Paper.* Photographic recording paper is a sensitized material for purposes other than printing from film negatives. This paper is used with photostat-type machines and furnishes both negative and positives. Table 5–1V lists the various photographic recording papers used in the Army.

*Table 5–IV. Photographic Recording Paper*

| Types or class | Description |
|---|---|
| Type XX | Extra lightweight base |
| Type XXI | Lightweight base |
| Class A | Matte surface |
| Class B | Semimatte surface |

*b.Photographic Reflex Copy Paper.* Reflex copy paper is used with reflex copy apparatus. The material being copied faces the emulsion of the reflex paper. Both direct ligth and light reflected back from the copy are essential for proper paper emulsion exposure. Table 5–V covers the different types of photographic reflex copy paper used in the Army.

*Table 5–V. Photographic Reflex Copy Paper*

| Types and classes | Description |
|---|---|
| Type I | Paper |
| Type II | Vellum |
| Type III | Tracing linen |
| Type IV | Card stock, glossy, sensitized on one side. |
| Type V | Duplex (sensitized on both sides). |
| Class A | Standard weight |
| Class B | Heavyweight, 95 gram |
| Class C | Medium weight, 80 gram |
| Class D | Lightweight, 55 gram |

*c. Dry Processing Direct Positive Paper.* Dry processing direct positive paper is used for diazo type duplication. Because the blue line paper does not copy well, black or sepia line papers are used for making copies that are to be photographed. Table 5–IV covers the various types of dry processing direct positive papers.

*Table 5–VI. Dry Processing Direct Positive Paper*

| Types and classes | Description |
|---|---|
| Type IB | Blue line |
| Type IIB | Black line |
| Type IIIC | Sepia line, transparentized, coated on both sides. |
| Type IIID | Sepia line, transparentized, coated on one side. |
| Class A | Standard speed |
| Class B | Rapid speed |

*Note.* The letters B, C, and D when used in the type designation indicate the paper weight. The letter B refers to 20½-pound stock, C refers to 16-pound stock, and D refers to 16-pound stock.

## Section III. DIFFUSION TRANSFER REVERSAL SYSTEM MATERIALS

### 5–26. General

The diffusion transfer reversal system, commonly called the Polaroid system is a photographic process that produces an immediate photographic print. One film of this type produces a finished print, another produces both a negative and a print, and a third produces a transparency. This material is used extensively by commerical interests, and the military has accepted it for use when production speed is essential.

### 5–27. The Materials of the Composite Film Process

A Polaroid picture is made from a composite film that contains, within itself, all the materials necessary for making a positive picture, including the light-sensitive negative, the printing paper, and the chemical reagents.

*a. Negative Material.* The negative material consists of a base coated with a gelatin emulsion that has suspended layers of silver halide crystals.

*b. Positive Paper.* The positive paper, which is not light sensitive, is the base on which the final positive print will appear.

*c. Reagent Pod.* The metal foil pod that lies between the negative and the positive material is filled with a viscous, jelly-like compound. This compound is the chemical reagent that transforms the latent image into a visible photograph.

## 5–28. The Process in Operation

*a.* The automatic developing process begins when the photographer advances the film, after exposure, to the next frame or removes the packet from the film holder (applicable for cut film cameras employing special film backs).

*b.* As the film is advanced, the exposed negative and the positive paper strip are joined between two steel rollers. The foil pod, which is located at the head of the paper, is forced through the rollers in such a way that the jelly-like liquid is spread evenly between negative and positive material, forming a .0003-thick layer.

*c.* The thin layer of chemical substance develops the exposed silver halide grains of the negative. The unexposed silver halide grains are converted to solubles, but are not fixed out as in conventional processes. Instead, the soluble silver complexes diffuse across the thin layer of the processing reagent and are transferred to the positive paper.

*d.* Upon transfer, the silver precipitates as metallic silver and forms the positive image. Both reactions occur almost simultaneously. The positive image is in the process of forming while negative development is taking place.

## 5–29. Types of Film

Each commercial (Polaroid) film type is assigned a number that relates the film to a specific camera model and to a particular pictorial result.

*a.* Film in the 30 series produces eight black-and-white 2½- by 3¼-inch prints. There is no final negative.

*b.* Film in the 40 series produces eight black-and-white 3¼- by 4¼-inch prints. There is no final negative.

*c.* Film type 46 produces 2¼- by 2¼-inch transparencies. These transparencies are ready for projection a few minutes after exposure.

*d.* Film types 52, 53, and 57 (film packets) are used in a special 4- by 5-inch film holder and produce a 4- by 5-inch black-andwhite positive paper print. Types 53 and 57 packets use an acetate base negative that can be reprocessed into a conventional negative.

## 5–30. Development Process

Diffusion transfer reversal system films require a development period ranging from 10 seconds to 2 minutes. Instructions in each film package must be followed closely to obtain best results.

*a.* Development starts with the pulling of the tab, or removal of the packet when using the special film holder (Polaroid Land Film Holder No. 500). The tab should be pulled out straight, swiftly, and firmly.

*b.* The length of time during which the image is subjected to the development action of the reagent will have some effect on contrast. Extended development will increase contrast and shortened development will reduce contrast.

*c.* Temperature will also have an effect on the development action of all films. *For example,* cold weather slows down the developing capability of the reagent. Therefore, the photographer, when operating in extremely cold climates, should carry the camera inside his jacket. Normal body heat will keep the pods of reagent from freezing.

## 5–31. Print Coating

Black-and-white photographs made with diffusion transfer reversal films require a print coating (provided with the film) to preserve delicate highlight renderings and to retain tonal values. This coating must be applied as soon as possible after development. Proceed as follows:

*a.* Use a flat, clean surface as an operating base.

*b.* Apply the coating material in firm, straight overlapping strokes, making sure that the image is completely covered.

*c.* Dry the prints. Ordinarily, prints will dry within minutes; in humid weather, however, the drying process may require more than 5 minutes.

## 5–32. The 4- by 5-Inch Film Holder

This holder is designed for press and view cameras equipped with Graphic, Graflock, and similar type backs. It permits the production of 3½- by 4-inch photographs on film material contained in individual packets. Proceed as follows in operating the film holder:

*a.* Insert the packet into the holder, and withdraw the envelope to permit film exposure.

*b.* After exposure, silde the envelope back into the holder forming a lighttight inclosure.

*c.* Move the processing lever on the holder to the *process* position. This closes the stainless steel pressure rollers on either side of the envelope.

*d.* Withdraw the entire packet through the rollers. These rollers press the developing reagent out of the pod and spread it in a uniform thin layer between the negative and positive materials.

*e.* After the required development time, pull the packet apart and separate the positive from the negative material.

## 5–33. Print Defects

The following table can be used as a troubleshooting guide when using diffusion transfer reversal system material. It shows a number of common faults and their probable causes.

*Table 5–VII. Print Defects*

| Print defect | Probable source of trouble |
|---|---|
| Total blank; black | Exposure did not reach film. Check all operations; make sure that the shutter is cocked and the tab is pulled. |
| Total blank; white | Overexposure to light; could be caused by badly damaged or outdated developer pod. |
| Print too light | Overexposure. |
| Print too dark | Underexposure. |
| Black area at end of print | Tab pulled only part way. |
| Streaks across print | Hesitant tab pulling. |
| Developer smear | Caused by developer sticking to print instead of negative. Could be due to hesitant print removal, or severe over or underdevelopment. To remove spots, rub them firmly with coating material. |
| Partial development | Usually caused by damaged developer pod, or use of old, outdated film. |
| White spots, repeated regularly across film. | Dirt or dried developer reagent on steel rollers. Keep rollers clean. |
| Flat, muddy toned prints | Underdevelopment. |
| Fading highlight | Due to improper coating; failure to coat; or bad storage conditions. |
| Streaky fading | Print not fully and evenly coated. |
| Edges fogged | Light leaked in at the edges of negative roll. |
| Brown stains | Developing reagent left on face of print. Prints should always be coated immediately. |

# Section IV. SELECTION AND USE OF FILM EMULSIONS

## 5–34. General

The primary reason for the great number and variety of film emulsion is to provide photographers with material best suited for specific photographic tasks. In other words, the photographer must choose the emulsion having the greatest number of favorable performance factors.

## 5–35. Negative Film Types

The physical shape of the film and the type of base are two vital considerations in the selection of a specific type of negative material. Included in the types of negative film materials are—

*a.* Roll film.

*b.* Cut film.

*c.* Glass plates.

*d.* Film packs.

## 5–36. Roll Film

Included in the category of roll film are film for standard roll-film cameras, motion picture film, miniature camera film, and aerial camera roll film. Emulsions can be manufactured to meet almost every possible requirement.

*a.* Ordinary roll film for small cameras consists of a strip of film attached to an opaque paper backing. This roll film is wound on a spool.

*b.* Aerial film is a special type of roll film and is supplied in a great number of widths and lengths. To minimize bulk, there is no paper backing on aerial film.

(1) The base of aerial film, which is thicker than that of ordinary roll film because of the large negative size, is often specially prepared to assure a minimal degree of shrinkage in processing.

(2) To facilitate drying in a machine dryer, aerial roll film has no anticurl backing.

(3) Aerial films are often prehardened to permit processing at high temperatures and to increase dimensional stability.

(4) An opaque leader and trailer are usually attached to the opposite ends of the roll of aerial film to protect it from light.

*c.* Motion picture film is supplied to the Army in 16-mm and 35-mm rolls. The base is relatively thin, and perforations along the edges permit proper feeding of the material through motion picture cameras, printers, and projectors. This type of film is supplied in a variety of emulsions to meet pictorial needs.

*d.* Miniature camera film is generally much like 35-mm motion picture film. However, special types have a thinner base and a lower sensitivity to retain the highest possible degree of resolving power.

## 5–37. Cut or Sheet Film

*a.* Cut or sheet film has a sensitive emulsion that is generally identical to that affixed to roll film. The base of the film, however, is much thicker than the base of roll film. This permits the film to retain a degree of stiffness, thereby approximating characeristics of a glass plate. This type film is most widely used in commercial photography, but it is also available in a variety of sizes for use with standard Army cameras. Sheet film has one definite advantage—individual sheets can be processed separately.

*b.* Cut film of all types has reference notches in one corner to identify the emulsion side and the type of emulsion. The emulsion side of cut film is toward the photographer when the notches are along the top edge of the upper right-hand corner of the sheet of film. Thus, the photographer, while in total darkness, can identify the type of film and the emulsion surface. Even though each film manufacturer uses a different notching code, there is no problem. A description of the code is placed on the film container.

## 5–38. Glass Plates

Glass was the original base for early sensitized photographic materials. Although it is heavy, cumbersome, and easily broken, it is unsurpassed as a flat, stable surface. Because it does not change physically, it is still the best choice for types of photographic work that demand image precision.

*a. Lantern Slides.* Lantern slide plates use a sheet of glass as a base. These plates are covered with a light-sensitive emulsion that is noncolor-sensitive in nature. The choice of emulsions is restricted to "Soft" (for contrasty continuous-tone negatives) "Medium" (for average negatives) and "Contrast" (for flat continuous-tone negatives or for average line-copy work). Lantern slides, like most films, have an antihalation coating of dye on the side opposite the emulsion. This dye is removed in the developer during processing.

*b. Large Glass Plates.* Special types of photographic work may demand extreme accuracy of image scale. In this case the photographer can use glass plates to produce the negative. This negative can then be developed to provide a positive transparency. A finished photograph of this type can be projected on a screen, or it can be viewed by placing a light-box behind the transparency. Large glass plates used in the production of transparencies have noncolor sensitized emulsions, because they need produce only the monochromatic variations in shades of a given negative.

## 5–39. Film Packs

Film packs are flat metal containers with 12 or 16 sheets of film. Attached to each sheet is a paper tab, numbered from 1 to 12 or 1 to 16. In front of the film is a black paper cover with a tab marked 0. This cover keeps light from entering the container.

*a.* When the cover tab is pulled, the first sheet of film is ready for exposure.

*b.* As each succeeding tab is pulled, the exposed film is moved to the rear of the pack. This leaves the next sheet in position for exposure.

*c.* When the last tab is pulled, a safety cover is left in front of the film pack.

## 5–40. Positive Materials

*a. General.* Positive emulsions, which are usually much thinner than negative emulsions, have finer inherent grain and slower speeds than negative emulsions. There are two general types of positive emulsions: those viewed by reflected light, and those viewed by transmitted light. Emulsions viewed by reflected light are usually on paper bases and are called paper positives. Those viewed by transmitted light are on either transparent or translucent bases and are called transparencies.

*b. Diapositives.* Diapositives are positive transparencies, such as motion picture positives and latern slides. They are viewed by transmitted light. Motion picture film has a bromide emulsion, and lantern slides have a bromide or chlorobromide emulsion.

## 5–41. Special Emulsions

Three emulsions used for special purposes are reversal, infrared, and X-ray.

*a. Reversal.* Reversal emulsions produce a positive image without an intermediate negative, or a duplicate negative without an intermedate positive. These special emulsions (Ansco Direct Copy or Kodak Autopositive Film), which have a cellulose acetate base, avoid a complicated chemical reversal and provide a duplicate of the original transparency.

*b. Infrared.* Infrared emulsions are sensitive not only to blue-violet radiations of the electromagnetic spectrum but also to infrared radiations. The use of a special red filter narrows exposure to infrared radiation.

*c. X-Ray.* Since X-rays in photography are usually of low intensity and only slightly affect silver halides, X-ray emulsions must be very thick. In some cases, the thickness of the emulsion is cut down by coating both sides of the film base. This latter system is preferred, since developing and fixing of a thick emulsion is difficult.

## 5–42. Film Speeds

Film speed is only one of several film characteristics. However, it is vital when subject illumination requires the use of a film with a high film speed. Under such conditions, other film characteristics are of secondary importance. On the other hand, if the photographer is more concerned with such film characteristics as contrast, grain, resolving power, or latitude, then film speed plays a secondary role. At present, there are two film speed systems: the ASA Film Speed Rating and the ASA Additive Speed Value.

*a. ASA Film Speed Rating.* The ASA Film Speed Rating system is based on a numerical evaluation assigned by the American Standards Association (ASA). It permits the photographer to determine camera shutter exposure and to associate the film with types of pictorial assignments. Numerical ratings are interrelated and are based on best performance with a practical margin of error. Exposure meters are calibrated to conform with the system.

*b. ASA Additive Speed Values.* The ASA Additive Speed Values system is an American standard based on logarithmic principles. Each succeeding number represents a doubling of film speed, and values are expressed in degrees. At present, the scale does not exceed 11°.

(1) If modern type B panchromatic emulsions are used in conjunction with exposure meters, these new markings are applicable. In the case of other panchromatic emulsions, both a daylight and a tungsten rating are still applicable.

(2) In the case of orthochromatic and colorblind films, both daylight and tungsten values are indicated.

(3) While the ASA Film Speed Rating system is an older approach to film speed evaluation, the ASA Additive Speed Values system is a new approach that ties in directly with the overall exposure value system explained in chapter 6.

c. *Relationship Between Film Speed Systems.* The following table indicates the relationship between the ASA Film Speed Rating system and the ASA Additive Speed Value system.

*Table 5–VIII. Comparison of ASA Speed Values*

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ASA Film speed rating | 3 | 6 | 12 | 25 | 50 | 100 | 200 | 400 | 800 | 1,600 | 3,200 | 6,400 |
| ASA Additive speed values | 0 | 1° | 2° | 3° | 4° | 5° | 6° | 7° | 8° | 9° | 10° | 11° |

*Table 5–IX. Negative Materials for Special Use*

| Subject classification | Chief requirements | Most suitable type of negative materials |
|---|---|---|
| Black and white | Panchromatism | Commercial panchromatic |
| Copies: | | |
| Line—black-white | High contrast | Press orthochromatic |
| Line—color | High contrast, color sensitivity | Process panchromatic |
| Copies: | | |
| Halftone—black-white | Medium contrast | Commercial panchromatic Commercial ortho. |
| Color | Medium contrast | Commercial ortho |
| | Color sensitivity | Commercial panchromatic |
| Duplicates: | | |
| By means of intermediate negative or positive. | Medium contrast negligible graininess. | Commercial panchromatic Fine-grain panchromatic |
| Lantern slides | Extremely fine-grain, good contrast | Lantern slide plates, normal and contrast. |
| Medical photography: | | |
| Surface lesions | Panchromatic materials | Fine-grain panchromatic Commercial panchromatic |
| Surgery, etc. | Speed in artificial light | Fast panchromatic |
| Action outdoors | Speed for full exposure at high shutter speeds. | Fast panchromatic |
| Indoors or extremely poor lighting. | Speed in artificial light | Fast panchromatic |
| Architecture: | | |
| Exteriors | Texture rendition | Fine-grain panchromatic |
| Interiors or night | Latitude, speed | Fast panchromatic |
| News: | | |
| Candid | High speed | Fast panchromatic |
| Photoflash | | Fast orthochromatic |
| Portraiture: | | |
| Children | Low contrast, high speed | Fine-grain panchromatic |
| Men | Ortho materials strengthen character. | Fast orthochromatic |
| Women | Pan materials, smooth skin texture and contours. | Fine-grain panchromatic |
| Landscapes: | | |
| Cloudscapes | Panchromatism, use of filters | All panchromatic materials |
| Marine views | Same | Same |
| Snowscapes | Same | Same |
| Still life: | | |
| Small object photography | Texture, modeling | Fine-grain panchromatic |
| Color separation: | | |
| Negatives | Balanced rendering by red, green, and blue light. | Fast panchromatic |

## 5–43. Negative Materials for Special Use

The data below indicates a variety of photographic situations, emulsion requirements, and type of film most suited for specific needs.

## 5–44. Types and Classes of Military Films

There are many types of film used in military photography, and it is essential to place them into specific categories. This arrangement simplifies the procurement of film and the selection of film for a specific pictorial task. The physical structure and emulsion characteristics of a film determine the purpose for which it will be used. The classification of sensitized materials is important to both photographers and laboratory technicians since it enables them to associate types and classes of films with specific performance characteristics of a particular emulsion.

*a. Types of Military Film.* The following table gives the types of military films and a brief physical description of each:

*Table 5–X. Types of Military Film*

| Type | Description |
|---|---|
| IA | Aerial roll film topographic base |
| IB | Aerial roll film, reconnaissance base |
| IC | Aerial roll film, thin base |
| II | Ground motion picture film, 35-mm |
| III | Ground motion picture film, 16-mm |
| IV | Miscellaneous roll film |
| V | Sheet film |
| VI | Film packs |
| VII | Photomechanical film |
| VIII | Aerial motion picture film |
| IX | Cathode ray tube recording film |

*b. Class Designation of Military Film.* The *class* designates the emulsion characteristics in accordance wth established standards. The following table gives appropriate class designations:

*Table 5–XI. Classes of Military Films*

| Class | Description |
|---|---|
| A | Regular speed panchromatic |
| A–1 | Regular speed panchromatic, processed manufacturer. |
| B | High speed orthochromatic |
| C | Low speed panchromatic |
| D | Regular speed orthochromatic |
| E | High contrast orthochromatic process |
| E–1 | Medium contrast orthochromatic process |
| F | Variable area sound recording |
| F–1 | Variable density sound recording |
| G | Blue sensitive, release positive |
| G–1 | Blue sensitive, master positive |
| G–2 | Blue sensitive, aerial duplicate |
| G–3 | Blue sensitive, variable contrast |
| H | High contrast panchromatic process |
| J | Panchromatic duplicating |
| K | Low speed infrared |
| K–1 | High speed infrared |
| L | High speed panchromatic |
| L–1 | High speed panchromatic, reversal, processed by manufacturer. |
| L–2 | High speed panchromatic, negative or reversal, processed by using activity. |
| L–3 | High speed panchromatic, low contrast |
| N | Extra high speed panchromatic |
| N–2 | Extra high speed panchromatic, negative or reversal, processed by using activity. |
| P | Blue sensitive; low speed; high contrast |
| Q | Panchromatic; low speed; high contrast |
| R | Ultra high speed panchromatic |

*c. Identification of Military Films.* In addition to the coding system devised as the standard for military procurement of films, manufacturers have their own numerical coding system. This coding system (app. III) describes the emulsion type, the emulsion batch, and the roll or cut from the roll.

## 5–45. Ordering Film

When ordering film from a manufacturer, give both the manufacturer's description (app. III) and the appropriate military description. *For example,* if a specific film is to be procured from Eastman Kodak, incorporate in the request all of the following: Eastman "Plus-X Panchromatic Negative Film," 5231, Eastman Kodak Company, Army Type II, Class A, Panchromatic, Regular Speed. Each military photographer must be able to identify a particular film emulsion when originating a request for film.

## Section V. STORAGE, SHELF LIFE, AND HANDLING OF SENSITIZED PHOTOGRAPHIC MATERIALS

### 5–46. General

Although storage is a responsibility of supply management, photographic personnel should understand the conditions involved in the storage of sensitized photographic materials to assure best usage of these materials. This subject is covered in greater detail in SB 11–514.

### 5–47. Packaging

*a. Perishability.* The given expiration date of sensitized photographic materials is valid only if these materials are not subjected to very high temperatures, extremely high relative humidities, or to radioactive emissions.

(1) When photographic materials are exposed to the conditions indicated above, they may lose their sensitivity to light, change in contrast values, lose emulsion speed, increase the fog level of the emulsion, or produce a combination of all of these factors.

(2) With respect to multilayer color film, each layer may be affected to a different degree and serious changes may occur in the color balance, speed, and contrast.

(3) Infrared film is so sensitive to adverse influences that the emulsion may completely deteriorate within minutes.

*b. Protective Measures.* Photographic films and papers are prepared for oversea shipment in hermetically sealed tropical packages to protect them from humidity. These packages must be protected from heat before the moisture seals are broken, and the photographic films and papers must be protected from heat and moisture after the seals are broken. In addition, they must be protected from radioactive emissions.

*c. Types of Packaging.* SB 11–514 indicates the methods to be used in packaging sensitized photographic materials.

*d. Repacking.* After exposure, film must either be processed without delay or repacked immediately. If the prevailing humidity is high, exposed film can be protected and preserved by making use of dehydrated storage or packing. The moistureproof and vaporproof papers used in preparing oversea packages of photographic materials may be reused to repackage film and papers for future shipment.

### 5–48. Storage of Unexposed Material

*a. Concept.* The underlying principle of stock rotation is first in, first out. By closely adhering to this storage concept, the sensitized photographic material normally will not be stored long enough to become outdated.

*b. Temperature.* Moisture - vaporproof or nonmoisture-proof packed material may be stored in locations where temperatures range from less than 50° Fahrenheit to —70° Fahrenheit. Infrared film is an exception; it should not be stored at temperatures below 32° Fahrenheit.

*c. Humidity.* Nonmoisture-vaporproof packed material and unit packs with seals opened should be stored in locations where the relative humidity is between 30 and 60 percent.

*d. Facilities.* Refrigerated facilities should be made available to insure maintenance of temperature and humidity controls. However, when a situation calls for temporary field expedients, photographic personnel may use household-type refrigerators, igloos, earth-covered buildings, or a dry underground facility. In any case, the temporary container must be made vaportight. If the facility is placed at least 3 feet underground, or if it is covered by 3 feet of earth, it will protect the sensitized photographic materials from radioactive contamination outside of the blast area.

*e. Other Factors.*

(1) When selecting a storage place, avoid positions under tin roofs or near heat sources (such as steam pipes).

(2) Do not store materials where they can be affected by X-ray machines, radium, harmful gases (such as formaldehyde, industrial gases, and exhausts from motors), and vapors from solvents, cleaners, and turpentine.

(3) In laboratories, film and paper are frequently kept in containers that have been broken open. Protect these items from chemical fumes, such as those emanating from acid, turpentine, varnish, hydrogen sulfide, or volatile gases.

(4) When transporting film containers, or when storing the containers under field conditions, protect them from the direct heat of the sun. Keep them in a shady place or under light-colored coverings.

*f. Readying Stored Material for Use.* When photographic material is removed from a refrigerated storage location, take every precaution to prevent moisture condensation. Permit the sealed materials to warm up to room temperature before opening the containers. The following table outlines normal warm-up periods for different types of film material.

*Table 5–XII. Warmup Periods in Terms of Hours*

| *Type of senitized photographic material* | *Degree of Fahrenheit rise* | |
|---|---|---|
| One roll of 35-mm film 36 exposures | 1.0 | 1.5 |
| One roll of 16-mm film, 100 to 1,200 feet. | 1.0 | 2.0 |
| One roll of 35-mm film, 100 to 1,000 feet. | 4.0 | 6.0 |
| A carton of ten 35-mm rolls of film | 28.0 | 46.0 |
| A box of 25 sheets of film | 1.5 | 2.0 |
| A box of 100 sheets of film | 3.0 | 5.0 |

*g. Storage in Cold Climates.* Store film at the same temperature as the equipment with which it will be used. Keep the film in its original container until used to avoid loss of moisture and consequent shrinkage.

## 5–49. Handling of Exposed Material

*a. Warm and Humid Climate.* After a film container, or a moisture-resistant wrapping, of tropically packed black-and-white or color film is opened, expose and arrange for processing as quickly as possible.

(1) In humid climates, film will absorb a percentage of moisture equal to the percentage of moisture in the atmosphere within 24 hours. Note, however, that tightly wound motion picture film will not absorb moisture as rapidly as single sheets of film in a film holder.

(2) After exposure in humid climates, dry the film with a desiccant agent before resealing it in tropical packing. Silica gel, dried rice browned in a dry oven, or dried tea leaves are suitable desiccant agents; dried newspaper can be used in an emergency. Approximately 2 pounds of dried rice or tea leaves are required to desiccate satisfactorily ten 100-foot rolls of 16-mm color film; 1 pound of rice or tea is sufficient for several rolls of 35-mm color film.

*b. Cold Climates.* When exposed film is moved to a warm place, such as a photographic laboratory, keep it wrapped and in tightly sealed cans or boxes until it reaches room temperature. This prevents a sudden sharp temperature change that can seriously affect the latent image and the normal characteristics of the film emulsion.

## 5–50. Film Dehydration

There are two methods used in the dehydration of film.

*a.* When metal film cans or containers and nonhygroscopic tape are available, proceed as follows:

(1) Wrap the film in black paper and place it in a large, closed container with several bags or open containers of activated silica gel.

(2) Leave the film in this container for 24 to 48 hours, or until the excess moisture has been removed. The time required for dehydration varies with local conditions and the moisture content of the film.

(3) Immediately after dehydration, place the paper-wrapped film in a metal film container and seal it with nonhygroscopic tape.

(4) If motion picture film is dehydrated, attach the following notation to the film container and the accompanying caption sheet: "Dehydrated motion picture film. Recondition before processing."

(5) Place several containers, or film cans,

in a closed wooden box or in a tin or galvanized metal container.

*b.* When metal film containers are not available, proceed as follows:

(1) Wrap the film in dry, black paper, and place it in a cardboard or other small nonmoistureproof container.

(2) Close the container with tape and attach the caption sheets.

(3) Place several of these small containers in an approved, sealed, waterproof bag or liner with freshly activated silica gel.

(4) Ship the material in a closed, nailed box. Consignments of film for shipment over rough terrain or for frequent handling, loading or unloading should not weigh more than 45 pounds per box.

## 5–51. Silica Gel

Silica gel is a desiccant, or dehydrating agent, that absorbs from the air almost half its own weight in moisture. It may be procured in bulk or in smaller quantities.

*a. Reactivation.* When packing equipment, use only fresh or recently activated silica gel. To reactivate silica gel, heat it for about 3 hours at 300° Fahrenheit under a circulating current of air. Remove the silica gel from the cotton bags during reactivation to avoid scorching the bags.

*b. Amounts Used.* The amount of silica gel used in shipping containers depends on the type of equipment and the volume of the shipping container. In general, 2 ounces to the cubic foot is sufficient.

*c. Precautions.* Make sure that the flakes or crystals of silica gel do not come into contact with the surface of sensitized materials. Excessive dehydration causes brittleness and shrinkage of film. However, film that has been overdried may be reconditioned without difficulty by storing it for 24 hours under normal humidity conditions.

*d. Containers.* The containers used as dehydrating boxes may be made of tightly sealed or covered wood or metal.

## 5–52. Expiration Date

Film or paper, when properly protected throughout storage, may be used long after the expiration date indicated on the container. The term used to designate a specific extension period is *extended expiration date.* If a given material meets the standards of appropriate tests, its expiration date may be extended. The following materials should not be considered in this procedure.

*a.* Color sensitized films.

*b.* Polaroid films.

*c.* Infrared films.

*d.* Motion picture films that are spooled for high speed cameras.

*e.* Direct positive (ammonia processing) papers.

*f.* Recording paper used with Processing Machine EH–5.

## 5–53. Procedure for Testing Outdated Negative Film

To test the characteristics of outdated negative film, the material is subjected to a camera test, a mottle test, and a fog test. Specific procedural details are given in SB 11–514.

## 5–54. Procedure for Testing Outdated Paper and Positive Film

To test the characteristics of outdated paper and positive film, the particular material is subjected to a printing test, a mottle test, a fog test, and a standard sensitometric test. Specific procedural details are given in SB 11–514.

## 5–55. Summary

*a.* Photography is essentially a chemical process made possible by the action of light on a gelatin emulsion containing light-sensitive silver halides.

*b.* Photographic film has a base support, an emulsion, a protective covering, a noncurl backing, and an antihalation backing.

*c.* Nonchromatic film emulsions are sensitive only to ultraviolet and blue-violet radiations of the electromagnetic spectrum.

*d.* Orthochromatic film emulsions have the same sensitivity as nonchromatic film and, in addition, are sensitive to green light.

*e.* Panchromatic film emulsions have the same sensitivity as orthochromatic film and, in addition, are sensitive to red light.

*f.* Infrared film emulsions have the same sensitivity as nonchormatic film; they are also sensitive to infrared radiations.

*g.* Film speed refers to the degree of sensitivity of a given emulsion to light.

*h.* Film contrast is the manner in which a given emulsion reproduces the different tonal values of a photographic subject.

*i.* Film latitude is the ability of an emulsion to record the range of brightness values of a subject.

*j.* Film grain is the result of the clumping of silver halides during development of the film emulsion; the size of the grain depends on the silver halide crystal structure prior to development, exposure time, the composition of the developer used, and the developing time.

*k.* Resolving power of a film emulsion is its capability to reproduce fine subject details.

*l.* Actuance of a film emulsion is the degree to which it retains sharp image divisions between subject area details of differing contrast.

*m.* Photographic paper has a paper base, a baryta layer, and a sensitive emulsion.

*n.* The diffusion transfer reversal system is a photographic process that produces an immediate photographic print.

## 5–56. Review Questions

*a.* Draw a cross section of a photographic film.

*b.* What is the fuction of the antihalation backing?

*c.* If you plan to produce a negative that permits the reproduction of large projection prints, what kind of film and processing method are appropriate?

*d.* What is the resolving power of medium speed panchromatic film emulsions?

*e.* Explain the function of the baryta layer in photographic paper.

*f.* Give the difference between chloride, bromide, and chlorobromide papers.

*g.* What are variable contrast papers?

*h.* List the ingredients of composite film.

*i.* What is the probable source of trouble if a diffusion transfer reversal system positive is flat and has muddy tones?

## 5–57. Review Answers

*a.* Refere to figure 5–1.

*b.* Antihalation backing of a photographic film minimizes the reflection of light from the back of the film base.

*c.* When planning to make large projection prints, record the subject image on a fine-grain emulsion and develop the film in a fine-grain developer.

*d.* Resolving power of medium speed panchromatic film emulsions ranges from 70 to 100 lines per millimeter.

*e.* The baryta layer in photographic paper increases the quality of the photographic print by increasing the degree of reflectivity of the paper.

*f.* Chloride paper emulsions contain silver chloride halides. Bromide paper emulsions are sensitized with silver bromide halides. Chlorobromide paper emulsions contain both silver chloride and silver bromide halides. Chloride paper has the lowest emulsion speed; it is suited for contact printing only. Bromide and chlorobromide papers have higher emulsion speeds and are used for projection printing.

*g.* Variable contrast papers have chlorobromide emulsions that combine complete contrast ranges in one paper. Varying contrasts are achieved by using different colored filters during projection printing.

*h.* Composite film, used in the production of Polaroid pictures, consists of a light-sensitive emulsion, a film base, printing paper, and the chemical reagent.

*i.* When a diffusion transfer reversal system positive appears flat and has muddy tones, the probable source of trouble is underdevelopment.

# CHAPTER 6
# EXPOSURE

## Section I. GENERAL

### 6–1. Tone Separation

The quality of a photograph is judged primarily on the basis of tone separation, i.e., a clear distinction among light, dark, and middle tones. Good tone separation means that the various light and dark parts of a picture correspond to those of the actual subject. Assuming proper development, tone separation depends almost entirely on exposure.

### 6–2. Definition of Exposure

Photographic exposure is the subjection of a sensitized emulsion to light. It is governed by the intensity and duration of the light permitted to affect the chemical structure of the sensitized material. Accordingly, exposure equals intensity multiplied by time.

### 6–3. Underexposure

Too little light, or underexposure, produces a loss of tone separation and detail in shadow areas of a picture. Underexposed negatives are difficult to print, because they are too transparent and have a short tonal range.

### 6–4. Overexposure

Too much light, or overexposure, produces a dense negative with poor tone separation in the lighter parts of the picture. Overexposed negatives are difficult to print, because the density of the negative requires extensive exposure in printing. With modern black-and-white materials, however, negatives can be very dense and still yield prints of good quality.

## Section II. OUTDOOR EXPOSURE

### 6–5. Daylight Photography

*a. General.* In the daylight photography there is one source of illumination—the sun. However, there are a number of conditions that will affect both the intensity and quality of the available light.

*b. Classes of Daylight Illumination.* Daylight illumination can be broken down into four classes: bright sun, hazy sun, cloudy bright, and cloudy dull. A typical daylight exposure chart (fig. 6–1) lists these four classes and indicates how they can aid a photographer in selecting appropriate exposure combinations.

*c. Bright Sun.* On a bright, sunny day, the sky is clear, bright, and free of large cloud masses or atmospheric haze. Any shadows cast by the sun on this type of day are sharply defined. Normally, this type of daylight illumination provides ideal photographic conditions.

*d. Hazy Sun.* On a hazy, sunny day, the sun is partially obscured by a thin haze. Since the light intensity is about one-half the light intensity of bright sun, the lens aperture should be one stop larger than the setting for bright sun. On a hazy, sunny day, the edges of shadows are slightly diffused or soft and are less clearly defined than those in bright sun. This type of lighting is preferred when the photographic mission requires slightly diffused light.

*e. Cloudy Bright.* On a cloudy, bright day, the sun is largely obscured by clouds or haze. The sun is in evidence, but the shadow areas are not apparent. This daylight condition exists when the light is bright—even glaring—

| DAYLIGHT EXPOSURE CHART | | | | |
|---|---|---|---|---|
| ILLUMINATION → / SUBJECT ↓ | BRIGHT SUN — STRONG SHADOWS | HAZY SUN — SOFT SHADOWS | CLOUDY BRIGHT — WEAK SHADOWS | CLOUDY DULL OR OPEN SHADE — NO SHADOWS |
| LENS APERTURE SETTING | | | | |
| **BRILLIANT** BEACH SCENES, SNOW SCENES, MARINE SCENES | f/32 | f/22 | f/16 | f/11 |
| **BRIGHT** WHITE BUILDINGS, LIGHT CLOTHING | f/22 | f/16 | f/11 | f/8 |
| **AVERAGE** BUILDINGS, STREET SCENES, PEOPLE | f/16 | f/11 | f/8 | f/5.6 |
| **DARK** DARK CLOTHING, DARK SUBJECTS | f/11 | f/8 | f/5.6 | f/4.5 |

NOTE:

1. Camera shutter speeds and film speed as follows:

   A.S.A. film speed rating 25, use shutter speed 1/25.

   A.S.A. film speed rating 50, use shutter speed 1/50.

   A.S.A. film speed rating 100, use shutter speed 1/100.

2. Side-lighted subjects require one additional lens stop.

   Back-lighted subjects require two additional lens stops.

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*Figre 6–1. Daylight exposure chart.*

and it seems there should be shadows but there are few, if any. The daylight exposure chart indicates that the lens aperture should be one stop larger than that for a hazy, sunny day.

*f. Cloudy Dull.* On a cloudy, dull day the sun is completely obscured by heavy layers of clouds or dense haze. On this type of day, light is extensively diffused and it is difficult to determine the exact location of the sun. Since there are no shadows, there is no contrast and subjects appear flat. The daylight exposure chart indicates that the lens aperture setting for a cloudy, dull day should be three stops larger than for a bright, sunny day.

### 6–6. Subject Brightness

There are four classes of subject brightness (fig. 6–1): brilliant, bright, average, and dark. In the discussion below, average brightness is treated first to permit comparison with the other classes.

*a. Average Subject.* An average subject is one that reflects approximately 18 percent of the light striking it and absorbs the remainder. Included in this category are people in medium-colored clothing, most buildings, landscapes with trees, street scenes, and interior views.

*b. Dark Subject.* A dark subject reflects only about 9 percent of the light striking it and absorbs the remainder. Because it is only one-half as bright as an average subject, it requires twice the exposure required for an average subject. Included in this category are vehicles and weapons, people in dark-toned clothing, and a barren rocky island in a stormy area.

*c. Bright Subject.* A bright subject is one that reflects twice as much light as an average subject; consequently, it absorbs a much smaller percentage of light. A bright subject requires much less exposure than an average subject—generally one lens stop less than for an average subject. Typical subjects in this category are a fair-skinned and light-haired person, people in light clothing, and light-colored buildings.

*d. Brilliant Subject.* A brilliant subject reflects about four times as much light as an average subject and absorbs very little light. A brilliant subject requires much less exposure than an average subject—generally two lens stops less than for an average subject. Typical subjects in this category are a landscape covered by snow, people in light-colored clothing on a white and sandy beach, a white sailboat against a blue sky and white buildings of a desert village.

### 6–7. Position of Sun

When the sun is less than 20° above the horizon, the rays become so long that much of the sunlight is scattered. Even though the sky light remains practically the same, direct sunlight is weakened at this low angle. Take this into consideration when setting the lens aperture. Then angle of the sun depends on the latitude, the hour of the day, and the season.

### 6–8. Front, Side, and Back Lighting

*a.* The direction from which sunlight strikes a subject also has a bearing on exposure. A subject is brightest when the sun is behind the photographer as he faces the area to be recorded. This is called front lighting.

*b.* If the rays of the sun form a right angle with the direction in which the camera is pointed, the effect is side lighting.

*c.* If the photographer must face the sun to record a subject the effect is back lighting. In this type of lighting, part of the subject is shaded.

*d.* In military photography, details in shadow areas are usually more important than any artistic lighting effect. With this requirement in mind, side lighting requires a one stop increase over front lighting, and back lighting requires two stops more than front lighting.

*e.* If dramatic lighting effects are desired, side lighting does not require a change in lens aperture, and back lighting needs an increase of only one stop.

*f.* The figures above apply only to subjects in bright or hazy sunlight, and not to subjects photographed on cloudy and overcast days. When daylight is sufficiently diffused and there are no noticeable shadows, the intensity of light falling on the subject is the major consideration.

### 6–9. Shade and Shadows

*a.* Because exposure of black-and-white film must be sufficient to record details in important shadows, the degree of darkness and physical extent of these shadows must be considered. To obtain details in a shadow area, use a wider lens opening than the one selected for a scene entirely in sunlight.

*b.* Most closeups have larger and more important shadow areas. In general, the more distant the center of interest of a picture, the smaller and less important the shadow area. In photographing an instrument panel of an aircraft, for example, a closeup must show detail in the darkest and smallest parts. At a greater distance, these details cannot be distinguished or photographed individually. At an event greater distance, large details are indistinguishable and further exposure adjustments are required.

## 6–10. Shadow and Distance

Large shadow areas of a scene must be carefully considered even when the camera viewpoint is increased. Exposure must be based on existing light conditions if details within the shadow areas are to be brought out in the photograph. This is especially important when long focal length or telephoto lenses are used to obtain coverage of distant terrain details. Generally, whether close or distant, exposure for shadow areas of a scene is identical.

*a.* A semidistant view, which includes large shadow areas with important details and resembles a closeup in shadow importance, requires the same lens setting as a closeup.

*b.* Long distance scenes do not usually have dark shadows, because atmospheric haze lightens the areas.

*c.* Since most subjects fall into the nearby group, it is safe to consider a scene as nearby when not sure of which type of exposure to select.

*d.* Scenes classified according to distance require the following changes in lens aperture:

(1) *Nearby scene.* One stop smaller than a closeup with shadow details.

(2) *Semidistant scene with little shadow detail.* Two stops smaller than a closeup.

(3) *Distant scene.* Three stops smaller than a closeup.

## 6–11. Cloudy Dull and Heavy Shade

If light from about half the sky strikes a subject, the situation is known as *cloudy dull,* or *open shade,* and requires an increase of three lens stops. If a subject is shielded not only from the sun, but also from most of the sky, it is in *heavy shade,* or *closed shade,* and an increase of four or more stops is needed. Examples of subjects in heavy shade are scenes in narrow streets and among tall buildings where, at a given angle, the sun is unable to penetrate.

## 6–12. Exposure Computation

*a.* Prior to setting the camera for the correct exposure, you must consider the following four factors:

(1) The sensitivity or speed of the film emulsion used.

(2) The type and intensity of the daylight.

(3) The degree of absorption or reflection of that portion of the light striking the photographic subject.

(4) The direction of the light (sidelight, backlight).

*b.* As indicated in figure 6–1, set the shutter speed to match the speed of the film emulsion. Next, consider the possible combinations of light conditions and subject types to determine the correct lens aperture setting. The difference between each light situation on the daylight exposure chart and each subject type is a one lens stop factor.

*c.* To illustrate the use of the daylight exposure chart (fig. 6–1), select anaverage subject illuminated by bright sunlight and proceed as follows:

(1) Set the shutter speed to correspond with the film speed. If you use a film rated ASA 100, set the shutter for 1/100 second.

(2) Set the lens aperature to f/16.

(3) With side lighting, set the aperature to f/11 and retain the 1/100-second shutter speed.

(4) With back lighting, set the aperture to f/8 and retain the 1/100-second shutter speed.

*d.* Figure 6–1 is to be used merely as a guide, since there are many other factors (such as season, location, etc.) to be considered in any photographic situation. After a photographer gains experience, he is able to weigh these factors and adjust the exposure accordingly.

## 6–13. Interpolation of F/Stops and Shutter Speeds

When you select an f/stop and shutter speed combination your primary concern is to get the proper amount of light to reach the film. The correct amount of light, in turn, results in proper negative density. Once you have determined the basic exposure, for any one of several reasons, you may decide to use a different f/stop or shutter speed. The important point to remember is that adjustment of one of the two exposure factors demands an adjustment of the other.

*a. Exposure Adjustment.* Assume that you have determined that the basic exposure is 1/100 second at f/11. However, with a rapidly moving subject, such as an automobile, you want to use a shutter speed of 1/400 second. Since changing the shutter setting from 1/100 second to 1/400 second reduces the amount of light reaching the film to ¼, you must compensate by adjusting the lens aperture to assure a four times increase of the light permitted to reach the film. The f/stop that transmits four times as much light as f/11 is f/5.6. Therefore, a balanced exposure of 1/400 second at f/5.6 gives the same amount of light as the basic exposure of 1/100 second at f/11.

*b. Selecting Combinations.* Whenever the correct basic exposure has been determined you can easily arrive at several combinations and select the one most useful for a given pictorial situation. The example in *a* above could be expanded by selecting the following exposures: 1/200 second at f/8, or 1/50 second at f/16. If, for example, the basic exposure is determined to be 1/25 second at f/22 but you prefer to set the f/stop at f/8, what change of the shutter speed would be indicated? Since the difference between f/22 and f/8 is three stops the shutter setting must be adjusted to compensate for the aperture change. With a larger aperture the amount of light transmitted is *increased,* accordingly, the shutter speed selected must *decrease* exposure. The shutter speed that balances the three stop increase of the lens aperture is 1/200 second. Therefore, a 1/25 second at f/22 exposure is equal to a 1/200 second at f/8 exposure. Through careful balance of both the shutter speed and the f/stop setting of the camera lens you can make best use of the camera for a great variety of photographic situations.

## Section III. EXPOSURE OF MOVING OBJECTS

### 6–14. General

The primary reason for action photography is to *stop* action, or to give the impression of motion and yet retain sufficient subject detail. Factors to consider in action photography are—

*a.* Speed of the subject.

*b.* Angle and direction of the subject in relation to the camera.

*c.* Distance from the subject to the camera.

*d.* Lighting conditions.

*e.* Focal length of camera lens.

### 6–15. Speed of Subject

*a.* In some action photographs, the shutter speed must be calculated to insure that the recorded image retains a slight degree of motion. *For example,* the partial blurring of the legs of running soldiers distinguishes them from men standing still. In this case, calculate the exposure for the most rapid movement, and then allow for the degree of movement to be retained. When it is necessary to prevent blur, the shutter speed must be so fast that subject movement during the exposure will not be apparent.

*b.* When determining subject speed, both the distance traveled and any movement within the object itself should be considered. In some cases, there is a definite peak to the movement, and the action may be stopped at a comparatively slow shutter speed if the exposure is made at the proper moment. *For example,* a ball thrown into the air losses, at one point, the impetus of its upward motion and pauses before it starts to fall.

### 6–16. Direction and Angle of Moving Objects

Exposure time is affected by the direction of motion with respect to the camera axis.

*a.* A subject moving directly across the field of view requires a faster shutter speed than one moving toward or away from the camera.

*b.* When the direction of motion is at a 90° angle to the camera axis, the shutter speed must be faster than when the motion is at 45° to the camera axis.

## 6–17. Distance

*a.* The closer the moving object is to the camera, the faster must be the shutter speed required to arrest the movement.

*b.* It is preferable to select the camera position and point of focus in advance if the type and path of the action are known factors. Proceed as follows:

(1) Select and focus on the spot where the action will be photographed. If there is no time to prefocus, judge the distance.

(2) To compute the exposure, use an exposure meter to take a reading on an object lighted similarly to the subject being photographed.

(3) Then use the chart to determine the shutter speed needed to stop the action.

(4) To follow the action, *pan* the camera. To do this, follow the moving subject through the finder until it reaches the prefocused area.

(5) Trip the shutter when the subject is in the prefocused area.

## 6–18. Lighting Conditions

Light direction and resulting shadows are factors in determining the correct exposure for a given subject.

*a.* A uniformly illuminated object, regardless of details or composition, will not provide the same disturbing emphasis of broken lines as the moving subject that accentuates shadow details created by sidelighting. Study carefully the subject matter to be recorded if motion is a part of the photographic problem.

*b.* Whenever there is ample light, the selection of a high shutter speed is no problem. With poor lighting conditions, use a high speed film and a relatively large lens aperture.

## 6–19. Focal Length of Lens

The closer the photographer is to the subject to be photographed, the more critical the movement of exposure. Long focal length lenses may be used to move the action closer to the viewing position. However, the longer the focal length of the camera lens, the more critical the shutter speed to arrest the action.

## 6–20. Shutter Speeds to Record Subjects in Motion

*a. Shutter Speeds of Miniature and Small Cameras to Stop Action.* Table 6–1 gives approximate shutter speeds adaptable to various types of subjects moving at indicated rates of speed.

*Table 6–1. Shutter Speeds of Miniature and Small Cameras*

| Approximate subject speed (miles per hour) | Camera to subject distance (feet) | Direction of motion | | | | | |
|---|---|---|---|---|---|---|---|
| | | Two-inch lenses | | | Four-inch lenses | | |
| | | Movement of subject matter | | | | | |
| | | Toward camera (second) | At 45° angle to camera (second) | At 90° angle to camera (second) | Toward camera (second) | At 45° angle to camera (second) | At 90° angle to camera (second) |
| 5 to 10 | 25 | 1/50 | 1/75 | 1/100 | 1/75 | 1/100 | 1/150 |
| | 50 | 1/35 | 1/50 | 1/75 | 1/50 | 1/75 | 1/100 |
| | 100 | 1/20 | 1/35 | 1/50 | 1/35 | 1/50 | 1/75 |
| 10 to 20 | 25 | 1/100 | 1/150 | 1/200 | 1/125 | 1/200 | 1/300 |
| | 50 | 1/50 | 1/75 | 1/125 | 1/75 | 1/125 | 1/200 |
| | 100 | 1/35 | 1/50 | 1/100 | 1/50 | 1/75 | 1/100 |
| 20 to 30 | 25 | 1/125 | 1/200 | 1/300 | 1/200 | 1/300 | 1/500 |
| | 50 | 1/75 | 1/125 | 1/200 | 1/125 | 1/200 | 1/300 |
| | 100 | 1/50 | 1/75 | 1/125 | 1/75 | 1/125 | 1/200 |
| 30 to 45 | 50 to 100 | 1/200 | 1/350 | 1/600 | 1/300 | 1/500 | 1/800 |
| 45 to 100 | 100 and over | 1/300 | 1/500 | 1/750 | 1/400 | 1/750 | 1/1,000 |

*b. Shutter Speeds of Press-Type Cameras to Stop Action.* Table 6–II gives approximate shutter speeds adaptable to various types of subjects. It is based upon an allowable circle of confusion of 1/200 inch, with a 5-inch lens and a 4- by 5-inch film size.

*Table 6–II. Shutter Speeds of Press-Type Cameras*

| Approximate subject speed (miles per hour) | Camera-to-subject distance (feet) | Movement toward camera | Movement at 45° angle to camera | Movement at 90° angle to camera |
|---|---|---|---|---|
| 5 to 10 | 25 | 1/100 | 1/200 | 1/400 |
| | 50 | 1/50 | 1/100 | 1/200 |
| | 100 | 1/25 | 1/50 | 1/100 |
| 25 to 30 | 25 | 1/200 | 1/400 | 1/800 |
| | 50 | 1/100 | 1/200 | 1/400 |
| | 100 | 1/50 | 1/100 | 1/200 |
| 60 and faster | 25 | 1/400 | 1/800 | ----- |
| | 50 | 1/200 | 1/400 | 1/800 |
| | 100 | 1/100 | 1/200 | 1/400 |

## Section IV. EXPOSURE WITH ARTIFICIAL LIGHT

### 6–21. General

Assuming a long enough exposure, almost any light intensity can be used to produce an image on a sensitive emulsion. However, dimly illuminated subjects often require an exposure too long to be practical. Accordingly, artificial light gives the photographer pictorial control. He can place light on different parts of a scene to achieve a variety of lighting effects. Special lamps have been developed for such purposes.

### 6–22. Flood Lamps

Flood lamps resemble home service lamps, but their filaments are designed to give more light of a bluer characteristic per watt than home service lamps. Sizes are designated by the numbers 1, 2, and 4, and relative light output is roughly proportional to the numbers. The letter B, sometimes used with the lamp number, indicates a blue glass lamp that adds the effect of daylight in color photography. The letter R, used with the lamp number, indicates a built-in reflector.

### 6–23. Photoflood Lamps

*a. No. 1 Photoflood Lamp.* This lamp, which is approximately the same size as a regular 75-watt, home-service, inside frosted light bulb, draws about 250 watts. For photographic purposes, it is equal in intensity to an ordinary 750-watt lamp. Its useful life on a 115-volt line is about 3 hours.

*b. No. 2 Photoflood Lamp.* This lamp, which is approximately the same size as a regular 150-watt lamp, draws about 500 watts. For photographic purposes, however, it is nearly equal in intensity to an ordinary 1,500-watt lamp. This is almost double the intensity of a No. 1 photoflood lamp. Its useful life is about 6 hours on a 115-volt line.

*c. No. 4 Photoflood Lamp.* This lamp consumes about 1,000 watts, has a useful life of about 10 hours, and produces about four times as much light as the No. 1 photoflood lamp. It has a Mogul base, and must be used with appropriate studio equipment.

*d. R2 Reflector Photoflood Lamp.* This lamp uses approximately the same filament as the regular No. 2 photoflood. It is funnel shaped, with a neck that tapers toward the base. The other end of the bulb is flattened and frosted on the inside. A deposit of aluminum on the inside of the funnel provides an efficient reflecting surface and enables the lamp to concentrate light over an angle of about 60°. Like the No. 2 photoflood, the R2 lamp draws about 5 amperes and has a useful life of about 6 hours on a 115-volt line.

*e. Sun Gun.* Sun guns are high efficiency lamps of a 3200° or a 3400° Kelvin color temperature rating designed primarily for motion picture photography. However, these practical lamps are also useful for still photography.

While some models are battery powered there are also models using standard line current. You can select lamps that will provide 30 minutes of powerful light having a center beam of 20,000 candlepower. Operational flexibility and portability, light intensity and quality, as well as selectivity of power source make these lamps useful for both black-and-white and color photography.

### 6–24. Photoflash Lamps

*a. General.* Flash lamps are single-use bulbs containing shredded foil, fine wire, or chemical paste, in oxygen. The contents, which are ignited electrically (3 volts are sufficient), burn brilliantly and noiselessly for about 1/50 second.

*b. Flashgun.* Flashlamps are used in a battery-operated flashgun that opens the camera shutter when the flash approaches full brilliancy. The flashgun also has a lamp reflector.

*c. Guide Number.* Flashlamps are given a numerical rating, called a *guide number,* for each lamp type and for a particular film speed and shutter speed. You can determine the approximate camera lens aperture by dividing the guide number by the lamp-to-subject distance.

*d. Focal Plane Shutters and Flashlamps.* Flashlamps designed for focal plane shutters produce a flash that lasts long enough to permit the shutter slit to travel the length of the film area to be exposed. The peak brilliance for the focal plane lamp is not as high as for other flashlamps, and a larger lens aperture is required. For this reason, a between-the-lens shutter is generally preferred in flash photography.

*e. Flashlamps and Exposure Meters.* Exposure meters may be used with flashlamps only when floodlamps having a known intensity relationship to the flashlamps are used first for composing and focusing and taking the meter reading. They are replaced by flashlamps for making the actual exposure.

### 6–25. Determining Exposure

Floodlighting is usually below sunlight in intensity and requires the use of larger lens apertures or longer shutter exposures. Only flashlamps at close range approximate the intensity of sunlight. In addition, illumination from a lamp is inversely proportional to the square of the lamp-to-subject distance (inverse square law). When the distance between a lamp and a subject is doubled, only one-fourth as much light reaches the subject. When the distance between the light and the subject is tripled, only one-ninth as much light reaches the subject. Illumination also varies with lamp wattage, the efficiency of the reflector, the angle at which light strikes the subject, the use of diffusers, if any, and the actinic quality of the light.

*a.* Lens settings for simple two-lamp setups, with lamp types and distances specified, can be determined quite easily. Approximate lens settings are given in computers and usually on film instruction sheets.

*b.* More complicated lighting setups require the use of an exposure meter or test exposures. Once a photographer has become familiar with certain lamp setups, however, he can, through experience, duplicate camera and lens adjustments to obtain a particular pictorial effect.

### 6–26. Fill Light

The fill light, which can be referred to as front light or general illumination, lightens the shadows and lowers contrasts of the scene or subject. When used alone, it produces a flat photograph that is shadowless.

### 6–27. Modeling Light

The modeling light, or key light, is the main light of a multiple lighting setup. Like the sun, it casts the shadows and forms the highlights. A floodlamp in an efficient reflector may serve very well as a modeling light. When used alone, a modeling light produces a negative with well exposed highlights and clear shadows that lack detail.

### 6–28. Light on Background

The tonal range of the background is very important. To insure that the subject will not merge into the background, make sure that the brightness of the background differs from the brightness of the important parts of the subject. Light background adequately by using a separate, shielded lamp that projects the light beam only on the background.

### 6–29. Speed Lamps

Sensitized emulsions can be exposed at speeds of 1/100,000 second or faster. Since no shutter is made to open and close that fast, this exposure is accomplished by using a light that flashes on and off in an almost incredible fraction of a second. Even though the shutter is open for a longer time, such as 1/500 or perhaps 1/100 second, the film is exposed only for the length of time during which the lamp gives off its high intensity light. The unit that has been developed to operate in this manner is called a speed lamp.

*a.* A speed lamp is a gas-filled tube that flashes when a high voltage spark passes through it. Hence, it is sometimes called a flash tube.

*b.* The unit of a speed lamp consists of a tube, a reflector, electronic devices to boost the voltage, and a switch or contacts for synchronizing the shutter. Modern units are small and portable.

*c.* The tube of the speed lamp is usually good for about 5,000 flashes. It can be replaced easliy.

*d.* Speed lamps function at 1/500 to 1/100,000 second or faster. Extremely high speeds are generally used in scientific photography; lower speeds are applicable for general photography when flash speeds of 1/1,000 second are adequate.

*e.* For other than scientific or technical photography, speed lamps with a flash duration of about 1/1,000 second are used.

### 6–30. Lighting Interiors

When lighting an interior, a photographer can use an electronic flash, single and multiple flash bulbs, floodlights, regular room illuminating lights, natural light from outdoors, painting with lights, or any combination of these. The appropriate lighting method is determined by the subject and available facilities.

*a.* An informal group photograph indoors usually requires one or more flash bulbs, while a formal portrait usually requires floodlights.

*b.* Interiors with still objects, but without people, are best photographed by painting with light.

*c.* Photographs of interiors and of small objects are often recorded with natural light.

*d.* A photographer generally prefers to photograph interiors at night, because he can then control the lighting and create the setup he desires. He can get similar results by drawing the shades or otherwise cutting off the flow of daylight through windows.

### 6–31. Painting With Lights

Painting with lights is a method used to obtain soft, even illumination. In this case, the subject and its background is *painted* with an even coating of light by moving the light source constantly up, down, and sideways across the subject during exposure. Never let the light or bright reflections shine into the lens, and never leave the light directed at any one part of the subject for too long a time.

### 6–32. Interior Exposure

Interior photograph normally requires the use of a tripod to hold the camera steady and level. A tripod leg brace assembly or a floor mat will prevent tripod legs from slipping. Proceed as follows:

*a.* Place the camera so that the desired view is composed in the most pleasing manner and meets required specifications.

*b.* Use the ground glass for focusing.

*c.* Arrange objects in relation to their position on the ground glass and not as they appear to the eye from the camera position.

*d.* Use an exposure meter to take an illumination reading of the section to be photographed. In this way, exposure for the interior can be determined even if the photographer intends to paint with light.

*e.* When operating space is limited, use a wide-angle lens to include the desired area.

## 6–33. Photoelectric Light Meters

The photographer may also use photoelectric light meters to measure the intensity of light. These light meters have photosensitive cells that control the current as light strikes them. This current is measured by a microammeter, and the calibrations on the meter can be interpreted to give the photographer the required camera shutter speed and the lens aperture setting with a given film speed.

*a. Reflected Light Meter.* In this type of photoelectric light meter, the ammeter is calibrated to permit measurement of the amount of light reflected by a particular subject. Average scene brightness readings are in terms of candles per square foot.

*b. Incident Light Meter.* In this type of photoelectric light meter, the ammeter is similar to the one used in reflected light meters; in this meter, however, a diffusing device is placed over the meter light window to permit measurement of the amount of light falling on a particular subject. Illumination readings are in terms of foot-candles falling on the scene.

## 6–34. Application of Photoelectric Exposure Meter

Photoelectric meters should be used discriminately, because they are valuable accessories only when applied with common sense. Since every subject reflects various intensities of light with some shadow areas, one general reading does not give a correct means of existing light values.

*a.* Before measuring light values, determine the type of photograph needed. If shadow detail is important, measure the shadow area carefully. If the highlight area is to be emphasized, base exposure on the measurement of the highlight area alone. To record both shadow and highlight areas in equal detail, measure both areas and use a compromise setting.

*b.* Do not make your light reading at a considerable distance from your subject, because this reading will include distracting areas that are not usually a part of the photograph. When taking specific readings, hold the meter close enough to the subject to indicate the average reflected light. The distance recommended is equal to the width of the subject.

*c.* Before using an exposure meter, make sure that the light value indicator points to zero while the photo cell unit is covered. If it does not, adjust the indicator carefull by means of the adjustment screw on the back of the meter.

*d.* Shield exposure meters from shock, strong magnetic influence, dampness, and extreme heat. Never point a reflection-type meter at the sun.

*e.* Check the calibration of a meter periodically against the quality of resulting photographs.

## 6–35. Photoelectric-Eye Lens Aperture Operation

Many commercial still and motion picture cameras are equipped with a built-in exposure meter. This device, which is activated by an electric eye, is capable of automatically adjusting the lens iris diaphragm to prevailing light conditions of the scene at which the camera is pointed. This innovation eliminates the need for manual lens setting and keeps the

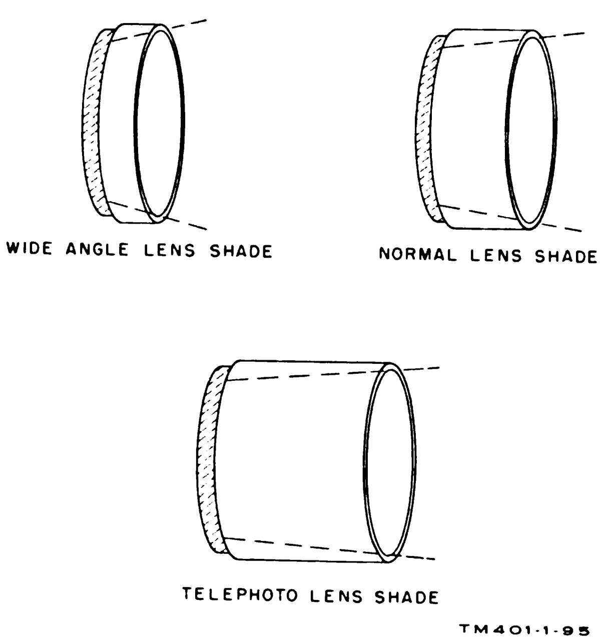


*Figure 6–2. Lens shades.*

aperture setting on par with fluctuating light values of the scene recorded.

### 6–36. Lens Shades

*a.* Lens shades are rectangular, cylindrical (fig. 6–2) or cone-shaped devices placed on the front of a lens to shield it from stray light. The length of a lens shade is based directly on the angle of view of the lens.

*b.* Army photographic lens shades are designed specifically for the lenses with which they are issued.

## Section VI. THE SIMPLIFIED EXPOSURE CONCEPT

### 6–37. General

Photographic film exposure consists of four basic variables: subject light, camera lens aperture setting, camera shutter speed setting, and speed of the selected film. In the new exposure value system, these variables are reduced to the lowest possible common denominator; then, through the use of simple mathematics, variables are arranged to best meet the photographic problem.

### 6–38. The Exposure Value System

The exposure value (EV) system is a new approach to a simple interrelationship between the factors involved in photographic exposure. Shutter speed values and lens aperture values are carefully selected and used in conjunction with the new ASA additive speed value of film emulsions.

*a. Shutter Speed Values.* The speed values are marked on the shutter of each camera in the following manner:

| Seconds | 1 | 1/2 | 1/4 | 1/8 | 1/15 | 1/30 | 1/60 | 1/125 | 1/250 |
|---|---|---|---|---|---|---|---|---|---|
| EV number | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |

*b. Lens Aperture Values.* The lens diaphragm settings are represented by the following numerical values:

| f/stop | 1.4 | 2.0 | 2.8 | 4.0 | 5.6 | 8 | 11 | 16 | 22 | 32 |
|---|---|---|---|---|---|---|---|---|---|---|
| EV number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

*c. Evaluation.* Any pair of numbers (given under *a* and *b* above) that have the same total will provide identical exposure of a given film emulsion. Accordingly, if EV = 8, the following relationships would be identical:

EV = 8 1 + 7, or ½ second at f/11
2 + 6, or ¼ second at f/8
3 + 5, or ⅛ second at f/5.6
4 + 4, or 1/15 second at f/4.0
5 + 3, or 1/30 second at f/2.8
6 + 2, or 1/60 second at f/2.0
7 + 1, or 1/125 second at f/1.4

### 6–39. Additive Speed Values and Light Values

The exposure value system considers only shutter speed values and lens aperture values. In addition, film speed values (additive speed values) and existing light values must also be reduced to simple terms and integrated.

*a. ASA Additive Film Speed Values.* Film speed rating systems have values that run from 0° to 11°. They may be used directly in conjunction with the exposure value system to determine vital relationships among all values.

*b. Additive Light Values.* Additive light values are represented on a scale that presents existing incident light in terms of foot-candles. These figures are established by reflected light meters calibrated in light values. Photographers who do not have a meter or prefer to work without a meter can refer to this table. The following additive light values are applicable:

| Foot candles (incident light) | Light valve |
|---|---|
| 6 | 0 |
| 12 | 1 |
| 25 | 2 |
| 50 | 3 |
| 100 | 4 |
| 200 | 5 |
| 400 | 6 |
| 800 | 7 |
| 1,600 | 8 |
| 3,200 | 9 |
| 6,400 | 10 |

*c. Evaluation.* After a photographer understands the values represented by additive numbers of the factors involved, it is quite simple for him to apply them to any practical situation. *For example,* assume that a light meter indicates that a particular scene has a light value of 6 and that the additive speed of the film is 4°; the total is ten (6 + 4 = 10). Therefore, any combination of shutter speed and lens opening totaling 10 will give a correct film exposure.

### 6–40. Memory Device

The exposure value system is a very simple approach to what has been greatly overcomplicated in the past. To be able to remember the relationships involved, simply think of the word SLAT (S + L = A + T). In this formula, S = speed, L = light, A = aperture, and T = time (shutter speed).

### 6–31. Summary

*a.* Assuming correct development, tone separation of a photographic negative depends almost entirely on exposure.

*b.* Photographic exposure is the product of the intensity of the light falling on the film emulsion multiplied by the time the emulsion is permitted to be subjected to the projection of light.

*c.* Four classes of daylight illumination are bright sun, hazy sun, cloudy bright, and cloudy dull.

*d.* Four classes of subject brightness are brilliant, bright, average, and dark.

*e.* Factors to consider in action photography are speed of the subject, angle and direction of the subject in relation to the camera, distance from the subject to the camera, lighting conditions, and focal length of the camera lens.

*f.* Floodlamps are designed to give light of a bluer characteristic per watt than home service lamps. In addition, they have a much higher light output.

*g.* Photoflash lamps are single-use bulbs that burn brilliantly and noiselessly for about 1/50 second.

*h.* Illumination from a lamp is inversely proportional to the square of the lamp-to-subject distance (inverse square law). Accordingly, when the distance between the light and the subject is doubled, only one-fourth as much light reaches the subject.

*i.* Speed lamps have a gas-filled tube that gives off a brief, high intensity light when a high voltage spark passes through it.

*j.* Reflected light meters permit measurement of the amount of light reflected by a phtotgraphic subject.

*k.* Incident light meters permit measurement of the amount of light falling on a photographic subject.

*l.* Lens shades are placed on the front of camera lenses to shield them from stray light.

*m.* The four basic variables involved in film exposure are subject light, camera lens aperture setting, camera shutter speed setting, and speed of the selected film.

*n.* The exposure value (EV) system is based on a simple interpretation of shutter speed and lens aperture values.

### 6–42. Review Questions

*a.* What are the characteristics of an underexposed negative?

*b.* What are the characteristics of an overexposed negative?

*c.* Explain front, side, and back lighting.

*d.* What is the different between light and heavy shade?

*e.* Give the three factors to be considered prior to setting the camera for the correct exposure.

*f.* What effect does the direction and angle of approach of moving objects have on the selection of shutter speed?

*g.* What is the relative light output of No. 1, 2, and 4 photoflood lamps?

*h.* How is the guide number of flashlamps used to determine proper exposure?

*i.* List the various types of lighting used in interior photography.

*j.* Explain the correct application of a photoelectric exposure meter.

### 6–43. Review Answers

*a.* Characteristics of an underexposed negative are poor tone separation and lack of detail in shadow areas of the subject.

*b.* Characteristics of an overexposed negative are overall density and poor tone separation in the lighter parts of the subject areas.

*c*. Front, side, and back lighting refers to the areas of the subject illuminated by the available light source. When the sun is behind the photographer as he faces the area to be recorded, it is referred to as front lighting. If the rays of the sun form a right angle with the direction in which the camera is pointing, the effect is side lighting. If the photographer must face the sun to record a subject, the effect is back lighting.

*d*. In situations known as light shade, light from about half the sky strikes a subject. If a subject is shielded not only from the sun, but also from most of the sky, it is in heavy shade.

*e*. Prior to setting the camera for the correct exposure, the following three factors must be considered:

(1) The sensitivity or speed of the film emulsion used.

(2) The type or intensity of the daylight.

(3) The degree of absorption or reflection of that part of the light striking the photographic subject.

*f*. A subject moving directly across the field of view requires a faster shutter speed than one moving toward or away from the camera.

*g*. The light output of photoflood lamps is as follows:

(1) The No. 1 lamp draws about 250 watts but is equal in intensity to an ordinary 750-watt lamp.

(2) The No. 2 lamp draws about 500 watts but is equal in intensity to an ordinary 1,500-watt lamp.

(3) The No. 4 lamp draws about 1,000 watts but is equal in intensity to about four times the output of a No. 1 photoflood lamp.

*h*. You can determine the approximate camera lens aperture by dividing the flashlamp guide number by the lamp-to-subject distance.

*i*. To provide light for an interior you can use an electronic flash, single and multiple flashbulbs, floodlights, regular room illuminating lights, natural light from outdoors, painting with lights, or any combination of these.

*j*. Photoelectric exposure meters are of help only when applied with common sense. Since every subject reflects various intensities of light with some shadow areas, several readings will provide the basis for arriving at the most useful average setting.

# CHAPTER 7
# PHOTOGRAPHIC CHEMISTRY

## Section I. GENERAL

### 7–1. Principles of Photographic Chemistry

*a.* When an exposure is made, a chemical change takes place in the light-sensitive emulsion of the film. During this chemical change, the silver halides suspended in the gelatin emulsion layer produce a latent, or invisible, image in the emulsion.

*b.* The film is then immersed in a photographic developer. The purpose of the developer is to continue the chemical reaction that began with the exposure by light.

*c.* After the image appears, the emulsion is rinsed in a stop bath and treated in a fixing solution to insure that the undeveloped portion of the film will not darken when exposed to light. The fixing solution converts the remaining silver halides into water soluble compounds.

*d.* The negative is then washed and the image is made permanent.

### 7–2. Nature of Chemicals

*a.* Many chemicals used in photographic laboratories are supplied in the form of white crystalline powders that appear to be physically similar. Therefore, all bottles containing chemicals must be labeled carefully to insure that laboratory personnel will not select the wrong chemical when mixing a solution.

*b.* Photographic solutions generally consist of one or more chemicals dissolved in water, and these solutions are usually clear. The quantity of a chemical that can be dissolved in a given volume of water varies with different compounds and with the temperature of the solution.

*c.* The following chemicals are used most frequently in photographic solutions:

(1) Alkalis, such as sodium or potassium hydroxide, sodium or potassium carbonate, and sodium borate (borax).

(2) Acids and acid salts, such as acetic acid, boric acid, citric acid, sulfuric acid, and sodium bisulfate.

(3) Salts, such as sodium sulfite, sodium sulfate, sodium thiosulfate, potassium bromide, and potassium alum.

## Section II. THE CHEMISTRY OF DEVELOPMENT

### 7–3. Functioning of Development Compounds

*a. Function of the Reducing Agent.* When a sensitized emulsion is exposed to light, the silver halides forming the latent image are so weakened by the action of light that they can be reduced to metallic silver. This reduction produces a visible image. In this reduction process, a chemical compound, known as the reducing agent, combines with oxygen and reacts with the exposed silver halides in the film emulsion. If used alone, however, this reducing agent will have very little or no affect on the silver halides, since it has a low rate of oxidation. Therefore, an accelerator must be added to the developer.

*b. Function of the Accelerator.* An accelerator or alkali is used to increase the rate of oxidation of the reducing agent. This accelerator energizes the reducer by increasing its rate of oxidation, softens the gelatin of the film emulsion, and speeds up solution penetration. However, a solution containing only a reducer and an accelerator will oxidize quickly and act too rapidly. Therefore, it becomes necessary to add a restrainer to the developer to prevent chemical fog (a veil of silver deposited throughout the entire emulsion), and rapid deterioration of the solution.

c. *Function of the Restrainer.* A restrainer is added to the developer to minimize the formation of stains. This preservative increases the life of the developing solution by preventing excessive oxidation.

## 7–4. Developing Agents

Although many chemicals are capable of reducing silver halides to metallic silver, many are not selective in their action.

a. One important factor in the selection of a reducing agent is its reducing potential, which is its relative ability to develop or reduce, the silver halides of a photographic emulsion. A reducing agent of high potential attacks the silver halides vigorously, while one of low potential acts slowly.

b. Another important factor in the selection is the characteristic activity of a reducing agent. Some agents are more active in highlight areas, others are active in shadow areas, and still others have overall activity.

c. Temperature is another factor, since it affects the activity of some agents much more than others.

d. The tone of a developed image is greatly affected by the type of reducing agent. Some agents produce blue-black, or cold tones; others yield brownish, or warm tones.

e. Some of the more widely known developing agents are hydroquinone, metol, amidol, glycin, and pyro. Table 7–I lists developing agents and their characteristics.

*Table 7–I. Characteristics of Developing Agents*

| Name of developing agent | Reduction potential | Type of application | Characteristic activity | Use |
|---|---|---|---|---|
| Amidol (diaminophenol). | 30–40 | Tropical. Used with chrome alum. | Requires weak alkali. Density builds up slowly, though image appears quickly. | For negatives and for blue-black tones on paper emulsions. |
| Metol | 20 | Used in fine-grain developers. | Builds image detail rapidly. Nonstaining. Low fogging tendency. | For fine-grain negatives. With hydroquinone for paper. |
| (Elon, Rhodol, Pictol). | | Gives low contrast | | |
| Pyrogallol | 16 | Produces two images, one silver and one pyro stain. Valuable in certain types of printing. | Full tonal range. Rapid oxidation without fog. | For negatives only. |
| Glycin | 1.6 | Nonstain, fine-grain. Powerful reducing agent. | Slow working, long tonal range. Low fogging tendency. | For underexposed negatives. For paper also. |
| Hydroquinone | 1 | High contrast. Used in combination with metol. | Dense highlights and clear shadows. Inactive at low temperatures. | With other agents for contrast developing of film and paper. |

## 7–5. Types of Developing Agents

a. *Hydroquinone.*

(1) Hydroquinone is a low potential developing agent that requires little or no restrainer at normal temperatures. Its activity is greatly reduced by low temperatures, and it becomes inert, or inactive, at about 50° Fahrenheit in normal solutions. At temperatures above 80° Fahrenheit, it produces fog.

(2) Hydroquinone is capable of producing highlight of great density in negatives, or shadows of great density in positive prints. This makes it an ideal developing agent for subjects requiring extreme contrasts, such as copies of black and white line drawings. For subjects requiring the correct rendering of half tones and shadows, it is combined with another reducing agent, such as metol.

(3) Hydroquinone deteriorates slowly in air, has good keeping qualities in solution, and does not stain the gelatin.

*b. Metol.*

(1) Metol is a trade name for monomethyl paraminophenol sulfate. Other trade names are elon, pictol and rhodol.

(2) Metol, which can be used alone or combined with hydroquinone, is a popular developer. It is a soft-working, high-potential developing agent that builds image detail rapidly.

(3) Metol is affected comparatively little by changes in temperature or by the presence of large amounts of restrainer.

(4) Although metol will develop without an accelerator, it is usually used with an alkaline carbonate. Borax and other alkalis may be used for special purposes.

(5) There are times when it is difficult to secure sufficient contrast with methol alone; it may then be necessary to combine it with hydroquinone. Other combinations are metol-glycin and metol-pyro.

(6) Metol is used in fine-grain negative developers, in general purpose developers with hydroquinone for prints and negatives, and in pyro developers for negatives.

(7) Metol solutions have good keeping qualities.

*c. Metol-Hydroquinone.* Metol-hydroquinone (M-Q) is the most versatile and popular of all developers. The combination of soft-working, detail-producing metol and the high-contrast hydroquinone is superior in many ways to either agent when used alone. M-Q developer keeps well in solution, does not stain, and is faster working than either metol or hydroquinone used separately.

*d. Amidol.* Amidol (diaminophenol) has the highest developing potential, and is one of the very few reducing agents that can be used without an accelerator or a restrainer. A solution of amidol and a preservative gives satisfactory results, but it will oxidize and deteriorate very rapidly.

*e. Glycin.* Glycin is a low-potential developing agent that works satisfactorily on the lesser exposed areas. It is nonstaining, produces fine grain, and does not readily oxidize in either air or alkali solutions, even when greatly diluted. This makes it very useful for machine development of motion picture film. Glycin is often combined with other developers.

*f. Pyro.* Pyro (pyrogallol) has been used longer than any other organic developing agent, but is has some disadvantages that limit its use. Because it deteriorates rapidly in a working solution and stains readily, it is suitable only for negative materials. However, the stain produces another image, in addition to the regular silver image, and this adds to the printing quality of a thin negative.

## 7–6. Fine-Grain Developers

*a.* The structure of a photographic image is composed of minute silver grains. If the image is enlarged sufficiently, the individual grains become visible. Since modern highspeed emulsions have much finer grain than film material used before 1930, the need for using a developer that produces fine grain is not as urgent today as it once was. When an extreme enlargement—more than ten times—is made, a very fine-grain negative is important.

*b.* There are a number of fine grain developers available today, many of which are designed to be used primarily with medium fine-grain films. These developers not only assure fine grain processing of the sensitive emulsion, but they also permit exposure of the emulsion at twice the speed designated by the film manufacturer.

## 7–7. Accelerators or Activators

Since all developing agents are either neutral or slightly acid, they usually have little reducing ability until placed in an alkaline state. To make a developing solution alkaline, an accelerator is added to energize the reducing agent and soften the emulsion, thereby permitting more rapid penetration of the developing solution. This must be accomplished with care, since a deficiency of alkali will retard development and an excess will cause an increase in activity and contrast, eventual chemical fog, and an overswelling of the gelatin. Accelerators are divided into three general types: mild, moderate, and strong.

*a. Mild Accelerators.* One of the mild alkalis used with low-contrast developers for fine-grain negatives is borax. It is sometimes called a buffer alkali, because it slowly and constantly forms and releases alkali in a solution and, in that way, keeps the alkalinity of the solution constant. Sodium metaborate, although slightly stronger than borax, is similar in its action.

*b. Moderate Accelerators.* Sodium carbonate, one of the moderate alkalis, is the accelerator most commonly used in developing solutions. It is used in many metol-hydroquinone and pyro solutions. Potassium carbonate, which can be substituted in formulas calling for sodium carbonate, is more soluble in water but less stable than sodium carbonate.

*c. Strong Accelerators.*

(1) Sodium hydroxide and potassium hydroxide are caustic alkalis used with certain developers to produce high contrast. Other alkalis that are more or less commonly used include ammonium carbonate, ammonia, aceton, and paraformaldehyde.

(2) Caustic alkalis are not used with fine-grain developers, because they soften and swell the gelatin excessively and permit the silver grains to clump together.

(3) A strong alkali does not give the same result as a weak one, even when allowance is made for the difference in strength. Therefore, do not use substitutes.

## 7–8. Accelerators and Graininess

Because an accelerator is a determining factor in the activity of a developing solution, it has a marked influence on the degree of graininess produced in the negative. This graininess depends on the clumping action of the silver grains during the development process. The more active the developer, the greater the clumping action. Therefore, the milder, less alkaline developing solutions yield the finest grain.

## 7–9. Preservatives

All organic developing agents in an alkali state have a strong affinity with oxygen. Therefore, it is necessary to add a preservative to developing solutions to prevent excessive oxidation. A preservative prolongs the usefulness of the developing solution and prevents the formation of colored oxidation products, which cause stains.

*a.* Sodium sulfite is the most commonly used preservative. Because sodium sulfite dissolves silver bromide to some extent, it is useful in fine grain developers to reduce the clumping effect of silver halides.

*b. Sodium bisulfite is also used.* This is an acidified sulfite, which is an alkaline developer converted to sodium sulfite and sodium bicarbonate. Developers containing sodium bisulfite give slightly less base fog than those containing sodium sulfite.

*c.* The quantity of preservative used varies greatly. The following factors determine the amount required:

(1) The tendency of the developing agent or agents to oxidize.

(2) The concentration of the developer. A diluted developer requires more preservative than a more concentrated solution.

(3) The temperature at which the developer is kept or used. The rate of oxidation increases as the temperature increases.

(4) The keeping properties required and the way in which the solution is used. A solution that is used once and then discarded requires only a small amount of preservative. Note that oxidation is greater when a developing solution is used in a tray than when it is used in a tank.

(5) The alkalinty of the solution. The more strongly alkaline the developer, the more rapid is the rate of oxidation.

## 7–10. Restrainers

*a.* Without a restrainer, most developers act too rapidly and reduce the unexposed halides near the surface of the emulsion. This produces chemical fog, developer streaks, and an image lacking contrast. When a restrainer is added, development time is prolonged and fog is minimized. In addition, contrast is increased, because the developing activity is cut down in unexposed areas.

*b.* Care must be exercised in the use of restrainers, since excessive amounts of restrainer will retard development and, under some conditions, cause greenish tones in prints.

*c.* All negative and some paper print emulsions are basically composed of silver bromide. In development, the bromide is released from the silver and acts as a restrainer. However, it is usually insufficient to prevent fog.

*d.* Potassium bromide is the chemical most commonly used at a restrainer, but sodium bromide, sodium chloride, or potassium iodine may also be used. Potassium iodine gives more restraining action than other restrainers and tends to produce blue-black tones. However, its use requires a longer fixing period of the developed material.

## Section III. THE CHEMISTRY OF FIXATION AND WASHING

### 7–11. General

When film development is completed, the emulsion contains a metallic silver image and a residue of unchanged silver halides.

*a.* The metallic silver image is that portion of the emulsion affected by camera exposure. Subsequent chemical treatment of the latent image by the developer compounds brings forth the image.

*b.* The unchanged silver halides are that protion of the emulsion not affected by camera exposure. If subjected to exposure by light during development, these unchanged silver halides immediately react to the exposure, decompose, and destroy the image. Therefore, it is necessary to fix the image.

*c.* The primary purpose of fixation is to convert insoluble silver halides into a soluble form.

### 7–12. Function of Fixation

Fixation makes unwanted silver halides soluble. This conversion from solid to liquid continues until all unchanged silver halides have been transformed. The rate of solubility varies with the different types of silver halides. Chloride is the most responsive halide, bromide is somewhat less soluble, and iodide is the least soluble of the silver halides. However, solubility is achieved by extending the period during which the particular emulsion is subjected to the action of the fixing solution. The two phases of fixation are—

*a.* The gradual spreading of the thiosulfate into the gelatin of the emulsion layer.

*b.* The chemical reaction of the chemical with the unchanged silver halides, thereby producing soluble products.

### 7–13. Silver Halide Solvent

All fixing baths contain a silver halide solvent, called a fixer or fixing agent. The chemical most widely used for this purpose is sodium thiosulfate, more commonly known as hypo. Sodium thiosulfate changes the silver halides to a compound that is soluble in water. Another chemical, sometimes used as a fixing agent, is ammonium chloride.

### 7–14. Acid or Neutralizer

The pores of an emulsion retain a considerable amount of developer, which will continue its activity if allowed to remain. This is true, even though an emulsion is thoroughly rinsed in a nonacid bath before being placed in the fixing solution. To prevent interaction between the preservative and the hardener—capable of producing an insoluble precipitate—acetic acid is added to the fixing bath. It stops development and prevents staining, while neutralizing the alkalinity of the developer.

### 7–15. Preservatives

When enough acid is added to the fixing bath to neutralize the alkalinity of any remaining developer, the hypo is decomposed into free sulphurous acid. This makes the bath unusable. To prevent decomposition of the fixing bath, sodium sulfite is added to the solution to serve as a preservative. Sodium sulfite combines with the sulphur to form a new hypo, prevents discoloration of the solution, and aids in the elimination of stains.

### 7–16. Hardener

Emulsions become soft and swollen during development, and undesirable effects, such as frilling and scratching, may occur if processing is continued without hardening the emulsion. The most common practice is to include a hardening agent in the fixing bath, so that the emulsion can be fixed and hardened at the same time. The most common hardening agent is potassium alum.

### 7–17. Emulsion Response

*a.* Chloride emulsions, being more soluble, are more responsive to fixation that chlorobromide emulsions, and much more responsive than the slow iodobromide emulsions.

*b.* Small grain structure emulsions are more responsive to fixation than those having larger grains. The smaller grains form a more extensive surface area per weight of silver halide than the larger grains and, therefore, accomodate the process.

### 7–18. Hypo Concentration

Experiments indicate that the rate of fixation increases up to a concentration of 20 percent hypo. The rate of fixation remains fairly constant beyond that point, even up to a 70 percent concentration of hypo.

### 7–19. Temperature of Fixative

The temperature of the fixing bath should be maintained between 60° and 70° Fahrenheit. Lower temperatures reduce the effectiveness of the bath. Higher temperatures induce excessive swelling of the emulsion, thereby interfering with the chemical diffusion of the fixative.

### 7–20. Washing

Washing completes the movement of all unwanted material out of the emulsion, disposes of hypo and other minute residue so that the negative will not be subject to chemical decomposition or staining. While it is actually impossible to be 100 percent effective, proper washing removes enough of the unwanted chemicals to safeguard the image for a long period of time. Circulating fresh water carries away unwanted chemicals and assures continuous and thorough washing.

## Section IV. STABILIZATION

### 7–21. General

Fixation is only one process used in handling the developed emulsion of a sensitized material. A second process, called stabilization, involves the conversion of silver halides into a compound that is not sensitive to light. This process is used primarily when lack of water prevents washing of the sensitive material. The stabilization process is applicable to both film and processing.

### 7–22. Stabilization Process

The chemical *thiourea* is brought into contact with the unexposed silver halides of the developed emulsion to form a minimal soluble complex. In this complex, which is both transparent and insensitive to light, the silver salts are complexed and remain in the emulsion layer. Only as mall amount of the complex is bleached out by the thiourea solution during the stabilization process.

### 7–23. Stabilization Operation

There are three separate operations in the stabilization process—

*a.* Latent image development by conventional processes.

*b.* Immersion of the film in a hardening bath (chromium ammonium sulfate) to condition the emulsion layer for further treatment and to protect the sensitive gelatin. In the case of paper, immersion of the developed material in a short-stop bath (sodium bisulfite). The hardening required for film emulsion is not necessary for paper emulsions.

*c.* Immersion of film or paper in the stabilization solution, which contains thiourea.

### 7–24. Paper Prints

To produce acceptable prints, the stabilization process requires the use of water-resistant type papers. Standard type papers are subject to staining if they are used in this particular process.

### 7–25. Characteristics of the Sabilization Process

*a. Film.* Stabilized film exposed to high temperatures and humidities acquires a uniform yellowish brown stain with no signs of bleaching. The stain reduces the amount of light that passes through the film but, since it is a uniform tone, does not affect the normal contrast of prints made from the negatives.

*b. Prints.* Prints stabilized by thiourea lack the permanence of prints fixed in hypo and washed in water. *For example,* stabilized prints stored at high temperatures and humidities are subject to accelerated decomposition of the complex, and, when the complex breaks down, highlights become stained. Under more normal storage conditions, decompositoin is much slower.

### 7–26. Summary

*a.* Upon exposure of a photographic emulsion to light, silver halides suspended in the gelatin layer produce a latent image.

*b.* The latent image is made visible through deveopment of the photographic emulsion.

*c.* The fixing solution converts remaining silver halides into water soluble compounds.

*d.* Chemicals most frequently used in photographic solutions include alkalis, acids, acid salts, and other salts.

*e.* Photographic developers include a reducing agent, an accelerator, a restrainer, and a preservative.

*f.* Washing disposes of hypo and other minute residue so that the negative will not be subjected to chemical decomposition or staining.

*g.* In stabilization, unused silver halides of the film emulsion are converted into a compound not sensitive to light. This process can be used when film or prints cannot be washed in water.

### 7–27. Review Questions

*a.* What is the function of the accelerator in a photographic developer solution?

*b.* List 4 commonly used developing agents.

*c.* What effect does developer action have on grain?

*d.* Explain the function of preservatives in developing solutions.

*e.* What is the function of a restrainer in a developing solution?

*f.* Describe the function of fixation.

*g.* Why are small grain structured film emulsions more responsive to fixation than large grain emulsions?

*h.* Explain the washing process.

*i.* List the three separate operations in the stabilization process.

### 7–28. Review Answers

*a.* The accelerator or alkali increases the rate of oxidation of the reducing agent, softens the gelatin of the film emulsion and speeds up solution penetration.

*b.* Four commonly known developing agents are hydroquinone, metol, amidol, and glycin (two additional ones are paraphenylene diamine, and pyro).

*c.* During development the silver grains of the film emulsion are forced to clump. The more active the developer, the greater the clumping action. Accordingly, the milder, less alkaline developing solutions yield the finest grain.

*d.* Preservatives prolong the usefulness of developing solutions and prevent the formation of colored oxidation products, which cause stains.

*e.* Restrainers control action of accelerator, thereby minimizing fog, and retaining contrast.

*f.* Fixation clears the emulsion of unwanted silver halides, not affected by exposure or development, and leaves only the metallic silver image.

*g.* Small grain structure emulsions are more responsive to fixation because the smaller grains form a more extensive surface area per weight of silver halide than the larger grains and, therefore, accommodate the process.

h. Washing disposes of hypo and other minute residue so that the negative will not be subject to chemical decomposition or staining.

*i.* Three separate operations of the stabilization process are—

(1) Latent image development by conventional processes.

(2) Immersion of the sensitive material (film or paper) in a hardening bath (chromium ammonium sulfate).

(3) Immersion of the sensitive material in the stabilization solution, which contains thiourea.

# CHAPTER 8
# PHOTOGRAPHIC PROCESSING

## Section I. HANDLING FILM AND PAPER

### 8–1. Handling Film

*a.* Film handling is complicated by the fact that the emulsion is sensitive to light and must be protected from exposure to light until fixation is well under way.

*b.* Procedure details must be adapted for each development method to reduce such difficulties as scratches, abrasion marks, and uneven development.

*c.* During processing, film emulsions become swollen and soften as a result of submersion into, and the action of, chemical solutions. Special care is necessary to protect them from damage as they are transported from one chemical solution to another, and while the film is subjected to treatment by a specific solution.

*d.* Observe the following procedures in handling film:

(1) Always handle film gently and along the edges.

(2) Never touch the film surface.

(3) To prevent defects from forming during processing of the film, manipulate it so that the solution can act uniformly over the entire film surface.

### 8–2. Handling Paper

Sensitized paper does not have to be handled as carefully as photographic film, but it is important to keep your hands away from the emulsion side of the paper.

*a.* In handling paper, observe carefully both sides of the paper near the edge. Photographic paper always curls slightly toward the emulsion sides.

*b.* Make sure that you do not handle the sensitive side of the paper too often. The natural oil present on your skin, or the traces of chemical deposits that adhere to your skin, can cause spots to appear on the paper after it has been processed.

*c.* After the paper is completely submerged in any one of the processing solutions, it should be agitated rapidly to insure complete coverage by the processing solution.

## Section II. DEVELOPING FILM AND PAPER

### 8–3. Effect of Development

*a.* The initial phase of development affects the density of highlights and shadow areas to approximately the same degree. As the developing action continues, however, highlight areas of negatives, or shadow areas of prints are rendered more dense. Therefore, the developing action should be stopped when the contrast between the light and shade tones is most satisfactory.

*b.* The speed of the developing action is determined primarily by the activity of the developer; however, the kind of film used is also a factor.

*c.* There are several types of developers, and each differs in activity and provides different qualities of development. In selecting a developer, consider the type of film, the conditions under which it was exposed, and the results desired. Accordingly, select a slow working developer for negatives requiring a low or medium degree of development, and an active developer to obtain a high degree of development. *For example,* aerial photographs, produced under poor light conditions, require a very vigorous developer to bring out as much of the image as possible, while portrait negatives usually call for a much less active developer.

## 8–4. Negative Density

Four principal factors are involved in the production of negatives: emulsion contrast, subject contrast, exposure, and development. The time required to produce a given degree of density in a negative varies with developers and film types.

*a.* Figure 8–1 shows a set of nine negatives and illustrates the effects of underexposure, and overexposure, as well as underdevelopment and overdevelopment. Reading from left to right, the portions of the illustration show the effect of exposure. Reading downward they show the effect of development.

(1) The center negative will produce the best print, because it has received normal exposure and development.

(2) The three negatives to the left have been underexposed, and the three to the right have been overexposed.

(3) The top row of negatives has been underdeveloped, and the bottom row has been overdeveloped.

b. The three underexposed negatives lack detail in the shadows, and an increase in development time does not produce an appreciable increase in shadow detail. Little can be done to improve the underexposed negative.

*c.* The three normally exposed negatives have good shadow detail. Even though the top underdeveloped negative seems flat and lacks the contrast of the center negative, it differs from the flat negatives of the underexposed group in shadow detail. The bottom negative, which has lost detail in the highlight areas and has too much contrast, is overdeveloped.

*d.* The three negatives on the right are overexposed. Although the top negative is flat and dense, detail can be seen over most of the negative. The normally developed and overdeveloped negatives are so dense that almost no details are visible.

*e.* Underexposure is indicated when the shadows lack detail, and overexposure when the shadows are dense. Underdevelopment is shown when there is good shadow detail, but the negative is flat. Too much contrast means overdevelopment.

*f.* When a subject is flat, or of low contrast, the negative can be improved by longer development. By decreasing the exposure and increasing the development time 50 to 75 percent, details in the highlights will not be lost and there will be an increased separation of all tones and increased brilliance in the photograph.

*g.* When a subject is too contrasty, the range from the deepest shadow to the highest light is too great. Therefore, the negative may be underdeveloped. In this case, the exposure must be increased to retain detail in the shadows.

*h.* Underdevelopment by 50 to 75 percent, depending on the subject, will prevent blocking of the highlights. In underdevelopment, however, the separation of all tones is decreased. Therefore, the results are not satiafactory if there is a need for fine separations of tone.

*i.* The developing time is affected by the temperature of the solution and by the type of agitation. Temperature directly affects developer activity, and agitation controls the rate at which a fresh solution is brought to the film surface.

## 8–5. Developer Temperature

The average developer temperature is 68° Fahrenheit (20° Centigrade). If the developer and wash water are above 70° Fahrenheit, the film emulsion swells excessively, becomes soft, and is easily damaged during handling. In some instances, the emulsion may even melt and separate from its support.

*a.* With care, films can usually be processed without damage at temperatures up to 75° or possibly 80° Fahrenheit. At such temperatures, however, it is necessary to use special processing solutions and procedures. There are even special solutions that will permit processing at temperatures above 100° Fahrenheit. These should be considered for emergency use only, when conditions make it impossible to maintain lower solution temperatures.

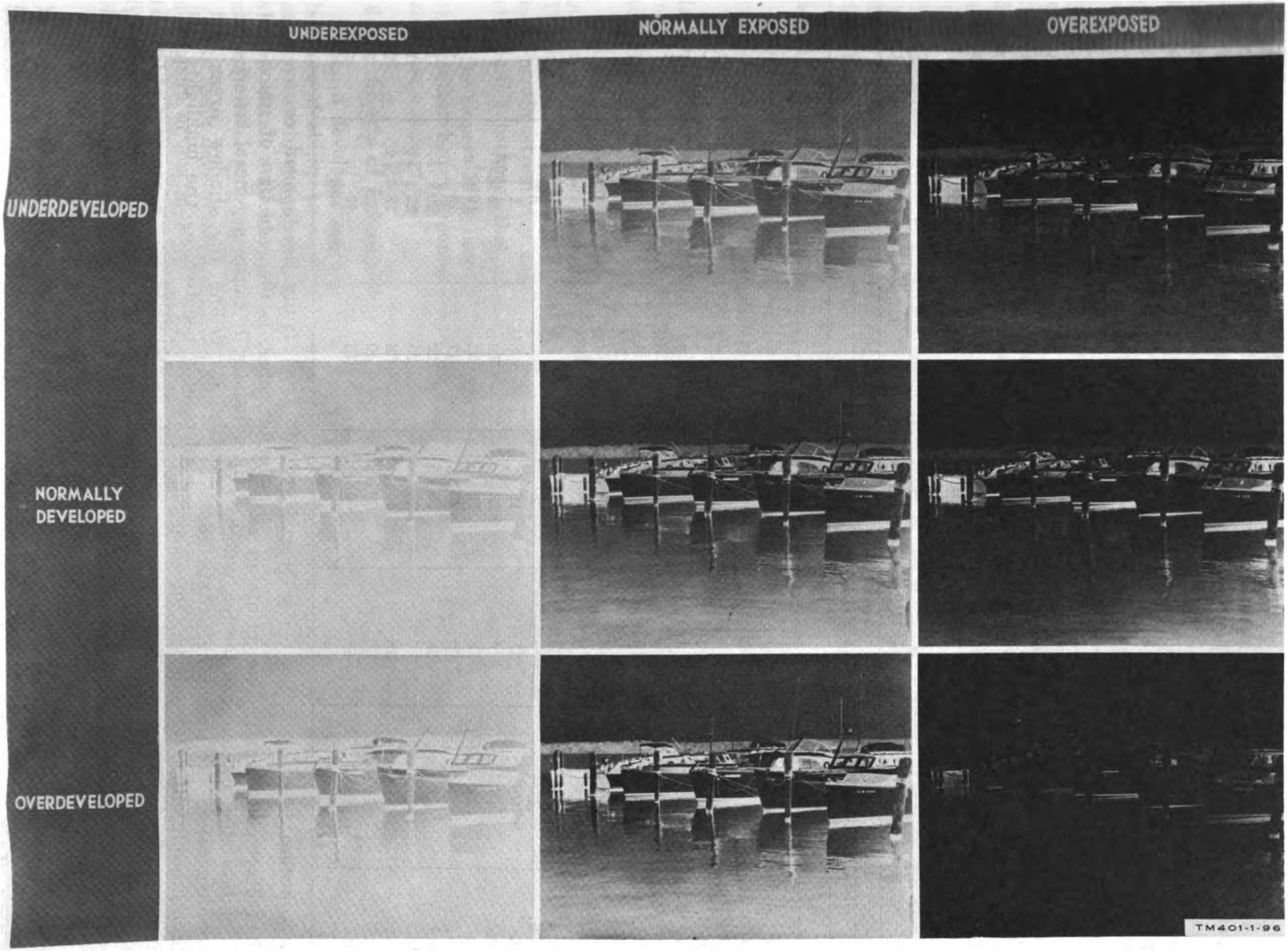


*Figure 8–1. The effect of variations of exposure and development on the negative.*

*b.* At temperatures below 65° Fahrenheit, there is no danger of excessive swelling but the activity of the solution is slowed down. This causes the processing time to become inconveniently long, and there is danger of incomplete action in development, fixing, and washing. Whenever possible, solutions should be maintained at a temperature between 65° and 70° Fahrenheit.

*c.* When the room temperature is within the suitable working range, there is no temperature control problem. When the room temperature is high, the solutions may be cooled by placing the tray or developing tank in a sink, tray, or tank containing cold water. If ice is available, it is usually satisfactory to put it in the outside container. It should never be added directly to the processing soltion. As it melts, it dilutes the solution and changes its strength.

## 8–6. Developer Temperature Guide

Table 8–I shows the relationship between developer temperatures and processing periods. It is a general guide for the development of average negatives under normal conditions.

*Table 8–1. Processing Times for Developer Temperatures*

| Temperatures (Fahrenheit) | | | | | | |
|---|---|---|---|---|---|---|
| 50° | 55° | 60° | 65° | 70° | 75° | 80° |
| Time equivalents in minutes | | | | | | |
| Above normal | | Normal | | | Below normal | |
| 4 | 3¼ | 2½ | 2 | 1½ | 1¼ | 1⅛ |
| 4¾ | 3¾ | 3 | 2½ | 2 | 1½ | 1¼ |
| 5½ | 4½ | 3½ | 3 | 2¼ | 1¾ | 1½ |
| 6 | 5 | 4¼ | 3½ | 2¾ | 2 | 1¾ |
| 7 | 5½ | 4¾ | 4 | 3 | 2¼ | 2 |
| 8 | 6½ | 5½ | 4½ | 3½ | 2¾ | 2¼ |
| 9 | 7¼ | 6 | 5 | 4 | 3¼ | 2¾ |
| 10 | 8¼ | 6¾ | 5½ | 4½ | 3¾ | 3¼ |
| 11¼ | 9¼ | 7½ | 6 | 4¾ | 4 | 3⅜ |
| 11¾ | 9¾ | 8 | 6½ | 5¼ | 4¼ | 3½ |
| 12¼ | 10 | 8½ | 7 | 5¾ | 4¾ | 4 |
| 13¾ | 11½ | 9½ | 8 | 6¾ | 5¾ | 4¾ |
| 16 | 13¾ | 11¾ | 10 | 8¼ | 7 | 6 |
| 19 | 16 | 14 | 12 | 10 | 8¾ | 7½ |
| 24 | 21 | 18 | 15 | 12 | 10½ | 8½ |
| 30 | 27 | 23 | 20 | 17 | 15 | 13 |
| 36 | 32 | 28 | 25 | 22 | 20 | 17 |
| 46 | 40 | 35 | 30 | 25 | 22 | 19 |
| 58 | 51 | 45 | 40 | 32 | 28 | 24 |
| 74 | 64 | 56 | 50 | 40 | 32 | 28 |
| 84 | 74 | 66 | 60 | 48 | 40 | 35 |

## 8–7. Agitation

When developing negatives or prints in a tray, agitate the solution constantly. When developing negatives in a small tank, agitate the solution intermittently (at intervals of once a minute, or less). With no agitation, objectionable streaks may appear on a negative from the convection currents set up by the products of development.

## 8–8. Fogging

Fogging of photographic material, which results from faulty development or overage film or paper, is the reduction of unexposed silver halides. It causes a general lowering of contrast by veiling the shadow areas and borders of a negative, or the highlights and borders of a positive.

*a.* Aerial fog occurs with some developers, especially those containing hydroquinone, when wet film is exposed to the air.

*b.* Chemical fog results from the presence of certain impurities, such as dyes and sulfides, in a solution.

*c*. Solvent fog occurs when sulfite, ammonia, hypo, or a combination of these act on an emulsion and permit the developing agent to reduce the dissolved silver halides to yellow colloidal metallic silver.

## 8–9. Used Developer

As a developer is used and the solution accumulates bromide and other development byproducts, the rate of development is retarded. Therefore, to obtain the degree of development produced by a fresh solution, increase the development time. The characteristic of a developer to produce good shadow detail also falls off gradually with use, and the photograph eventually suffers. Loss of shadow detail is more serious when developing to low, rather than high, contrast.

## 8–10. Exhaustion of Developer

A developer is exhausted when its developing power has been greatly depleted.

*a*. One cause of developer exhaustion is oxidation. When air reacts with several chemicals in a solution, there is a loss of developer activity.

*b*. In a developer containing metol or hydroquinone, the hydroquinone is oxidized first. The metol is not affected until the hydroquinone is almost entirely changed over to other chemical substances that do not develop.

*c*. Developers also become exhausted when the solution becomes contaminated with fixing solution.

## 8–11. Effects of Exhaustion

When a developer becomes exhausted, there is a loss of ability to render shadow detail and an increase in the tendency to stain. Loss of shadow detail may be partially offset by increasing developing time.

*a*. In tank development, and especially with developers of low activity, a replenisher must be used to counteract loss of detail. Exhaustion is indicated when there is a general flattening of contrast and a drop in density.

*b*. Loss of activity is not usually encountered in tray development, because the solution is discarded before the effects of exhaustion appear.

*c*. In exhaustion, certain developing agents, such as pyro, catechol, and diaminophenol,are oxidized and form strongly colored products that tend to stain the gelatin.

## 8–12. Replenisher

A developer is replenished when its developing power is almost completely restored by the addition of certain chemicals.

*a*. In the simplest method of replenishment, fresh replenisher solution is added to the used developer. When properly used, there is little or no increase in developing time.

*b*. In replenishment, it is always necessary to follow the directions given on developer containers. The quantity of replenishment solution and the changes in developing time vary with the type of developer.

*c*. A typical replenisher contains a little more developing agent and alkali than the original developer and enough sulfite to maintain the original concentration. It does not contain any bromide, because bromide is formed as a byproduct of development.

*d*. Replenishment is not necessary for small-scale work, except with low activity developers. It is necessary in tank development, especially if a large volume of work is involved.

## 8–13. Discarding Developer

The following factors should be considered prior to the discarding of a developer: its use, the time that has elapsed since it was mixed, and the ease with which it may be replaced. Except when the developer is properly replenished, the time required to produce a definite contrast increases with use; when this time exceeds the maximum time allotted for development, the developer ceases to be useful. Developers should be discarded before there is an excess of chemical fog, excess staining of the gelatin layer, or loss of shadow detail.

## Section III. RINSING FILM AND PAPER

### 8–14. General

When a negative or print is removed from the developing solution, the emulsion is soft and small amounts of developer remain in the emulsion and on its surface. If the developer is not removed, it will continue its reaction and cause stains. To remove surplus developer, the negative or print is placed in a rinse bath There are three general types of rinse baths: water, acid, and hardening. Each has its specific purpose and should be used accordingly.

### 8–15. Water Rinse Bath

As a rinse, water helps to retard development and removes excess developer from the emulsion. This prevents contamination of the fixing bath. It is suitable for both negatives and prints, and sometimes precedes the acid rinse in print processing to avoid the formation of gas bubbles that may cause damage to the emulsion.

### 8–16. Acid Rinse Bath

An acid rinse is more effective than water, because it stops all development by neutralizing the action of the developer; this action prolongs the life of the fixing bath.

*a.* When working with photographic paper, use the recommended plain acetic acid rinse bath. Use 1½ ounces of 28-percent acetic acid to 32 ounces of water. Do not use this bath for negatives developed in a highly alkaline solution, because the violent reaction of the alkali with the acid may cause pinholes in the emulsion.

*b.* If an acid bath is not available, rinse the emulsion thoroughly in water.

*c.* Use litmus paper or a testing outfit to check the acidity of a stop bath. The testing outfit usually contains some type of chemical that will change in color when the stop bath becomes alkaline. As soon as the stop bath becomes alkaline, discard it.

### 8–17. Hardening Rinse Bath

Use a hardening rinse bath (chrome alum) to harden an emulsion in high temperatures and under tropical conditions.

*a.* If temperatures are above 75° Fahrenheit (24° Centigrade), the acid stop bath should contain an antiswelling agent, such as sodium sulfate, and a hardening agent, such as chrome alum. Sodium sulfate is recommended for temperatures between 75° and 85° Fahrenheit, and a chrome alum bath for temperatures between 75° and 95° Fahrenheit.

*b.* Under ordinary conditions, the hardening agent in the fixing bath is sufficient. Therefore, a water or acid rinse may be used.

### 8–18. Print Rinsing

Though rinsing is even more important in print processing than in film processing, because paper is much more absorbent than film. Therefore, quite a bit of developer may be carried by the print as it goes from the developer to the rinse to the fixing bath. Since the presence of developer in the hypo can hasten deterioration of the fixing bath, it becomes necessary to use an acid stop bath.

## Section IV. FIXING FILM AND PAPER

### 8–19. General

When sensitized photographic materials—paper or film—are moved from the rinse bath into the fixing bath, silver halides unaffected by the developing solution are changed to a soluble state. The fixing bath contains one or more of the following chemical agents: silver halide solvent, acid or neutralizer, preservative, and hardener.

### 8–20. Fixing Time

*a.* The general yardstick for fixing time is twice the time required for cleaning. After repeated use, the solution is weakened by the dissolved silver halides and clearing time becomes progressively longer.

*b.* Working at 68° Fahrenheit, most negative materials should be fixed from 10 to 20 minutes; paper prints and lantern slides from 5 to 10 minutes.

## 8-21. Types of Fixing Baths

There are several different types of fixing baths: a plain fixing bath, an acid fixing bath. an acid hardening fixing bath, a boric acid hardening fixing bath, a chrome alum fixing bath, a double fixing bath, and an ultrarapid fixing bath.

*a. Plain Fixing Bath.* The standard plain fixing bath, which is seldom used as a fixing solution, is a 25-percent solution of hypo. It consists of 2 pounds of hypo to each gallon of water.

*b. Acid Fixing Bath.*

(1) One satisfactory acid fixing bath can be made by adding sodium bisulfite, an acidified sodium sulfite, to a hypo solution. The acid of the bisulfite stops development, and the sulfite preserves and prevents discoloration of the solution.

(2) A second satisfactory acid fixing bath contains a mixture of hypo, acetic acid, and sodium sulfite. This type of bath, which has no hardening qualities, is unsatisfactory for negatives, but can be used to fix prints.

*c. Acid Hardening Fixing Bath.* An acid hardening fixing bath contains a hardening agent, usually potassium alum, as well as a silver halide solvent, a neutralizing agent, and a preservative.

*d. Boric Acid Hardening Fixing Bath.* The hardening agent in an acid hardening fixing bath causes the precipitation of aluminum sulfite when the acid becomes neutralized. Therefore, the boric acid hardening fixing bath, which has much slower sludging tendencies and excellent hardening characteristics, is the recommended fixing bath for films.

*e. Chrome Alum Fixing Bath.* This bath is especially suitable for hot weather fixing, because the chrome alum has a greater hardening action on gelatin than potassium alum. However, it has one disadvantage—its hardening properties deteriorate rapidly, and the bath must be replaced frequently. To save chemicals, use the chrome alum in a separate rinse bath, and then use a regular fixing bath.

*f. Double Fixing Bath.* In the mass production of prints, it is generally advisable to use two fixing baths. This procedure will produce a more uniform and thorough fixation, conserve chemicals, and speed up the production of prints. Proceed as follows:

(1) Use two trays with equal amounts of the solution.

(2) Fix the prints or negatives for half the time in the first tray, and then move them to the second tray. Since the products of the development process are usually eliminated in the first bath, this bath deteriorates more quickly than the second.

(3) When the first fixing bath shows signs of exhaustion, move the second bath into its place, and replace the second bath with a fresh solution.

*g. Ultrarapid Fixing Bath.* Fixing time may be shortened appreciably by adding ammonium chloride to the hypo solution. Add the ammonium chloride to the hypo solution rather than the final fixing solution, since addition of the ammonium chloride to the hardener in the final fixing solution will form sludge. A rapid fixing bath that contains ammonium chloride, will cut the fixing time from 30 to 50 percent.

## 8-22. Fixing Methods

*a.* The standard fixing bath formula, F-5, will fix prints completely within 5 to 10 minutes, if the solution is fresh and the prints are agitated at regular intervals. A fresh gallon of F-5 will fix more than one hundred 8- by 10-inch prints if the prints have been thoroughly rinsed in a stop bath.

*b.* Standard practices in fixation must be followed closely, since there are dangers in both overfixation and underfixation. Inadequate fixing often produces stains on prints. Overfixation tends to produce a thinning or weakening of the photographic image.

## 8-23. Agitation

Agitation prevents exhausted hypo from settling near the surface of the emulsion and thus prevents quick and effective entry of the thiosulfate into the gelatin of the emulsion. Of the projected time required for complete fixation, the greatest proportion involves the entry and spread of the chemical into the emulsion. Accordingly, it is important to agitate the solution to speed up the process of chemical diffusion. Do *not* permit prints to overlap each other in the fixing bath for more than a few seconds, to minimize unequal fixing.

### 8–24. Fixing Small Prints on Single-Weight Paper

As soon as prints reach full development, they are transferred to the stop bath; here they are rinsed thoroughly for 10 to 20 seconds. Then they are placed in the hypo and are agitated to make certain that they do not stick together. After about 2 minutes, they can be inspected by white light, but they should be returned promptly to the hypo for complete fixing.

### 8–25. Fixing Large Prints on Double-Weight Paper

*a.* Use of a stop bath is even more important with large double-weight prints than with small single-weight prints, because the larger sheets of paper absorb more of the developing solution and contaminate subsequent baths more easily. Double-weight papers absorb the most chemical solutions. Each print should be rinsed thoroughly in a full strength stop bath before it is placed in a fixing bath.

*b.* The actual fixing process does not differ from the procedure outlined for small single-weight prints.

## Section V. WASHING AND DRYING FILM AND PAPER

### 8–26. General

Negatives and prints are washed to remove the chemical byproducts of the fixing bath. If these byproducts remain in the emulsion, they will, in time, cause the emulsion to change color, stain, or fade. Washing time depends largely on water temperature and the amount of fresh water coming in contact with a negative or print.

*a.* Figure 8–2 shows the rate of hypo elimination from a negative, giving time and temperature. Water temperature should be within the range of 50° to 75° Fahrenheit.

*b.* It is true that most salts diffuse more rapidly in warm water; with photographic material, however, the warmer the water, the more the film gelatin swells. This retards the diffusion of chemicals from an emulsion in about the same proportion as the rise in temperature accelerates it.

*c.* The removal of hypo from the gelatin is more rapid when the hypo concentration in the water is low; therefore, it is best to change the water as often as possible.

*d.* The hardening of the gelatin in a fixing bath does not influence washing time, except when the emulsion has been dried after fixing. If the gelatin has been dried, it will not swell as much when it is soaked again; consequently, chemicals deep in the emulsion will not wash out as quickly.

*e.* As the washing proceeds, the hypo in the sensitized material is halved in equal periods of time. *For example,* the average negative gives up approximately half of its hypo in 15 seconds of direct contact with running water. After 30 seconds, one-fourth of the hypo remains, and so until eventually the remaining hypo is negligible. Accordingly, washing time depends on the degree of agitation and the amount of fresh water coming into contact with the emulsion.

*f.* Drying is the final processing step. Its effectiveness depends on the cleanliness of the airspace within which it is accomplished and the speed with which the particular material is dried.

### 8–27. Effect of Temperature

*a.* Films should not be washed at temperatures above 75° Fahrenheit, nor papers at temperatures above 80° Fahrenheit, without a special hardening treatment.

*b.* Low temperatures have no harmful effects on negatives and prints, unless there is a drop of 10° or 15° Fahrenheit between the fixing solution and the washing water. A sudden lowering of temperature, from one bath to another, may cause reticulation of the emulsion.

*c.* When the temperature of the water is below 50° Fahrenheit, more time is needed to effect a complete washing.

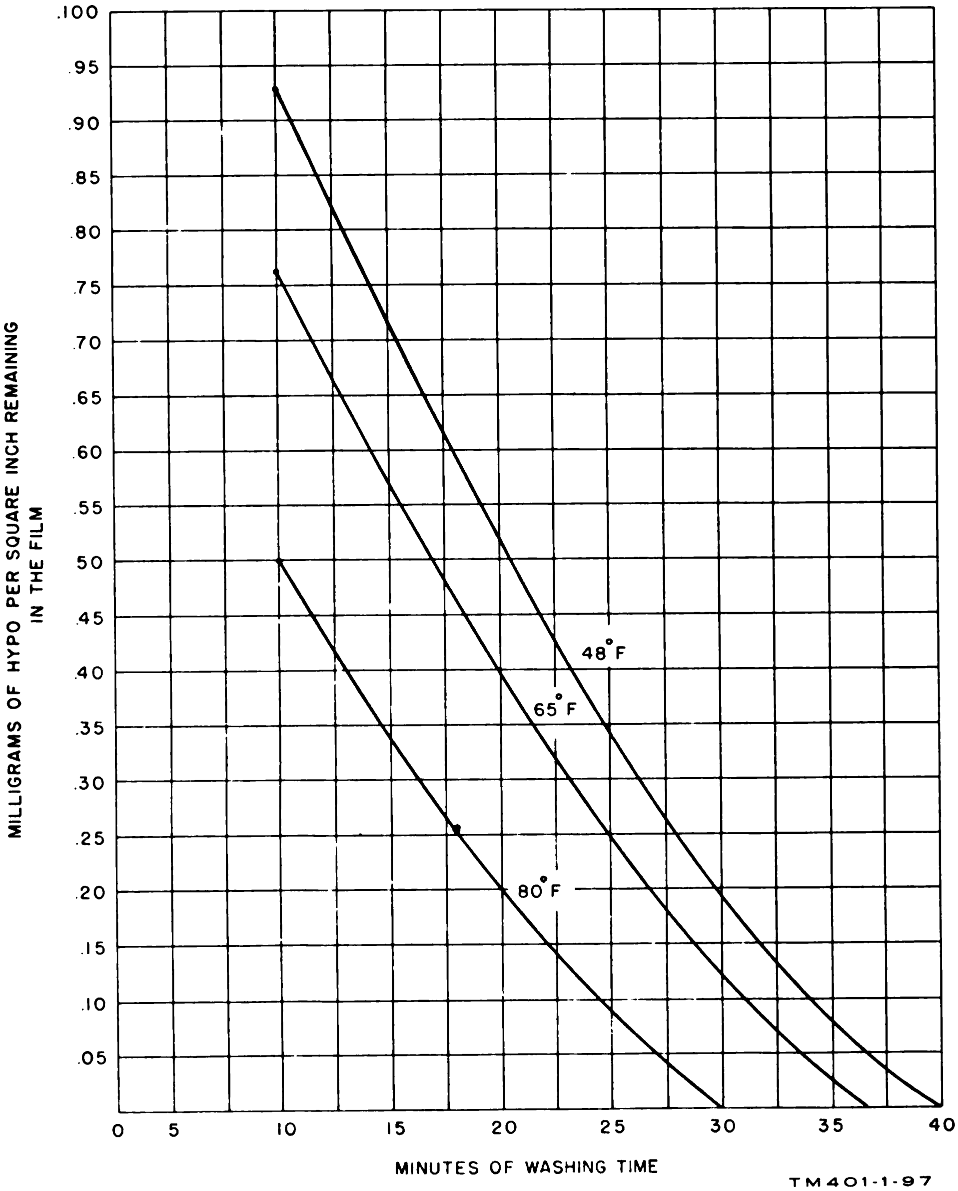


*Figure 8–2. Rate of hypo elimination from a negative.*

## 8–28. Eliminating Hypo From Negatives

*a.* The structure of the film base is such that very little, if any, hypo is absorbed by the material. However, the gelatin layer, which carries the sensitive image-forming particles is more porous, and hypo will seep into these tiny apertures to convert undeveloped silver halides to a soluble form. Figure 8–2 indicates the rate at which circulating water washes into the tiny pores of the gelatin layer of the film and washes out these unwanted chemicals.

*b.* In washing hypo from a negative, make sure that the wash water is at the proper temperature and that the film is submerged the required length of time. Agitate the water constantly and replace the water frequently to insure that the waste will be carried off and will not contaminate the water or film.

## 8–29. Eliminating Hypo From Paper Prints

*a.* To eliminate hypo from paper prints, wash the prints for about 30 minutes in water of 65° or 70° Fahrenheit (18° to 21° Centigrade). Then, immerse each print in a solution of ammonia and hydrogen peroxide (hypo eliminator HE–1) for about 3 minutes. Before drying, wash these prints again for about 10 minutes.

*b.* To check the efficiency of this procedure, process an unexposed white sheet of photographic paper that is the same weight and size as the prints to be processed. After the final wash, cut off a strip of the paper and immerse it in a 1-percent silver nitrate solution for 3 minutes. Then rinse it in water and, while it is still wet, compare it with the wet untreated portion. If the hypo has been removed, there will be no difference in color. If the hypo remains, the paper will have a yellow-brown tint.

*c.* To minimize the fading of silver images, wash the photographic material and then immerse it in a 1-percent solution of sodium thiocynate containing 0.1 gram of gold chloride per liter.

### 8–30. Washing in Trays

There are three methods used to wash negatives and prints in trays.

*a.* In the simplest method, the negatives or prints are placed in a tray of water and the water is changed every 5 minutes. This changing of water is repeated at least six times.

*b.* In the second method, a continuous stream of water runs into the tray for a minimum of 30 minutes.

*c.* In the third method, a device is attached to the edge of the tray to siphon water from the bottom of the tray while fresh water enters on top. This action continues for a minimum of 30 minutes.

*d.* Regardless of the method used, always separate the prints or negatives to insure that fresh water will reach all areas. Note that single-weight paper should be washed a minimum of 30 minutes and double-weight paper a minimum of 1 hour.

### 8–31. Washing in Tanks

Negatives that have been processed in a tank can also be washed in the same or a similar tank. Fresh water is directed into the tank, and the negatives are suspended in the tank by metal or plastic frames.

### 8–32. Mechanical Washers

A convenient method used in the washing of a large batch of small and medium size prints is the mechanical washer. In this process, a washer sprays fresh water on the prints and, at the same time, siphons off the contaminated water from the bottom of the tank. This type of washer sometimes contains a large tray that is revolved either by the force of the water spray or by a motor. Thus, the prints are agitated constantly.

### 8–33. Film Drying

*a.* When film is dried under normal temperature conditions, the process is relatively simple.

(1) Remove film from wash and insert it in a wetting agent. Wetting agents are solutions that prevent the formation of water marks.

(2) Then, since cleanliness is important, the film is dried in a dustproof room or container.

*b.* If speed is essential, the film can be dried in a diluted methol alcohol bath or a cabinet with warm circulating air.

*c.* Special problems arise when film is dried in hot and humid climates. These problems are discussed in TM 11–401–4 (when published).

### 8–34. Drying of Prints

The method used in the drying of prints depends upon the type of paper used, the urgency of the job, and the use for which the prints are intended.

*a.* Matte and semimatte surfaced papers are placed face down on cheesecloth stretchers after the surface moisture has been squeegeed or blotted out. Normally, the prints should dry within an hour.

*b.* In a second system, the prints are placed between strips of blotting paper and cardboards. The blotting paper and cardboards are then rolled together tightly with print emulsions facing outward, to minimize curling. This is a slower procedure, but it reverses the natural tendency of dry prints to curl.

### 8–35. Ferrotyping

In ferrotyping, wet prints are squeegeed face down on the polished surface of ferrotype tins.

As the prints dry, they can be peeled off smoothly if the ferrotype tins have been thoroughly cleaned and polished. The prints must be swabbed with clean, preferably filtered water before applying them to the tins. When large drying machines are used, heated rotating drums replace the tins and produce dry prints in a matter of minutes.

## Section VI. PROCESSING FILM AND PAPER

### 8–36. Film Processing Methods

Basically, there are only two processing methods: tray and tank processing. Tray processing involves the use of rectangular trays. Tank processing employs an open tank or a closed daylight processing tank. A daylight tank is equipped with a lighttight cover, and processing solutions are poured in and out without removing the cover.

### 8–37. Processing Sheet Film in Tray

To insure good negative uniformity in the processing of sheet film, proceed as follows:

*a.* Use four trays slightly larger than the film. Arrange the solutions in the following order:

(1) Preliminary water bath.
(2) Developer.
(3) Acid stop bath.
(4) Fixing bath.

*b.* Pour at least ½ inch of solution into each tray.

*c.* Arrange the trays in a row so that the preliminary water bath is at the far left, the developer is in the left center, the acid stop bath is in the right center, and the fixing bath is at the far right.

*d.* Place the trays about 4 inches apart so that the solutions cannot be splashed from one tray to the next.

*e.* Bring solutions to the proper temperature, and set the timer. Arrange the holders containing the exposed films in a convenient position, turn off the lights, and remove films from their holders.

*f.* Guard against dirt and fingerprints, especially when handling panchromatic film in total darkness.

*g.* Immerse the exposed films, one at a time, emulsion side up, in the tray of water. Each Film must be completely covered with water before the next film is placed over it.

*h.* When all the films are in the tray, draw one film carefully from the bottom and place it on the top. Handle the film only at the extreme edges, and do not let a corner or an edge of any sheet of film dig into the film emulsion below it. Repeat this replacement from bottom to top until individual film sheets have been leafed through twice. This will prevent films from sticking together, and will dislodge any air bubbles that may have formed.

*i.* Start the timer, and transfer films quickly, one sheet at a time, from the bottom of the pile into the developer tray. Continue rotation of the films from the bottom to the top throughout the development period.

*j.* At the end of the correct developing time, transfer the films, one at a time, to the acid bath. Then, leaf through the pile twice. Keep track of the order in which the films were placed in the developer, so they can be put into the stop bath in the same order. Failure to do so will result in overdevelopment of some films.

*k.* Transfer the sheets of film, one at a time, to the fixing bath. Continue replacement from bottom to top until the negatives are completely fixed.

*l.* Wash the negatives thoroughly in running water for 30 minutes by continuing the rotation method or by placing the negatives in developing hangers and using a washing tank.

*m.* After the washing is completed, swab the negatives carefully to remove loose particles or deposits. Then attach a clip to one corner of each negative and hang the negatives in a drying cabinet. Excess surface moisture is best removed with a viscose sponge.

### 8–38. Processing Sheet Film in Tank

In a tank, films are much less subject to scratching or other mechanical damage, and solutions are less exposed to the action of air. Solutions in a tank last longer and can be used for processing a greater number of films than solutions in a tray. To process sheet film in a tank, proceed as follows:

*a.* Use at least three tanks—one for the developer, one for the acid stop bath, and one for the fixing bath.

*b.* Bring the solutions to the correct temperature, and set the timer for the appropriate development time.

*c.* Arrange sheet film holders and film developing hangers so that they are easily accessible. Then turn off the light.

*d.* Remove the films from the holders and load them into the hangers.

*e.* Start the timer and lower the hangers into the developer.

*f.* Agitate the hangers vertically under the solution for about 5 seconds, striking the tops of the hangers sharply against the top of the tank once or twice to dislodge air bells clinging to the film.

*g.* Leave the hangers undisturbed for 1 minute. Then, lift them clear of the solution, drain for 1 or 2 seconds, and replace them in the solution. Repeat this procedure at 1-minute intervals, alternating the bottom corners from which the solution is permitted to drain.

*h.* At the end of the development time, lift the hangers from the developer, drain them, and transfer them to the stop bath. Lift and drain the hangers several times in this bath.

*i.* Transfer the hangers to the fixing tank, and agitate them vertically under the surface of the solution for about 30 seconds. Lift and drain them at 2-minute intervals until fixing is completed. Fixing time is usually twice the cleaning time of the film. The room lights may be turned on after the first 2 minutes.

*j.* Wash the negatives thoroughly in running water for 30 minutes.

*k.* Remove the hangers from the wash water.

*l.* Take the film out of the hanger, and swab it carefully to remove dirt or any form of deposits.

*m.* Attach a film clip to one corner of the film and hang it in a drying cabinet. Eliminate excess surface moisture with a chamois or viscose sponge.

## 8–39. Processing Roll Film in Tray

Four trays are needed for the preliminary water bath, developer bath, acid stop bath, and fixing bath. Although small trays, slightly wider than the width of the film can be used, it is better to use a large tray for fixing and, if possible, another large tray for washing. In processing roll film in a tray, proceed as follows:

*a.* Bring the solutions to the required temperature, and set the timer. Turn off the light.

*b.* Unroll the paper backing, and fasten a film clip to the end of the film. Attach the clip to a hook on the wall, about 6 feet above the floor, and slowly unwind the remainder of the film. Maintain a slight tension to prevent coiling.

*c.* Detach the film at its lower end from the protective paper backing, and attach a second film clip.

*d.* Remove the upper clip from the hook, and allow the film to sag in a U-loop with the emulsion side down.

*e.* Dip the bottom of the loop into the preliminary water bath, and pass the film back and forth through the water by alternately lowering one end while raising the other. Continue constant agitation for 1 minute to prevent the formation of air bubbles when the film is placed in the developer. This also reduces the tendency of the film to curl and become unwiedly.

*f.* Start the timer.

*g.* Turn the film so that the emulsion side is up, and transfer it promptly to the developer tray. While developing, pass the film back and forth through the solution, subjecting the emulsion to constant agitation.

*h.* Transfer the film to the acid stop bath, and pass it back and forth through the solution two or three times.

*i.* Place the film in the fixing bath, so that it is completely submerged, and agitate it for 2 minutes. Thereafter, move the film at intervals to insure uniform fixation.

*j.* When fixing is complete, place the film in a deep washing tray. Wash it thoroughly in running water for 30 minutes.

*k.* Swab the film surface under water with a tuft of cotton or a viscose sponge to dislodge any grit or scum. Then, hang up the film to dry.

*l.* Remove water drops from both sides of the film with a damp chamois or viscose sponge to prevent drying marks.

## 8–40. Processing Roll Film in Small Tank

It is much simpler to process single rolls of film in a small tank than in a tray. In addition, results are better, and the possibilities of film damage are minimized. Small tanks, designed for small size roll film, are similar to those used for larger size roll films. They are constructed so that all operations, including the loading, can be carried out in light.

*a.* Use a small tank with a lighttight cover.

*b.* Turn out darkroom lights and load the film into the reel.

*c.* Place the loaded reel in the tank and replace the lighttight cover.

*d.* Turn on darkroom lights and pour in developer.

*e.* Normally, agitate the solution by twisting or shaking the tank. In some tanks, however, it is necessary to rotate the reel within the tank.

*f.* At the end of the development time, pour the developer solution from the tank through the appropriate aperture.

*g.* Fill the tank with an acid stop bath solution. Do this several times to rinse the film.

*h.* After the film has been rinsed, pour the fixing solution into the tank and agitate the film continuously for about 30 seconds. Continue this agitation at intervals during the fixing.

*i.* Wash the film by removing the cover and allowing a stream of water to run through the tank or by removing the film reel to a washing tank.

*j.* Swab the film under water to remove grit.

*k.* Hang the film and remove water drops.

## 8–41. Processing Film Pack

Individual sheets of a film pack can be processed in small tanks or by the tray method.

*a.* In most small tanks, the films are supported in cages or racks. Loading, agitation, and the changing of solutions vary according to the tank design.

*b.* By using special racks fitted with a number of clips, the thin sheets of this type of film can also be developed in deep tanks.

## 8–42. Processing 35-MM Miniature Camera Film

Although perforated 35-mm film used in miniature cameras can be processed in either a small tank or a deep tank, short lengths are best processed in trays. The deep tank processing procedure is the same as that for regular roll film.

## 8–43. Printing Quality

A good print is the result of proper exposure, full development, correct solution temperatures, and the right grade of paper. Because prints are developed under safelight illumination, it is easy to be misled by the apparent contrast in image. It may seem to be fully developed before it has been run through its prescribed processing time; therefore, it is wise to favor full development. Underdeveloped prints, when dry, have a gray and flat appearance.

## 8–44. Processing Prints

*a.* In the processing of prints, it is necessary to use three trays that are larger than the prints and deep enough to hold ample solution. If possible, the trays used for the stop bath and hypo should be somewhat larger than the developer tray.

*b.* Proceed as follows in processing a single print:

(1) Slip the exposed print into the developer, emulsion side up.

(2) Make sure that the entire print is immersed at once and that no air bubbles cling to the surface.

(3) Agitate the paper as development gets under way and watch the appearance of the image. A normal print should develop gradually — shadows first, then half tones, and finally highlights. Development should occur within 1 minute, assuming that the developer

has the proper strength and correct temperature. If the image appears quickly with a general mottling the print was overexposed.

*c.* Proceed as follows in processing a large number of prints:

(1) Make a trial exposure, using a test strip (consisting of a piece of printing paper) or a test sheet of printing paper.

(2) Follow processing steps as described in *b* above.

(3) After processing is completed, study the test strip carefully and modify exposure. The actual printing process, during which the paper is exposed, is described in TM 11–401–4 (when published).

(4) When a test strip appears to develop properly in the recommended time, rinse it in clear water or in the stop bath, and then immerse it in the fixing bath for about 2 minutes.

(5) If the test does not produce the results desired and if a variation of exposure does not give satisfactory results, try a different contrast paper. If the test strip is muddy and lacks clean highlights and shadows, try a paper with more contrast. If the print has only a few middle tones, use a softer paper.

(6) After deciding on the correct paper and proper timing, print the entire order. Handle the first two or three prints individually, and run each print through the process by itself to make sure that everything is working properly. Then run the prints through in groups of three or four at a time. Keep them separated, and agitate them so that the solution reaches all parts of each print uniformly.

## Section VII. PROCESSING PROBLEMS

### 8–45. Negative Troubles

Photographic film is susceptible to damage before and during processing. The following are some of the most frequent causes of trouble:

*a. Abrasions.* Abrasions are fine lines or streaks that occur when a sharp or rough object rubs againse the emulsion surface before development. Abrasions are also caused by grit or rough spots in the camera, by twisting the roll to tighten the film on the spool, or by touching the film before development.

*b. Air Bells.* Air bells are small air bubbles that adhere to the film surface and prevent the processing solution from acting on the film. Air bells on a film during development will leave small clear spots; air bells on the film during fixing will produce many spots.

(1) To avoid air bells, immerse the film in the solution slowly, so that air bubbubbles are not carried below the surface of the solution.

(2) To dislodge any air bells that have formed, tap the film hanger or reel against the side or bottom of the tank after the film is immersed.

*c. Streaks.* Streaks of varying densities are often caused by uneven development.

(1) If the film is not placed in the developer evenly, development will start in some areas before others are even wet. Sharp edges will result from this uneven immersion of the film in the developer.

(2) Diffuse or indefinite boundaries are usually caused by lack of agitation, or by uneven stopping of development by the fixing bath or acid stop bath.

(3) Under some conditions, streaks may be caused by excessive or improper agitation. It is always best to follow the agitation procedure recommended for the processing method used.

*d. Reticulation.* Reticulation of the emulsion is a network of lines having a grainy, leather-like appearance. This action occurs when film is subjected to sudden temperature changes in transferral from one solution to another.

*e. Dust and Dirt.* Dust and dirt coming into contact with the soft sticky surface of the film will adhere and become embedded as the film dries. It is then impossible to remove it, even by rewashing the film. Avoid this difficulty by drying film in a clean room or cabinet that is supplied with a stream of filtered air.

*f. Drying Marks.* Drying marks are usually formed by water drops that remain on the film during drying. Such marks may be surrounded by a line of low density.

(1) Avoid dry marks by first moving the film from the developing clip or hanger to a dry clip; then remove the surface drops with a moist chamois or viscose sponge.

(2) If the developing hanger is used, do not shake it or disturb it after the film has started to dry. This shaking action may cause water drops from the hanger to fall on the film and cause drying marks.

## 8–46. Preventive Measures for Paper Print Troubles

Paper processing is basically a very simple procedure. However, it is vital to give attention to certain fundamental conditions that must be met if the laboratory worker expects to produce quality prints.

*a.* Make sure that the working area is clean and free from chemical dust that can contaminate working solutions.

*b.* Equip the darkroom with an appropriate safelight. This will insure the best visual control, and, at the same time, prevent paper exposure (fogging).

*c.* Arrange processing trays so that prints can be moved from tray to tray without solution contamination. A certain degree of convenience is also important when there is considerable printing to be accomplished.

*d.* Make sure that processing solutions are at the recommended temperature. This will insure that the chemical reaction between the sensitive paper emulsion and each processing solution is most effective. Low temperatures delay effectiveness, and high temperatures speed the process.

*e.* Insure that processing solutions are of the right strength, so that chemical reaction can be maintained at the prescribed rate.

## 8–47. Contrast Control in Prints

Basiclly, little can be done to alter the inherent characteristics of photographic paper emulsions. Accordingly, the best solution to any contrast problem is to select the correct emulsion for a given negative. Unfortunately, however, there are situations in the field when the ideal contact or projection paper is not available and photographic prints must be produced. In such cases, what can be done to control contrast?

*a.*To increase contrast, prolong development or use a more concentrated developer.

(1) Assuming that 60 seconds is normal developing time, contrast can be increased by developing for an additional 30 seconds. However, there is danger of chemical fogging and graying of highlight if the development time is extended beyond 30 seconds.

(2) Development can be accelerated by using a one-to-one proportion of developer or an undiluted developer. This may, however, easily get out of control, unless the photographer gets the print out of the developer and into a short stop bath at precisely the right moment.

*b.* To lower overall contrast, use a heavily diluted developer and a somewhat longer developing time.

(1) Dilutions as great as one-to-ten have been used, but such extremes require excessive development. One-to-four is usually sufficient to achieve the desired results.

(2) A fairly common practice is to begin development in the usual one-to-one developer. As soon as the image appears, the print is shifted to a clear water bath; at this point, the developer carried over in the emulsion of the paper continues development at a low contrast rate. It is generally necessary to put the print back into the developer briefly to produce full development.

(3) A third possibility involves the use of a developer cooled below 65° Fahrenheit. In this case, however, there is a danger that the picture will be low in both contrast and strength.

*c.* Another approach is to use two developers —a hard-working and a soft-working developer to achieve some degree of contrast control of printing paper.

## 8–48. Contact Printing

As its name implies, a contact print is made by placing a sheet of photographic paper in direct contact with a negative. When white light is directed toward the negative, the negative image controls the amount of light transmitted to the paper. The dense areas of the negative bar the passage of light, while the clear, or low density, areas permit light to pass freely. The image formed on the sensitized coating of the paper is, therefore, a reverse of the negative. In reality, this makes it a positive that approximates the true black-and-white relationships of the subject.

## 8–49. Contact Printing Equipment

The basic requirement for photographic contact printing is to hold the negative and paper tightly together during exposure to the printing light. Contact prints can be made with a printing frame or with a printer.

## 8–50. Printing Frames

A printing frame is a simple device involving a wooden or plastic frame, a clear glass face, and a padded spring-clamp back. The negative and the paper are held, emulsion to emulsion, between the glass and the back. The negative is placed on the glass side. For the exposure, the frame is held or placed with its glass face toward a light for a few seconds. The printing frame works well enough, but it is slow and inefficient when compared with the printer or printing box.

## 8–51. Printer or Printing Box

A printer is simple and efficient. It is actually a box, with a plate glass across the top. A hinged cover clamps down over the glass and holds the negative and paper in tight, uniform contact. As this hinged cover is pressed into position, a light or set of lights inside the box is automatically switched on to provide the exposure light. The lights are switched off when the pressure cover or plate is lifted. Inside the printer is a low-power ruby lamp that remains lighted throughout printing operations. This lamp will aid you in positioning and judging the negative.

## 8–52. Projection Printing

Projection printing is the second of the two basic means by which photographic prints are obtained. It differs radically from contact printing in that the negative image is projected on photographic paper, much as a color slide or color transparency is projected on a screen. The image is brought to focus on a sheet of photographic paper, which may be anywhere from a few inches to several feet from the enlarger's lens. In general, projection printing is a highly elastic, adaptable, and versatile process in which great skill and control can be exercised.

## 8–53. Projection Printing Equipment

The many different types and models of projection printing equipment have five basic characteristics in common. All of them have a light source, a negative holder, a lens, a bellows, and a paper board or easel. Any enlarger is, essentially, a camera in reverse, because it projects rather than receives the image. There are three primary types of enlargers—the diffusion, the condenser, and the diffuse-condenser.

## 8–54. Diffusion Enlargers

Enlargers are classed according to the type of light that is directed through the negative to the lens. The light source in a diffusion enlarger is a frosted or an opal glass electric light bulb located within the enlarger dome. This bulb directs the light rays down toward the negative carrier. To make sure that the light is evenly diffused without a hot spot, a sheet of opal glass is placed between the light and the negative.

## 8–55. Condenser Enlargers

From a purely technical and optical viewpoint, a condenser enlarger is the most efficient. It has a very precise optical system that includes a point source of light—electric arcs are sometimes used—and a set of accurately ground optical condenser lenses that direct the light through the negative to the lens. Diffusion is eliminated as completely as possible.

*a.* An enlarger of this type produces an extremely sharp image on the paper. However, this sharpness includes not only the desired image but also all tiny and otherwise inconsequential scratches and blemishes on the film. In addition, the image tends to be high in contrast.

*b*. Condenser type enlargers work well for enlargements from miniature negatives up to 4- by 5-inch negatives, but only when such film has been processed and handled carefully to minimize scratches, hairlines, and dust. Larger negative sizes of all subjects, with the exception of portraits are normally enlarged with condenser type enlargers.

### 8–56. Diffuse-Condenser Enlargers

A diffuse-condenser enlarger is a successful compromise between the other two types. The light source is diffuse. The spherical enlarger dome directs the reflected rays down to condensers that straighten them out for their passage through the negative. In general, the print contrast obtained falls between that of the other types of enlargers. Surface blemishes are not as obvious, and detail is adequate for work with miniature negatives.

### 8–57. Summary

*a*. The four principal factors involved in the production of negatives are emulsion contrast, subject contrast, exposure, and development.

*b*. The average developer temperature should be 68° Fahrenheit.

*c*. The main cause of developer exhaustion is oxidation.

*d*. The simplest method of developer replenishment involves the addition of fresh replenisher solution to the used developer.

*e*. Developers should be discarded when there is an excess of chemical fog, excess staining of the gelatin layer, or too much loss of shadow detail.

*f*. To neutralize the action of the developer, negatives or prints are placed in a rinse bath.

*g*. The fixing bath contains one or more of the following chemical agents: silver halide solvent, acid or neutralizer, preservative and hardener.

*h*. Most negative materials should be fixed from 10 to 20 minutes; paper prints and lantern slides from 5 to 10 minutes.

*i*. Washing time depends largely on water temperature and the amount of fresh water coming into contact with a negative or print. Negatives should be washed from 20 to 30 minutes, paper from 30 to 60 minutes.

*j*. In contrast printing, the negative and light-sensitive printing paper are held tightly together during exposure to the printing light.

*k*. In projection printing, the negative image is projected on light sensitive paper that may be from a few inches to several feet from the enlarger's lens, depending on the intended size of the final print.

### 8–58. Review Questions

*a*. List the three procedures to be considered in the handling of exposed photographic film.

*b*. How can you identify the sensitized side of photographic paper?

*c*. What happens to the negative if the developing tray or tank is not agitated during film development?

*d*. What causes aerial fog in a negative?

*e*. Name three general types of rinse baths.

*f*. What is the function of sodium thiosulfate in the fixing bath?

*g*. Give the advantages of a double fixing bath.

*h*. What is reticulation and what causes this film processing problem?

*i*. What are the five basic characteristics common to all types of projection printers?

*j*. What are the three primary types of projection printers?

### 8–59. Review Answers

*a*. The following procedures should be considered when handling film:

(1) Always handle film gently and along the edges.

(2) Never touch the film surface.

(3) During processing of the film manipulate it so that the solution can act uniformly over the entire film surface.

*b*. The smoother surface of photographic paper is the sensitive side.

*c*. If the developing tray or tank is not agitated during film development, objectionable streaks may appear on a negative from the convection currents set up by the products of development.

*d.* Aerial fog occurs with some developers when wet film is exposed to the air.

*e.* The three general types of rinse baths are water, acid, and hardening.

*f.* Sodium thiosulfate, more commonly known as hypo, is a silver halide solvent used as the necessary fixing agent in film or paper processing.

*g.* The use of double fixing baths produces more uniform and thorough fixation, conserves chemicals, and speeds up the production of prints.

*h.* Reticulation is the contraction of the film emulsion into unsymmetrical patterns and fine lines. It is caused when the film is subjected to a sudden lowering of temperature as it is transferred from one processing solution to another.

*i.* The five basic characteristics common to all types of projection printers are—

(1) A light source.
(2) A negative holder.
(3) A lens.
(4) A bellows (or related mechanical device).
(5) An easel, or paper board.

*j.* The three primary types of projection printers are—

(1) The diffusion type.
(2) The condenser type.
(3) The diffuse-condenser type.

# CHAPTER 9

# PHOTOGRAPHY IN CLIMATIC EXTREMES

## Section I. CARE OF PHOTOGRAPHIC EQUIPMENT IN HOT TEMPERATURES

### 9–1. General

*a.* Excessive heat and humidity can cause a high incidence of failure of photographic equipment. There is no known method to eliminate these failures entirely, but the number can be reduced by proper application of preventive and remedial tropicalization procedures.

*b.* The two primary causes of equipment failures in tropical climates are corrosion and fungus attacks, or a combination of both. To recognize the condition and to apply tropicalization measures correctly, personnel must understand the basic causes of tropical deterioration.

### 9–2. Corrosion

Corrosion is a chemical action that eats away metal. Since it is accelerated by high temperatures, it is quite prevalent in tropical areas.

*a.* Corrosive action is doubled with every increase of 18° Fahrenheit (10° Centigrade). It is further increased whenever two dissimilar metals are brought into contact or are connected by an electrically conductive solution, such as water. In the latter case, an electrolytic effect, similar to that occuring in a wet cell battery, produces pitting and corrosion of one of the two metals.

*b.* Corrosion may be halted or retarded by protecting the metal with a sealing or waterproof coating, such as paint or varnish; by inclosing the metal component in a moistureproof case or housing; or by using protective films of oil or grease.

### 9–3. Fungus

Fungus is a parasitic growth that draws nourishment from particles of organic matter in the air or from material on which is rests. It cannot live without moisture, and it flourishes at temperatures of 75° Fahrenheit and higher.

*a.* Fungus acts in several ways to reduce the operating efficiency of equipment.

(1) It acts as a water collector, and this promotes corrosion.

(2) It releases corrosive byproducts that are capable of etching glass and pitting weather-resistant materials.

(3) It cuts down the efficiency and resolving power of optical systems.

(4) It causes leakage and interference in electrical components.

(5) It slows down or stops delicate mechanisms, such as camera shutters.

*b.* Tropical deterioration may be controlled by—

(1) Exposing equipment to sunlight frequently and for prolonged periods.

(2) Sealing off nutritive materials.

(3) Depriving the fungus of moisture.

(4) Applying heat.

(5) Using toxic or fungicidal sprays and varnishes.

### 9–4. Equipment Treatment and Handling

*a. General.* Most photographic equipments can be adequately protected from tropical hazards by using one of several moistureproofing processes. Utilization of these preventive measures, when coupled with frequent cleaning and intelligent use of desiccants and dry boxes, will help to extend the efficiency and length of service of equipment in the tropics.

*b. Materials Required.* Moistureproofing and fungiproofing materials required for support and lower level maintenance treatment of photographic equipment are listed below: (These materials, which may be ordered in bulk or in appropriate size containers, may be conveniently incorporated into a field tropicalization kit.)

(1) Leather treating compound (Shirlan).

(2) Fungus-resistant lacquer.

(3) Thinner for lacquer.

(4) Drycleaning solvent.

(5) Camel's-hair (touchup) brush.

(6) Brush for lacquering.

(7) Typewriter brush for cleaning.

(8) Cheesecloth.

## 9–5. Lacquer Treatment

In this treatment, spray or brush the equipment with a fungus-resistant lacquer or dip the equipment into the lacquer.

*a.* Use the lacquer treatment on hard, nonflexible, nonabsorbent surfaces, such as metal, painted wood, and water-resistant or coated nonflexible fabric.

*b.* Under field conditions, apply the lacquer with a brush to reduce the need for complicated masking procedures.

*c.* Do not brush lacquer on sliding, rotating, and bearing surfaces; on electrical contact surfaces; on finely balanced elements; on matte surfaces, where a glossy or shiny finish is undesirable; or on the surface of materials that must retain flexibility.

*d.* Do not use this lacquer near an open flame, since it is inflammable and highly explosive.

*e.* When spraying lacquer, cover all electrical contacts, sliding and bearing surfaces, gears, screw threads, other threaded surfaces, glass windows, lens surfaces, mirrors, flexible surfaces, and matte surfaces with tape or a suitable substitute.

*f.* Renew the lacquer treatment whenever an inspection of the equipments indicates caking, chipping of lacquer coat, or formation of local fungus colonies. When renewal is necessary, clean all surfaces and parts thoroughly with drycleaning solvent and apply a new coat of lacquer.

## 9–6. Shirlan Treatment

In the Shirlan treatment, a moisture- and fungus-resistant leather-treating compound is applied to leather, felt, plush, cloth, linen, and other textiles without affecting, to any great extent, their flexibility.

*a.* Apply this compound to the equipment with a brush or cloth pad, or dip the equipment in the compound.

*b.* Apply the compound to both sides of the material and in sufficient quantity to insure complete penetration. Dry the treated item for at least 1 hour before using it.

*c.* Renew the treatment at least once every 6 months. In the interim period, clean equipment frequently with drycleaning solvent.

*d.* Do not use this compound on focal plane shutter curtains or camera bellows.

## 9–7. Preventive Maintenance

In a general sense, all tropicalization treatments are basic preventive maintenance measures. However, they do not replace the routine preventive maintenance measures outlined below.

*a. Cleaning.* At the first sign of fungus growth, clean equipment thoroughly to guard against the corrosive fungus byproducts. In addition, clean textile materials with drycleaning solvent.

*b. Dry Storage Boxes.* In combat areas where air-conditioned storage is not available, store photographic equipment in a ventilated box heated by a 100-watt lamp, or in an airtight storage chest containing actuated silica gel. A combination chest for both heating and drying is one of the most effective means of keeping photographic equipment in operating condition.

*c. Heating.*

(1) In applying heat to general photographic equipment, make sure that temperatures are held below 160° Fahrenheit. Do not subject lenses and optical systems, including plastic elements, to temperatures above 140° Fahrenheit.

(2) Apply heat to the equipment by exposing it to sunlight, gasoline heaters, or electric lamps. Open the equipment to permit circulation of air.

*d. Lubrication.* Lubricants are of particular importance in tropical maintenance to eliminate friction between moving parts, and to create a moistureproof film over metal components. However, fungus feeds on substances contained or collected in some lubricants, and the lubricants must be renewed frequently and at the first sign of fungus formation.

*e. Dubbing.* This is a process in which wax is applied to leather articles. It is not recommended for use in areas where fungus is prevalent, since the wax contains animal fats and other organic material that can support fungus growth.

## Section II. CARE OF PHOTOGRAPHIC EQUIPMENT IN COLD TEMPERATURES

### 9–8. General

Most photographic operational difficulties in cold weather involve the camera shutter or the lens.

*a.* If a camera is properly lubricated and adjusted, the focal plane and between-the-lens shutters will continue to function properly, but at a slower speed. This slower shutter speed acts as a partial or complete compensation for reduced film sensitivity in cold weather.

*b.* The slower shutter speed poses no problem if the photographer takes into account the variation between the actual shutter speed and the calibrated speed when making exposure computations. In general, actual shutter speed will be as much as 50 percent slower than calibrated speeds.

*c.* To determine the shutter performance for individual cameras, proceed as follows:

(1) Make a series of test exposures at different settings.

(2) Use meter readings at prevailing temperatures with the type of film normally used.

(3) Record the results in the form of a chart, and keep the chart with the equipment for easy reference.

### 9–9. Specific Problems

*a. Mechanical.* Because of the contraction of metals and other materials, equipment designed for normal temperatures tends to drag or bind when used in low temperatures.

*b. Lubrication.* Lubricants lose their viscosity and antifriction qualities, thereby causing a slowdown or stoppage of equipment.

*c. Exposure.* Lower sensitivity of emulsions, a slowing down of shutter speeds, and difficulty in estimating outdoor illumination levels are problems that affect exposure.

*d. Condensation.* Extreme differences in temperature cause condensation of moisture, which will freeze and cause rust.

*e. Materials.* Film becomes stiff and brittle and breaks easily. Rubber, leather, fabrics, and various plastics lose their elasticity and will tear, crack, or break easily.

*f. Processing.* Processing is complicated by insolubility, precipitation, and lowered activity of chemicals at low temperatures.

*g. Operation.* The physical problems of handling and operating equipment are increased considerably. The need for wearing heavy gloves makes certain operations, such as manipulation of small levers, extremely difficult.

*h. Dehydration.* Low humidity, a typical characteristic of the arctic climate, can seriously affect the physical performance of all types of photographic film. Accordingly, steps must be taken to store and to protect the film in such a way that it will retain the necessary degree of flexibility. Motion picture film in particular can become brittle and operationaly useless unless stored in containers that maintain the essential humidity level.

### 9–10. Focal Plane Shutters

Some cameras have a focal plane shutter of reclaimed rubber, which is not as flexible as latex. To overcome the resulting stiffness, either operate the shutter at a higher tension or increase the tension of the bottom spring roller from the normal 8 to 12 turns. Before removing the safety slide, operate the shutter several times to break up surface tension and drag.

## 9–11. Between-the-Lens Shutters

*a.* Although these shutters can not be mechanically adjusted they may be disassembled, cleaned, buffed, and reassembled. However, *do not lubricate between-the-lens shutters.*

*b.* Operational failure of between-the-lens shutters is usually caused by moisture that congeals within the shutter housing. Disperse this moisture by removing the front and rear lens cells, warming the shutter housing, replacing the lens elements, and returning the equipment to low temperature storage. This also prevents mist from forming on the interior surfaces of the lens.

## 9–12. Camera Bellows

Bellows are subject to much wear and tear and require care. Open and focus all bellows-type cameras carefully to prevent cracking of the bellows material.

## 9–13. Miniature Cameras

Because of their small size and ease of operation, miniature cameras may be used with complete success in all temperatures.

*a.* When operating under low temperature conditions—

(1) Carry the miniature camera suspended around your neck and under the outer layer of clothing.

(2) Expose the camera to the outer air only long enough to make one or two exposures. This will keep the camera at a moderate operating temperature.

*b.* To speed up the actual operation, observe the following:

(1) Preset the lens and shutter adjustments.

(2) Do not use the rangefinder, except for closeups or where critical focusing is essential.

(3) Take full advantage of the depth of field of the miniature camera lens.

## 9–14. Flash Equipment in Cold Weather

*a. Flash Equipment.*

(1) Since the output of dry-cell batteries decreases greatly with low temperatures, use only fresh cells in flash equipment. Note that commonly used dry-cell batteries are completely inoperative at temperatures below —10° Fahrenheit.

(2) When using dry-cell batteries in a standard flash gun battery case, resynchronize the synchronizer to 1/25 second and use a tripod.

*b. Synchronization.* To facilitate flash synchronization, rewire the flashgun and carry the batteries under your clothing (fig. 9–1). When batteries are protected from the cold in this manner, no change in synchronization will be required. In this case, a single 4½- to 6-volt battery unit will be more convenient, but it is still possible to use the three separate cells normally employed.

## 9–15. Winterization of Equipment

Winterization is the preparation of equipment for cold weather operation.

*a.* In winterizing photographic equipment, adjust it, when permissable and practical; clean it thoroughly; and lubricate it with tested and recommended low temperature lubricants.

*b.* Winterize only that photographic equipment which is normally used outdoors, such as cameras, tripods, batteries, and accessories.

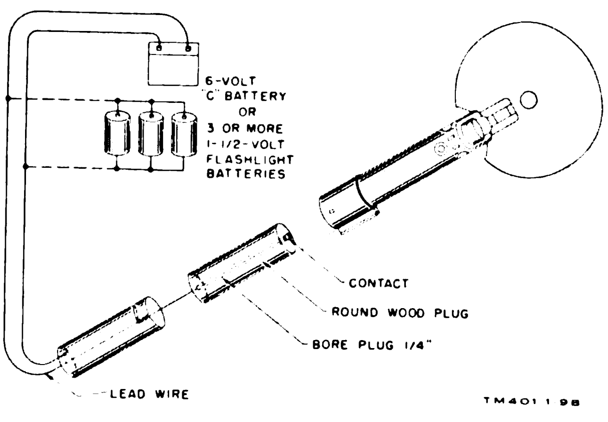


*Figure 9–1. Diagram of winterized flash battery case.*

*c.* When disassembling and preparing cameras for winterization, use the appropriate manual or instruction book. If no publication is available, proceed with caution and make written notes of the part-by-part disassembly of the equipment. Work on a clean table and use receptacles for parts.

*d.* When winterizing photographic equipment, use the same tools as those issued for photographic maintenance.

## 9–16. Lubrication

Lubrication reduces wear and facilitates the operation of moving parts. It provides an oily film over meshing and contacting surfaces of the mechanism and protection against moisture, chemical action, corrosion, and rust. Each lubricant has characteristics that adapt it to a specific job.

*a. Recommended Lubricants.* Table 9–I shows lubricants recommended for winterization of both motion picture and still cameras:

*Table 9–T. Winterization Lubricants*

| Grade symbol | Nomenclature |
| --- | --- |
| Univis P–38 | Oil, low temperature |
| PL-Special | Oil, lubricating, preservative, special. |
| M51–A | Grease, low temperature |
| GL | Grease, lubricating, special |
| GA | Graphite powder |

*b. Preparatory Cleaning.* Before lubricating any equipment for cold weather, completely remove any lubricants previously used. Do this by disassembling the equipment as required, cleaning or flushing affected components with drycleaning solvent, and removing all residue completely. Be sure that the solvent does not come in contact with leather, rubber, fabrics, lenses, and other optical components, and that scum or oily residue does not remain on parts that come in contact with the film.

*c. Procedure.* For complete lubrication information on specific equipments, check the latest lubrication orders for the equipment.

*d. Inspection.* Photographic equipment operated at low temperatures is subject to more than normal wear and oxidation, particularly when treated sparingly with low viscosity lubricants. For this reason, inspect and lubricate the equipment more frequently. Do not operate a camera after all lubricants have been removed, except in an emergency.

## 9–17. Adjustment for Winterization

*a.* To adjust photographic equipment for cold weather operations, proceed as follows:

(1) If possible, select used and free-running equipment for cold weather photography, rather than new and tight equipment.

(2) Clean the equipment thoroughly, since a minute piece of lint in an assembly of closely fitted parts can jam the clearance of the running parts.

(3) Make sure that adjustments do not affect the operating life and effectiveness of the equipment at normal temperatures.

(4) In adjusting the equipment, break in the motor; change spring tensions; and loosen, but do not ream or machine, certain gears and bearings.

*b.* When new or recently overhauled equipment is used, break in the motor before attempting mechanical adjustments. Proceed as follows:

(1) Lubricate the equipment for low temperature operation, and operate for 15 minutes.

(2) Inspect the equipment thoroughly for excessive wear. Then, relubricate and operate for 1 hour or more.

(3) After the equipment has been operating for an hour or more, flush with drycleaning solvent and relubricate for low temperature operation.

(4) When breaking in a precision 35-mm motion picture camera, thread it with a dummy load of fresh, undeveloped, unspliced, negative stock.

## 9–18. Storage

Cold weather conditions, and particularly sudden temperature changes, can have an adverse effect on photographic equipment and film. Therefore, special attention must be given to the storage of photographic items.

*a. General.* When cold photographic equipment or film is brought into a warm place, moisture will condense on the surfaces and cause rusting of the equipment or softening and swelling of the film emulsion. If equipment or film is returned to low temperatures before this moisture has been evaporated or removed, the moisture will freeze and cause damage to equipment or film.

*b. Cameras.* In cold weather, store cameras in an unheated room or on a protected outdoor shelf. When it is necessary to move a camera from a cold to a warm place, make the change gradually.

*c. Lenses.* Sudden temperature changes have a harmful effect on lenses and may cause them to separate or crack.

*d. Film.* Store film at the same temperature as the equipment with which it will be used.

(1) To prevent loss of moisture and consequent shrinkage, keep the film in its original container until it is to be used.

(2) When film is moved to a warm place for development, keep it wrapped and in tightly sealed cans or boxes until it reaches room temperature.

(3) Note that film is not adversely affected by storage at low temperatures.

*e. Storage Batteries.* Keep storage batteries fully charged and at normal room temperature when not in use or when stored overnight.

## 9–19. Handling Equipment

When handling photographic equipment and film at low temperatures, proceed cautionsly.

*a.* Cover camera parts that may come in contact with your face with felt or soft chamois. The skin of your hands and face can stick to cold metal parts, and thereby cause painful and serious injury.

*b.* Wear one or two pairs of cotton or silk gloves under heavy mittens, and remove the mittens for short intervals when adjusting or handling equipment.

*c.* Be careful when loading and handling cold film; it is brittle when cold and can cause serious cuts.

## 9–20. Operating Motion Picture Equipment

Skill and ingenuity of the operator is important in the operation of motion picture camera equipment for any extended period of time; even under ordinary climatic conditions, motion picture cameras may fail. In emergencies, make any adjustments or repairs necessary to obtain the pictorial coverage.

*a. Coverage.* If possible, use a suitable heated shelter when using motion picture cameras that are not adapted to low temperature operations.

*b. Electric Motors.*

(1) Whenever possible, warm up the motor before putting it in use; then, cover it with a jacket of heavy skins or parka material to retain its warmth.

(2) If it is impossible to warm up the motor prior to use, operate the camera by hand until the motor is capable of running by itself. This not only warms up the motor, but also breaks up the initial resistance or surface tension of the camera mechanism.

(3) Since a cold motor will not run at a normal operating speed, check it frequently. Compensate for the loss of operating speed by increasing the motor speed setting and by connecting the battery for higher voltage.

*c. Camera Adjustments.*

(1) Make as few camera adjustments as possible.

(2) Use the wide-angle lens to increase depth of field and simplify focusing and framing.

(3) Check lens calibrations in advance of operations.

(4) Focus according to hyperfocal settings rather than optical devices.

## 9–21. Storage Batteries

Since the output of a storage battery is reduced at low temperatures (fig. 9–2), it is necessary to keep it warm while in storage. To keep a storage battery warm, proceed as follows:

*a.* Place the battery in a light wooden box that has a hinged cover. Make sure that the cover fits closely into the sides of the box and has a seal of rubber or weather stripping.

*b.* Cover the box with two or more layers of insulating material, such as Masonite or Celotex.

*c.* Place a 5-volt lamp and lamp socket inside the box. Connect the 5-volt lamp to the battery to provide enough heat to protect the battery from freezing.

*d.* Wire the electrical connections to a receptacle on the outside of the box.

*e.* Always keep batteries fully charged, since the fluid content of storage batteries becomes more susceptible to freezing when the specific gravity of the solution is reduced by a low charge. The acid content of the electrolyte is lower at low charge, and the freezing point of the solution more nearly approximates that of water (fig. 9–3).

*f.* Never add water to a battery when it is cold, since dilution has the same effect as a low charge. It reduces the specific gravity of the battery electrolyte and raises the freezing point.

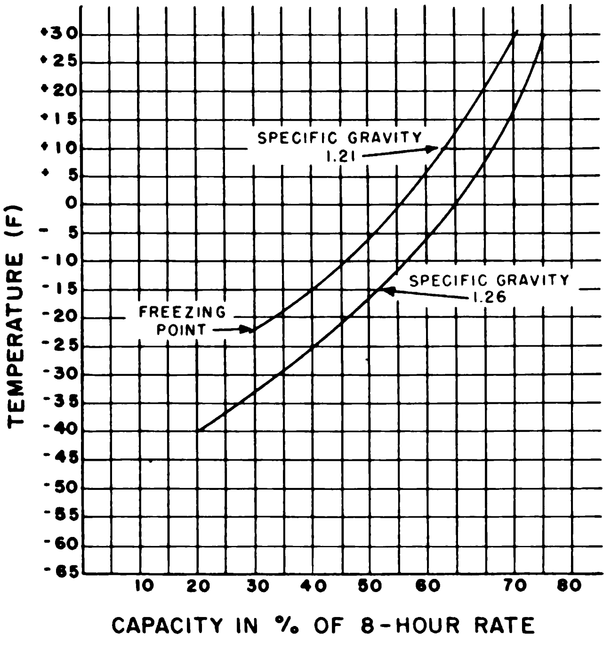


*Figure 9–2. Storage battery capacity at low temperatures.*

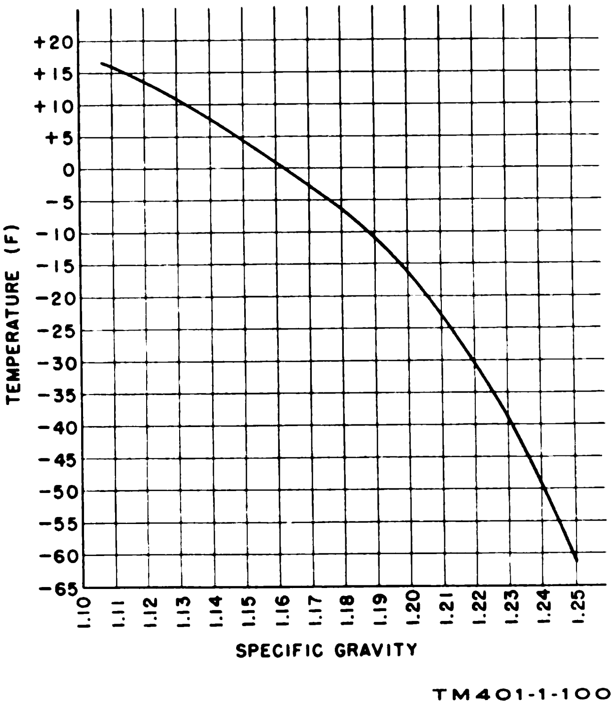


*Figure 9–3. Freezing point of storage battery solutions.*

## 9–22. Lenses

*a. General.*

(1) When working in low temperatures, do not breathe on lenses. This will form frost, and it is quite difficult to remove frost without damaging the lenses.

(2) If mist forms on the interior lens surfaces, remove the front and rear elements and gradually dissipate the moisture between the elements. To do this, warm the shutter housing and the two elements, replace them, and then return the unit to low temperature storage.

*b. Cement.* The multiple lenses in a camera system are generally cemented together. In most cases, lens elements are cemented with Canada balsam, which may check or crack at low temperatures. Other lenses are held together by a synthetic cement that withstands extreme temperatures. Lenses cemented with this synthetic material generally have a yellow dot on the front of the lens; however, some assembled with this cement are not identified in any manner.

*c. Checked Lens.* A checked lens element has an irregular geometrical pattern of straight lines.

(1) A mildly checked lens may produce acceptable definition and should be tested to determine if there is a need for immediate repair.

(2) If there is a definite need for repair, the work should be accomplished, whenever possible, by experienced optical technicians. These technicians will separate the affected elements, remove the checked cement, recement, and reassemble the lens.

(3) If regular repair facilities are not available, the following emergency measures may be tried:

(*a*) Remove the checked lens element and slowly warm it to 160° Fahrenheit. Inspect the lens element frequently.

(*b*) Keep the lens element at 160° Fahrenheit for about 5 minutes after the checking has disappeared. The heating process may melt the balsam and clear the checking within about 30 minutes after the heat has reached 160° Fahrenheit.

(*c*) Turn off the heat about 5 minutes after the lens has cleared, and allow the lens to cool slowly.

(*d*) If the lens does not clear within 1 hour at 160° Fahrenheit, do not continue the treatment. Only an experienced optical technician can solve this lens problem.

## 9–23. Summary

*a.* Preventive and remedial tropicalization procedures can reduce photographic equipment failure in hot temperatures.

*b.* Two primary causes of equipment failures in tropical climates are corrosion and fungus attacks.

*c.* Corrosion is a chemical action that eats away metal.

*d.* Fungus is a parasitic growth that draws nourishment from particles of organic matter in the air or from material on which it rests.

*e.* Most photographic equipments can be adequately protected from tropical hazards by using one of several moistureproofing and fungiproofing processes.

*f.* The lacquer treatment is intended for hard, nonflexible, nonabsorbant surfaces, such as metal, painted wood, and water-resistant or coated nonflexible fabric.

*g.* The Shirland treatment is applied to leather, felt, plush, cloth, linen, and other textiles to make them moisture- and fungus-resistant.

*h.* In tropical combat areas lacking air-conditioned storage facilities, photographic equipment should be stored in a ventilated box heated by a 100-watt lamp, or in an airtight storage chest containing actuated silica gel.

*i.* Most photographic operational difficulties in cold weather involve the camera shutter or the lens.

*j.* Extreme differences in temperatures cause condensation of moisture, which will freeze and cause rust.

*k.* Winterize only that photographic equipment which is normally used oudoors, such as cameras, tripods, batteries, and accessories.

*l.* Store film at the same temperature as the photographic equipment with which it will be used.

## 9–24. Review Questions

*a.* In what ways can the corrosion of photographic equipment be retarded in tropical climates?

*b.* List four ways in which fungus reduces the operating efficiency of photographic equipment.

*c.* List four ways in which tropical deterioration of photographic equipment can be controlled.

*d.* Why is the dubbing process impractical in hot, humid climates?

*e.* Describe how you can determine actual shutter performance in cold temperatures.

*f.* What can you do to make a focal plane shutter more responsive in cold temperatures?

*g.* What is the main reason for operational failure of between-the-lens shutters in cold temperatures?

*h.* Explain the recommended procedure for using miniature cameras under low temperature conditions.

## 9—25. Review Answers

*a.* Corrosion may be retarded by protecting the metal of photographic equipment with a sealing or waterproof coating, such as paint or varnish; by inclosing the metal component in a moistureproof case or housing; or by using protective films of oil or grease.

*b.* Fungus acts in several ways to reduce the operating efficiency of equipment.

(1) It acts as a water collector, and this promotes corrosion.

(2) It releases corrosive byproducts that are capable of etching glass and pitting weather-resistant materials.

(3) It cuts down the efficiency and resolving power of optical systems.

(4) It causes leakage and interference in electrical components.

(5) It slows down or stops delicate mechanisms, such as camera shutters.

*c.* Tropical deterioration may be controlled by—

(1) Exposing equipment to sunlight frequently and for prolonged periods.

(2) Sealing off nutritive materials.

(3) Depriving the fungus moisture.

(4) Applying heat.

(5) Using toxic or fungicidal sprays and varnishes.

*d.* Dubbing is not recommended for use in areas where fungus is prevalent, since the wax contains animal fats and other organic material that can support fungus growth.

*e.* To determine shutter performance in cold temperatures for individual cameras, proceed as follows:

(1) Make a series of test exposures at different speed settings.

(2) Use meter readings at prevailing temperatures with the type of film normally used.

(3) Record the results in a form of chart, and keep the chart with the equipment for easy reference.

*f.* To make a focal plane shutter more responsive in cold temperatures, either operate the shutter at a higher tension or increase the tension of the bottom spring roller from the normal 8 to 12 turns. Before removing the safety slide, operate the shutter several times to break up surface tension and drag.

*g.* The main reason for operational failure of between-the-lens shutters in cold temperatures is moisture that collects and congeals within the shutter housing.

*h.* When using miniature camera under low temperature conditions—

(1) Carry the miniature camera suspended from the neck and under the outer layer of clothing.

(2) Exposure the camera to the outer air only long enough to make one or two exposures. This will keep the camera at a moderate operating temperature.

# APPENDIX I
# REFERENCES

## 1. DA Pamphlets

| | |
|---|---|
| DA Pam 108–1 | Index of Army Motion Pictures, Film Strips, Slides, Tapes, and Phono-Recordings |
| DA Pam 310–4 | Index of Technical Manuals, Technical Bulletins, Supply Manuals (types 7, 8, and 9), Supply Bulletins, Lubrication Orders, and Modification Work Orders |

## 2. Technical Manuals

| | |
|---|---|
| TM 11–415 | Primary Batteries (Dry and Reserve Types) |
| TM 11–487F | Directory of U. S. Army Signal Equipments: Pictorial Equipment |
| TM 11–661 | Electrical Fundamentals, Direct Current |
| TM 11–681 | Electrical Fundamentals, Alternating Current |
| TM 11–6140–203–12 | Operator, and Organizational Maintenance Manual: Nickel-Cadmium Storage Batteries |

## 3. Technical Bulletins

| | |
|---|---|
| TB SIG 158 | Glossary of Principal Photographic Chemicals: Their Properties, Characteristics and Names in Six Languages |
| TB SIG 189 | Cold Weather Photography |
| TB SIG 246 | Stabilization Processing (Photographic) |

## 4. Supply Bulletins

| | |
|---|---|
| SB 11–6 | Dry Battery Supply Data |
| SB 11–30 | Transportation, Storage, Testing, Sheld Life, and Quantity Unit Pack Requisitioning of Dry Batteries |

## 5. Film strips

| | |
|---|---|
| FS 11–65 | The Photographic Negative |
| FS 11–70 | Photographic Chemistry |

## 6. Miscellaneous Films

| | |
|---|---|
| MF 45–9521 | Photo Optics at White Sands |

# APPENDIX II
## LENS FORMULAS

Symbols Used in Formula:

- **F** — The focal length of the lens.
- **o** — Distance of object from the lens.
- **i** — Distance of image from the lens (camera extension in copying, lens-easel distance when enlarging).
- **D** — Distance from object to image, regardless of nodal space.
- **R** — Times of enlargement (linear size of image divided by that of object).
- **r** — Times of reduction (linear size of object divided by that of image).

*Focal Length*

1. $F = \frac{o \times R}{R + 1} = \frac{o}{r + 1}$

2. $F = \frac{i}{R + 1} = \frac{i}{r + 1}$

3. $F = \frac{D \times R}{(R + 1)^2} = \frac{D \times r}{(r + 1)^2}$

4. $F = \frac{D}{R + 2} = \frac{D}{r + 2}$ (Approx.)

5. $F = \frac{o \times i}{D}$

*Distance of Object From Lens*

6. $o = \frac{i}{R} = i \times r$

7. $o = \frac{F}{R} + F = (r + 1) \times F$

8. $o = \frac{F \times i}{i - f}$

9. $o = \frac{D}{R + 1} = \frac{r \times D}{r + 1}$

*Distance of Image From Lens*

10. $i = o \times R = \frac{o}{r}$

11. $i = (F \times R) + f = \frac{f}{r} + f$

12. $i = \frac{F \times o}{o - F}$

13. $i = \frac{R \times D}{R + 1} = \frac{D}{r + 1}$

*Object Image Distance*

14. $D = F \times \left(R + \frac{1}{R} + 2\right) = F \times \left(r + \frac{1}{r} + 2\right)$

15. $D = \frac{F \times (R + 1)^2}{R} = \frac{F \times (r + 1)^2}{r}$

16. $D = F \times (R + 2) = F \times (r + 2)$ (Approx.)

17. $D = \frac{i \times (R + 1)}{R}$ $i \times (r + 1)$

18. $D = o \times (R + 1) = \frac{o \times (r + 1)}{r}$

# APPENDIX III

## IDENTIFICATION OF FILM

# APPENDIX IV

# HYPERFOCAL DISTANCE TABLES

The following tables are provided to simplify selection of data for the more common focal lengths of lenses used in military photography.

*a. Hyperfocal Distance and Death of Field of 2 inch Lenses at Various Apertures.* The data in this table are based on a 1/1,000-inch circle of confusion.

*Table III–1. Identification of Aerial Roll Films*

| Type | Class | Description of film class | Commercial designation | Manufacture's code number |
|---|---|---|---|---|
| IA | G–2 | Blue sensitive, aerial duplicating, topographic. | Eastman "Aerographic Duplicating Film" | 5227 |
| IB | G–2 | Blue sensitive, aerial duplicating, reconnaissance base. | Eastman "Aerial Duplicating Film (RP)" | 8227 |
| | | | "DuPont Aerial Duplicating Film" | 228 |
| IA | A | Panchromatic sensitive, regular speed, topographic base. | Eastman "Aerial Plus-X Aerographic Film" | SO–1159 |
| IB | A | Panchromatic sensitive, regular speed, reconnaissance base. | Eastman "Aerial Plus-X (RP)" | 8401 |
| IC | A | Panchromatic sensitive, regular speed, thin base. | Eastman "Aerial Plus-X, Thin Base" | 8402 |
| IA | K–1 | Infrared, high speed | "Kodak Infrared, Aerographic" | H–5224 |
| IA | L | Panchromatic, high speed, topographic base. | "Aerographic Super-XX, Topographic Base" | 5225 |
| IB | L | Panchromatic, high speed, reconnaissance base. | "Kodak Super-XX, Aerial Recon (RP)" | 8226 |
| | | | "Ansco Triple-S Pan Aerial" | 2241 |
| IB | N | Panchromatic, extra high speed, reconnaissance base. | "Kodak Aerecon Tri-X (RP)" | 8403 |
| I | ------ | Camouflage detection film, aerial. | Eastman "Aero Ektachrome, Camouflage Detection" | SO– 456 |

*Table III–2. Identification of 35-MM Motion Picture Films*

| Type | Class | Description of film class | Commercial designation | Manufacture's code number |
|---|---|---|---|---|
| II | A | Panchromatic, regular speed | Eastman "Plus-X Panchromatic Negative" | 5231 |
| | | | "Ansco Supreme" | 453 |
| | | | "DuPont Superior 2" | 9268 |
| II | C | Panchromatic, low speed | Eastman "Background-X Panchromatic Negative" | 5230 |
| | | | "DuPont Superior 1 Fine Grain Panchromatic" | 904B |
| II | D | Orthochromatic, regular speed | Eastman "Linagraph Ortho" (gray and clear base) | 5211 and 7211 |
| | | | "Ansco Plenachrome, 35-mm" | 2261 |

*Table III-2. Identification of 35-MM Motion Picture Films—Continued*

| Type | Class | Description of film class | Commercial designation | Manufacture's code number |
|---|---|---|---|---|
| II | F | Sound recording, variable area | Eastman "Fine Grain Sound Recording" | 5372 |
| | | | "DuPont Fine Grain Sound Recording, V.A." | 831B |
| II | F-1 | Sound recording variable density. | Eastman "Fine Grain Sound Recording" | 5373 |
| | | | "DuPont Fine Grain Safety Sound Recording" | 836B |
| II | G | Blue sensitive, release positive | Eastman "Fine Grain Release Positive Safety Film" | 5302 |
| | | | "DuPont Fine Grain Release Positive" | 852B |
| II | G-1 | Blue sensitive, master positive | Eastman "Fine Grain Duplicating Positive" | 5365 |
| | | | "DuPont Fine Grain Master Positive" | 828B |
| II | J | Panchromatic, duplicating | Eastman "Fine Grain Panchromatic Duplicating Negative Safety Film" | 5203 |
| | | | "DuPont Fine Grain Duplicating Negative" | 908B |
| II | K | Infrared | Eastman "Infrared Negative Safety Film" | 5210 |
| II | K-1 | Infrared, high speed | Eastman "High Speed Infrared Negative Safety Film" | ---------- |
| II | L | Panchromatic, high speed | "Ansco 35-mm, Ultra Speed Pan" | 456 |
| | | | "DuPont Superior 3 Negative Film" | 927B |
| II | N | Panchromatic, extra high speed. | Eastman "Tri-X Panchromatic Negative" | 5233 |
| | | | "DuPont Superior 4 Negative Film" | 928B |
| II | Q | Panchromatic, low speed high contrast. | "Kodak Linagraph Shellburst Pan" (gray base) | 5214 |
| | | | "Kodak Linagraph Shellburst Pan" (clear base) | 7214 |

*Table III-3. Identification of 16-MM Motion Picture Films*

| Type | Class | Description of film class | Commercial designation | Manufacture's code number |
|---|---|---|---|---|
| III | A | Panchromatic, regular speed | "DuPont Superior 2" | 901A |
| III | A-2 | Panchromatic, regular speed, negative or reversal, processed by using activity. | Eastman "Plus-X Blue Base Reversal" | 5276 |
| | | | "DuPont Superior 2" | 901A |
| III | C | Panchromatic, low speed | Eastman "Background-X Panchromatic Negative Safety Film" | 7230 |
| | | | "DuPont Superior 1" | 904A |
| III | F | Sound recording, variable area | Eastman "Fine Grain Sound Recording Safety Film" | 7372 |
| III | F-1 | Sound recording, variable density. | Eastman "Fine Grain Sound Recording Safety film" | 7373 |
| III | G | Blue sensitive, release positive | Eastman "Fine Grain Release Positive Safety Film" | 7302 |
| | | | "DuPont Fine Grain Release Positive | 825A |
| III | G-1 | Blue sensitive, master positive | Eastman "Fine Grain Duplicating Positive" | 7365 |
| | | | "DuPont Fine Grain Master Positive" | 828A |
| III | J | Panchromatic duplicating | Eastman "Fine Grain Panchromatic Duplicating Negative Safety" | 7203 |
| | | | "DuPont Fine Grain Duplicating Negative" | 908A |

*Table III–3. Identification of 16–MM Motion Picture Films—Continued*

| Type | Class | Description of film class | Commercial designation | Manufacture's code number |
|---|---|---|---|---|
| III | K–1 | Infrared, high speed | Eastman "High Speed Infrared Negative Safety Film" | ---------- |
| III | L–2 | Panchromatic, high speed, negative or reversal, processed by using activity. | "DuPont High Speed Rapid Reversal" | 931A |
| III | N–2 | Panchromatic, extra high speed, negative or reversal, processed by using activity. | Eastman "Tri-X Reversal Film" | 5278 |

*Table III–4. Identification of Roll Films*

| Type | Class | Description of film class | Commercial designation | Manufacture's code number |
|---|---|---|---|---|
| IV | A | Panchromatic, regular speed | "Kodak Plus-X Panchromatic Film, 35-mm" | 5241 |
| | | | Eastman "Verichrome Pan Film" | 6013 |
| | | | "Ansco Supreme, 35-mm | 264 |
| | | | "Ansco All Weather Pan Film" | ---------- |
| IV | C | Panchromatic, low speed | "Kodak Panatomic-X Film, 35-mm" | 5240 |
| | | | "Kodak Panatomic-X Film" (rolls) | 6020 |
| IV | K | Infrared | "Kodak Infrared Film, 35-mm" | 5212 |
| IV | L | Panchromatic, high speed | "Ansco Ultra-Speed Pan Film, 35-mm" | 456 |
| | | | "Ansco Superpan Press" (rolls) | 267 |
| IV | N | Panchromatic, extra high speed | "Kodak Tri-X Film, 35-mm" | 5243 |
| | | | "Kodak Tri-X Film" (rolls) | 6043 |
| IV | R | Panchromatic, ultra high speed. | "Kodak Royal-X Pan Film" (120 and 620 size) | 6045 |

*Table III–5. Identification of Sheet Films*

| Type | Class | Description of film class | Commercial designation | Manufacture's code number |
|---|---|---|---|---|
| V | A | Panchromatic, regular speed | Kodak Portrait Panchromatic Film | 6114 |
| | | | Ansco Isopan and Superpan Portrait Films. | 282 and 288 |
| | | | DuPont X-F Pan | 416 |
| V | B | Orthochromatic, high speed | Ansco Triple-S Ortho | 281 |
| | | | DuPont High Speed Ortho | ---------- |
| V | B–1 | Orthochromatic, extra high speed. | Kodak Royal Ortho Film | 6144 |
| | | | DuPont Fine Grain Pan Film | 418 |
| V | D | Orthochromatic, regular speed. | Kodak Super Speed Ortho Portrait Film | 6122 |
| | | | DuPont X-F Ortho Film | 421 |
| V | E | Orthochromatic, process, high contrast. | Kodak Contrast Process Ortho Film | 6111 |
| | | | Ansco Process Ortho Film | 200 |
| V | E–1 | Orthochromatic, process, medium contrast. | Kodak Commercial Ortho Film | 6107 |
| | | | Ansco Commercial Ortho Film | ---------- |
| V | H | Panchromatic, process, high contrast. | Kodak Contrast Process Panchromatic Film | 6112 |
| | | | DuPont Process Pan | 420 |
| V | K | Infrared | Kodak Infrared Film | 6130 |
| V | K–1 | Infrared, high speed | Kodak High Speed Infrared Film | ---------- |
| V | L | Panchromatic, high speed | Kodak Super-XX Panchromatic Film | 6142 |
| | | | Kodak Super Panchro-Press Film, Type B | 6146 |
| | | | Ansco Superpan Press Film | ---------- |
| | | | DuPont High Speed Film | 428 |

*Table III–5. Identification of Sheet Films*

| Type | Class | Description of film class | Commercial designation | Manufacture's code number |
|---|---|---|---|---|
| V | N | Panchromatic, extra high speed. | Kodak Royal Pan Film | 6141 |
| | | | Kodak Tri-X Panchromatic Film | 6143 |
| | | | Ansco Triple-S Pan Film | 285 |
| | | | DuPont Arrow Pan Film | |
| V | P | Blue sensitive, low speed, high contrast. | Kodak Aerial Positive Film | 5574 |
| | | | Kodak Commercial Film | 6124 |
| | | | Ansco Commercial Film | |
| | | | DuPont Commercial Film | |
| V | R | Panchromatic, ultra high speed. | Kodak Royal-X Pan Film | |

*Table III–6. Identification of Film Packs*

| Type | Class | Description of film class | Commercial designation | Manufacture's code number |
|---|---|---|---|---|
| VI | A | Panchromatic, regular speed | Kodak Verichrome Pan Film | 6014 |
| | | | Ansco Supreme | 464 |
| VI | L | Panchromatic, high speed | Ansco Supreme Press | 467 |
| VI | N | Panchromatic, extra high speed. | Kodak Tri-X Film | 6044 |
| VI | R | Panchromatic, ultra high speed. | Kodak Royal-X Pan Pack Film | 6046 |

*Table III–7. Identification of Photomechanical Films*

| Type | Class | Description of film class | Commercial designation | Manufacture's code number |
|---|---|---|---|---|
| VIIA | E | Orthochromatic, process, high contrast, low shrinkage base. | Kodalith Ortho, Type II | 6553 |
| VIIA | H | Panchromatic, process, high contrast, low shrinkage base. | Kodalith Panchromatic | 6562 |
| VIIA–1 | E | Orthochromatic, process, high contrast, extra low shrinkage base. | | |
| VIIA–1 | H | Panchromatic, process, high contrast, extra low shrinkage base. | | |
| VIIC | E | Orthochromatic, process, high contrast, thin base. | Kodalith Ortho, Type II, Thin Base | 6558 |
| VIID | E | Orthochromatic, process, high contrast, stripping base. | Kodalith Transparent Stripping Film | 6559 |
| | | | Defender Litho (stripping) | |

*Table IV–1. Hyperfocal Distance and Depth of Field of 2-Inch Lenses at Various Apertures*

| Lens aperture | Hyperfocal distance (ft) | Focus (ft) | Depth of field | |
|---|---|---|---|---|
| | | | From— | To— |
| f/2 | 166 | 166 | 83 | Inf. |
| 2.8 | 119 | 119 | 59 | Inf. |
| 3.5 | 95 | 95 | 47 | Inf. |
| 4.5 | 74 | 74 | 37 | Inf. |
| 5.6 | 59 | 59 | 29 | Inf. |
| 6.3 | 52 | 52 | 26 | Inf. |
| 8 | 41 | 41 | 20 | Inf. |
| 11 | 30 | 30 | 15 | Inf. |
| 16 | 20 | 20 | 10 | Inf. |
| 22 | 15 | 15 | 7 | Inf. |
| 32 | 10 | 10 | 5 | Inf. |

*b. Hyperfocal Distance and Depth of Field of 5-Inch Lenses at Various Apertures.* The data in this table are based on a 1/250-inch circle of confusion.

*Table IV–2. Hyperfocal Distance and Depth of Field of 5-Inch Lenses at Various Apertures*

| Lens aperture | Hyperfocal distance (ft) | Focus (ft) | Sharp (ft) | |
|---|---|---|---|---|
| | | | From— | To— |
| 4.5 | 116 | 116 | 58 | Inf. |
| 5.6 | 93 | 93 | 47 | Inf. |
| 6.3 | 69 | 69 | 34 | Inf. |
| 8 | 65 | 65 | 32 | Inf. |
| 11 | 47 | 47 | 23 | Inf. |
| 16 | 32 | 32 | 16 | Inf. |
| 22 | 24 | 24 | 12 | Inf. |
| 32 | 16 | 16 | 8 | Inf. |

*c. Hyperfocal Distance and Depth of Field of 6-Inch Lenses at Various Apertures.* The data in this table are based on a 1/250-inch circle of confusion.

*Table IV–3. Hyperfocal Distance and Depth of Field of 6-Inch Lenses at Various Apertures*

| Lens aperture | Hyperfocal distance (ft) | Focus (ft) | Sharp (ft) | |
|---|---|---|---|---|
| | | | From— | To— |
| f/4.5 | 166 | 166 | 83 | Inf. |
| 5.6 | 148 | 148 | 74 | Inf. |
| 6.3 | 119 | 119 | 59 | Inf. |
| 8 | 94 | 94 | 47 | Inf. |
| 11 | 68 | 68 | 34 | Inf. |
| 16 | 47 | 47 | 23 | Inf. |
| 22 | 34 | 34 | 17 | Inf. |
| 32 | 23 | 23 | 11 | Inf. |

*d. Hyperfocal Distance and Depth of Field of 10-Inch Lenses at Various Apertures.* The data in this table are based on a 1/100-inch circle of confusion.

*Table IV–4. Hyperfocal Distance and Depth of Field of 10-Inch Lenses at Various Apertures*

| Lens aperture | Hyperfocal distance (ft) | Focus (ft) | Sharp (ft) | |
|---|---|---|---|---|
| | | | From— | To— |
| 4.5 | 185 | 185 | 93 | Inf. |
| 5.6 | 149 | 149 | 75 | Inf. |
| 6.3 | 132 | 132 | 66 | Inf. |
| 8 | 104 | 104 | 52 | Inf. |
| 11 | 83 | 83 | 42 | Inf. |
| 16 | 52 | 52 | 26 | Inf. |
| 22 | 38 | 38 | 19 | Inf. |
| 32 | 26 | 26 | 13 | Inf. |

# APPENDIX V

## DEPTH OF FIELD TABLES

*a. Depth of Field Table for 2-Inch Lenses.* The data in this table is based on a 1/1,000-inch circle of confusion.

*Table V–1. Depth of Field Table for 2-Inch Lenses*

| Distance focused | f/2 | | | | f/2.8 | | | | f/3.5 | | | | f/4 | | | | f/5.6 | | | | f/8 | | | | f/11 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feet | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. |
| | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | |
| 3 | 2 | 11 | 3 | ½ | 2 | 11 | 3 | ¾ | 2 | 11 | 3 | 1 | 2 | 11 | 3 | 1 | 2 | 10 | 3 | 2 | 2 | 9 | 3 | 3 | 2 | 9 | 3 | 4 |
| 4 | 3 | 11 | 4 | 2 | 3 | 10 | 4 | 2 | 3 | 10 | 4 | 2 | 3 | 9 | 4 | 2 | 3 | 8 | 4 | 3 | 3 | 8 | 4 | 5 | 3 | 6 | 4 | 7 |
| 5 | 4 | 10 | 5 | 2 | 4 | 9 | 5 | 3 | 4 | 9 | 5 | 3 | 4 | 8 | 5 | 4 | 4 | 7 | 5 | 5 | 4 | 6 | 5 | 8 | 4 | 3 | 6 | 0 |
| 6 | 5 | 9 | 6 | 3 | 5 | 9 | 6 | 4 | 5 | 8 | 6 | 5 | 5 | 7 | 6 | 6 | 5 | 5 | 6 | 8 | 5 | 3 | 7 | 0 | 5 | 0 | 7 | 6 |
| 7 | 6 | 8 | 7 | 4 | 6 | 7 | 7 | 5 | 6 | 6 | 7 | 7 | 6 | 5 | 7 | 8 | 6 | 3 | 7 | 11 | 6 | 0 | 8 | 5 | 5 | 8 | 9 | 1 |
| 8 | 7 | 8 | 8 | 5 | 7 | 6 | 8 | 7 | 7 | 5 | 8 | 9 | 7 | 3 | 8 | 10 | 7 | 1 | 9 | 3 | 6 | 9 | 9 | 11 | 6 | 4 | 10 | 10 |
| 9 | 8 | 6 | 9 | 6 | 8 | 4 | 9 | 9 | 8 | 3 | 9 | 11 | 8 | 1 | 10 | 1 | 7 | 10 | 10 | 7 | 7 | 5 | 11 | 6 | 7 | 0 | 12 | 10 |
| 10 | 9 | 5 | 10 | 8 | 9 | 3 | 10 | 11 | 9 | 0 | 11 | 2 | 8 | 11 | 11 | 4 | 8 | 7 | 12 | 0 | 8 | 1 | 13 | 2 | 7 | 6 | 14 | 11 |
| 12 | 11 | 2 | 12 | 11 | 10 | 9 | 13 | 4 | 10 | 8 | 13 | 9 | 10 | 6 | 14 | 0 | 10 | 0 | 15 | 3 | 9 | 4 | 16 | 10 | 8 | 7 | 19 | 10 |
| 14 | 12 | 11 | 15 | 3 | 12 | 6 | 15 | 10 | 12 | 2 | 16 | 5 | 12 | 0 | 16 | 10 | 11 | 4 | 18 | 5 | 10 | 6 | 21 | 1 | 9 | 7 | 26 | 0 |
| 16 | 14 | 7 | 17 | 8 | 14 | 1 | 18 | 6 | 13 | 7 | 19 | 3 | 13 | 5 | 19 | 10 | 12 | 7 | 22 | 0 | 11 | 7 | 26 | 0 | 10 | 6 | 33 | 9 |
| 18 | 16 | 3 | 20 | 2 | 15 | 8 | 21 | 2 | 15 | 2 | 22 | 2 | 14 | 9 | 22 | 11 | 13 | 10 | 25 | 10 | 12 | 7 | 31 | 8 | 11 | 3 | 44 | 4 |
| 20 | 17 | 10 | 22 | 9 | 17 | 1 | 24 | 0 | 16 | 6 | 25 | 4 | 16 | 1 | 26 | 4 | 15 | 0 | 30 | 1 | 13 | 6 | 38 | 6 | 12 | 0 | 58 | 10 |
| 25 | 21 | 3 | 29 | 5 | 20 | 8 | 31 | 8 | 19 | 10 | 33 | 11 | 19 | 3 | 35 | 9 | 17 | 7 | 41 | 11 | 15 | 7 | 62 | 6 | 13 | 8 | 143 | 0 |
| 30 | 25 | 5 | 36 | 7 | 23 | 11 | 40 | 1 | 22 | 10 | 43 | 9 | 22 | 1 | 46 | 10 | 19 | 11 | 60 | 6 | 17 | 5 | 107 | 2 | 15 | 1 | Inf. | |
| 35 | 28 | 11 | 44 | 4 | 27 | 0 | 49 | 7 | 25 | 7 | 55 | 4 | 24 | 8 | 60 | 4 | 21 | 1 | 81 | 3 | 19 | 0 | 218 | 11 | 16 | 3 | Inf. | |
| 40 | 32 | 3 | 52 | 8 | 29 | 11 | 60 | 3 | 28 | 2 | 69 | 0 | 27 | 0 | 76 | 11 | 23 | 11 | 121 | 11 | 20 | 5 | 1,003 | 10 | 17 | 3 | Inf. | |
| 45 | 35 | 5 | 61 | 8 | 32 | 8 | 72 | 4 | 30 | 6 | 85 | 4 | 29 | 3 | 97 | 10 | 25 | 9 | 184 | 6 | 21 | 8 | Inf. | | 18 | 1 | Inf. | |
| 50 | 38 | 6 | 71 | 5 | 35 | 2 | 86 | 3 | 32 | 9 | 105 | 3 | 31 | 3 | 125 | 0 | 27 | 2 | 312 | 7 | 22 | 9 | Inf. | | 18 | 10 | Inf. | |
| 60 | 44 | 1 | 93 | 9 | 39 | 4 | 121 | 0 | 36 | 10 | 162 | 2 | 34 | 11 | 214 | 4 | 29 | 10 | Inf. | | 24 | 7 | Inf. | | 20 | 2 | Inf. | |
| 75 | 51 | 9 | 136 | 4 | 46 | 0 | 202 | 10 | 41 | 11 | 353 | 1 | 39 | 6 | 750 | 3 | 33 | 2 | Inf. | | 26 | 9 | Inf. | | 21 | 6 | Inf. | |
| 100 | 62 | 6 | 250 | 0 | 54 | 4 | 626 | 4 | 48 | 9 | Inf. | | 45 | 5 | Inf. | | 37 | 4 | Inf. | | 29 | 5 | Inf. | | 23 | 3 | Inf. | |

*b. Depth of Field Table for 3-inch Lenses.* The data in this table are based on 1/500-circle of confusion.

*Table V-2. Depth of Field Table for 3-Inch Lenses*

| Distance focused | f/2.8 | | | | f/3.5 | | | | f/4.5 | | | | f/5.6 | | | | f/8 | | | | f/11 | | | | f/16 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feet | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. |
| | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | |
| 3 | 2 | 11 | 3 | 1 | 2 | 11 | 3 | 1 | 2 | 10 | 3 | 1 | 2 | 10 | 3 | 2 | 2 | 10 | 3 | 2 | 2 | 9 | 3 | 3 | 2 | 8 | 3 | 5 |
| 4 | 3 | 11 | 4 | 1 | 3 | 10 | 4 | 2 | 3 | 10 | 4 | 2 | 3 | 9 | 4 | 3 | 3 | 8 | 4 | 4 | 3 | 7 | 4 | 6 | 3 | 5 | 4 | 10 |
| 5 | 4 | 10 | 5 | 2 | 4 | 9 | 5 | 3 | 4 | 9 | 5 | 4 | 4 | 8 | 5 | 5 | 4 | 6 | 5 | 7 | 4 | 4 | 5 | 10 | 4 | 1 | 6 | 4 |
| 6 | 5 | 9 | 6 | 3 | 5 | 8 | 6 | 4 | 5 | 7 | 6 | 6 | 5 | 6 | 6 | 7 | 5 | 4 | 6 | 11 | 5 | 1 | 7 | 3 | 4 | 9 | 8 | 1 |
| 7 | 6 | 8 | 7 | 5 | 6 | 7 | 7 | 6 | 6 | 5 | 7 | 8 | 6 | 4 | 7 | 10 | 6 | 1 | 8 | 3 | 5 | 10 | 8 | 10 | 5 | 5 | 10 | 0 |
| 8 | 7 | 6 | 8 | 6 | 7 | 5 | 8 | 8 | 7 | 3 | 8 | 10 | 7 | 2 | 9 | 1 | 7 | 0 | 9 | 11 | 6 | 6 | 10 | 5 | 6 | 0 | 12 | 2 |
| 9 | 8 | 5 | 9 | 8 | 8 | 4 | 9 | 10 | 8 | 1 | 10 | 1 | 7 | 11 | 10 | 5 | 6 | 0 | 11 | 2 | 7 | 1 | 12 | 3 | 6 | 6 | 14 | 6 |
| 10 | 9 | 4 | 10 | 10 | 9 | 2 | 11 | 0 | 8 | 11 | 11 | 4 | 8 | 8 | 11 | 9 | 8 | 3 | 12 | 8 | 7 | 9 | 14 | 2 | 7 | 0 | 17 | 5 |
| 12 | 11 | 0 | 13 | 2 | 10 | 9 | 13 | 6 | 10 | 6 | 14 | 0 | 10 | 2 | 14 | 7 | 9 | 7 | 16 | 1 | 8 | 10 | 18 | 6 | 7 | 11 | 24 | 7 |
| 14 | 12 | 8 | 15 | 8 | 12 | 5 | 16 | 1 | 12 | 0 | 16 | 10 | 10 | 4 | 17 | 8 | 10 | 9 | 20 | 0 | 9 | 11 | 23 | 3 | 8 | 9 | 34 | 9 |
| 16 | 14 | 3 | 18 | 2 | 13 | 11 | 18 | 10 | 13 | 5 | 19 | 10 | 12 | 11 | 21 | 0 | 11 | 11 | 24 | 3 | 10 | 11 | 30 | 2 | 9 | 6 | 50 | 5 |
| 18 | 15 | 10 | 20 | 9 | 15 | 5 | 21 | 7 | 14 | 10 | 22 | 11 | 14 | 2 | 24 | 7 | 13 | 0 | 29 | 3 | 11 | 9 | 34 | 5 | 10 | 2 | 77 | 8 |
| 20 | 17 | 5 | 23 | 6 | 16 | 10 | 24 | 7 | 16 | 1 | 26 | 4 | 15 | 5 | 28 | 9 | 14 | 0 | 34 | 11 | 12 | 7 | 40 | 7 | 10 | 9 | 136 | 7 |
| 25 | 21 | 1 | 30 | 9 | 20 | 3 | 32 | 7 | 19 | 3 | 35 | 9 | 18 | 2 | 39 | 11 | 16 | 4 | 53 | 7 | 14 | 5 | 93 | 9 | 12 | 1 | | Inf. |
| 30 | 24 | 6 | 38 | 8 | 23 | 5 | 41 | 8 | 22 | 1 | 46 | 10 | 20 | 9 | 54 | 4 | 18 | 3 | 83 | 4 | 15 | 11 | 250 | 0 | 13 | 2 | | Inf. |
| 35 | 27 | 9 | 47 | 5 | 26 | 5 | 52 | 0 | 24 | 8 | 60 | 4 | 22 | 11 | 73 | 4 | 20 | 0 | 138 | 2 | 17 | 3 | | Inf. | 14 | 0 | | Inf. |
| 40 | 30 | 10 | 57 | 0 | 29 | 1 | 63 | 10 | 27 | 3 | 76 | 11 | 25 | 0 | 99 | 4 | 21 | 7 | 287 | 5 | 17 | 6 | | Inf. | 14 | 9 | | Inf. |
| 45 | 33 | 8 | 67 | 9 | 31 | 8 | 77 | 7 | 29 | 3 | 97 | 10 | 26 | 11 | 137 | 3 | 22 | 10 | 1,127 | 11 | 19 | 4 | | Inf. | 15 | 5 | | Inf. |
| 50 | 36 | 5 | 79 | 9 | 34 | 1 | 93 | 9 | 31 | 3 | 125 | 0 | 28 | 7 | 197 | 5 | 24 | 2 | | Inf. | 20 | 3 | | Inf. | 15 | 11 | | Inf. |
| 60 | 41 | 5 | 108 | 8 | 38 | 5 | 136 | 4 | 34 | 11 | 214 | 4 | 31 | 8 | 577 | 3 | 26 | 4 | | Inf. | 21 | 9 | | Inf. | 16 | 10 | | Inf. |
| 75 | 48 | 1 | 170 | 3 | 44 | 1 | 250 | 0 | 39 | 6 | 760 | 3 | 35 | 5 | | Inf. | 28 | 10 | | Inf. | 23 | 5 | | Inf. | 17 | 10 | | Inf. |
| 100 | 57 | 3 | 394 | 10 | 51 | 9 | 1,500 | 0 | 45 | 5 | | Inf. | 41 | 0 | | Inf. | 31 | 11 | | Inf. | 25 | 5 | | Inf. | 19 | 0 | | Inf. |

*c. Depth of Field Table for 4-Inch Lenses.* The data in this table are based on a 1/250-inch circle of confusion.

*Table V–3. Depth of Field Table for 4-Inch Lenses*

| Distance focused | f/3.5 | | | | f/4.5 | | | | f/5.6 | | | | f/8 | | | | f/11 | | | | f/16 | | | | f/22 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feet | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In |
| | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | |
| 3 | 2 | 11 | 3 | 1 | 2 | 11 | 3 | 1 | 2 | 10 | 3 | 2 | 2 | 9 | 3 | 3 | 2 | 9 | 3 | 4 | 2 | 7 | 3 | 6 | 2 | 6 | 3 | 9 |
| 4 | 3 | 10 | 4 | 2 | 3 | 9 | 4 | 3 | 3 | 9 | 4 | 3 | 3 | 8 | 4 | 5 | 3 | 6 | 4 | 7 | 3 | 4 | 4 | 11 | 3 | 2 | 5 | 5 |
| 5 | 4 | 4 | 5 | 3 | 4 | 4 | 5 | 4 | 4 | 7 | 5 | 5 | 4 | 6 | 5 | 8 | 4 | 3 | 6 | 0 | 4 | 0 | 6 | 7 | 3 | 9 | 7 | 6 |
| 6 | 5 | 8 | 6 | 5 | 5 | 7 | 6 | 6 | 5 | 5 | 6 | 8 | 5 | 2 | 7 | 0 | 5 | 0 | 7 | 6 | 4 | 8 | 8 | 5 | 4 | 3 | 9 | 11 |
| 7 | 6 | 6 | 7 | 7 | 6 | 5 | 7 | 9 | 6 | 3 | 7 | 11 | 6 | 0 | 8 | 5 | 5 | 8 | 9 | 1 | 5 | 3 | 10 | 6 | 4 | 9 | 13 | 0 |
| 8 | 7 | 5 | 8 | 9 | 7 | 3 | 9 | 0 | 7 | 1 | 9 | 3 | 6 | 9 | 9 | 11 | 6 | 4 | 10 | 10 | 5 | 9 | 13 | 0 | 5 | 3 | 16 | 11 |
| 9 | 8 | 3 | 9 | 11 | 8 | 0 | 10 | 3 | 7 | 10 | 10 | 7 | 7 | 5 | 11 | 2 | 6 | 11 | 12 | 10 | 6 | 3 | 15 | 10 | 5 | 7 | 22 | 2 |
| 10 | 9 | 0 | 11 | 2 | 8 | 10 | 11 | 6 | 8 | 7 | 12 | 0 | 8 | 1 | 13 | 2 | 7 | 6 | 14 | 11 | 6 | 9 | 19 | 3 | 6 | 0 | 29 | 5 |
| 12 | 10 | 8 | 13 | 9 | 10 | 4 | 14 | 4 | 10 | 0 | 15 | 0 | 9 | 4 | 16 | 10 | 8 | 7 | 19 | 10 | 7 | 7 | 28 | 4 | 6 | 8 | 57 | 9 |
| 14 | 12 | 2 | 16 | 5 | 11 | 9 | 17 | 3 | 11 | 4 | 18 | 4 | 10 | 6 | 21 | 1 | 9 | 7 | 26 | 0 | 8 | 4 | 42 | 9 | 7 | 3 | 184 | 5 |
| 16 | 13 | 8 | 19 | 3 | 13 | 2 | 20 | 5 | 12 | 7 | 21 | 11 | 11 | 7 | 26 | 0 | 10 | 6 | 33 | 2 | 9 | 0 | 69 | 1 | 7 | 9 | | Inf. |
| 18 | 15 | 2 | 22 | 2 | 14 | 6 | 23 | 9 | 13 | 10 | 25 | 10 | 12 | 7 | 31 | 8 | 11 | 3 | 44 | 4 | 9 | 8 | 132 | 11 | 8 | 3 | | Inf. |
| 20 | 16 | 6 | 25 | 4 | 15 | 9 | 27 | 5 | 15 | 0 | 30 | 1 | 13 | 6 | 38 | 6 | 12 | 0 | 58 | 10 | 10 | 2 | 507 | 10 | 8 | 7 | | Inf. |
| 25 | 19 | 10 | 33 | 11 | 18 | 8 | 37 | 9 | 17 | 7 | 43 | 1 | 15 | 7 | 62 | 6 | 13 | 8 | 142 | 11 | 11 | 4 | | Inf. | 9 | 6 | | Inf. |
| 30 | 22 | 10 | 43 | 9 | 21 | 4 | 50 | 5 | 19 | 11 | 60 | 6 | 17 | 5 | 129 | 3 | 15 | 1 | 3,030 | 0 | 12 | 3 | | Inf. | 10 | 1 | | Inf. |
| 35 | 25 | 7 | 55 | 4 | 23 | 9 | 66 | 4 | 23 | 0 | 84 | 11 | 19 | 0 | 218 | 11 | 16 | 3 | | Inf. | 13 | 1 | | Inf. | 10 | 7 | | Inf. |
| 40 | 28 | 2 | 69 | 0 | 26 | 0 | 87 | 0 | 23 | 11 | 122 | 0 | 20 | 5 | 1,003 | 10 | 17 | 3 | | Inf. | 13 | 8 | | Inf. | 11 | 0 | | Inf. |
| 45 | 30 | 7 | 85 | 4 | 28 | 0 | 114 | 8 | 25 | 7 | 184 | 6 | 21 | 8 | | Inf. | 18 | 1 | | Irf. | 14 | 3 | | Inf. | 11 | 4 | | Inf. |
| 50 | 32 | 9 | 105 | 3 | 29 | 10 | 153 | 10 | 27 | 2 | 323 | 3 | 22 | 9 | | Inf. | 18 | 10 | | Irf. | 14 | 8 | | Inf. | 11 | 7 | | Inf. |
| 60 | 36 | 10 | 162 | 2 | 33 | 2 | 315 | 10 | 29 | 10 | | Inf. | 24 | 7 | | Inf. | 20 | 1 | | Irf. | 15 | 5 | | Inf. | 12 | 1 | | Inf. |
| 75 | 41 | 11 | 353 | 1 | 37 | 3 | | Inf. | 33 | 1 | | Inf. | 26 | 9 | | Inf. | 21 | 7 | | Inf. | 16 | 3 | | Irf. | 12 | 7 | | Inf. |
| 100 | 48 | 9 | | Inf. | 42 | 7 | | Inf. | 37 | 4 | | Inf. | 29 | 5 | | Inf. | 23 | 3 | | Inf. | 17 | 3 | | Irf. | 13 | 2 | | Inf. |

*d. Depth of Field Table for 5-Inch Lenses.* The data in this table are based on a 1/250-inch circle of confusion.

*Table V–4. Depth of Field Table for 5-Inch Lenses*

| Distance focused | f/4.5 | | | | f/5.6 | | | | f/6.3 | | | | f/8 | | | | f/11 | | | | f/16 | | | | f/22 | | | | f/32 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feet | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. |
| | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | |
| 8 | 7 | 6 | 8 | 6 | 7 | 4 | 8 | 9 | 7 | 3 | 8 | 10 | 7 | 2 | 9 | 1 | 6 | 10 | 9 | 7 | 6 | 5 | 10 | 6 | 5 | 11 | 12 | 3 | 5 | 4 | 16 | 8 |
| 10 | 9 | 3 | 10 | 11 | 9 | 0 | 11 | 2 | 8 | 11 | 11 | 14 | 8 | 8 | 11 | 9 | 8 | 3 | 12 | 8 | 7 | 8 | 14 | 4 | 7 | 0 | 17 | 8 | 6 | 2 | 26 | 0 |
| 15 | 13 | 4 | 17 | 2 | 12 | 11 | 17 | 10 | 12 | 9 | 18 | 3 | 12 | 3 | 19 | 6 | 11 | 5 | 22 | 0 | 10 | 4 | 27 | 6 | 9 | 1 | 43 | 0 | 7 | 9 | 240 | 0 |
| 30 | 25 | 0 | 40 | 0 | 22 | 8 | 44 | 0 | 22 | 0 | 47 | 0 | 20 | 6 | 56 | 0 | 18 | 4 | 83 | 0 | 15 | 9 | 330 | 0 | 13 | 0 | | Inf. | 10 | 5 | | Inf. |
| 50 | 35 | 0 | 88 | 0 | 32 | 0 | 108 | 0 | 31 | 0 | 126 | 0 | 28 | 0 | 217 | 0 | 24 | 3 | | Inf. | 19 | 10 | | Inf. | 15 | 9 | | Inf. | 12 | 2 | | Inf. |
| 100 | 54 | 0 | 725 | 0 | 48 | 0 | | Inf. | 450 | 0 | | Inf. | 39 | 0 | | Inf. | 32 | 0 | | Inf. | 25 | 0 | | Inf. | 18 | 8 | | Inf. | 13 | 9 | | Inf. |
| Infinity | 116 | 0 | | Inf. | 93 | 0 | | Inf. | 83 | 0 | | Inf. | 65 | 0 | | Inf. | 47 | 0 | | Inf. | 33 | 0 | | Inf. | 23 | 0 | | Inf. | 16 | 0 | | Inf. |

*e. Depth of Field Table for 6-inch Lenses.* The data in this table are based on a 1/200-inch circle of confusion.

*Table V–5. Depth of Field Table for 6-Inch Lenses*

| Distance focused | f/4.5 | | | | f/5.6 | | | | f/8 | | | | f/11 | | | | f/16 | | | | f/22 | | | | f/32 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feet | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. |
| | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | | *From—* | | *To—* | |
| 3 | 2 | 11 | 3 | 1 | 2 | 11 | 3 | 1 | 2 | 11 | 3 | 1 | 2 | 10 | 3 | 2 | 2 | 9 | 3 | 3 | 2 | 8 | 3 | 4 | 2 | 7 | 3 | 5 |
| 4 | 3 | 11 | 4 | 1 | 3 | 10 | 4 | 2 | 3 | 9 | 4 | 3 | 3 | 9 | 4 | 4 | 3 | 7 | 4 | 6 | 3 | 6 | 4 | 8 | 3 | 3 | 5 | 1 |
| 5 | 4 | 10 | 5 | 2 | 4 | 9 | 5 | 3 | 4 | 8 | 5 | 4 | 4 | 7 | 5 | 6 | 4 | 5 | 5 | 9 | 4 | 3 | 5 | 8 | 3 | 11 | 6 | 10 |
| 6 | 5 | 9 | 6 | 3 | 5 | 8 | 6 | 4 | 5 | 7 | 6 | 6 | 5 | 5 | 6 | 9 | 5 | 2 | 7 | 2 | 4 | 11 | 7 | 8 | 4 | 6 | 8 | 10 |
| 7 | 6 | 8 | 7 | 6 | 6 | 7 | 7 | 6 | 6 | 5 | 7 | 9 | 6 | 2 | 8 | 0 | 5 | 11 | 8 | 7 | 5 | 7 | 9 | 5 | 4 | 8 | 11 | 2 |
| 8 | 7 | 7 | 8 | 6 | 7 | 5 | 8 | 8 | 7 | 3 | 8 | 11 | 7 | 2 | 9 | 7 | 6 | 7 | 10 | 2 | 6 | 2 | 11 | 4 | 5 | 7 | 13 | 11 |
| 9 | 8 | 5 | 9 | 8 | 8 | 4 | 9 | 10 | 8 | 0 | 10 | 3 | 7 | 7 | 10 | 9 | 7 | 3 | 11 | 10 | 6 | 9 | 13 | 5 | 6 | 1 | 17 | 4 |
| 10 | 9 | 4 | 10 | 10 | 9 | 2 | 11 | 0 | 8 | 10 | 11 | 6 | 8 | 5 | 12 | 3 | 7 | 11 | 13 | 8 | 7 | 4 | 15 | 9 | 6 | 6 | 21 | 5 |
| 12 | 11 | 0 | 13 | 2 | 10 | 9 | 13 | 6 | 10 | 4 | 14 | 3 | 9 | 10 | 15 | 5 | 9 | 1 | 17 | 8 | 8 | 4 | 21 | 5 | 7 | 4 | 33 | 4 |
| 14 | 12 | 8 | 15 | 8 | 12 | 5 | 16 | 1 | 11 | 9 | 17 | 3 | 11 | 2 | 18 | 10 | 10 | 2 | 22 | 4 | 9 | 3 | 28 | 9 | 8 | 0 | 55 | 3 |
| 16 | 14 | 3 | 18 | 2 | 13 | 11 | 18 | 10 | 13 | 2 | 20 | 4 | 12 | 4 | 22 | 8 | 11 | 3 | 27 | 11 | 10 | 1 | 38 | 9 | 8 | 8 | 109 | 1 |
| 18 | 15 | 10 | 20 | 10 | 15 | 5 | 21 | 8 | 14 | 6 | 23 | 8 | 13 | 6 | 26 | 10 | 12 | 2 | 34 | 7 | 10 | 10 | 52 | 11 | 9 | 2 | 450 | 0 |
| 20 | 17 | 5 | 23 | 6 | 16 | 10 | 24 | 7 | 15 | 9 | 27 | 3 | 14 | 7 | 31 | 7 | 13 | 0 | 42 | 10 | 11 | 6 | 75 | 0 | 9 | 8 | | Inf. |
| 25 | 21 | 1 | 30 | 9 | 20 | 3 | 32 | 7 | 18 | 9 | 37 | 6 | 17 | 2 | 46 | 2 | 15 | 0 | 75 | 0 | 13 | 0 | 300 | 4 | 10 | 9 | | Inf. |
| 30 | 24 | 6 | 38 | 8 | 23 | 5 | 41 | 8 | 21 | 5 | 50 | 0 | 19 | 4 | 62 | 7 | 16 | 8 | 150 | 0 | 14 | 3 | | Inf. | 11 | 6 | | Inf. |
| 35 | 27 | 9 | 47 | 5 | 26 | 5 | 52 | 0 | 23 | 10 | 65 | 7 | 21 | 4 | 97 | 8 | 18 | 1 | 525 | 0 | 15 | 4 | | Inf. | 12 | 2 | | Inf. |
| 40 | 30 | 9 | 57 | 2 | 29 | 10 | 63 | 10 | 26 | 1 | 85 | 9 | 23 | 1 | 150 | 0 | 19 | 4 | | Inf. | 16 | 3 | | Inf. | 12 | 9 | | Inf. |
| 45 | 33 | 8 | 67 | 11 | 31 | 8 | 77 | 7 | 28 | 1 | 112 | 6 | 24 | 8 | 257 | 3 | 20 | 5 | | Inf. | 17 | 0 | | Inf. | 13 | 3 | | Inf. |
| 50 | 36 | 4 | 80 | 0 | 34 | 1 | 93 | 9 | 30 | 0 | 150 | 0 | 26 | 1 | 600 | 8 | 21 | 5 | | Inf. | 17 | 8 | | Inf. | 13 | 8 | | Inf. |
| 60 | 41 | 4 | 109 | 1 | 38 | 5 | 136 | 4 | 33 | 4 | | Inf. | 28 | 7 | | Inf. | 23 | 1 | | Inf. | 18 | 8 | | Inf. | 14 | 3 | | Inf. |
| 75 | 48 | 0 | 170 | 2 | 44 | 1 | 250 | 0 | 37 | 6 | | Inf. | 31 | 6 | | Inf. | 25 | 0 | | Inf. | 20 | 0 | | Inf. | 15 | 0 | | Inf. |
| 100 | 57 | 2 | 400 | 0 | 51 | 9 | 1,500 | 6 | 42 | 10 | | Inf. | 35 | 3 | | Inf. | 27 | 3 | | Inf. | 21 | 5 | | Inf. | 15 | 9 | | Inf. |

*f. **Depth of Field Table for 10-inch Lenses.*** **The data in this table are based on a 1/100-inch circle of confusion.**

*Table V–6. Depth of Field Table for 10-Inch Lenses*

| Distance focused | f/4.5 | | | | f/6.3 | | | | f/8 | | | | f/11 | | | | f/16 | | | | f/22 | | | | f/32 | | | | f/64 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feet | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. | Ft. | In. |
| | From— | | To— | | From— | | To— | | From— | | To— | | From— | | To— | | From— | | To— | | From— | | To— | | From— | | To— | | From— | | To— | |
| 3 | 2 | 11 | 3 | 1 | 2 | 11 | 3 | 1 | 2 | 11 | 3 | 1 | 2 | 11 | 3 | 1 | 2 | 10 | 3 | 2 | 2 | 9 | 3 | 3 | 2 | 8 | 3 | 5 | 2 | 5 | 3 | 10 |
| 4 | 3 | 11 | 4 | 1 | 3 | 11 | 4 | 1 | 3 | 10 | 4 | 2 | 3 | 9 | 4 | 3 | 3 | 9 | 4 | 4 | 3 | 7 | 4 | 6 | 3 | 6 | 4 | 9 | 3 | 1 | 5 | 9 |
| 5 | 4 | 10 | 5 | 2 | 4 | 10 | 5 | 2 | 4 | 9 | 5 | 3 | 4 | 8 | 5 | 4 | 4 | 7 | 5 | 8 | 4 | 5 | 5 | 9 | 4 | 2 | 6 | 2 | 3 | 7 | 8 | 1 |
| 6 | 5 | 10 | 6 | 2 | 5 | 9 | 6 | 3 | 5 | 8 | 6 | 4 | 5 | 7 | 6 | 6 | 5 | 5 | 6 | 9 | 5 | 2 | 7 | 1 | 4 | 10 | 7 | 9 | 4 | 1 | 11 | 4 |
| 7 | 6 | 9 | 7 | 3 | 6 | 8 | 7 | 5 | 6 | 7 | 7 | 6 | 6 | 5 | 7 | 9 | 6 | 2 | 8 | 1 | 5 | 11 | 8 | 8 | 5 | 6 | 9 | 7 | 4 | 7 | 15 | 2 |
| 8 | 7 | 8 | 8 | 4 | 7 | 6 | 8 | 6 | 7 | 5 | 8 | 8 | 7 | 3 | 8 | 11 | 6 | 11 | 9 | 5 | 6 | 8 | 10 | 2 | 6 | 1 | 11 | 6 | 4 | 11 | 20 | 9 |
| 9 | 8 | 7 | 9 | 5 | 8 | 5 | 9 | 8 | 8 | 3 | 9 | 10 | 8 | 0 | 10 | 3 | 7 | 8 | 10 | 11 | 7 | 3 | 11 | 10 | 6 | 8 | 13 | 9 | 5 | 4 | 29 | 2 |
| 10 | 9 | 6 | 10 | 7 | 9 | 3 | 10 | 10 | 9 | 0 | 11 | 1 | 8 | 10 | 11 | 6 | 8 | 5 | 12 | 4 | 7 | 11 | 13 | 7 | 7 | 3 | 16 | 3 | 5 | 8 | 43 | 1 |
| 12 | 11 | 9 | 12 | 10 | 11 | 0 | 13 | 2 | 10 | 9 | 13 | 7 | 10 | 4 | 14 | 3 | 9 | 10 | 15 | 7 | 9 | 1 | 17 | 7 | 8 | 3 | 22 | 3 | 6 | 3 | 153 | 2 |
| 14 | 13 | 0 | 15 | 2 | 12 | 8 | 15 | 8 | 12 | 6 | 16 | 2 | 11 | 10 | 17 | 2 | 11 | 0 | 19 | 2 | 10 | 3 | 22 | 3 | 9 | 1 | 30 | 3 | 6 | 9 | | Inf. |
| 16 | 14 | 9 | 17 | 6 | 14 | 3 | 18 | 3 | 13 | 10 | 20 | 0 | 13 | 2 | 20 | 3 | 12 | 3 | 23 | 1 | 11 | 3 | 27 | 8 | 9 | 11 | 41 | 6 | 7 | 2 | | Inf. |
| 18 | 16 | 5 | 19 | 11 | 15 | 10 | 20 | 10 | 15 | 4 | 21 | 9 | 14 | 6 | 23 | 7 | 13 | 4 | 27 | 6 | 12 | 2 | 34 | 3 | 10 | 8 | 58 | 3 | 7 | 7 | | Inf. |
| 20 | 18 | 1 | 22 | 5 | 17 | 4 | 23 | 7 | 16 | 9 | 24 | 9 | 15 | 10 | 27 | 2 | 14 | 5 | 32 | 6 | 13 | 1 | 42 | 5 | 11 | 4 | 86 | 3 | 7 | 11 | | Inf. |
| 25 | 22 | 0 | 28 | 10 | 21 | 0 | 30 | 10 | 20 | 2 | 32 | 10 | 18 | 9 | 37 | 4 | 16 | 11 | 47 | 1 | 15 | 1 | 73 | 7 | 12 | 9 | 626 | 4 | 8 | 7 | | Inf. |
| 30 | 25 | 10 | 35 | 10 | 24 | 5 | 38 | 10 | 23 | 4 | 42 | 1 | 21 | 6 | 49 | 3 | 19 | 0 | 70 | 9 | 16 | 9 | 144 | 4 | 13 | 11 | | Inf. | 9 | 1 | | Inf. |
| 35 | 29 | 5 | 43 | 2 | 27 | 8 | 47 | 7 | 26 | 3 | 52 | 6 | 23 | 11 | 65 | 1 | 20 | 11 | 106 | 9 | 18 | 1 | 461 | 11 | 14 | 11 | | Inf. | 9 | 6 | | Inf. |
| 40 | 32 | 11 | 51 | 0 | 30 | 7 | 57 | 4 | 28 | 8 | 64 | 10 | 26 | 2 | 84 | 9 | 22 | 7 | 172 | 5 | 19 | 5 | | Inf. | 15 | 9 | | Inf. | 9 | 10 | | Inf. |
| 45 | 36 | 2 | 59 | 5 | 33 | 7 | 68 | 2 | 31 | 5 | 79 | 0 | 28 | 3 | 110 | 10 | 24 | 2 | 331 | 0 | 20 | 7 | | Inf. | 16 | 6 | | Inf. | 10 | 1 | | Inf. |
| 50 | 39 | 4 | 68 | 6 | 36 | 3 | 80 | 5 | 33 | 10 | 95 | 9 | 30 | 1 | 143 | 2 | 25 | 6 | 1,251 | 11 | 21 | 6 | | Inf. | 17 | 1 | | Inf. | 10 | 4 | | Inf. |
| 60 | 45 | 4 | 88 | 9 | 41 | 3 | 109 | 10 | 38 | 1 | 140 | 11 | 33 | 6 | 288 | 7 | 27 | 11 | | Inf. | 23 | 3 | | Inf. | 18 | 2 | | Inf. | 10 | 8 | | Inf. |
| 75 | 53 | 3 | 126 | 1 | 47 | 10 | 173 | 3 | 43 | 8 | 263 | 5 | 37 | 8 | 7,575 | 0 | 30 | 9 | | Inf. | 25 | 2 | | Inf. | 19 | 4 | | Inf. | 11 | 1 | | Inf. |
| 100 | 64 | 11 | 217 | 5 | 56 | 11 | 409 | 11 | 51 | 1 | 2,322 | 3 | 43 | 1 | | Inf. | 34 | 3 | | Inf. | 27 | 6 | | Inf. | 20 | 8 | | Inf. | 11 | 6 | | Inf. |

# APPENDIX VI

## HEIGHTS OF IMAGE ON A CAMERA GROUND GLASS

In the chart below, the column on the left indicates various focal lengths; the numbers 2 through 10 at the top of the chart indicate image sizes on the camera ground glass, or focal plane; the numbers within the body of the chart indicate subject-to-camera distances in inches.

*a. Determining Subject-to-Camera Distance.* Let us assume that you are using a lens with a focal length of 6 inches and that you want an image 4 inches high on the camera ground glass. Move your finger down the left-hand column to the 6 and then across the chart to the column under 4. The number in the chart is 108, which means that the subject-to-camera distance must be 108 inches to produce a 4-inch image on the ground glass when you are using a 6-inch focal lenth lens.

*b. Determining Image Size.* Let us assume that the subject-to-camera distance is 148 inches and that the focal length of the lens is 12 inches. The image on the ground glass in this case will be 6 inches.

*c. Determining Focal Length.* Let us assume that the subject-to-camera distance is 180 inches and you want an image 4 inches high on the ground glass. In this instance you should use a 10-inch focal length lens.

*Table VI-1. Subject-to-Camera Distance*

| Focal length of lens (in.) | Heights of images on ground glass in inches | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 2 | 70 | ---- | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 3 | 105 | 71 | ---- | ---- | ---- | ---- | ---- | ---- | ---- |
| 4 | 140 | 95 | 72 | ---- | ---- | ---- | ---- | ---- | ---- |
| 5 | 175 | 118 | 90 | 73 | ---- | ---- | ---- | ---- | ---- |
| 6 | 210 | 142 | 108 | 88 | 74 | ---- | ---- | ---- | ---- |
| 7 | 245 | 166 | 126 | 102 | 86 | 75 | ---- | ---- | ---- |
| 8 | 280 | 189 | 144 | 117 | 99 | 86 | 76 | ---- | ---- |
| 9 | 315 | 213 | 162 | 131 | 111 | 96 | 86 | 77 | ---- |
| 10 | 350 | 237 | 180 | 146 | 123 | 107 | 95 | 86 | 78 |
| 11 | 385 | 260 | 198 | 171 | 135 | 118 | 105 | 94 | 86 |
| 12 | 420 | 284 | 216 | 175 | 148 | 129 | 114 | 103 | 94 |
| 13 | 455 | 308 | 234 | 190 | 160 | 139 | 124 | 111 | 101 |
| 14 | 490 | 331 | 252 | 204 | 173 | 150 | 133 | 120 | 109 |
| 15 | 525 | 355 | 270 | 219 | 185 | 161 | 143 | 128 | 117 |
| 16 | 560 | 379 | 288 | 234 | 197 | 171 | 152 | 136 | 125 |
| 17 | 595 | 402 | 306 | 248 | 210 | 182 | 162 | 145 | 133 |
| 18 | 630 | 426 | 324 | 263 | 221 | 194 | 171 | 154 | 140 |
| 19 | 665 | 450 | 342 | 277 | 234 | 203 | 181 | 163 | 148 |
| 20 | 700 | 473 | 360 | 292 | 247 | 214 | 199 | 171 | 156 |

*Note.* Distances from lens to subject for an average figure of 68 inches. Distances stated in the above table are in inches, measured from the subject to the photographic lens.

# GLOSSARY

## GENERAL PHOTOGRAPHY TERMS

This glossary contains terms that apply to all types of photography. Glossaries in other manuals of the TM 11–40-series contain terms that apply to specific phases of photography.

*Aberration*—An optical defect in a lens which causes imperfect images.

*Abrasion marks*—Dark lines or scratches on negative or print emulsions, usually caused by winding roll film too tightly, or by rubbing the emulsion prior to development.

*Absorption*—Optically, absorption is the partial or total retention of light entering a lens.

*Accelerator*—An alkali, added to a developing solution to increase the rate of development.

*Acetate base*—A noninflammable photographic film base; also known as safety base.

*Achromatic lens*—A lens corrected for chromatic aberration.

*Actinic light*—Light capable of causing photochemical changes in a sensitive emulsion.

*Air bells*—Small air bubbles which stick to the surface of an emulsion during processing and leave small spots unaffected by the solution. These bubbles are removed through agitation.

*Alkali*—A substance used to neutralize acids. Added to photographic developers, they accelerate development.

*Anastigmat*—A lens, corrected for astigmatism, capable of focusing vertical and horizontal lines with equal brightness and definition. These lenses are also free from other common aberrations.

*Angle of view*—The resulting angle when two lines are plotted from the center of a lens of the two distant corners of a negative produced by the lens.

*Anhydrous*—Refers to chemical salts and means the same as desiccated; namely, free of water and especially water of crystallization.

*Antihalation backing*—An opaque film backing, preventing reflection from the back surface of the film base.

*Aperture*—The lens opening that regulates the intensity of light permitted to reach the sensitive emulsion.

*Apochromatic lens*—A lens of a special design capable of focusing the rays of all colors on practically the identical plane. Consequently, it is used for the most exacting types of color photography.

*Avoirdupois*—System of weights and measures consisting of grains, ounces, pounds, fluid ounces, and quarts. Common in United States and Great Britain.

*Bleach*—Converting a silver image into silver halides prior to toning a print or intensifying a negative.

*Blisters*—Small bubbles forming under an emulsion due to the detachment of the emulsion from its base. Blisters are caused by faulty processing.

*Brightness range*—Variation of light intensities from maximum to minimum. Normally, it refers to the photographic subject. *For example,* a particular subject may have a range of one to four; that is, four times the amount of light is reflected from the brightest highlight as from the least bright portion of the subject.

*Brilliance*—The degree of intensity of a color or colors.

*Brilliant*—The quality of a print or negative showing distinguishable tones from highlights to shadows.

*Bromide paper*—A photographic printing paper with an emulsion composed largely of silver bromides. This type of paper is relatively fast and normally used in the production of enlargements.

*Carbonates*—Certain alkaline salts, such as potassium carbonate and sodium carbonate, used as accelerators in developing solutions.

*Characteristic curve* (*of Photographic Emulsions*)—A plotted curve showing the relation of density to exposure. Sometimes called the H and D curve, it represents density values of photographic emulsions (film or paper).

*Chloride paper*—A photographic printing paper with a sensitive emulsion containing primarily silver chloride. Normally used for contact printing, it requires longer exposure than bromide or chloro-bromide papers.

*Chloro-bromide paper*—A photographic printing paper with a sensitive emulsion containing mixture of silver chlorides and silver bromides. It is used mainly for enlarging.

*Circle of confusion*—The size of an image point formed by a photographic lens. It is a decisive factor in establishing the maximum and minimum performance of a lens.

*Clumping*—The effective increase in emulsion grain size caused by the partial overlapping of grains of silver.

*Color sensitivity*—The response of a photographic emulsion to light of various wavelengths.

*Condenser*—An optical system in projection printers used to collect divergent rays of the light source and to concentrate them on the enlarger lens.

*Contact print*—A phtographic print made by placing a sensitized emulsion in direct contact with a negative and permitting light to pass through the negative to expose the sensitive emulsion.

*Contrast*—Subject contrast is the difference between the reflective ability of various areas of a subject. Lighting contrast is the difference in intensities of light falling on various parts of a subject. Inherent emulsion contrast, determined by the manufacturer, is the possible difference between the maximum and minimum densities of the silver deposits with a minimum variation of exposure. Development contrast is the gamma to which an emulsion is developed. It is controlled by the developer, time, temperature, and agitation.

*Convertible lens*—A photographic lens consisting of two or more elements, which can be used individually or in combination to give several focal lengths.

*Covering power*—The capacity of a lens to give a sharply defined image to the edges of the pictorial area limit of the sensitized material, it is designed to cover at the maximum aperture.

*Curtain aperture*—The slit in a focal plane shutter permitting light to reach the film. The size of the slit may be either fixed or variable.

*Densitometer*—A device for measuring the density of a silver deposit is a photographic image. It is usually limited to measuring even densities in small areas.

*Density*—The degree of blackening of a silver deposit in a film emulsion in relation to the light incident upon it. Photometrically, density is log ten (10) times the opacity of an emulsion. (See opacity).

*Desensitizer*—A chemical agent that decreases the color sensitivity of a photographic emulsion. Used to facilitate developing with comparatively bright light conditions.

*Desiccated*—A term applied to chemical in which all moisture has been eliminated.

*Developer*—A chemical solution which makes the latent image in an exposed emulsion visible.

*Diaphragm*—An adjustable aperture which controls the amount of light passing through a photographic lens.

*Dichroic fog*—A two-color stain observed on films and plates. Appears green by reflected light and pink by transmitted light.

*Diffraction*—The spreading of light rays after they pass the edge of an obstacle.

*Diffusion*—The scattering of light rays from a rough surface, or the transmission of light through a translucent medium.

*Dispersion*—The separation of light into its component colors resulting when directing white light through a prism.

*Double exposure*—The intentional or unintentional recording of two separate images on a single piece of sensitized material.

*Double extension*—The extended length of a camera bellows about twice the focal length of the lens being used.

*Efflorescence*—The process by which a chemical salt loses its water of crystallization upon exposure to air.

*Emulsion*—A light-sensitive layer of silver slat suspended in gelatin, spread over a permanent support, such as film, glass, or paper.

*Emulsion speed*—The factor which determines the exposure necessary to produce a satisfactory image. It is commonly expressed in A.S.A. or Weston emulsion numbers. However, values are subject to change as systems are being adjusted and modernized.

*Enlargement*—A print made from a negative or positive by projecting an enlarged image on sensitized material.

*Exposure*—The product and time and intensity of illumination actiong upon photographic material.

*F/number*—A term denoting lens aperture. It represents the focal length of the photographic lens divided by the diameter of the front surface of the lens. However, lens diameter is controlled by setting the lens diaphragm.

*Fading*—The gradual elimination, usually of a print image, due to the action of light or other forms of oxidation.

*Filter*—A piece of colored glass or gelatin used to modify or exaggerate contrast, to compensate for the difference in color sensitivity between the film emulsion and the human eye, or to provide primary color separation in color photography.

*Filter factor*—The number by which the correct exposure without a filter must be multiplied to obtain the same effective exposure with a filter.

*Flat*—The lack of contrast in a print or negative.

*Focal length*—The distance between the center of a lens and the point at which the image of a distant object comes into critical focus.

*Focal plane*—The plane at which the image is brough into critical focus. It is the plane occupied by the film inside a camera.

*Focus*—The point at which rays of light converge to form an image after passing through a lens.

*Fog*—A veil or haze over a negative or print, caused by undesired chemical action or light.

*Frilling*—Detachment of the emulsion from its support around the edges. Caused by excessively warm developer or excessive amounts of alkali.

*Gamma*—A numerical measure of the contrast to which an emulsion is developed.

*Gamma infinity*—The maximum contrast to which an emulsion can be developed.

*Gradation*—The range of densities in an emulsion from highlights to shadow.

*Grain*—Silver particles or groups of particles in an emulsion, which become noticeable and objectionable when enlarged.

*Gray scale*—A series of densities in definite steps ranging from white to black. Same as sensiometric strip.

*Halation*—A blurred effect, resembling a halo, usually occuring around bright objects. Caused by reflection of light rays from the back of the sensitive emulsion base.

*Halftones*—Middle tones lying between shadows and highlights.

*Halides (or haloids)*—Binary compounds containing any of the following elements: chlorine, bromine, iodine, fluorine.

*Halogen*—Iodine, fluorine, chlorine, and bromine are known as halogen.

*Hard*—Excessive tonal contrast.

*Hyperfocal distance*—The distance from the photographic lens to the nearest plane in sharp focus, when the lens is focused at infinity.

*Infinity*—A distance so far removed from an observer that the rays of light reflected to a lens from a point at that distance may be regarded as parallel. A distance setting on a camera focusing scale (or lens distance setting), beyond which all objects are in focus.

*Latent image*—The invisible image formed in an emulsion by exposure to light, focused by a photographic lens. It is rendered visible by the process of development.

*Latitude*—Exposure latitude is the characteristic of a film, plate, or paper, permitting variations in exposure without damaging the image quality. Development latitude is the allowable variation in the recommended developng time without noticeable differences in contrast or density.

*Meniscus*—A single element, or cemented lens combination, concave on one side and convex on the other.

*Monochromatic*—A single color.

*Opacity*—Resistance of a material to the transmission of light. It is the reciprocal of the light transmission of an emulsion.

*Opaque*—A condition of an object which prevents the transmission of visible light.

*Oxidation*—The process of combining a substance with oxygen.

*Preservative*—A chemical, such as sodium sulfite, which, when added to a developing solution, tends to prolong its life.

*Restrainer*—Any chemical, such as potassium bromide, which, when added to a developing solution, slows down developing action and makes it more selective.

*Reticulation*—The formation of a wrinkled or leather-like surface on a processed emulsion due to excessive expansion or retraction of the gelatin caused by temperature changes or chemical action.

*Reversal*—A process by which a negative image is converted to a positive. A negative is developed, reexposed, bleached, and redeveloped to form a positive.

*Sensitizer*—Dyes used in the manufacture of photographic emulsions. Sensitizers can be of two types: one to increase the speed of an emulsion; the other to increase its color sensitivity.

*Sensitometer*—A device for producing on sensitized material a series of exposures increasing at a definite ratio. Such a series is needed in studying the characteristics of an emulsion.

*Sensitometric strip*—A series of densities in definite steps ranging from white to black.

*Soft*—A term used to describe prints and negatives with low contrast.

*Stock solution*—Photographic solution in concentrated form and intended to be diluted for use.

*Time-gamma-temperature curve*—A curve of developing time plotted against developed gamma. The gamma for any given time may be read directly from the curve, or vice versa. The curve applies only to one particular developer and film emulsion at a specific temperature.

*Tone* (*Tones*)—The color of a photographic image or, refers to the visible shade of gray of the image.

*Toning*—A method for changing the color or tone of a monochromatic image by chemical action.

*Translucent*—A medium which passes light but diffuses it so that objects cannot be clearly distinguished.

*Transmission*—Ratio of the incident light to the light passing through, or reflected by, an emulsion. Usually expressed in percent transmission.

*Transparency*—An image on a transparent base, which must be viewed by transmitted light. Also refers to the light transmitting capacity of the silver deposit in a negative and is the inverse of opacity.

*Working solution* — Photographic solution which is ready for use.

# INDEX

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*NG:* State AG (3); units—same as active Army except allowance is one copy to each unit.

*USAR:* Same as active Army except allowance is one copy to each unit.

For explanation of abbreviations used, see AR 320–50.

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