

Figure A-3.—Spectral density characteristics of clear gelatin, 0.1 mm thick (from Kodak Wratten Filters, Kodak Publication No. B-3).

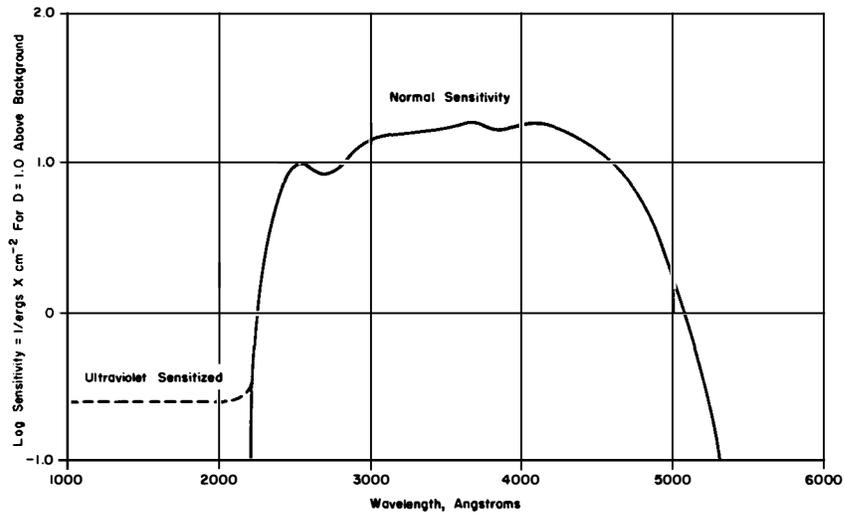


Figure A-4.—Spectral sensitivity response of Spectroscopic Type 103-0 which has been sensitized to ultraviolet with Kodak Ultraviolet Sensitizer No. 2.

The addition of certain dyes to the silver halide grains in the emulsion increases the sensitivity to longer wavelengths. When sufficient energy is absorbed by the absorbed-sensitizing dye, a photochemical reaction occurs and the emulsion becomes effectively sensitive to those wavelengths where previously there was little or no response. Not all dyes will react in this manner. Only a certain few are considered as spectral sensitizers for photographic films and only when they are absorbed in critical amounts to the silver halide grains.

Sensitizing dyes are available which extend the photosensitive capabilities to wavelengths somewhat beyond 1 micrometer (10,000 Å). The resultant peak sensitivity in the infrared seldom occurs at wavelengths greater than 10,000 to 11,000 Å and the sensitivity beyond 13,000 Å is negligible. For practical exposures in recording pictorial scenes, spectral sensitivity beyond 9000 Å is of little value because of the rapid decline in sensitivity just short of this wavelength. The spectral response of a high-speed infrared sensitive film is plotted in figure A-5 along with a common type of negative material, Eastman Kodak Plus-X, for purposes of comparison.

Image Quality

The ability of a photographic emulsion to produce sharply defined detail in an exposed and processed image may be described

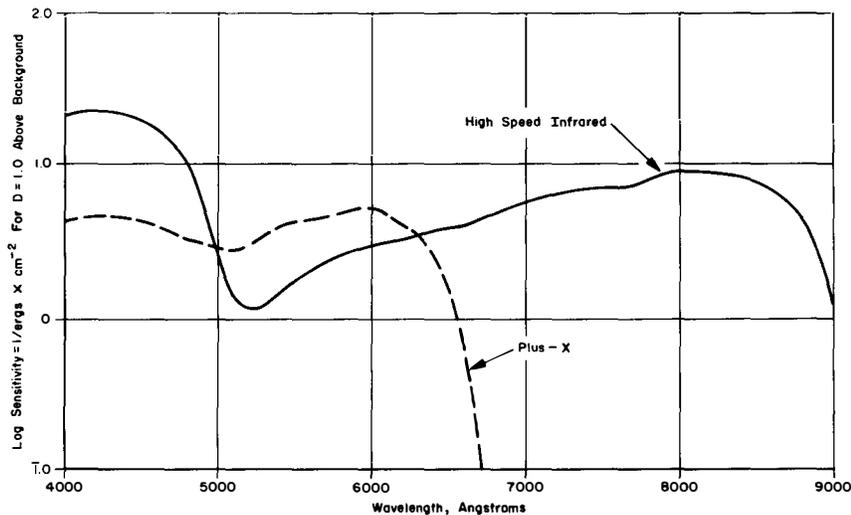


Figure A-5.—Comparison of spectral response of Kodak High-Speed Infrared and Kodak Plus-X negative films plotted at the same scale.

in terms of the film's resolving power and acutance. The resolving power of an emulsion is a measure of the limit to which fine detail in an image can be recorded, while acutance is a measure of the degree of sharpness apparent in the borders or edges of the recorded-image elements. The combined effects of an emulsion in altering resolution and acutance are included in the modulation transfer characteristics of the film. These characteristics describe the overall effect of diffusion and scattering of light upon the elementary image structure.

Resolving power

Photographic resolution is associated with the emulsion characteristics of granularity, turbidity, and sharpness as well as the exposure used. A measure of the resolving power of an emulsion is obtained by imaging a test pattern of alternating dark and light lines of varying sizes onto the film. The result, after processing, is usually expressed as the maximum number of dark lines per millimeter just distinguishable in the developed image. The range of brightness between the dark and light lines of the test-target influences the photographic resolving power. Resolution increases as the target brightness range increases, reaching a maximum at a range of 1000. It is, therefore, customary to test resolving power of photographic films using a target contrast of 1000.

Most of the popular camera films show a resolving power limit of the order of 100 lines per millimeter. Many of the less-sensitive materials have higher values, whereas ultrafast films are generally limited to somewhat lower resolution. The grains of even the fastest films are small by comparison to the resolution values obtained. Hence it is believed that individual grain size does not limit resolving power. Regardless of film speed, which is governed basically by grain size, the best emulsion resolution is attained when the grains are all small and nearly the same size.

Photographic emulsions are suspensions of silver halide grains in a layer of gelatin and, except for silver chloride which is nearly transparent, exhibit a considerable degree of turbidity. Incident light, upon striking the various grains, is partially absorbed, reflected, and diffused as it progresses through the emulsion. The reflected and scattered light affects nearby grains outside the area of the image pattern. These accidental exposures cause a spreading of the image elements and result in loss of resolving power. Restriction of exposure to the emulsion surface minimizes the solution. However, if the surface grains are widely separated, the

edges of the image elements are not continuous and this results in an apparent reduction of sharpness.

Acutance (Refs. 1 and 6)

The density distribution across the border of an image element affects judgment of picture sharpness. Turbid emulsions scatter and generally diffuse the incident light in all directions. This causes elementary image edges to diffuse and the image appears to be unsharp if contrast of the elementary image border increases the apparent sharpness. The term "acutance" is a measure of the density distribution across the boundaries of microimages, produced by diffusion of non-image-forming light. Acutance, hence apparent sharpness, increases as the edge density gradient increases. Although emulsion turbidity plays a dominant role in the mechanism of image sharpness, emulsion composition appears to be the governing factor in controlling acutance. Emulsions, containing grains of predominantly uniform size regardless of film speed, produce sharper images than those containing a large distribution in grain size.

Modulation transfer function (Refs. 7 and 8)

The modulation transfer characteristics describe the behavior of an emulsion as influenced by the factors of exposure, acutance, and resolving power. Instead of using the normal sharp-edged parallel-line test pattern, a special target is employed which has a sine-wave-type density distribution across the edges. The target consists of a series of straight parallel lines varying arithmetically in both width and spacing from one end of the pattern to the other. The density distribution across each line of the series varies sinusoidally, as shown in figure A-6, with a density difference between minimum and maximum of the order of 3.0.

The test pattern is used as a negative with which printed images are exposed onto the photographic film to be evaluated. The varying density serves as the exposure modulator, and the changing frequency of line spacing tests the reproduction capacity of the emulsion. Figure A-7 shows the density distribution across each line of the exposed and processed image. Except for opposition values of density, an ideal response would produce an exact duplicate of the original test-pattern negative. Deviation in the minimum and maximum densities, as spatial frequency increases, represents the modulation change occurring in the response of the film. This modulation change is caused by the effects of emulsion

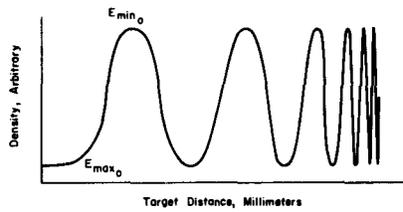
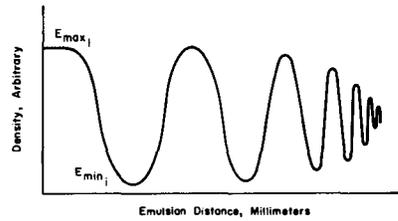


Figure A-7.—Density distribution across lines of film being tested.

Figure A-6.—Density distribution across lines of test pattern.



turbidity and the edge contrast of microimages. At low spatial frequencies the pattern is faithfully duplicated with little distortion. Distortion occurs as frequency increases, and the areas which should be low in density commence filling-in while the corresponding high-density areas show a decrease in value. Ultimately, both levels attain an intermediate but uniform density as the limit of response is reached. A plot of the ratio of modulation in the image and the original pattern as a function of the spatial frequency is the modulation transfer characteristic of the emulsion being tested and is illustrated in figure A-8.

Spectral Sensitivity

Natural

The silver halide grains suspended in gelatin have an inherent spectral sensitivity which is closely associated with their absorption of radiant energy. All primitive silver halide grains have strong absorption in the ultraviolet and violet portions of the energy spectrum, and this is in close agreement with their spectral photographic response. Energy absorption in the emulsion increases with decreasing wavelength and becomes so efficient at 3000 Å that very little energy is transmitted beneath the first few layers of grains. Being restricted to the topmost grains, an image exposed by ultraviolet radiation and subsequently processed will be found to suffer from lack of density and contrast. At still shorter wavelengths, the gelatin containing the suspended grains further absorbs the incident energy before it reaches the silver halide. Below 2500 Å the effect of absorption by the gelatin is so

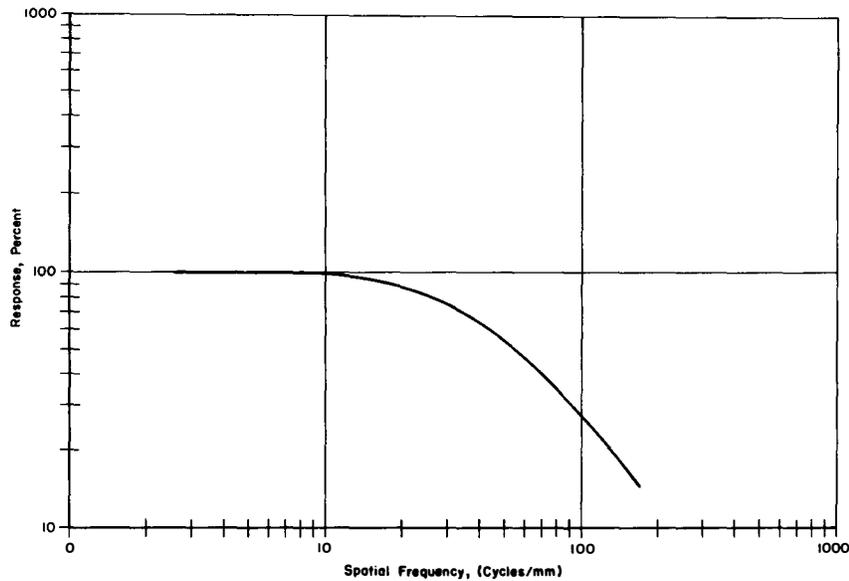


Figure A-8.—Modulation transfer characteristic of Kodak Panatomic-X film (ref. 8).

severe that no effective energy reaches the grains, and film sensitivity approaches zero. Commercially available films with considerable improvement in sensitivity to short-wavelength radiation contain a minimal amount of gelatin with the grains almost on top of the binder. Such films are extremely delicate and difficult to handle because the gelatin affords little protection to the grains. The gelatin cannot be completely eliminated because of its required protective capacity for the silver halide. Practical considerations demand that the grains be physically held in place by an adequate bond and this function is suitably performed by gelatin. An additional protective factor required of the gelatin is provision of the mechanism whereby the developing agent can discriminate between exposed and unexposed silver halide grains. Without a thin layer of gelatin surrounding them, all grains, whether exposed or not, would be reduced to metallic silver by the developing agent and there would be no detectable image.

Ultraviolet

The special photographic emulsions available for short-wavelength radiation are intended for spectrographic recording. Although they are sensitive to wavelengths shorter than 2500 Å and even respond to wavelengths approaching 500 Å, they are not

suitable for practical pictorial recording because of low sensitivity, low contrast, and limited-exposure latitude. In addition, such emulsions have greater sensitivity to longer wavelengths than they have at 2500 Å. A spectrograph physically separates, by dispersion, the various wavelength regions and prevents overlap of other spectral zones to which the emulsion is more sensitive. Thus, spectral lines, even though weak, can be recorded without interference from those spectral regions to which the emulsion is much more sensitive. A nonspectrographic pictorial record, on the other hand, cannot be successfully obtained in the 2000- to 2500-Å range unless all longer wavelengths are excluded. This prevents the weak image, produced by the short wavelengths, from being dominated and effectively masked by the much stronger image from longer wavelength radiation. Optical filters required to accomplish this task are not available, and since the solar light source radiates less energy in this region than in the longer wavelengths, it will not be possible to obtain pictorial records with wavelengths shorter than 2500 Å.

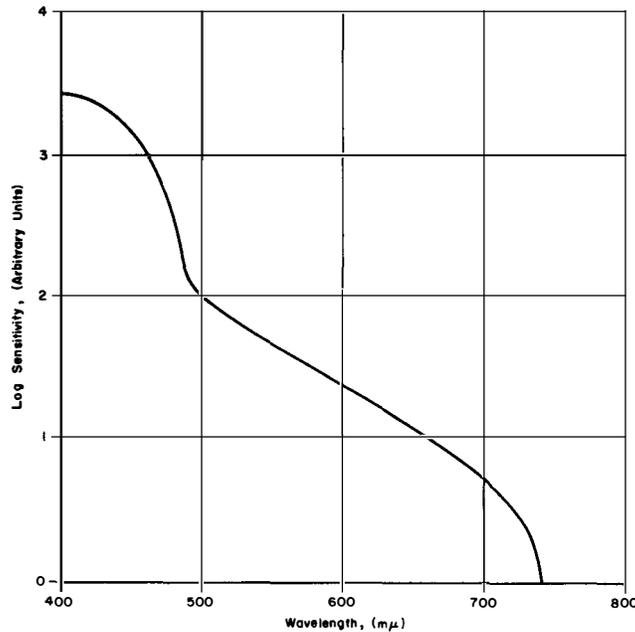


Figure A-9.—Spectral sensitivity of a typical silver bromide emulsion showing sensitivity extending to the near infrared (from Mees, *Theory of the Photographic Process*, revised edition, 1954).

Visible

Chemical sensitization

A silver chloride emulsion is colorless and appears to be translucent to the eye. It has a spectral sensitivity extending from the ultraviolet into the visible spectrum of blue or violet. Silver bromide emulsions, pale yellow in color, have ultraviolet sensitivity in addition to a considerable sensitivity to the blue-green portion of the visible spectrum. As noted in the curves of figure A-9, the sensitivity of silver bromide emulsions, even though exceedingly low, extends through the visible and into the near-infrared spectrum. The photographic limit, however, does not extend beyond 4900 Å. The addition of varying proportions of silver iodide to a silver bromide emulsion increases the sensitivity to longer wavelengths as shown in figure A-10. Extended spectral sensitivity produced by these and other chemical methods is limited in a practical sense to wavelengths barely in the visible green region. Optical

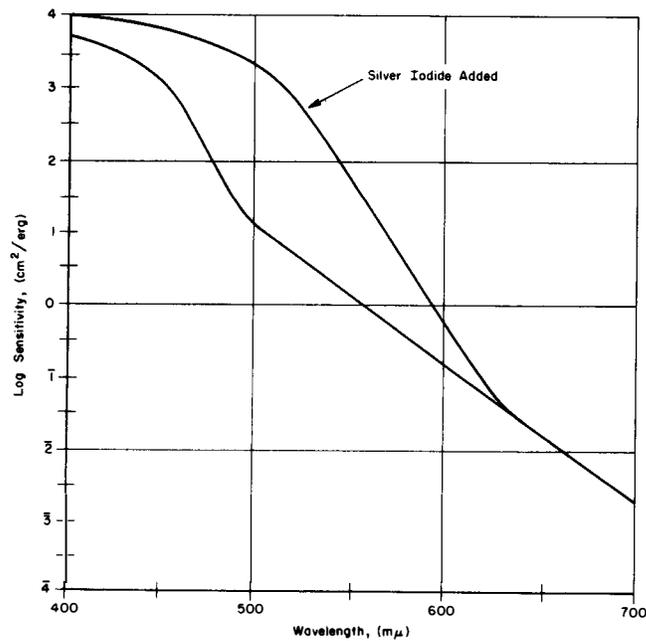


Figure A-10.—Spectral sensitivity of silver bromide emulsion showing increased sensitivity toward longer wavelengths when silver iodide is added (from Mees, *Theory of the Photographic Process*, revised edition, 1954).

sensitization of the silver halide grains is a more effective method for extending spectral response.

Optical sensitization

Optical sensitization requires the absorption of a critical amount of certain organic dyes to silver halide grains. This gives sensitivity in spectral regions of longer wavelengths to which the primitive grains are insensitive. The resultant extended sensitivity depends upon the light-sensitive characteristics of the absorbed dye. The dye is tightly held to the silver halide crystal by strong van der Waals forces and provides a source of energy transfer through photochemical action of light absorbed by the dye.

Although the spectral absorption characteristics of the absorbed dye dictate the effective photosensitivity created, the action of the colored dye is not one of simple filtration of the incident energy. The effectiveness of the dye to confer sensitivity to the silver halide depends completely upon absorption of the energy by the dye and the transfer of the liberated electrons to the grain sensitivity centers. For optimum efficiency of the reaction, the absorbed dye seldom covers the grain completely and is never present in more than a monomolecular layer. Excessive amounts of dye tend to produce desensitization of the grain.

Infrared

Effective sensitization may be achieved in almost any portion of the visible and near-infrared spectrum through use of the numerous dyes or dye combinations now available. However, no dye has yet been discovered which will optically sensitize a film to the far infrared. The practical limit for peak sensitivity to the infrared appears to be about 8000 Å, although satisfactory pictorial records at practical exposure levels can be obtained at 9000 Å. Special sensitizers are available which extend the photographic response beyond 13,000 Å, but the level of sensitivity is extremely low and emulsions thus sensitized are of little value for pictorial photography at wavelengths of about 9000 Å.

Film Speed

The speed of a photographic material is a numerical expression of its sensitivity to light for conditions of normal exposure and development (ref. 9).

Throughout the evolution of the photographic process, various

methods have been used to describe the relative speed of photographic emulsions. Only in recent years, however, has there been an attempt made for standardization between manufacturers and users of photographic products. In the United States the two most common methods now being used to define film speed are the ASA method and the Exposure Index method.

Film-speed numbers are derived from the D -log E curve of a particular type of film which describes the inherent sensitivity of an emulsion for specific conditions of exposure and development. Arithmetic film speed is defined as the reciprocal of the exposure required to produce a specific tonal value (density) as indicated by the equation

$$S = \frac{k}{E}$$

where k is a constant and E is the exposure which produces a density 0.10 above background.

It is necessary that a rigidly fixed procedure be followed to determine the speed of an emulsion. Specifications must be set on the exposure time, modulator, type of light source, and spectral filtration. Processing of the sample must be accomplished in a special formula developer at a specified temperature and in a container of a certain size. Agitation, fixing, washing, and drying are also thoroughly stated in the procedures.

The characteristic curve of the emulsion is measured, using the ASA's units of diffuse density. The density, thus obtained, is plotted against the log of the exposure to form the characteristics curve for the emulsion.

ASA Film Speed—Black-and-White Negative Material

The new ASA procedure for determining film speed is illustrated in figure A-11, where two points, M and N , are shown on the curve. Point M is located 0.1 density units above fog-plus-base density. Point N lies 1.3 log-exposure units from Point M in the direction of greater exposure. The developing time of the negative material is so chosen that Point N lies at a density interval $\Delta D = 0.80$ above the density at Point M . When this condition is satisfied, the exposure E_m , corresponding to Point M , represents the parameter from which film speed is computed.

The arithmetic speed is computed by use of the formula $S_a = 0.8/E_m$ where S_a is the arithmetic speed, and E_m is the exposure (expressed in meter-candle-seconds) corresponding to the Point M on the D -log E curve.

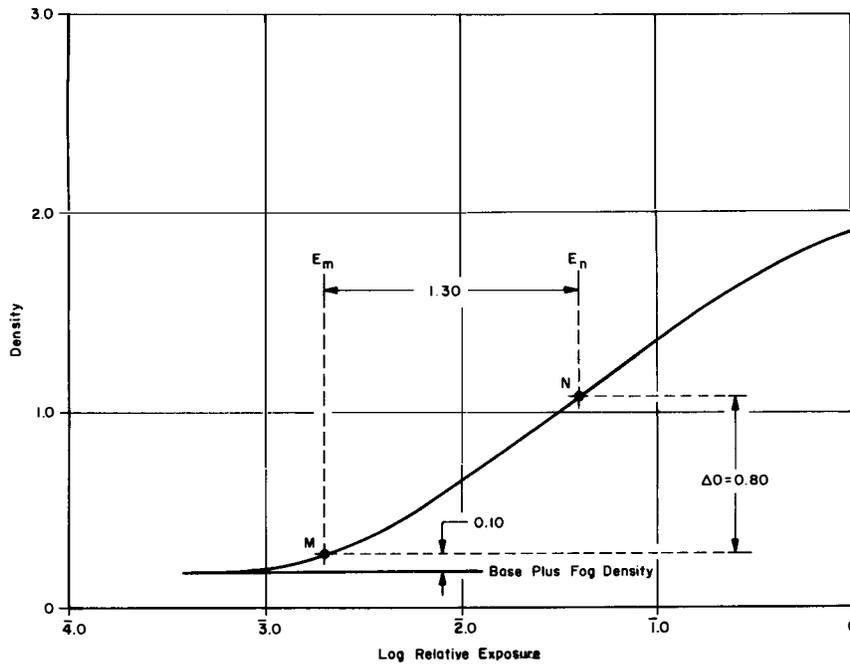


Figure A-11.—Method for determining speed.

Exposure Index

An exposure index is a measure of the speed of a photographic film and is used to determine the proper camera settings to produce a high-quality pictorial record.

Forced development of a film can produce an apparent increase in film speed because it permits an acceptable picture, but not of high quality, to be obtained with less exposure. In any method of determining film speed, a true increase in speed is represented on the D - $\log E$ curve by a lateral shift along the exposure axis. By definition, this is only possible by altering the emulsion composition and not by changes in the development procedure, since the developing procedure is fixed. The exposure index of an emulsion can be altered by forced development, creating the effect of increased speed.

Exposure Reciprocity Effects on Film Speed

Exposure is defined as the product of intensity of illumination I , and exposure time t . The photographic reciprocity law states that identical film response should result if the product of I and t remains constant. Although this law is valid over a normal range of

intensities, it fails seriously at both low- and high-intensity levels and is perhaps best known for its failure.

Failure of the reciprocity law quite often results in an apparent increase or decrease in film speed. Most photographic emulsions exhibit both a high- and a low-intensity speed change with a minimum effect occurring usually between 0.1 and 10 seconds. A true failure of the reciprocity law is sensitometrically illustrated by a shifting of the D -log E curve along the exposure axis. This is characteristic of a loss or gain of film speed. Some emulsions do not exhibit a change in apparent speed but are subject to a lowering or an increase of the slope of the curve. Most emulsions, besides exhibiting a change in effective speed, are also subject to a change in slope of the characteristic curve, resulting in a change in image contrast. Figure A-12 illustrates the relationship between the reciprocity failure and the reciprocity effect.

Color Photography

Color is a natural extension of black-and-white photography and adds another dimension to the pictorial representation of the original scene. The general theory describing the photographic

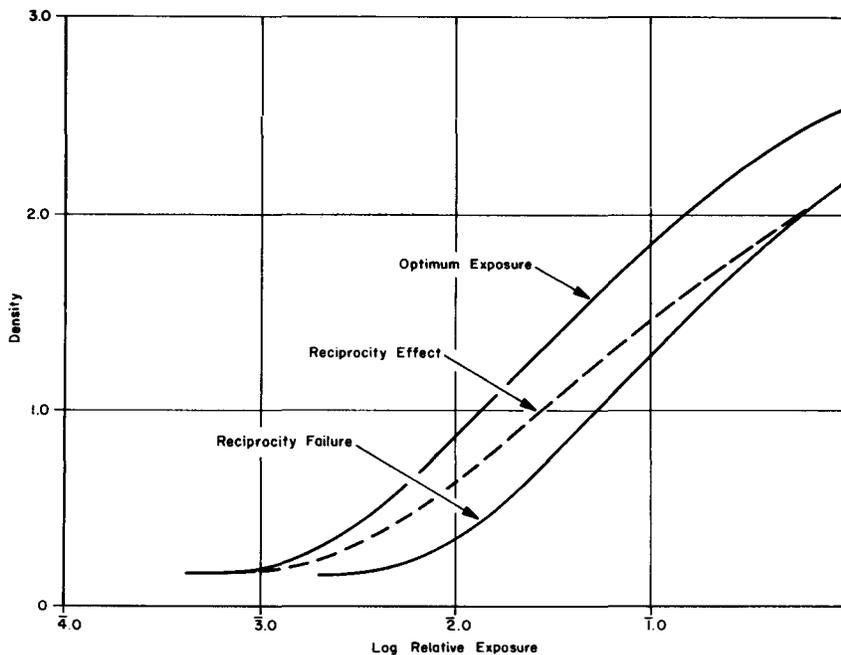


Figure A-12.—Exposure reciprocity.

process for black-and-white materials is also applicable for color films because silver halide grains are the light-sensitive elements for both systems. Major differences are in the film construction and chemical ingredients of the processing chemicals.

Theory

Color rendition in photography is based upon color sensations produced in normal vision. Circumstantial evidence suggests that the mechanism of human vision is responsive over no more than three broad spectral bands in which variation in stimulation produces a multitude of color sensations. A goal of color photography is, therefore, photographic representation of a scene in which the mechanism of vision receives the proper stimulus to create the same illusion of color as that produced from direct observation of the scene.

An ideal photographic color process would generate separate spectral band pictures of a scene in which each recorded image would stimulate only one of the eye's color sensors. Current physiological knowledge of the human eye lacks sufficient detail for such a color process.

Attempts have been made to define the ideal division of the spectrum to produce satisfactory color reproduction by means of photography. The minimum number of spectral bands which photographically produces an effect of color vision appears to be two, and a variation of the two-color concept was most recently reported by Land (ref. 10). Limitation of two spectral recording bands introduces considerable distortion in color fidelity in which certain color sensations are conspicuously poor. The minimum spectral division for practical color photography producing satisfactory color fidelity appears to be three, with one band covering the blue, another the green, and a third the red spectral region (refs. 1, 2, 3, and 11).

Methods

Three-color photography may be generally described by two different processes called additive and subtractive color. Each process employs the same spectral bands for recording the primary exposure. The major difference between them is the method of final presentation to the observer. The additive process most nearly duplicates the eye's response because each record is presented as a separate primary color.

Additive color

Stimulation of the human eye color receptors by appropriate amounts of the primary colors—blue, green, red—produces a neutral color sensation ranging from white to black depending upon the degree of stimulus. Maximum stimulation of all three colors produces white, hence the terminology “additive” wherein the addition of all colors produces white. Unequal portions of primary colored light produce a color differing from the primaries. For example, yellow is the color sensation produced by equal portions of green and red light with a deficiency of blue light. Yellow is, therefore, considered as minus blue because of the absence of a blue stimulus. A deficiency of green is a color sensation called magenta or minus green. The closest natural color of magenta is the flower of the fuchsia plant. Likewise the sensation of cyan, which is a blue-green, is referred to as minus red or the absence of a red stimulus.

Dye colors of the three primaries—blue, green, red—cannot be intermixed or superposed because each color absorbs two thirds of the spectrum. A mixture of only two would absorb all the spectral colors and the mixture would appear black. For this reason blue, green, and red colored photographic images cannot be registered together to form a color photograph. They can, however, be separately projected with all three images being registered at the screen.

Taking advantage of a psychological phenomenon associated with color vision, it is possible to produce a color picture with a single film. Because the eye will fuse small adjacent areas of different colors into a single color sensation, the photographic image may be composed of a geometric pattern of small areas of blue, green, and red. Colored light from each area is visually fused and produces the proper color sensation in the eye. Thus, the picture appears to be a color photograph. A similar process is the basis of color television.

Subtractive color

The subtractive process does not require direct superposition of the primary colors previously described and, therefore, is a more practical approach to color photography. The three colors contained in the superimposed picture presented to an observer are complementary to the blue, green, and red primaries. Ideally each of these complementary colors would absorb only one-third of the spectrum and completely transmit or reflect the remaining two-thirds. Superposition of equal amounts of any two would not affect

one-third of the spectrum and would modulate the remaining two-thirds in proportion to the concentration of the colors. Addition of the third color of equal concentration would produce a neutral gray or black, depending upon the degree of light absorption. The colors used in the subtractive process are yellow, magenta, and cyan, and are the colors which artists use and improperly term primaries of yellow, red, and blue.

Negative

The ability to superimpose colored photographic images of the subtractive process permits use of a single film in which three images are recorded in separate layers. Such multilayer color films can be processed as negatives or reversal positives. Although the exposure of each layer is accomplished using the primary spectral bands of blue, green and red, the color comprising the images of either negative or positive system must always be yellow, magenta, and cyan, respectively. In all negative systems, the tonal scale of the original scene ranging from white to black is reproduced in an opposite relation with white producing the greatest density. Color must also be reproduced in the opposite manner in a color negative. For example, yellow in the original scene will be reproduced as a primary blue in the negative and a primary red would produce a cyan image.

Reversal

Color reversal films reproduce both tonal and color scales in proportion to the original scene because the intended use is usually for direct viewing or projection. The dyes used in the subtractive process have certain deficiencies which do not permit attainment of complete color fidelity. Although reproduction by reversal gives a close approximation to the original scene, the color deficiencies are amplified with a considerable departure from fidelity when making duplicates. The effect of color distortion when making duplicates can be minimized by use of a special color negative which contains integral color correcting masks (ref. 12). This procedure distorts the appearance of the color negative but is effective in removing undesirable color from the succeeding prints.

A primary objective of a color photograph is the creation of an impression which is consistent with the viewer's concept of the appearance of the original scene. In particular, the picture must faithfully reproduce neutral tones as contained in the scene. A color film is essentially a combination of three separate films operating as a unit. Each of the separate emulsions, after process-

ing, produces a colored image which may be described by a D -log E characteristic curve. Ideally, all three curves would have the same shape and would be coincident along the exposure axis. When an approximation of the ideal match is attained, the color film will reproduce neutral tones, and it is in color balance. A change in the color of the exposure illumination will cause an unequal shift in position of the D -log E curves, and the film will no longer reproduce neutral tones. This deviation in apparent speed of the three emulsions may be rectified during exposure by use of colored filters. Essentially, this procedure repositions the D -log E curves back into coincidence to achieve a new color balance which is a prime requirement for reversal films.

Color negatives have a somewhat greater exposure range than reversal films and therefore are less critical to color balance during exposure. A color negative may be used over a broad change in effective color temperature of the light source. Proper color balance is achieved in making the print. Commercially available Kodacolor negative film has sufficient exposure range to cover color temperature differences ranging from tungsten to daylight illumination, whereas no available color reversal film can tolerate more than a 200° K shift in color temperature.

Image Quality

The same factors which influence the quality of a black-and-white photographic image also apply to color photography. Instead of having a single emulsion to contend with, the image quality of color films is modified by the effects produced in three separate images. The turbidity effects upon acutance and resolving power are most noticeable in the bottom layer of a multilayer color film. Unfortunately, the cyan image color of the bottom layer is the most predominant visual color of the three colors used and thus most strongly influences the visual appearance of total image quality.

In order to minimize the effects of diffusion of image-forming light, the various emulsion layers are held to minimal thickness. Red light must be transmitted by both the blue and green sensitive layers before reacting with the red sensitive layer. In traversing the blue and green emulsions, it becomes diffused, thereby modifying the image quality of the bottom layer. Reduction in thickness and turbidity of the blue and green sensitive layers also reduces the diffusion and permits better image quality to be achieved in the bottom layer. As a result of the precautions taken in the con-

struction of multilayer color films, the image quality is only slightly inferior to black-and-white films. Although many black-and-white films are capable of resolving 100 lines per millimeter or better, the average photograph as normally recorded is limited to a much lower value because of inaccuracies in lens focus. A nominal value of 30 lines per millimeter appears to be the practical level most often achieved. For this reason, an image-quality difference is seldom encountered between color pictures and black-and-white photography. Image resolution of 75 to 100 lines per millimeter appears to be the order of magnitude for multilayer color films.

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Abbreviations

A.S.A.: American Standards Association. Now known as United States of American Standards Institute (USASI).
A.S.C.: American Society of Cinematographers.
CC: color compensating (filter).
cd: candlepower.
cm: centimeter.
D.I.N.: Deutsche Industrie Norm, a German system of film-speed designations.
DW: double-weight (paper).
f.p.m.: feet per minute, also: fpm.
f.p.s.: feet per second, also: fps.
m: meter or meters.
ND: neutral density.
ortho.: orthochromatic (preferably spelled out).
P.S.A.: Photographic Society of America.
R.H.: relative humidity.
rpm: revolutions per minute.
S.M.P.T.E.: Society of Motion Picture and Television Engineers.
std.: standard or standards.
SW: single-weight (paper).

Glossary

A

- aberration:** an optical defect in a lens.
- absorption:** in an optical sense, the property of a material to absorb a part of the energy falling upon it while the remainder of the energy is reflected or transmitted.
- absorption band:** in the spectrum of a dye or other substance, a more or less broad region in which light is absorbed.
- achromatic:** without color; applied to a lense corrected for chromatic aberration at two different wavelengths of light.
- acutance:** the objective measure of the image characteristic which relates to the subjective impression of sharpness.
- actinic light:** light capable of causing photochemical changes.
- additive process:** a photographic color process which produces color by the superimposition of the separate primary color lights in the same viewing plane.
- aerial image:** a real image existing in space; it can be received on a ground-glass, film, or other surface, or picked up by another lens system.
- aerial perspective:** an impression of depth or distance in a photograph by means of progressively diminishing detail due to aerial haze.
- aero:** applied to a lens, camera, or film intended for use in photography from aircraft.
- afocal:** applied to a lens system which has both foci at infinity; afocal systems include certain wide angle and telephoto attachments for lenses which do not change the lens extension.
- agitation:** the action or techniques for keeping film surface exposed to fresh processing solutions.
- Airy disk:** the image of an infinitely distant point as focused by a lens. Due to the wave structure of light, this image is a small disk, no matter how perfect the lens corrections. Distinguished from *circle of confusion*, the result of tolerance in focusing, and residual aberrations.
- amplifying:** the process by which a signal is increased. In photography, the physical chemical process by which exposed silver is developed; to amplify the optical signal.
- amplitude:** the maximum height, or maximum depth of a wave or varying signal as measured from the baseline or zero reference.
- anamorphic:** a lens or optical system in which the magnification is different in two directions at right angles; used in wide-screen movie processes to "squeeze" a wide image into standard format and to "unsqueeze" it in projection on a wide screen.
- anastigmatic lens:** a lens which is free from astigmatic aberrations, focusing both vertical and horizontal lines without distortion and with equal brightness and definition.

- angle finder:** a viewfinder containing a mirror or prism so that pictures may be taken while aiming the camera sideways.
- angle-of-view:** the angle formed when two lines are plotted from the center of a lens to the two distant corners of the film record.
- answer-print:** the first combined sound and picture print from a completely edited motion picture negative.
- antiabrasion:** a protective layer on film emulsion, intended to avoid markings due to pressure or rubbing.
- antihalations:** a film or plate, treated with an opaque backing, to prevent halation; abbr. AH.
- aperture:** the opening of a lens, its size being controlled by means of a diaphragm; in a motion-picture camera or projector, the opening in the film track which outlines the picture.
- apochromatic lens:** a lens which is corrected for chromatic aberration for three wavelengths of light rather than two as in the achromatic lens; generally used by photoengravers and color photographers for very precise color-separation work.
- art work:** a term applied to the retouching, lettering, and drawing which may be added to a photograph.
- A.S.A.:** refers to the American Standards Association (now the United States of American Standards Institute) through whose offices industry-wide standardization of photography is executed. The ASA rating of a film is a uniform method of rating the speed or sensitivity of camera films.
- astigmatism:** a lens defect which appears as an inability to focus vertical and horizontal lines in the same plane near the edges of the field.
- asymmetrical (nonsymmetrical):** applied to a lens having differently shaped elements on either side of the diaphragm.
- attenuation:** reduction of intensity; applied to an electric current, sound wave, optical energy, etc.
- auxiliary lens:** a lens element which is added to the regular camera lens to shorten or increase its focal length.
- available light:** photography is said to be available light photography if the sole source of illumination is the light provided by the natural environment.

B

- back lighting:** the illumination of the picture, whether by artificial or natural light, where the predominant source of illumination is on the side of the subject away from the camera or "in back of the subject" as he faces the camera.
- barrel distortion:** a condition in a lens which causes the lines in an image to be bowed outward from the center.
- barrel mount:** a simple tube in which a lens is mounted; no shutter is provided, though an iris or other type of diaphragm may be supplied.
- beam-splitter:** a prism or mirror, or combination of prisms and/or mirrors, so designed that a certain fraction of the incident light is transmitted without change, the remainder being reflected at some angle to the axis of the unit.
- between the lens:** the location of the shutter mechanism in the same mechanical support as the lens, with the shutter blades located in the central region of the lens between the principal planes.

- boresight:** an optical device for alining an engineering or motion picture camera by viewing through the lens.
- boresight camera:** a camera used to photographically record a scene being observed by some other photo-optical devices as a visual record for orientation and/or calibration.
- brightness range:** the scene luminance range which is the range of luminance being presented by the scene to the camera. Scene luminance range in excess of that capable of being recorded by the camera film system will result in a loss of information at either the high or low end of the scale, depending on the choice of exposure level.
- bulb:** shutter setting in which the shutter remains open as long as the actuator is depressed and closes as soon as the actuator is released; marked "B" on cameras.
- burned out:** applied to an overexposed negative or print lacking in high-light detail.
- burning in:** a method of darkening parts of a print in which certain parts of the image are given extra exposure while the rest of the image is protected from the light.

C

- candela:** a unit of luminous intensity; the luminance of a blackbody radiator at the temperature of solidification of molten platinum is 60 candelas per sq cm.
- candlepower:** luminous intensity expressed in terms of the standard candle.
- cartridge:** a light-tight container which is supplied loaded with film and can be placed in the camera in daylight.
- cassette:** an alternate term for cartridge.
- characteristic curve:** a graphical plot of the input-output relationship of a photographic process. It is a plot of the optical density of the photographic emulsion which results from a given exposure plotted on a log exposure scale. The logarithmic scales are used because they most closely resemble behavior of the human eye.
- chromatic aberration:** a defect in a lens in which rays of light of different colors are not brought to a focus in the same plane.
- chromatic difference of magnification:** a lens defect differing from chromatic aberration in that the rays of various colors are brought to a focus in the same plane, but at different points; in color-separation work, this defect produces three-color images of different sizes; sometimes called lateral color.
- cinching:** tightening a roll of film by holding the spool and pulling the free end; invariably results in parallel scratches or abrasion marks.
- cine:** word or prefix referring to motion picture.
- claw:** metal tooth or finger which advances the film frame by frame in a motion-picture camera.
- closeup picture:** picture which is taken from a point nearer than the normal viewing perspective of the scene.
- coating, lens:** a thin, transparent coating applied to a lens to reduce surface reflections and internal reflections; also cuts down transmission of ultraviolet rays, acting somewhat like a haze filter.
- collimate:** to produce parallel rays of light by means of a lens or a concave mirror.

- collimating lens:** a lens so adjusted as to produce a parallel beam of light.
- color-blind:** applied to an emulsion sensitive only to blue, violet, and ultraviolet light; see color-sensitive.
- color-sensitive:** an emulsion which is not colorblind; for example, an emulsion sensitive not only to blue, violet, and ultraviolet, but also to yellow and green, is called orthochromatic; if sensitive to red as well, it is called panchromatic.
- coma:** a lens aberration affecting the rays which are not parallel to the lens axis; images of points near the edges of the picture appear as ovals pointing toward the center of the picture.
- complementary colors:** colors of pigment which when mixed produce a gray; colors of light which when mixed produce white light.
- composite:** a film that contains both the picture and sound records.
- concave:** hollowed out; curved inward; applied to negative lenses which are thinnest in the center.
- concave lens:** a lens having one or two concave surfaces.
- concavo-convex lens:** a lens having one concave and one convex surface.
- condenser:** a lens used in an enlarger or a projector to collect the light rays from the source and direct them through the negative or the slide to the objective lens.
- conjugate (adj.):** applied to the position of the object and image points of a given lens; for every possible position of an object from the front focal point of the lens to an infinite distance, there is a corresponding (or conjugate) image point on the opposite side of the lens.
- conjugate foci:** the distance from lens to image and from lens to subject when the image is in focus.
- contact print:** a print made by placing a negative in contact with sensitive paper while exposure is being made.
- continuity:** plan and order of sequences in a motion picture.
- continuous printer:** a motion-picture or still-picture printer in which the negative and positive films travel continuously past the exposing light source; also applied to a machine which prints microfilm negatives on a continuous roll of paper.
- contrast:** generally used to describe the rate of change in the brightness or luminance values of the scene. When used with relationship to the characteristic curves, it indicates the change of the density with respect to the change of the logarithm of the exposure.
- contrast filter:** a color filter so chosen as to make a colored subject stand out distinctly from surrounding objects.
- contrast paper:** photographic paper having a contrasty emulsion in order to produce good prints from soft negatives; also called hard paper.
- convergent lens:** a lens which bends rays of light passing through it toward its axis.
- convex:** the opposite of concave; curved outward; applied to a lens which is thicker in the center than at the edges.
- core:** a wood, plastic, or metal spindle which is removable from the camera on which film is wound, having a cylindrical form. No part extends along the side of the film and thus unexposed photographic film on cores must be handled in the dark room.
- coupled rangefinder:** a rangefinder connected to the focusing mechanism of the lens that measures the distance to the subject while the lens is focused.

- cover glass:** thin glass plates used to protect lantern slides or transparencies.
- covering power:** applied to a lens, referring to the area of image plane where a sharp image is formed by the lens.
- critical focus:** exact focus, usually attained with the aid of a focusing magnifier.
- curvature of field:** a lens aberration in which the image is not formed on a plane but in a concave surface; thus the entire image cannot be brought into focus on a flat film or plate.
- curvilinear distortion:** a lens aberration in which straight lines near the edges of the picture are imaged as curves. (See **barrel distortion** and **pillow distortion**.)
- cut-film:** a term for sheet film.
- cutoff:** an obstruction of light rays to the lens, either by the sunshade, the camera bed, or an adjacent lens on a turret.

D

- daylight loading:** any arrangement on a camera, a film magazine, or a developing tank permitting insertion of film in daylight without the use of a darkroom or a changing bag.
- definition:** the clarity, sharpness, resolution, and brilliancy of an image formed by a lens.
- dense:** very dark; applied to a negative or positive transparency which is overexposed, overdeveloped, or both.
- densitometer:** an instrument designed to measure the density of a negative or a print.
- density:** the measure of the optical absorption of material on a logarithmic scale. The specific definition of density is the logarithm of the ratio of the energy incident upon an object to that which results from the modulation whether it be absorption, scattering, or transmission of the object.
- depth of field:** the range of distances when a camera has a given setting through which all objects are said to be in acceptable focus.
- depth of focus:** the allowable error in lens-to-film distance within which an acceptably sharp image of the subject focused upon will still be obtained.
- development:** the process by which the final image is generated on photosensitive material by means of chemical or physical treatment which effectively amplifies the basic photochemical reaction which took place at the moment of exposure.
- development by inspection:** development of negatives or prints by inspection, depending on the operator's judgement as to when development is complete.
- diaphragm:** a mechanical device inserted in the center of a lens between the principal planes for controlling the amount of light passing through the lens.
- diffraction:** the bending of a light ray in passing the edge of an opaque barrier.
- diffraction disk:** see **Airy disk**.
- diffused light:** light which does not reach the subject in a single beam, but is scattered by a medium such as clouds, groundglass, spun glass, or thin fabric.
- diffuser:** a tracing cloth or glass-wool screen placed in front of a light source to soften the light.

- diffusion:** an optical process by which a material modulates light so as to cause partial or total disturbance of the light beams, resulting in partial or total reduction in the total information in an image.
- diffusion transfer process:** a method of producing a positive image by transfer of unused silver salts from the negative during development; used in office copying machines, Polaroid-Land cameras, etc.
- direct finder:** a viewfinder through which the subject is seen directly, such as the wire finder on various cameras.
- direct positive:** a positive image obtained in a basic photochemical process directly without the use of a negative or negative step in the process. (Distinguish from reversal.)
- dispersion:** the separation of a single ray of white light into a group of colored rays by a prism or other optical device.
- distortion:** an incorrect rendering of the shape of a subject.
- divergent lens:** a lens which bends the rays of light away from its axis; also called a negative element.
- double coating:** the coating of a fast emulsion on top of a slow one, to secure greater latitude of exposure.
- double exposure:** two exposures on a single negative, either by accident or by design.
- double weight:** the heavier weight in which photographic papers are supplied.
- duplicates:** photographic copies made of photographic originals having same tone scale (positive from positive; negative from negative) and generally the same size.

E

- easel:** a device used to keep sensitive paper flat while enlarging; occasionally used to hold photographs flat while they are being copied.
- edge fog:** fog on film due to leakage of light between the flanges of the spool on which it is wound.
- effective aperture:** the diameter of the lens diaphragm as measured through the front lens element; the unobstructed useful area of a lens; it may actually be larger than the opening in the lens diaphragm, owing to the converging action of the front lens element.
- emulsion:** the combination of silver salts and gelatin support which constitutes a light-sensitive system and is coated on the base support to create a photographic film or plate.
- emulsion speed:** the inherent sensitivity of the photographic emulsion to light as measured as a reciprocal of the amount of energy required to produce a given effect.
- enlarged negative:** a negative made from a smaller one by optical projection.
- enlargement:** a print made from a smaller negative through a projection process.
- exposure:** the actual act of allowing image forming energy to strike the photographic film. Also, a measure of the total energy allowed to the film. This energy is a product of intensity (a unit of power) times time.
- exposure index:** a measure of the sensitivity of the film as derived from the reciprocal of the exposure required to produce a given effect.
- exposure indicator:** a device attached to a camera to indicate the number of exposures; also to a plate holder to show whether the plate has been exposed.

- exposure meter:** a device for measuring the light level of a scene together with a calculator for determining a desirable photographic exposure.
- exposure time:** the time period during which the exposure takes place.
- extension tube:** a tube device placed between the lens and the camera to extend its focusable range, primarily for using the camera very close to objects.
- eyepiece:** the lens element of a microscope, viewfinder, or telescope to which the eye is applied in order to view the image.

F

- f/ (as: f/2.8; f/5.6; f/11):** the designation of the relative aperture of a lens; it is calculated by dividing the focal length of the lens by its effective aperture.
- far point:** the farthest object from the camera which is still acceptably sharp when the camera is focused at a given distance.
- ferrotype plate:** a highly polished plate used to produce a glossy finish on prints.
- ferrotyping:** the procedure of drying a glossy photograph in intimate contact with a highly polished surface in order to impart a high gloss on its surface finish to the photograph.
- film base:** the transparent material on which an emulsion is coated.
- film cement:** a solution of cellulose acetate or nitrate used to join strips of motion-picture film in editing.
- film chamber:** the section of a motion-picture film camera which contains the film, film gate, and the film-moving mechanism during operation.
- film cleaner:** a liquid used to remove dirt, dust, and grease from a film without injuring the base or the emulsion.
- film gate:** a combination of the aperture plate, film channel, pressure plate, pads and springs used to maintain the position of the film in the focal point of the lens. May be applied either to a motion-picture camera or projector.
- film pack:** a metal case containing a number of films, so arranged that films may be changed by pulling out paper tabs.
- film-pack adapter:** a holder by means of which the film packs may be used in a camera designed for plates or sheet films.
- film-slide:** most commonly identified as individual frames mounted in cardboard or glass mounts for projection.
- filmstrips:** a series of still pictures on motion-picture film, generally in the same format of motion-picture films which are shown by a special projector one picture at a time. It is convenient for audiovisual work as the bulkiness of slide mounts is eliminated.
- film tank:** a container holding solutions and films to be processed therein.
- filter factor:** the number of times exposure must be increased to compensate for light absorbed by the filter.
- filter ratio:** the ratio between the factors of two or more filters used with the same film and illuminant; frequently used in color separation work in preference to the actual filter factors, since no exposure is normally made without filters in such work.
- filters:** transparent material having a specific absorption characteristic to modify the spectral distribution of energy in a light source or passing through a lens.

- finder:** a viewer through which the picture to be taken may be seen and centered.
- fine-grain developer:** a developer of low potential which prevents a mottled image formed by the clumping of silver grains.
- fine-grained:** applied to a negative with very little granularity; one which may be enlarged from 7 to 10 diameters or more with satisfactory quality.
- fixed-focus:** applied to a simple camera (box camera) or folding camera having a short-focus, small-aperture lens, whose great depth of field makes focusing unnecessary; also called **universal focus**. In aerial photography many cameras are fixed-focus with the lens set for the infinity focus condition.
- fixing:** that part of the chemical processing which takes place after development is completed which removes or neutralizes unwanted sensitive components of the film. This permits it to be viewed in direct light without further photochemical reaction.
- flange:** a threaded metal ring used to fasten lenses and/or shutters to the front of a camera.
- flare:** light reaching the photosensitive emulsion, resulting from internal reflections within the lens, such as occur from noncoated air-glass lens surfaces.
- flash gun:** formerly, an apparatus for firing flash powder; now used as a term for the battery case, lamp socket, and reflector used with photoflash lamps or electronic flash units.
- flashtube:** a glass or quartz tube, usually wound in helical shape, containing two electrodes and filled with xenon or other inert gases at a very low pressure; it is used as the light source in electronic-flash units and stroboscopic lighting.
- flat:** lacking in contrast.
- flood:** a light source providing a wide, diffused beam of light.
- floodlamp:** in general, any lamp or lighting unit producing a broad beam or flood of light; colloquially used as a contraction for photoflood lamp; see **photoflood lamp**.
- fluorescence:** the property possessed by certain substances of emitting light of longer wavelength when exposed to light of short wavelength.
- f-number (*f/stop*) (*f/5.6*; *f/8*; *f/11*):** the relative aperture of a photographic lens, expressed as the ratio of the focal length to the effective aperture diameter.
- focal length:** a general term used to designate the characteristic of the lens in terms of the distance between the point of focus and the corresponding principal plane of the lens.
- focal plane:** the position in a camera occupied by the plate or film.
- focal-plane shutter:** a shutter consisting of a curtain or a roller-blind with slits of various sizes, traveling as close to the film as possible.
- focal point:** where all light rays transmitted from a given object point intersect. With the object at infinity, i.e., the incident rays parallel to the axis of the lens, the image is the principal focal point. The principal focal point lies on the lens axis.
- focus (n):** the point at which converging rays of light from a lens meet.
- focus (v):** the act of adjusting a photographic system for best image formation.

- focusing magnifier:** a lens through which the image on the groundglass is viewed for critical focusing.
- focusing mount:** a spirally threaded tube in which a lens is mounted; focusing is accomplished by rotating the mount, which moves the lens to and from the film.
- focusing scale:** a graduated scale on a lens or a camera, permitting focusing on a given subject by estimating its distance from the camera and setting an indicator to correspond.
- focusing screen:** the groundglass in a camera on which the subject is focused.
- fog:** a dark, hazy deposit over the entire film or paper, or portions thereof.
- foot-candle:** a measure of light intensity.
- foot-lambert:** a measure of source brightness or luminance.
- frame:** one individual picture on a strip of motion-picture film, microfilm, or 35-mm film.
- frame counter:** a dial counter indicating the number of frames passing through a camera.
- frame line:** narrow exposed area between adjacent frames or pictures on a strip of film.
- front lens:** the first element of a lens system; that which the ray enters; also sometimes used for a supplementary lens to be placed in front of a lens system.
- full aperture:** the maximum opening of a lens or lens diaphragm.

G

- gamma:** a numerical index of the rate of change of density with log exposure derived from the characteristic curve.
- gamma infinity:** since characteristic curve varies with the type and duration of development, this variation is reflected as a change in the gamma value; gamma infinity is a numerical value indicative of the steepest rate of change obtainable with a particular film and developer combination.
- gate:** see film gate.
- ghost:** the reflection of an image on one or more lens surfaces recorded by the negative.
- global photography:** a term used by meteorologists to define photographs of the Earth and its environment in a very comprehensive picture that gives a scale of the entire photograph covering distances greater than 5,000 kilometers.
- glossy:** photographic papers heavily coated with gelatin so that they may be ferrotyped.
- gradation:** a term applied to the negative or positive; the rate of increase of density with exposure, as one factor of contrast.
- gradient:** applied to the characteristic curve, the slope of any chosen part of the curve; distinguished from gamma, which refers to the slope of the straight-line portion of the curve only.
- grain:** the random assortment of silver deposits in a developed photographic image in varying particle sizes and shapes.
- graininess:** the subjective impression of variation in density resulting from the grain structure of the photographic sample when viewed at a high magnification.
- granularity:** the objectively determined characteristic of the developed

photographic material which results from the image being formed by elements having perceptible size and shape which are referred to by the general term grain.

gray scale: a test pattern consisting of patches of various shades of gray, or having different reflections without color, which is used for control purposes in precision photography.

groundglass: a screen at the back or top of the camera upon which the image may be focused.

gun camera: a special aerial motion-picture camera which automatically photographs any subject being fired upon by the gun to which it is connected.

H

halation: in its simplest terms, a designation of unwanted flare resulting from reflection of light which has passed through the photographic emulsion by the back of the film support.

haze: An atmospheric phenomenon which tends to destroy the contrast and image quality in photographs taken from high altitudes or from long distances across ground.

helical mount: a spirally threaded lens mount permitting focusing by rotating the movable part of the lens tube.

high-speed camera: a framing motion-picture camera capable of very fast frame rates for engineering studies. Generally greater than 100 fps., may work up to 10,000 fps.

hypo: sodium thiosulfate (incorrectly called sodium hyposulfite), a chemical used in fixing baths; the word is also applied to the complete fixing bath, containing sodium thiosulfate and various acids, hardening agents, etc.

hypo test: a method of checking the completeness of washing by running the drippings of wash water from the film or print into various testing solutions; also, commercial solution used to test strength of hypo.

I

image: the representation of an object formed by optical means and its recording by photochemical means.

image, anamorphic: an image which has been produced by an optical system having different horizontal and vertical magnifications.

image dissection: the technique by which the information contained in the photograph which is a two-dimensional record in space is scanned so as to produce the information sequentially in a one-dimensional record generally on a time base; a significant technique when it is desired to transmit pictures over a long distance or to enter picture information into a computer for further analysis.

incident light: the light which falls on a subject, either from natural or artificial sources, by which the photographic record is made.

index of refraction: the mathematical expression of the deviation of a light ray entering a given medium at an angle to its surface.

infinity: photographically, a distance from which light appears to reach the lens in parallel rays; symbol: ∞ .

infrared rays: invisible radiation whose wavelength is greater than 700 nanometers; the shorter wavelengths of heat rays.

intensification: a postprocessing procedure by which the density or contrast of the image is increased.

- interference:** an effect resulting from the meeting of two light rays of identical wavelength but different phase; when the phase difference is $\frac{1}{2}$ wavelength, the two light waves cancel and darkness results; interference between two rays of heterochromatic light results in colored patterns similar to the spectra produced by a prism.
- intermittent movement:** a mechanism in a camera or projector which causes film to move past the exposing aperture one frame at a time instead of a continuous flow.
- intervalometer:** a device used on aerial or engineering data cameras which automatically operates the camera at predetermined intervals.
- inverse square law:** the intensity of light received at a point varies inversely as the square of the distance from the source.
- invisible rays:** light rays which cannot be seen by the eye, such as ultraviolet and infrared rays.
- iris diaphragm:** a lens control composed of a series of overlapping leaves operated by a revolving ring to vary the aperture of the lens.

K

- kinescope recording:** a motion-picture film of a television broadcast, made by photographing the image on the face of a kinescope or cathode-ray tube.

L

- laboratory packing:** unexposed motion-picture film which is wound on a core, instead of a daylight-loading spool.
- lambert:** a photometric unit of surface luminance.
- lamphouse:** that part of a projector or an enlarger which contains the light source.
- lantern slides:** small transparencies, either 2×2 , $3\frac{1}{4} \times 3\frac{1}{4}$, or $3\frac{1}{4} \times 4$, intended for projection. In recent times used to distinguish $3\frac{1}{4} \times 4$ " slides from smaller sizes.
- latensification:** a form of hypersensitization which consists of applying the hypersensitizer after exposure but before development; usually applied to the use of a long exposure to very dim light to raise the threshold of exposure of the emulsion.
- latent image:** the image recorded by light on the sensitive emulsion, remaining invisible until developed.
- lateral color:** see **chromatic difference of magnification**.
- latitude of exposure:** the amount by which a negative may be overexposed or underexposed without appreciable loss of image quality.
- leader:** unusable film or a special opaque material supplied at the beginning and end of the roll to facilitate threading and to protect the basic film from damage by light. On motion-picture projection prints it will contain identification and cueing information.
- lens:** an optical element, generally glass, with properly designed curved surfaces for the purpose of creating a real image of a scene.
- lens board:** a detachable board carrying a lens and a shutter, which is fastened to the front of the camera to permit interchange.
- lens cap:** a cover used to protect a lens from dust and damage when not in use.
- lens hood:** a shade to keep extraneous light from the surface of a lens.
- lens paper:** a fine soft tissue paper used for cleaning lenses.
- lens turret:** a revolving plate carrying several lenses attached to the front

- of the camera in such a way that any lens may be placed in position for use by revolving the plate.
- light filter:** see **filter**.
- light fog:** the fog produced over an image by accidental exposure of film to extraneous light.
- light trap:** a system of staggered passageways or double doors so that a darkroom may be entered or left without light being admitted.
- linear perspective:** the impression of depth or distance in a photograph due to the diminishing of the size of objects in proportion to their distance from the camera.
- line copy:** original material to be copied, containing only black-and-white areas or lines, without intermediate tones.
- line original:** see **line copy**.
- loop:** the slack portion of the film between sprockets and aperture which absorbs the shock of intermittent motion imparted to the film by the advance mechanism.
- lumen:** photometric unit, equal to the luminous flux on 1 square foot of surface from a standard candle 1 foot away.
- luminance:** that characteristic of an object which defines the amount of light radiated from the surface.
- lux:** lumen per square meter.

M

- magazine:** the container holding the film feed and takeup spools of a motion-picture or still camera, also a device for holding and exposing from 12 to 18 sheet films or plates in succession. The container is reusable and is reloaded in the darkroom by the operator.
- mask:** a sheet of opaque material or controlled density used to control the exposure on certain areas of the film or paper.
- matte:** a thin metal plate containing an opening which may be one of various shapes, such as circle, oval, double circle (binoculars), etc., used to frame the scene taken by a motion-picture camera; also applied to a dull-surfaced photographic material.
- matte back:** a film frosted on the reverse side for easier retouching.
- matte box:** a large sunshade for a motion-picture camera, containing a slide to hold mattes of various shapes before the lens.
- meniscus:** see **concavo-convex**.
- meter-candle-second:** a unit of exposure in sensitometry; 1 second of exposure at a distance of 1 meter from a light source of 1 candlepower.
- microdensitometer:** a special form of densitometer for reading densities in very small areas; used for studying astronomical images, spectroscopic records, and for measuring graininess in films.
- microfiche:** a micro reproduction system for the storage and retrieval of documents where the images are contained on a 4- by 6-inch piece of film with manual storage and retrieval much like index cards.
- microfilming:** a generic name used for microreproduction of documents for efficient storage and retrieval systems.
- micrometer:** a unit of length; 1/1000 of a millimeter; abbr.: μ . formerly called a micron.
- micrometer mount:** a very precise, helical lens mount; see **helical mount**.
- microphotography:** a process for making minute, precision photographs of an object, or little pictures of large subjects. The microfilming of a check produces a microphotograph.

- miniature camera:** a generic name originally used for cameras taking still pictures on 35-mm motion-picture stock. Generally refers to any cameras taking pictures on 35 mm or smaller size films.
- monochromatic:** containing light of one wavelength or color.
- mottling:** a nonuniformity of density which appears in negatives or prints and is more gross than that caused by grain. It is generally associated with an agglomeration of silver grains due to deficiencies during processing.
- multilayer:** a film or glass plate coated with two or more layers of emulsion of differing characteristics; these include double-coated plates for reduction of halation effects and for change in latitude and the two- or three-layer films used for color photography.
- multilayer color film:** a color film in which the red, green, and blue recording emulsions are coated superimposed on a single film base. The three emulsions yield color images which, because of the superimposition, present a full color reproduction of the original scene.

N

- nanometer:** a unit of length; 1/1,000,000 of a millimeter, or 1/1000 of a micron; abbr.: m μ . Originally known as a millimicron.
- near point:** the nearest object to the camera which is still acceptably sharp when the camera is focused for a given distance.
- negative:** a photographic image in which the amount of silver present is more or less proportional to the quantity of light reflected from the original object; thus bright objects are black and dim ones white: abbr.: neg.
- negative element:** another name for divergent lens; see **divergent lens**.
- neutral:** without color; gray; chemically, a solution which is neither acid or alkaline.
- neutral density filter:** a gray filter used to reduce exposure when a lens cannot be stopped down sufficiently. It produces no measurable color change in the light which it transmits.
- non-color-sensitized:** a photographic emulsion having only the inherent sensitivity of the silver salt; sensitive only to blue, violet, and near ultraviolet light; see **color blind**.
- noncurling:** applied to film which has a clear gelatin coating on the back to minimize curl caused by shrinkage of the emulsion in drying.
- nonhalation:** see **antihalation**.
- numerical aperture:** the sine of half the angular aperture, used as a measure of the transmission and optical power of an objective lens.

O

- objective:** the lens which actually forms the primary image in an optical system; it may be used in conjunction with a condenser to direct the light rays through the object and in the case of a microscope, finder, etc., with an eyepiece to magnify further the image formed by the objective.
- oblique:** applied to an aerial photograph taken at an angle from the air-plane.
- opacity:** the light-stopping power of the silver deposit in a negative.
- opal glass:** a white, milky, translucent glass used as a maximum diffusion medium in optical systems.
- opaque:** not capable of transmitting light; also a term applied to a red or

- black pigment used to block out portions of a negative which are not to be printed.
- optical axis:** an imaginary line passing through the centers of all the lens elements in a compound lens.
- optical center:** the point, usually within a lens, at which the light rays are assumed to cross; certain types of telephoto lenses may have this point outside the combination.
- optical contact:** the adhesion of two glass surfaces by means of a transparent medium so that there is no air between them.
- optical flat:** a filter or other glass plate, ground to a plane-parallel condition with a high degree of precision.
- ortho:** an abbreviation for orthochromatic; see **orthochromatic**.
- orthochromatic:** the word actually means correct color; in photography, a term applied to film which is sensitive to blue and green light but not to red.
- overdevelopment:** the result of permitting film or paper to remain in the developer too long, resulting in excessive contrast or density.
- overexposure:** the result of too much light being permitted to act on a negative, with either too great a lens aperture or too slow a shutter speed or both.
- oxidation:** the loss of activity of a developer due to contact with the air.

P

- pan:** an abbreviation for panchromatic; see **panchromatic**.
- panchromatic:** applied to photographic material sensitive throughout the entire visible spectrum.
- panning:** allowing the camera to scan across the scene while taking motion pictures in order to produce a general overall view of a scene or to follow a moving object through a scene over a distance greater than the normal field of view of the camera.
- panoram:** to move a motion-picture camera while it is operating so as to include a sweeping view.
- panoramic head:** a revolving tripod head, so graduated that successive photographs may be taken which can be joined into one long panoramic print.
- parallax:** the error caused by using the viewfinder at any point closer than nominal infinity. It occurs in a camera system when the viewfinder has an optical axis parallel to, but displaced from, the optical axis of the lens.
- parallax adjustment:** adjustment for tilting a viewfinder so that its field is the same as that of the picture-taking lens for a given distance.
- paraxial:** referring to the space or rays closely surrounding the principal axis of a lens system.
- parfocalized:** a group of lenses, all mounted so that they will come into focus when secured in the same mount, are said to be parfocalized; term applies especially to sets of microscope objectives to be used in a multiple revolving nosepiece.
- pellicle:** a thin film or membrane; for example, the extremely thin, semi-transparent mirrors used as a beam-splitter in a camera making more than one picture at a time.
- pentaprism:** a five-sided prism used in single-lens reflex viewing hoods to turn the image right-side-up and laterally correct.

- perspective:** the relative size and alinement of objects as recorded on a plane surface.
- photoengraving:** a method of producing etched printing plates by photographic means.
- photofinishing:** the commercial processing and printing of amateur photographs in high-volume operations.
- photoflash lamp:** a light bulb filled with aluminum wire or shreds in an atmosphere of oxygen; the heating of the filament ignites the primer which in turn fires the aluminum, giving a short brilliant flash of light.
- photoflood lamp:** an electric lamp designed to be worked at higher than normal voltage, giving brilliant illumination at the expense of lamp life.
- photogrammetry:** the science of mapping by the use of aerial photographs; the science of precision determination of geometrical dimensions from a photograph.
- photomacrography:** a process for making either moderately magnified or unmagnified pictures of small objects. Note that no compound microscope is used. Often it is considered that a photomacrograph represents an enlargement of no more than about $\times 20$ diameters. A photograph of a coin at twice life-size is a photomacrograph.
- photometer:** device for measuring light energy.
- photomicrography:** a process for making greatly magnified photographs of minute objects through a compound microscope, or for making big pictures of microscopic subjects. A photograph of a gnat's eyebrow is a photomicrograph.
- phototheodolite:** a camera characterized by its ability to measure and record the principal geometric data on the film while simultaneously taking the picture. A cinetheodolite uses motion picture techniques.
- phototopography:** the mapping or surveying of terrain by means of photography.
- physical development:** a method of developing a photographic image by the deposition of metallic silver on the latent image nucleus.
- pillow distortion:** a type of distortion in a lens system which causes the lines in the image to be bowed inward toward the center of the field. Sometimes called "pincushion" distortion.
- pinhole camera:** a camera that creates an image by pure diffraction techniques utilizing an extremely small opening in the camera wall without requiring a lens.
- pinholes:** tiny clear spots on negative or positive images, caused by dust, air bells, or undissolved chemicals.
- plano-concave lens:** a lens having one side convex and one side flat.
- plate back:** an attachment to certain roll-film cameras such as the older Kodaks, the Rolleiflex, etc., now used with optical reconstruction equipment to permit the use of plates or sheet film; incorrectly used as a description of a camera primarily designed for use with plates; such cameras are plate cameras, not plate-back cameras.
- plate holder:** a lightproof holder in which sensitized plates are held for exposure in the camera.
- plate magazine:** a lightproof box containing mechanism to expose a number of plates successively in a camera.
- polarized light:** light energy which has a preferred direction of orientation

about the axis of the direction of propagation; the orientation refers to the wave nature of light energy in propagation.

portrait attachment: a supplementary lens permitting the camera to be focused on objects closer than is normally possible.

positive: an image in which the tones correspond to those of the original, light objects being light and dark objects being dark; abbr.: pos.

power (of a lens): the reciprocal of the focal length of a lens in meters; expressed in diopters. This terminology is derived from and is primarily used in the science of ophthalmology.

preexposure: exposure of a sensitized material to light either during manufacture or by the user before exposure in the camera, as a means of intensifying the latent image, particularly in shadow areas.

prefocused: applied to a lamp having a special type of base and socket which automatically centers the filament with respect to an optical system.

pressure plate: the movable channel plate which by means of light spring tension holds a film flat against the aperture which is the focal plane of the lens.

principal focus: of a lens or spherical mirror, the point of convergence of light coming from a source of infinity.

principal plane: a set of planes perpendicular to the axis of a lens, passing through the principal points such that a ray of light entering the lens in the direction of one leaves the lens as if it originated in the other and parallel to the original direction.

printer: a machine for making photographic reproductions of photographic master copies, such as a negative or reversal transparency, which performs in several ways. A contact printer makes the reproduction by direct contact of a receiving sheet to a transparent master. A projection printer projects the master onto the sheet. In addition to printers for still films, there are continuous printers for motion pictures, in which the film runs at a constant rate through the printer, and a step printer, in which the film is stepped and printed frame by frame. In motion-picture work a projection printer is often called an optical printer.

printing: the generic name for the process of producing reproductions of photographic originals in a final form ready for display and viewing. This applies both to production of opaque or reflection type originals of single photographs, as well as for the final copy of a motion picture which is projected for final viewing.

printing frame: a frame designed to hold a negative in contact with paper, under pressure, for the purpose of making prints.

printing-out paper: a photographic paper forming a visible image immediately on exposure, without development; it must be fixed, however, for permanence of the image.

prism: an optical device which directs a ray of light at a different angle than that at which it entered; it is sometimes used to break down white light into its component colors in certain optical instruments.

process camera: a specially designed camera for high precision and metric photography generally associated with photoengraving, lithography, and cartography. It has found very recent application in the preparation of photographic masters for the manufacture of microelectronics. It is characterized by solid, unit construction, mechanical design to minimize vibration errors.

process lens: a highly corrected lens used for precise color-separation work and/or critical geometry in process camera work.

projection print: an enlarged or reduced photographic print made by projection of an image of the negative on the sensitized material.

projection printer: an enlarger.

projection screen: the screen on which transparent photographic images are displayed by projection, whether they be slides or motion pictures. The screen must be designed to provide maximum optical efficiency to the viewing audience.

projector: an optical device for the projection of transparent photographic images, whether slides or motion pictures, in an enlarged format for comfortable viewing.

Q

quartz lens: a special lens used for ultraviolet photography.

R

radiography: the application of photography for recording images produced by energy in the X-ray spectrum. Such energy is capable of penetrating human tissues and, at higher levels, metal parts.

rangefinder: an optical device for measuring distance.

ratio: the degree of enlargement or reduction of a photographic copy with respect to the original.

raw film: unexposed, undeveloped film.

reading machine: a projector with a self-contained screen, used for reading microfilm copies.

real image: any image formed by a lens or mirror which can be focused on a screen, plate, film, or other surface; such an image exists in space, as can be proved by blowing smoke across the image space; this space image is called an aerial image; distinguished from virtual image; see **virtual image**.

rear projection: projection of a motion picture or still picture from behind a translucent screen or from the side of the screen opposite that of the viewer.

reciprocity law: the photosensitive effect produced by the response of the photographic film to incident energy or, in photographic terms, exposure. There are two reciprocal components to the quality of exposure: the intensity (or power), the rate at which energy is delivered; and time, the duration through which it is delivered. The reciprocity law states that the photosensitive reaction should be independent of intensity, or time, at a constant energy, or exposure. Silver photographic systems, as well as others, fail to obey this reciprocity law.

reduce: to make a print smaller than the original negative; for example, to make lantern slides from large negatives, or to make a print on 16-mm motion-picture film from a 35-mm negative.

reel: a version of the spool, but with open flanges, used for finished film in projector systems. Arbitrarily, 1000 feet of 35-mm film or 400 feet of 16-mm.

reflection: the redirection of a beam of light from a surface.

reflex camera: a camera in which the primary image in a vertical plane is bent at 90 degrees by means of a mirror to a horizontal plane for more convenient viewing and focusing.

- relative aperture:** the ratio between the effective aperture of a lens and its focal length; the relative aperture is usually given in inverse whole numbers rather than fractions; thus a lens whose relative aperture is $\frac{1}{4}$ is called an *f/4* lens, etc.
- reseau plate:** a glass plate, which contains high precision calibrated marks, incorporated as part of a precision photogrammetric camera system to provide both a reference point for subsequent data reduction and a means for correcting for lack of film stability.
- resist:** in photoengraving, a material applied to the image, and other parts of the plate, to protect the metal from the action of the etch bath. A photoresist permits the formation of image by photographic means.
- resolving power:** a characteristic of a film which defines its ability to make a distinguishable record of small periodic images.
- reticle:** a scale or grid engraved on a glass plate, placed in an optical system for measurement or to provide a reference point; also, but less correctly, spelled *reticule*: British preference is for the word *graticule*.
- rewind:** to reroll the film in its original order. Also, devices used to wind film from one reel to another or to rewind motion pictures after they have been projected.
- roll:** film supplied in long lengths at working width. May be supplied on cores, spools, in cassettes, or in bulk, depending on the system in which it is to be used.
- roll film:** a strip of flexible film, wound on a spool between turns of a longer paper strip, for daylight loading into roll-film cameras. Distinguish from long lengths supplied in bulk for motion picture and automatic cameras.
- roll-film holder:** an accessory permitting the use of roll film in sheet-film cameras.
- rotating stops:** a series of different-sized holes in a rotating metal disk used in place of the iris diaphragm in certain lens systems.

S

- safelight:** a nonactinic light used for darkroom illumination.
- safety film:** film with a cellulose acetate base; so called because it burns very slowly.
- safety shutter:** a shutter of metal or heat-absorbing glass which is automatically inserted between the lamp and the film whenever a motion-picture projector stops for any reason, to avoid burning or blistering the film.
- scale:** the entire range of tones of a photographic paper or film; also, the distance markings to which a lens may be set for focusing.
- Schlieren photography:** an optical technique for making visible and photographing original phenomena which are occurrences of purely a change in index of refraction, or density, of gas or other optical media.
- screen:** a glass plate, ruled with intersecting lines, used by photoengravers to produce a dot image on halftone plates.
- screw mount:** a lens mount which is threaded to fit the front of the camera.
- self-capping shutter:** a focal-plane shutter in which the slit automatically closes while the curtain is being rewound, to avoid fogging the film.
- semi-matte:** applied to smooth-surfaced papers with a slight luster.
- sensitizing:** a process in which the basic inherent sensitivity of a photo-

- chemical process is increased or made responsive to other wavelengths of light over its natural response.
- sensitometer:** an instrument which exposes a photographic film in a known manner so that its light-sensitive properties may be measured.
- sensitometry:** the science of determining the characteristic responses of a photosensitive product.
- sequence camera:** an engineering camera used to make a series of pictures in rapid sequence or in very short time intervals between pictures; the frame rate is fast enough to require automatic mechanical drive in ranges up to motion-picture speeds which is generally 24 frames per second.
- sheet film:** individual films loaded into separate holders for exposure; usually on a heavier base than roll films and film packs.
- shutter:** a mechanical device which regulates the time that light is allowed to act on the photographic film.
- shutter efficiency:** as applied to shutters, the percental relationship between the total time a shutter remains open (counting from half-open to half-closed position) and the time required for the shutter to reach the half-open and the fully closed positions.
- single weight:** applied to a photographic paper with a lightweight stock.
- slide:** a positive print on glass, or a film transparency bound between glasses for projection; also the removable cover of a sheetfilm, plate or film-pack holder.
- slidefilm:** another name for filmstrip; see **filmstrip**.
- slow motion:** action, filmed with the camera running at high speed and projected at normal rates.
- soft-focus (adj.):** applied to a lens which has been deliberately under-corrected to produce a diffused image; also applied to pictures made with such a lens.
- sound track:** the strip with variable area or variable density which is photographed on the edge of a motion-picture film and carries the sound signals.
- spectrogram:** a photograph of a spectrum, made by the use of a spectrograph.
- spectrophotometer:** an instrument for comparing the intensities at the corresponding wavelengths of two spectra.
- spectrum:** a colored band formed when light is passed through a prism or a diffraction grating; it contains all the colors of which the light is composed; plural: **spectra**.
- specular (adj.):** (1) in sensitometry, applied to a measurement made by collimated or essentially parallel light rays; (2) referring to direct reflection, without scattering or diffusion.
- spherical aberration:** a lens defect in which the various rays forming a single image point on the axis are not brought to a focus in the same plane.
- splice:** a joint where two sections of the film are fastened together.
- splicer:** a mechanical device for joining strips of film.
- spool:** a cylindrical spindle with side flanges for use in handling film. Most spools are designed with solid flanges and permit daylight loading of certain film which is properly packaged with leader and trailer.

- step tablet:** see **wedge, gray scale.**
- stereo camera:** a camera having two lenses or the equivalent through which the pair of pictures making up a stereogram may be taken simultaneously.
- stereogram:** a pair of pictures taken from positions separated by a definite distance laterally, and mounted side by side for viewing.
- stereoscope:** a device containing lenses, prisms, or mirrors, through which a stereogram is seen as a single, three-dimensional picture.
- stereoscopic photography:** the application of photography utilizing a camera with dual lens taking two simultaneous pictures separated by a suitable base line for the purpose of creating a stereogram.
- stills:** photographs as distinguished from motion pictures.
- stripping film:** a film whose emulsion may easily be removed from the base and transferred to another support; used mainly by photoengravers.
- stroboscopic photography:** a technique for reproducing pictures of high-speed events by synchronization of the photographs to the event cycles.
- subminiature camera:** a still camera using 16-mm or smaller film for size and packaging advantages.
- substratum:** the binding layer which causes the emulsion to adhere to the glass or film base.
- subsynoptic photography:** in a meteorological definition any photography of the earth's environment which is done at relatively close distance yielding a camera scale of overall coverage, less than 1,000 kilometers.
- subtractive process:** a color photographic system where yellow (minus blue), magenta (minus green), or cyan (minus red) dyes are used to control the amount of absorption or subtraction of light energy in its process. All multilayer color processes must be, by definition, subtractive processes.
- sunshade:** a hood placed over a lens to keep stray light from its surface; similar to lens **hood.**
- symmetrical lens:** a lens combination with identical front and rear elements.
- synchronizer:** a device which trips the camera shutter simultaneously with the firing of a flashlamp.
- synoptic photography:** in a meteorological sense photography of the Earth's surface and the environment in a camera scale that produces coverage over the range of approximately 1,000 to 5,000 kilometers.
- synoptic terrain photography:** high-quality photography of selected areas of the Earth for multiple purposes such as geologic, geographic, and oceanographic study. In a meteorological sense the scale of picture coverage is in the range of 1,000 to 5,000 kilometers.

T

- takeup:** that part of a camera or a projector which winds up the film after it has passed through the mechanism.
- target:** microcopying term denoting identification or filing information photographed on a microfilm.
- telephoto lens:** a lens of long focal length having a separate negative rear element; it is used to form larger images of distant objects; it is similar in results to a telescope.
- test strip:** an exposed strip of photographic material containing several different exposures used to determine the correct exposure for printing. Also known as **sensitometric strip.**
- thermoplastic recording:** a system of recording television images as **waves**

- or ripples in a plastic material; the resulting image is barely visible to the eye but can be projected in full contrast through a special optical system based on the Schlieren principle.
- thin:** applied to a weak negative lacking density in the highlights and detail in the shadows.
- thread:** to insert film in the various guides, tracks, apertures, and through sprockets of a camera or projector. Also, to insert films through the various rollers on a processing machine.
- tilt-top:** a device attached to a tripod head to permit the camera to be set at various angles in elevation.
- time condensation:** single frames taken at intervals and projected at normal rate to speed action and shorten time for a given operation commonly referred to as time lapse photography.
- time exposure:** an exposure in which the shutter is opened and closed manually with a relatively long interval between.
- time lapse photography:** see **time condensation**.
- timer:** a special darkroom clock giving audible or visible indications of various time intervals.
- T-number, T-stop:** a system of marking lens apertures in accordance with their actual light transmission, rather than by their geometrical dimensions as in the *f*-stop system.
- tone:** any one density of a photographic image; sometimes, the general color of a photographic image; for example, a blue-black tone.
- trailer:** a piece of black film or other opaque material at the end of the reel which wraps up and protects the film from exposure to light. See **leader**.
- translucent:** permitting the passage of light but scattering light sufficiently so that no image can be formed through the material.
- transparent:** permitting the passage of light without scattering, so that an image may be formed.
- tri-metrogon:** a system of three cameras used in aerial reconnaissance taking sets of three pictures, one vertical, the other two, high obliques, so that each set of three pictures is a complete view from horizon to horizon.
- tropical packing:** moisture-resistant containers in which film is packed at the factory when intended for shipment to hot climates.
- turret-head:** a revolving plate on the front of the camera used to hold two or more lenses allowing them to be interchanged quickly.

U

- ultraviolet absorbing filter:** a filter used mainly for cutting atmospheric haze in photography with color films to avoid excessive bluishness in the pictures; usual designations are U.V.; Haze; Wratten 2A.
- ultraviolet filter:** a filter which transmits ultraviolet light, as used for photography by the reflected ultraviolet light method.
- ultraviolet photography:** photographs made with the invisible radiation of the near-ultraviolet spectrum provides images showing details based on differential reaction to this ultraviolet light which is not normally perceived by the human eye.
- ultraviolet rays:** invisible rays whose wavelength is shorter than the visible ray of light.

underdevelopment: insufficient development; due to developing either for too short a time in a weakened developer or, occasionally, at too low a temperature.

underexposure: the result of insufficient light being allowed to pass through the lens to produce all the tones of an image; or of sufficient light being allowed to pass for too short a period of time.

universal finder: a finder which can be adjusted to show the field covered by various lenses.

universal focus: see **fixed focus**.

V

variable area: type of motion picture sound track in which the density of silver image is constant. The sound signals are caused by varying the area or width of the black part of the sound track.

variable contrast papers: photographic papers having emulsions of mixed sensitivity so that by choice of exposing filter different contrasts are produced.

variable density track: a sound track of constant width. The signals are caused by variation in the optical density of the line.

view camera: a camera generally made in larger sizes which has several degrees of freedom of motion on both the lens board and film or focal plane. These motions, known as "swings and tilts" permit maximum versatility in "drawing" or correcting the perspective and focal plane of a photograph.

viewer: a device which magnifies film for inspection during editing.

viewfinder: see **finder**.

viewpoint: the place from which a picture is taken or viewed.

vignetting: underexposure of the extreme edges of a photographic image; occasionally caused by improper design of lenses or too small a sunshade; also sometimes intentionally done in portraiture.

virtual image: an image having no actual existence in space; it is the image which is seen in a mirror, or through a lens of negative power.

visual angle: the angle at the eye subtended by the limits of the object; if the object is at the threshold of resolution, the angle is from $0^{\circ}1'$ to $0^{\circ}2'$.

W

wavelength: the distance from crest to crest, or from trough to trough, of any regularly recurring wave.

wedge: a series of tones continuously ranging from white to black, usually on film or a glass plate; when the variations are in discrete steps, it is called a gray scale or sometimes a step tablet.

wide-angle lens: a lens of short focal length and great covering power used to cover a larger angle of view than a normal lens will include from a given viewpoint.

X

X-rays: electromagnetic waves shorter than light or ultraviolet rays, which affect the photographic emulsion and have the property of passing through certain otherwise opaque objects.

Z

zonal aberration: a defect in a lens in which the point of focus shifts when the lens is stopped down.

zoom lens: a lens which can be varied in effective focal length while maintaining focus on a given object; it gives the effect of change of angle of coverage.