SUBCOURSE
SS0514

EDITION
A

INTRODUCTION TO BASIC COLOR PHOTOGRAPHY

EDITION DATE: SEPTEMBER 1994

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM

INTRODUCTION TO BASIC COLOR PHOTOGRAPHY

Subcourse Number SS0514

EDITION A

United States Army Signal Center and School
Fort Gordon, GA 30905-5074

5 Credit Hours

Edition Date: September 1994

SUBCOURSE OVERVIEW

This subcourse presents you with information on color photography, including theory, exposure, and printmaking. Topics covered include the theory of light, how colors are formed, and color print materials--their structure and exposure. Color negative developing using the popular C-41 process is explained, as well as the Ektaprint 2 process that is most often used to make color prints from negatives. The E6 reversal processing and the two methods of making prints from slides are examined (color coupler (conventional reversal paper) and dye destruction (like Cibachrome)). In addition, this subcourse defines general quality control procedures. Since duplicate transparencies are often required, the generation process is explained.

There are no prerequisites for this subcourse.

This subcourse reflects the doctrine which was current at the time it was prepared. In your own work situation, always refer to the latest official publications.

Unless otherwise stated, the masculine gender of singular pronouns is used to refer to both men and women.

<u>TERMINAL LEARNING OBJECTIVE</u>

ACTION: You will identify procedures for color negative printing techniques, color reversal film processing and printing, and slide duplicating techniques.

CONDITION: You will be given information from TM 11-401-2, STP 11-25S13-SM-TG, and Photographer's Mate Training Series NAVEDTRA 373-02-45-83, MOD 2.

STANDARD: To demonstrate competency of this task, you must achieve a minimum score of 70% on the subcourse examination.

TABLE OF CONTENTS

LESSON 1

INTRODUCTION TO BASIC COLOR PHOTOGRAPHY PRINCIPLES

Critical Tasks: 113-578-1012
113-578-3035

OVERVIEW

LESSON DESCRIPTION:

In this lesson you will learn several basic color photography principles and procedures. These principles and procedures include: light theory, the color wheel, the additive and subtractive color processes, the color characteristics of hue, brightness, saturation, color temperature, the structure of film, the use of light sources and reciprocity, and the proper storage of color film.

TERMINAL LEARNING OBJECTIVE:

ACTIONS: a. Describe the light theory and use of the color wheel.

b. Describe the additive and subtractive processes.

c. Explain elementary film structure.

d. Describe filter use.

CONDITION: You will be given information from TM 11-401-2.

STANDARD: Basic color photography principles will be in accordance with TM 11-401-2.

REFERENCES: The material contained in this lesson was derived from the following: TM 11-401-2.

INTRODUCTION

This lesson will provide you with the theory and principles behind color photography. You will learn about types of radiant energy, concentrating especially on the visual part of the spectrum. In addition, you will study how primary colors of light combine to produce additive and subtractive colors. You will also learn the attributes of the additive and subtractive processes of color reproduction. Characteristics of color, including hue, brightness, and saturation will be covered.

Color films, matching film to the temperature (Kelvin (K)) of the light source, the effect of filtration upon them, and storage conditions are also discussed.

PART A - THEORY OF LIGHT, ADDITIVE AND SUBTRACTIVE PROCESSES, AND COLOR CHARACTERISTICS

Color photography is the art of making a photograph that faithfully represents the subject in form, tone, gradation, and color. Color brings life, realness, and depth to a picture more than any other photographic phenomenon. Color is natural because we see in color. While black and white film is sensitive to the frequency of the light, the shades of gray produced do not represent a specific color. For instance, it is possible for black and white film to produce the same shade of gray for green and orange, thus hiding oranges in the trees. Color helps identify an item in a photograph, such as the girl in the red dress. Color can show condition, such as the green and ripe red apples. Color can represent a mood, such as a blue day.

Colors express mode and mood. Cleverly using color will help bring out the thought behind your photograph. Everyone does not interpret colors the same; therefore, do not accept the following color interpretations as fact. Use them as guides to improve the photographs you take. The interpretation of color is often a function of culture. For example, in the U.S., white often portrays purity, while in India it symbolizes death. The following examples represent the general color interpretation within the American culture: red depicts anger, excitement, danger, passion, and heat; blue portrays quiet, cold, sadness, and truth; green is relaxing and makes objects appear lighter; black is depressing and may give an impression of death and disaster.

Color cannot be perceived in the absence of light. In a very dimly lit room, all objects are various shades of gray. Is gray a color? Gray is a degree of whiteness or a degree of blackness. Color is perceived by the eye and the lens by the amount of light the item reflects. Black objects reflect no light; thus no color. White objects reflect all colors. Light not reflected is absorbed by the object. Gray is a dark white or stage between white and black, but not a single color. Color is light, so let's begin our discussion of color photography with radiant energy of which light is a form.

1. <u>Radiant Energy</u>.

Various types of radiant energy affect photographic materials. To consistently produce high-quality photography, we must know something about radiant energy, what effect it has on the photographic material, and how to manage this energy to produce the desired results.

a. What Light Is. Light is a form of radiant energy that travels in wave motion. Radiant energy travels at the speed of light. The speed of light is approximately 186,000 miles per second (mps) in a vacuum.

(1) Differences in wavelength and frequency distinguish one form of radiant energy from another.

(a) Frequency is the number of waves that pass a given point in 1 second.

(b) Wavelength is the distance from the crest of one wave to a corresponding point on the crest of the next wave.

(2) The product of wavelength and frequency is equal to the speed of travel. Figure 1-1 illustrates a wavelength.

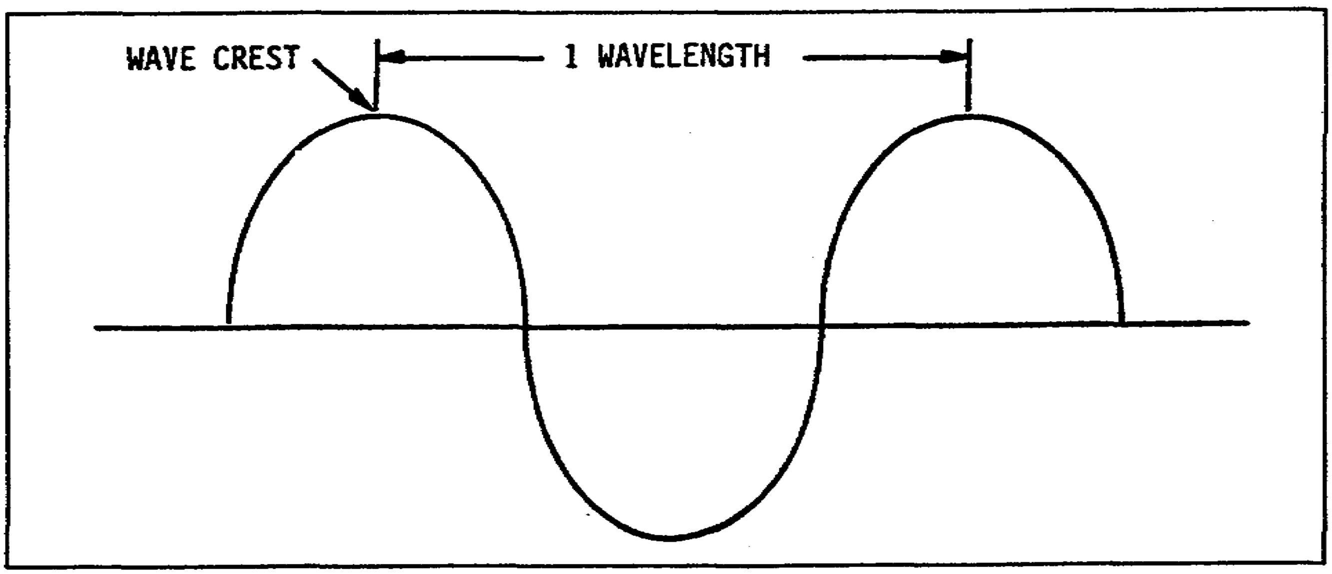

Figure 1-1. A wavelength

b. The Speed of Light. For a given medium, the speed of light is constant.

(1) When light enters a medium of different density, the speed changes. For example, the speed of light drops to about 124,000 mps when it enters glass. Of course, this varies depending upon the refractive index of the glass.

(2) If the speed of light is the product of wavelength and frequency, it follows that a change must have taken place in the wavelength, frequency, or both.

(3) Information, provided by physicists, tells us that when light enters a medium of greater or lesser density, the frequency remains constant and it is the wavelength that changes. Figure 1-2 illustrates this process.

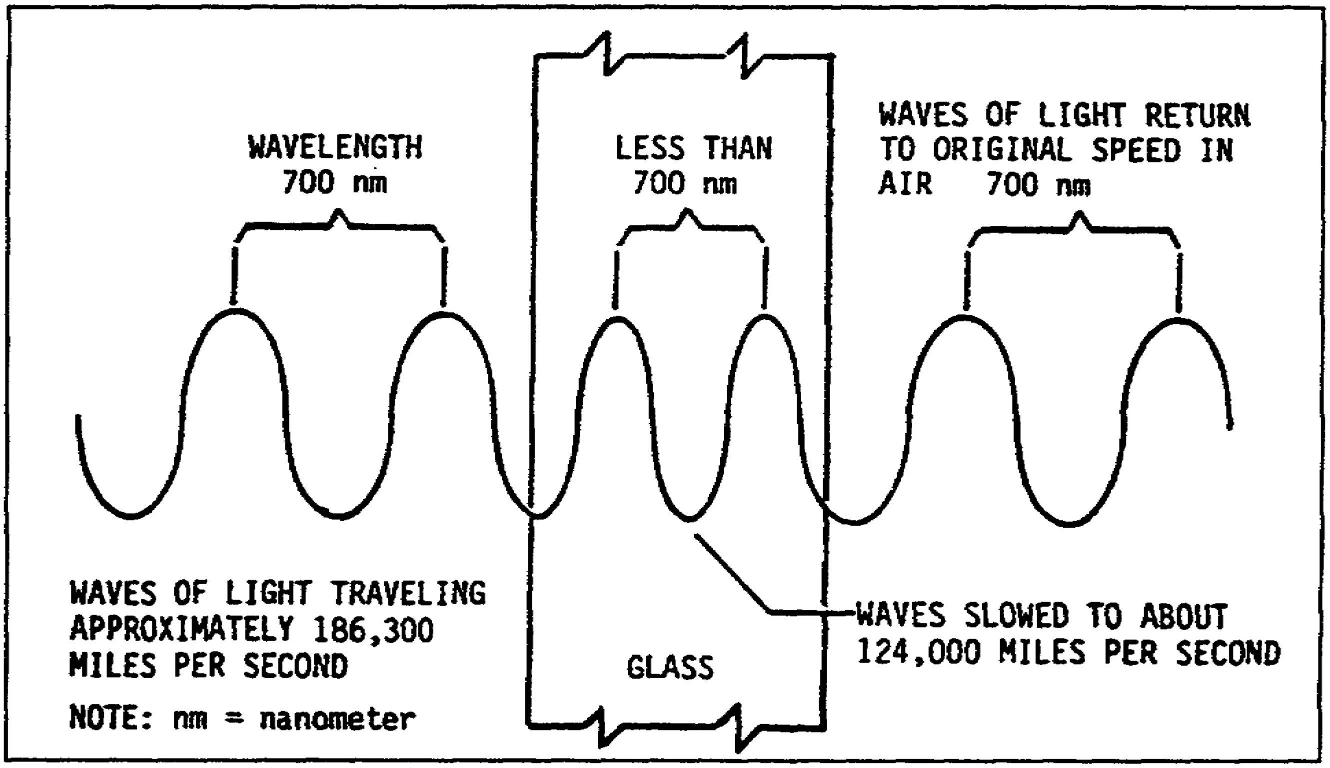

Figure 1-2. Traveling of light waves

It is difficult to accurately measure the frequency of radiant energy. Therefore, identify it according to its wavelength in air. Imagine the difficulty involved in measuring ultraviolet radiation that has a frequency of 750 trillion waves per second.

2. Electromagnetic Spectrum.

a. Radiant Energy in Sequence. Arranging the various forms of radiant energy in sequence according to wavelength forms the electromagnetic spectrum. Refer to figure 1-3. It would extend from cosmic rays with extremely short wavelengths on one end, to radio waves with extremely long wavelengths on the other end.

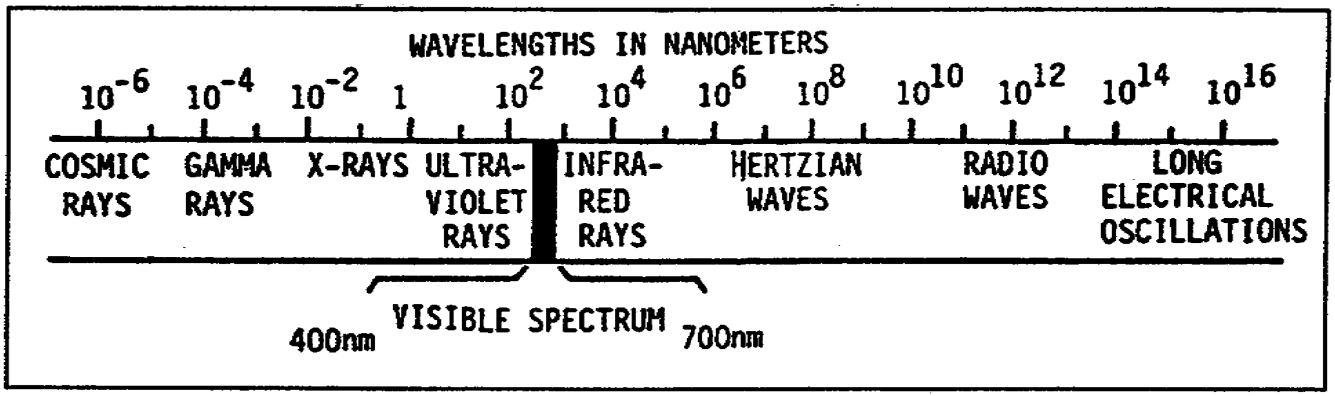

Figure 1-3. Electromagnetic spectrum

b. Using the Spectroscope. Evaluation of the electromagnetic spectrum involves the use of a spectroscope, an instrument that disperses radiant energy either through a prism or a diffraction grating so that the spectrum can be observed and measured. Using a spectroscope, it is possible to isolate individual wavebands of color. By rotating the prism, we can see the colors change from red to yellow, from yellow to green, from green to blue-green (cyan), and finally to blue.

c. Visible Portion of the Spectrum. The radiant energy we are primarily concerned with occupies a relatively small part of the overall electromagnetic spectrum. For the most part, we are concerned with wavelengths that range from approximately 400 to 700 nanometers (nm). This is the visible portion of the spectrum, the portion called light.

NOTE: A nanometer is a metric measurement equal to 1 billionth of a meter. It has the same value as the millimicron, which it replaces in scientific literature.

3. Color Vision.

The definition of light is that portion of the electromagnetic spectrum that affects the sensory organs of the eye and produces the sensation of vision. For this reason, other portions of the energy spectrum do not meet the definition of visible light. How often have you heard someone mention infrared or ultraviolet light? They would have been correct, according to our definition, to have said infrared or ultraviolet radiations.

a. Infrared and Ultraviolet Radiations. The visible portion of the electromagnetic spectrum is the part primarily responsible for photographic exposure. Infrared (IR) and ultraviolet (UV) also play a significant part in the field of photography. Infrared and ultraviolet radiations fall into the spectrum immediately above and below the range of visible radiations. Infrared falls immediately above the 700 nm portion of the spectrum and ultraviolet immediately below the 400 nm portion as illustrated in figure 1-4.

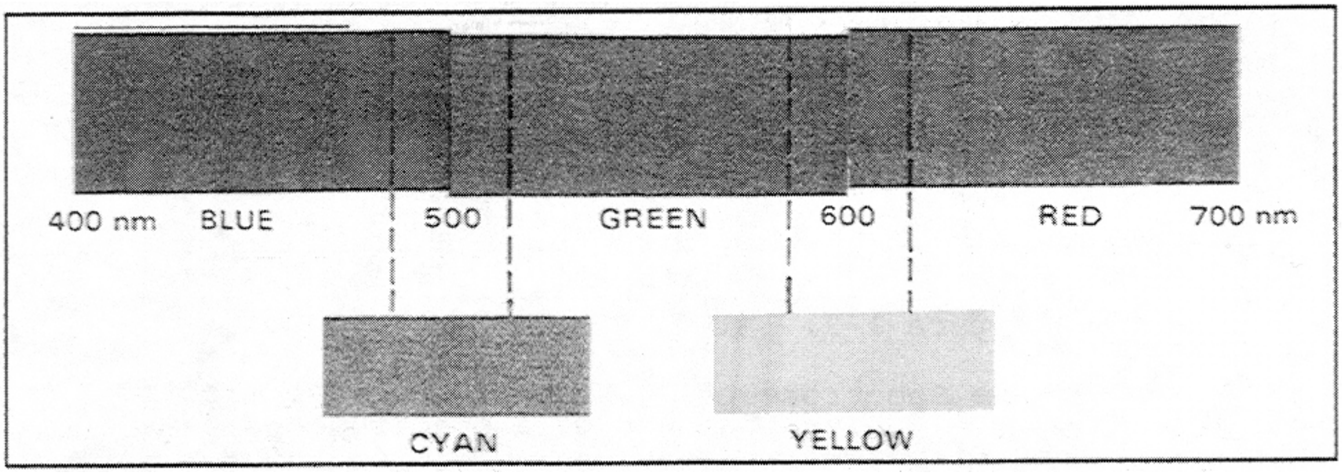

Figure 1-4. Visible spectrum

b. The Visible Spectrum. "White light" is a term used to identify the visible spectrum when all the wavelengths, from 400 nm to 700 nm, are present in nearly equal amounts. Due to the adaptability of the eye and other human and psychological reasons, it is impossible to establish a standard for white light. For example, indoor lighting and sunlight both appear to be white.

(1) Why do both types of light appear white when they do not contain the same amounts of visible radiation?

They appear white because the receptors in the eye are sensitive to red, green, and blue wavelengths of light. They adapt their sensitivity to compensate for imbalances in wavelength proportions.

(a) For example, sunlight has a higher percentage of blue and green wavelengths and is relatively deficient in the red region of the spectrum.

(b) As a result, the red receptor increases in sensitivity until there is the necessary balance of wavelength impulses reaching the brain. For this reason, the viewer perceives the sensation of white light.

(2) While the individual receptors have the capability of adjusting in sensitivity, the eye itself is not selective regarding to individual wavelengths. In order for the eye to

see a single wavelength, it must be isolated and presented alone. For example, the eye cannot be selectively turned to red, green, or blue radiations when presented in combination.

(a) However, it is possible for the eye to visualize colors not present in the spectrum. If equal amounts of red and blue wavelengths strike the eye, we see a purplish or magenta color.

(b) Because red and blue are at opposite ends, magenta does not exist in the visible spectrum. We see magenta because the surface is reflecting equal amounts of red and blue radiation and absorbing the green.

(c) Yellow is another example of this phenomenon. Yellow occupies only a small part of the visible spectrum, approximately 575 to 590 nanometers. If only yellow radiations are reflected to the eye, the reflecting surface appears black. Most yellows seen by the eye are the result of the surface absorbing blue radiations and reflecting the red and green.

(3) Color vision takes place when the receptors in the eye receive various combinations of visible wavelengths and transmit them to the brain. Therefore, color vision is both a physiological and a psychological perception.

(a) Any damage to the collection, transmission, or reproduction system will affect color vision. Damage to the optic nerves, for instance, can result in color blindness.

(b) There are, conceivably, as many variations in the development of eyesight as there are in fingerprints.

(c) Color vision depends upon the individual; therefore, it is subjective.

4. Producing Color.

When you think about primary colors, those colors that cannot be made but are used to make all others, you are likely to recall the colors red, yellow, and blue. These are the colors that we learned about in grammar school. These are primaries for pigments, such as paint. When we speak of light, it's a different story.

a. Producing Color with Light. It is possible to produce any color by combining amounts of red, green, and blue light. To control the various components so that we can achieve a specific result, it is necessary to use filters. There are many different types of filters, each having definite applications in the photographic process.

(1) What a filter does. To effectively apply filtration techniques to the photographic process, remember this rule: a filter transmits its own color(s) and absorbs all others. Filters selectively transmit portions of the electromagnetic spectrum. A red filter, for instance, appears red because it transmits the red portion of the visible spectrum while absorbing the blue and green portions.

(2) Additive primary colors. All colors can be created by mixing different amounts of red, green, and blue light. The eye sees color when mixtures of the visible radiations stimulate the receptors. Because red, green, or blue cannot be reproduced by mixing the other two colors, we call these primary colors. Since matching a wide range of colors involves the addition of colored light, we further refer to the primary colors as additive primary colors. When we use mixtures of these colors to produce color images, we are using the additive color process.

b. Additive Process. The first color images were produced using the additive process. Around 1861, James Clerk Maxwell presented the first known demonstration of color photography.

Maxwell made three exposures through a filter that transmitted the primary colors of light. The resulting black and white negative represented the parts of the subject that were red, green, and blue. Next, a positive was made from each black and white negative. Then the positives were projected through the same color filter used to make the negative. Using separate light sources, the positive made from the red negative was projected through a red filter, the green positive through a green filter, and the blue positive through a blue filter. When the three images were superimposed, they formed a color reproduction of the original subject.

(1) Example of the additive process. The additive system might be better explained if we use the following example. Suppose that we use three separate projectors and project three beams of light, each a different additive color, onto a screen. If we arrange the beams of light so that they partially overlap, we produce white light. By adding red, green, and blue light, we have combined all the necessary wavelengths to produce the visual sensation of white light. Figure 1-5 illustrates this example.

(a) When we arrange the lights used in the above example so that there are areas where only two of the additive colors are combined, we produce three new colors of light. Where the red and green light overlap, they combine to make yellow light. The red and blue light would combine to make magenta light, and the blue and green light would combine to make cyan. Refer again to figure 1-5. Yellow, magenta, and cyan are called subtractive primary colors. We will discuss these colors in more detail later.

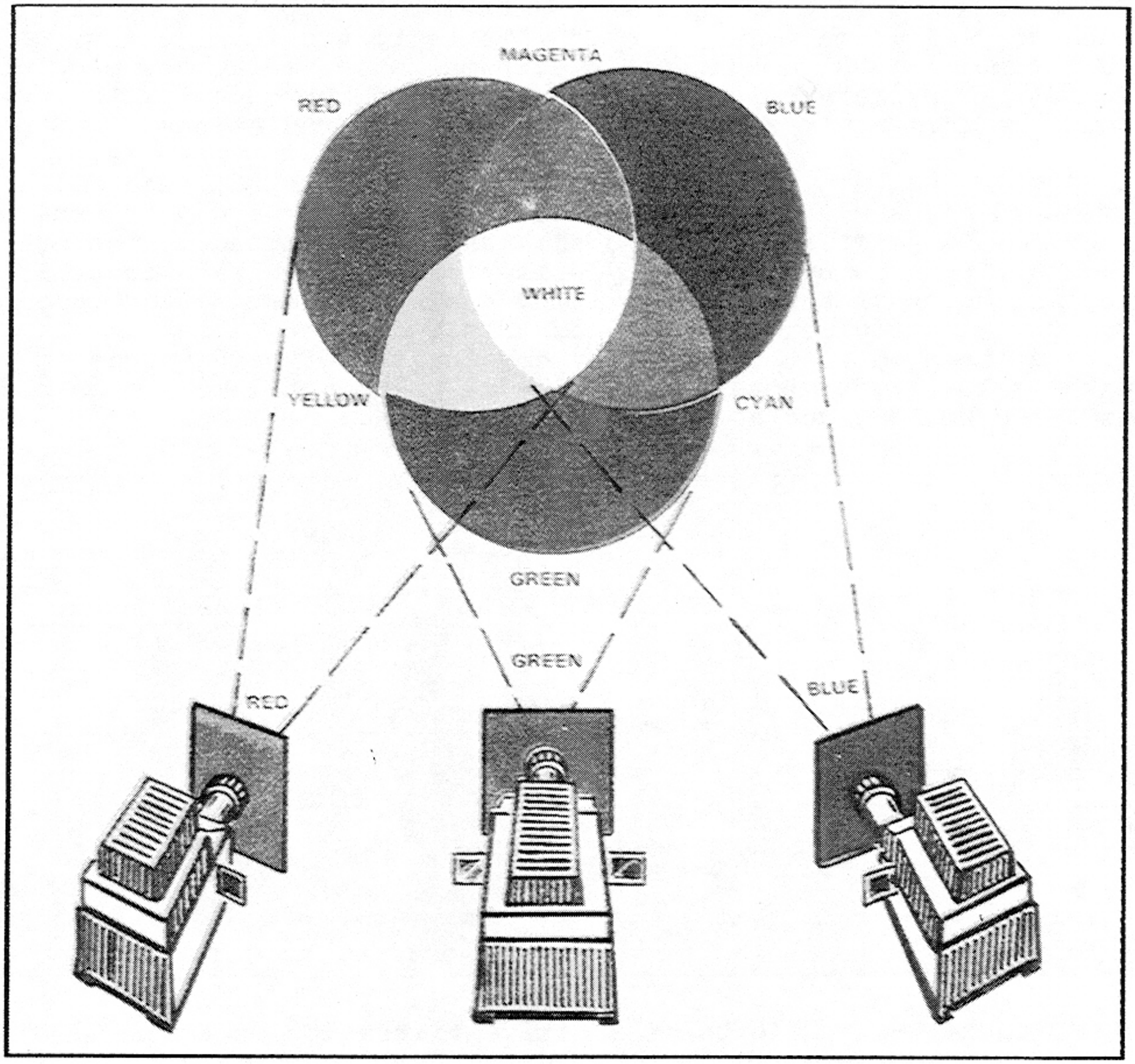

Figure 1-5. Principle and colors of the additive color process

While the additive color system is impractical for most color reproduction requirements, all color materials in use today start with an application of the additive principle. When we expose these materials, they make individual red, green, and blue records of the subject.

(b) If we examine the effects of primary filters on light, it becomes evident why it is not feasible to produce color photographs using the additive system. The additive system can reproduce reds, greens, and blues without difficulty. We encounter difficulties when we attempt to reproduce colors such as yellow, magenta, or cyan. To reproduce such colors, we must combine equal amounts of electromagnetic radiations present in certain primary colors. For example, to reproduce yellow, we would require equal amounts of green and red radiations.

Suppose we want to use the additive system to reproduce a yellow image in a transparency. Remember that when viewing a transparency, light penetrates the emulsion then transmitted to the eye. The varying amounts of density present in the emulsion control the intensity of the light striking the eye, creating the image we see. If we were to superimpose red and green images in an attempt to produce the necessary combination of wavelengths to make yellow light, total absorption of the light incident on the emulsion would occur as shown in figure 1-6.

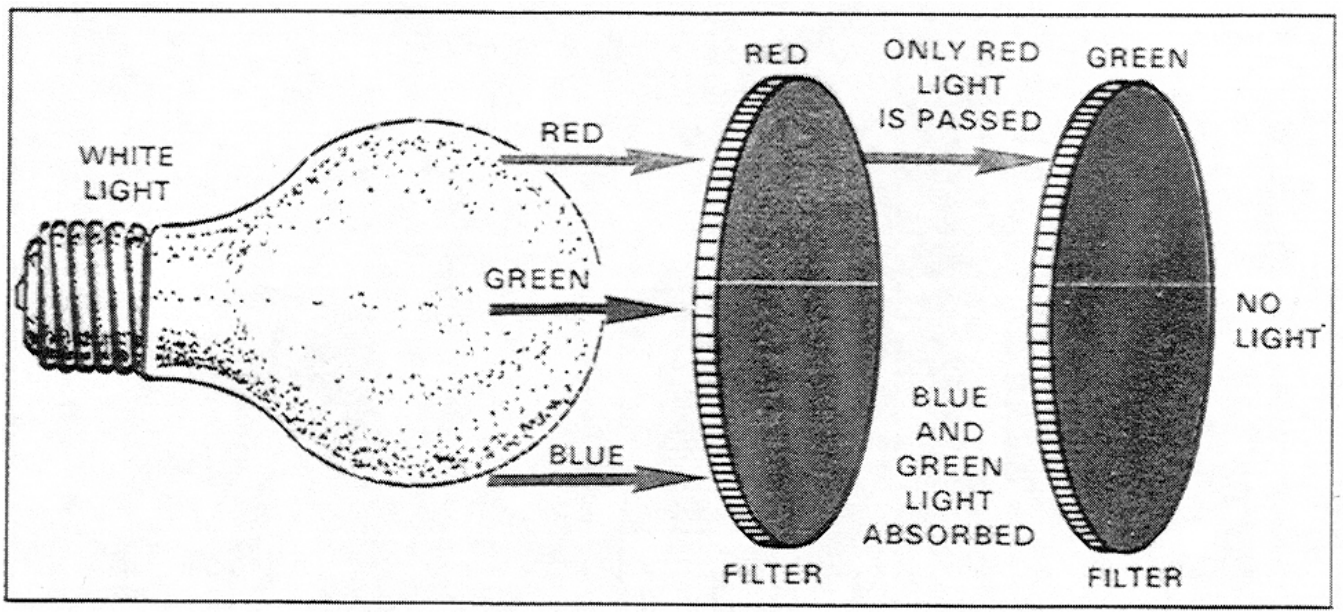

Figure 1-6. Effects of additive filtration on a single light source

The superimposed color images would have the same effect as additive colored filters. We know, from previous information, that filters transmit their color(s) and absorb all others. If the light striking the surface of the transparency passes through the red image first, only the red portion of the incident light will be transmitted. In essence, the red image will absorb two-thirds of the incident radiation (blue and green) and transmit one-third. At this point, there is only red light incident on the surface of the green image. The green image will absorb the red light and result in a lack of visible radiation transition to the eye. Remember, any two additive primary filters over a single light source will result in no light being transmitted.

(2) Capabilities of filters. The previous illustration assumes that the intensity of the light source does not exceed the absorption capabilities of the filters used. In theory, a primary filter will only transmit wavelengths of its own color. In reality, filters are only partially selective. For example, yellow, magenta, and cyan filters are used extensively in color photography. While the yellow filter functions efficiently enough, there are deficiencies in the dyes used to construct magenta and cyan filters.

(a) Current technology is unable to produce completely efficient magenta and cyan dyes. These dyes absorb some radiant energy they should transmit. Due to these deficiencies, filters that absorb all the wavelengths for a given color are presently unavailable.

(b) Another factor to be considered is the expense involved in producing highly exclusive filters. The more selective the filter, the higher the production cost. It is not necessary to use the most expensive filters in most color photographic tasks. The filters currently in use are adequately selective in transmission and absorption characteristics. However, you should be aware of the discrepancies in theoretical results and those achieved in practical application.

c. Subtractive Process. Most color processes use some application of the subtractive principle to reproduce colors. The increased transmission capabilities of yellow, magenta, and cyan make them more suitable for making color transparencies and color prints.

Subtractive filters may be used individually or in pairs to produce the entire spectrum of colors. Two subtractive primary filters superimposed over a single light source will transmit the color they have in common. Yellow (red-green) and magenta (blue-red) superimposed will pass red light. It is also evident that any one subtractive color will, since it is composed of two additive colors, transmit two-thirds of the visible spectrum and absorb one-third. Each color subtracts one additive primary, hence the term "subtractive primary." Yellow subtracts blue, magenta subtracts green, and cyan subtracts red. By using various amounts of yellow, magenta, and cyan dye in the color emulsion, the subtractive process controls the amount of blue, green, and red light reaching the eye, thereby controlling the color of the image reproduced. See figure 1-7.

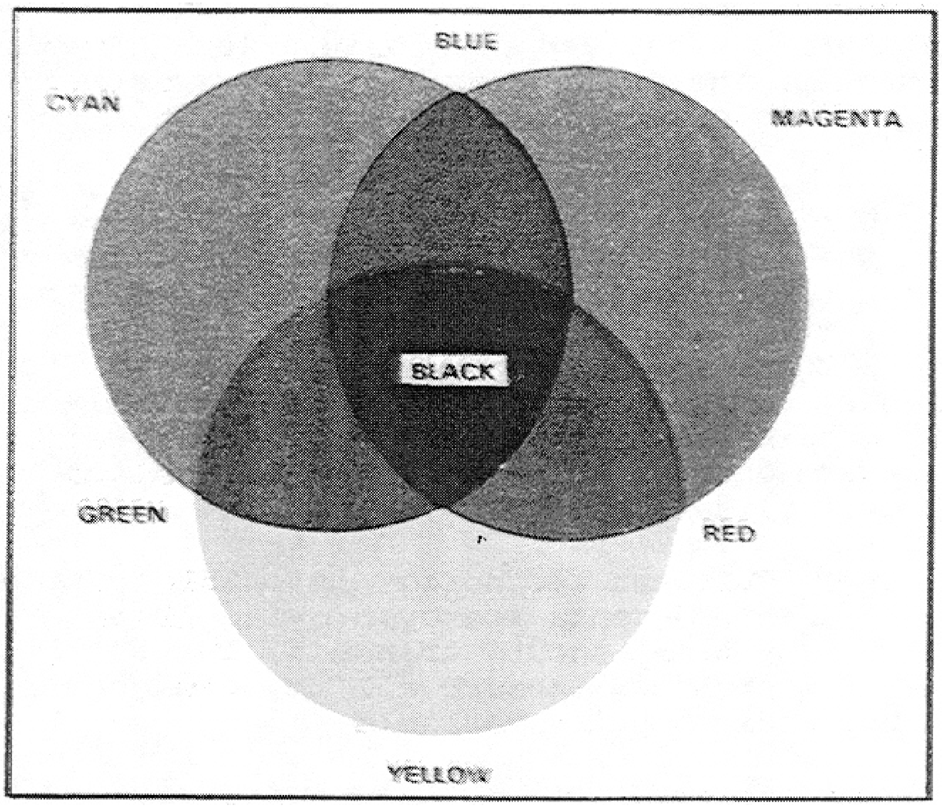

Figure 1-7. Subtractive color process

d. Color Star. The color star can be used to illustrate the relationship between the additive and subtractive colors as shown in figure 1-8.

It also demonstrates the relationship between complementary colors. Additionally, between any two points on the star representing additive colors, you will find they combine to form the subtractive color. Colors opposite each other on the star are complementary.

"Complementary colors" is a term used to describe two colors that can be combined to produce white light. Since all three of the primary colors must be present to produce white light, it is reasonable to assume that we must combine the additive and subtractive colors to provide the required amounts of these wavelengths. Therefore, red and cyan (blue-green) are complementary. Blue and yellow (red-green) are complementary. Green and magenta (red-blue) are also complementary to each other. The additive will transmit one-third of the wavelengths necessary, and the complementary will transmit the remaining two-thirds of the wavelengths necessary to produce white light.

Memorizing and being able to construct the color star will aid immeasurably in understanding and solving many of the problems associated with color photography.

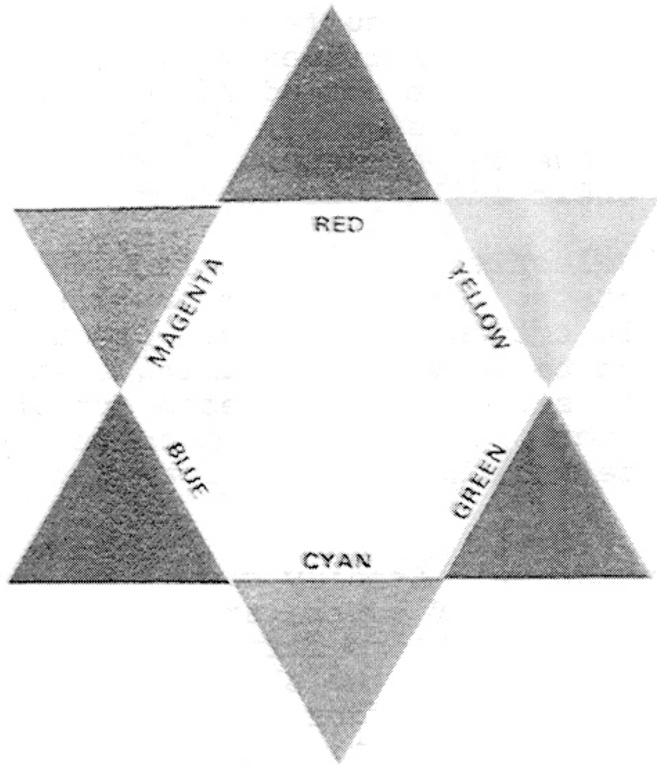

Figure 1-8. Color star

5. Color Evaluation.

Influences on color quality such as absorption, reflection, haze, scattering, interference, dispersion, and fluorescence must be considered when evaluating color quality.

a. Absorption. Most color occurs when illumination, falling on the subject, is not evenly absorbed at all wavelengths. If the subject did absorb all wavelengths equally, we would have to illuminate the subject with colored light to see color. Thus, under normal conditions, the color of the subject is dependent on its absorption and reflection characteristics in relation to the various wavelengths present in illumination.

b. Specular and Diffused Light. If the surface of the medium contacted by the incident light ray is smooth and polished, the surface reflects the light at the same angle to the surface as the incident light. The path of the light reflected from the surface forms an angle exactly equal to the one formed by its path in reaching the medium. In this case, the angle of incidence is equal to the angle of reflection, which is a universal characteristic of specular light. If the surface is rough and irregular, the incident light rays are reflected in more than one direction. This form of reflected light is termed diffused. Practically all surface media reflect both specular and diffused light; smooth surfaces reflect more specular light, and rough surfaces reflect more diffused light. Since diffused light is more common than specular light, it is this light that is of greatest value in photography. Keep in mind that all surfaces vary in their ability to reflect light.

c. Selective Reflection. Selective reflection is a characteristic displayed by certain metals. Gold, copper, and brass are some of the metals that exhibit these qualities. Specular reflections from many metals tend to be white, assuming a white light source. Gold, for example, selectively reflects red and yellow light, giving it its characteristic color. A selective is a reflection that is not white but the same color as the object.

d. Haze. Variations in atmospheric density caused by airborne particles such as dust, droplets of water, and ice crystals effect the shorter wavelengths in the spectrum to a greater degree. When light enters the atmosphere, the shorter wavelengths of light are scattered more than longer wavelengths. This alters the quality of the incident light. Haze is the result of light scattered by the atmosphere.

e. Scattering. The redness of the sun at early morning and late afternoon is caused by atmospheric scattering of light. At this time of day, the amount of atmosphere that light waves must penetrate is increased due to the angle of the sun.

Increased atmospheric density results in increased scattering of the blue wavelengths. The higher penetration ability of red light waves produces our colorful sunrises and sunsets.

f. Interference. Have you ever noticed the patterns of color produced by oil on the surface of water and wondered what caused them? They are produced by light wave interference from two surfaces spaced a few nanometers apart. When light is reflected from these two surfaces, a portion of the reflected light will be cancelled when the two light waves, one reflected from each surface, meet. This interference produces the color you see. The color patterns formed are known as Newton's rings. Under certain circumstances, Newton's rings can present problems when working with color materials. They may occur if you are printing color material using a glass negative carrier. The irregular contact between the glass and the negative surface may produce interference effects. This effect may also occur in glass-mounted slides. The use of a glassless carrier and a special glass for the slide mounts can remedy these problems.

g. Dispersion. The rainbow is a natural example of dispersion. As the wavelength of light increases for a given medium, the angle of refraction decreases. Light waves striking droplets of water in the atmosphere are refracted according to wavelength into colors of the spectrum. Dispersion of these wavelengths creates one of nature's most colorful spectacles. Figure 1-9 illustrates this dispersion. A prism may also be used to disperse light.

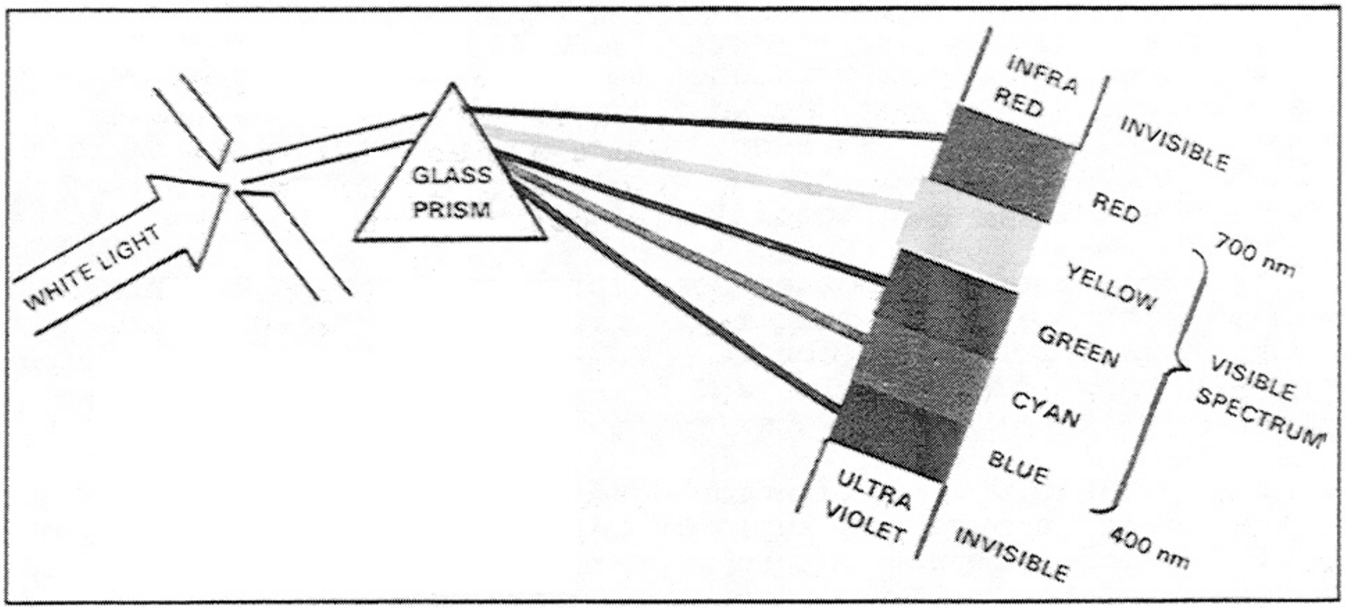

Figure 1-9. Dispersion

h. Fluorescence. Color can also be produced through fluorescence. Fluorescence is the ability of a material to absorb radiations of one wavelength and reradiate them at another wavelength, usually longer. This is what takes place in the fluorescent lamp. The fluorescent lamp is really a mercury vapor lamp that has been coated with a powder that fluoresces when bombarded with ultraviolet radiation. When you apply power to the lamp, the mercury emits ultraviolet radiations that are absorbed by the fluorescent powder and reradiated as visible light. The spectral quality of a fluorescent lamp can be altered by using cadmium borate as the fluorescing material instead of calcium tungstate. The light can be altered by adding cadmium to the mercury emitter. Lamps using mercury have predominantly blue, green, and yellow spectral qualities and are not usually recommended for color photography.

6. <u>Color Characteristics</u>.

When we assign a color to anything, we are attempting to describe certain color characteristics of the object under normal conditions. These characteristics will vary with changes in spectral quality and intensity of illumination. Since it is impossible to specify color under all conditions of illumination, most colors are identified when viewed under normal daylight or tungsten light conditions.

Three terms used to help identify color are hue, brightness, and saturation. Use them as tools to assist in color communications. If we are to be more explicit in color communication, we should know something about these terms.

a. Hue. Hue is a term used to assign a general color to the subject. If we say the subject is red or yellow, we are identifying the hue. However, there are as many shades as wavelengths in that portion of the spectrum. If we assign a hue only, we are less than specific in color identification.

b. Brightness. Another descriptor of color is brightness, such as light green or dark red. Light and dark are relative descriptors and are subjective. This is an attempt to describe the brightness of the color and is some measure of its absorption and reflection characteristics.

c. Saturation. Saturation describes the purity of a color. If the color is pure, it could be called a brilliant color, as a brilliant red. Impure colors appear dull. Determine saturation by comparing the color to a neutral gray of the same brightness.

The problem with color identification is that one term used to identify a color might have a different meaning for other persons. For example, each individual has their idea of what light green looks like. In an attempt to standardize color identification, the Munsell and CIE systems of color specification were developed. While helpful, their usefulness is limited by the physical and psychological difference of the individuals using these systems.

7. Color Temperature.

The color spectral quality of the light used to illuminate the subject plays an extremely important part in color photography. Color temperature is a useful means of identifying the spectral quality of certain types of light sources. Since the use of color temperature to describe a light source can be misleading, let's examine this subject more thoroughly.

a. Kelvin Color Temperature System. Experiments by Lord Kelvin developed the color temperature system that bears his name. The Kelvin ratings of the most commonly used light sources are listed in figure 1-10. To the eye, most of these light sources appear the same but they will not photograph the same with color films.

LIGHT SOURCE	DEGREES KELVIN
Tungsten House Lamps	2670 - 2810
Lamps for Color Photography	3200
Photoflood Lamps	3400
White Fluorescent Lamps	3500
Clear Flashlamps	3800
Photoflash"22B"or"5B"(Blue Flash Bulbs)	5400
Daylight (Standard)	5400
Average 10 AM to 3 PM Sunlight	6000 - 6200
Daylight Fluorescent Lamps	6500
Electronic Flashtubes	5800 - 7000
Overcast Sky	6800
Clear Blue Sky	12,000 and up

Figure 1-10. Approximate color temperature of commonly used light sources

(1) These experiments involved observing the color changes in a "black body" when heated to a high temperature. A black body is a perfect temperature radiator. It absorbs all the heat incident upon it and reradiates it immediately. A true black body does not exist; therefore, actual Kelvin values are based on scientific experimentation and mathematical calculations.

(2) When the black body was heated and a color change occurred, the temperature was noted and, thereafter, used to identify that particular color. Lord Kelvin used "absolute" temperatures (Kelvin temperatures) in his measurements. Kelvin temperature is written as K and is centigrade temperature of the black body plus 273 degrees. Lord Kelvin used his process to establish values for the special characteristics of light.

b. What Color Temperature Is. Notice that color temperature refers only to the visual appearance of the light source, not to its photographic characteristics.

(1) For example, fluorescent and tungsten lamps may present a visual match but the photographic results differ appreciably. Color temperature is most reliable when used to describe the spectral quality of tungsten light sources.

(2) The spectral quality of a light source is related to its Kelvin temperature. Incandescent lamps produce light when electrical current passes through a thin filament to glow.

(a) The hotter the filament becomes, the brighter the light. With the increase in temperature, there is a change of color quality.

(b) At lower incandescent temperatures, the filament glows red, as the temperature rises, the color changes to orange and yellow hues then finally to white. Thus, you can see color is related to temperature.

8. Undesirable Radiations.

Some radiations produce undesirable effects in photographic emulsions. These radiations are ultraviolet, infrared, gamma, and X-rays. The results can range from a completely unusable photographic image to minor losses in image definition.

a. Ultraviolet. Ultraviolet radiation and some visible blue light, if scattered by the atmosphere, can result in a loss of image definition. This scattering, caused by moisture and other airborne particles, is called haze. Light scatter may restrict the exposing of color materials during the early morning and late afternoon. Light scatter can become objectionable when it causes undesirable shifts in color balance.

b. Infrared. Infrared is always associated with heat. This heat has an adverse effect on the stability of the dyes used in color materials. At 3000K, three-fourths of the radiation emitted by a tungsten lamp is infrared. Color printing enlargers, using tungsten lamps as light sources, employ heat-absorbing filters to prevent damage to the negative during printing. Heat also can cause significant increases in the fog level of photographic materials. You must consider this factor when you store color materials for any length of time.

c. Gamma and X-rays. Photographers should also be aware of the undesirable results produced by exposing photographic materials to uncontrolled gamma and X-radiations. Photographic assignments in areas where the presence of the radiation is present will usually produce unsatisfactory results. The photographer must be aware of their presence and take the necessary precautions if he is to successfully accomplish his mission.

PART B - COLOR FILM STRUCTURE, COLOR CONVERSION AND COLOR-COMPENSATING FILTERS, AND COLOR FILM STORAGE AND HANDLING

Professional photography is far more demanding today than it was a few years ago. It is not enough just to know the procedures you must perform to obtain good results. Today's professional photographer must have a thorough knowledge of the construction of the film used and the action of the process to have complete control and consistently produce good results.

9. Film Structure.

Most modern techniques for color reproduction stem from research on color vision. Around 1801, Young and Helmholz advanced the theory that color vision is based on some system of three-color analysis. James Clerk Maxwell, in attempts to prove this theory, used photography to demonstrate the trichromatic method of color formation.

a. Early Experiments in Color Formation. Separate records of blue, green, and red light reflected from a photographic subject presented a considerable challenge for many years. Attempts included three sheets of film exposed through the additive primary filters, through three separate lenses and filters, a sophisticated prism and mirror camera to split the light from a single lens, and a tripack or sandwich-like arrangement of three films. None of these proved practical.

b. Introduction of a Multilayered Film. A multilayer film, coating all three emulsions on the same film support, would eliminate or minimize the disadvantages of the other methods. In 1935, Kodachrome film was introduced and provided this capability. The three emulsions, separated by layers of gelatin, coated on safety film with antihalation backing are comparable to ordinary thin black and white emulsions. This principle is credited for rapid advancement of modern color photography.

c. Modern Emulsions. Color reproduction consists of separating and recording the colored components of light. Modern emulsions are constructed so that the red, green, and blue light reflected from the subject is recorded in different layers. Colors, such as skin tones, browns, oranges, yellows, etc., reflect light in several areas of the spectrum and may be recorded to some extent in each light-sensitive layer.

10. Integral Tripack.

Most color films, whether reversal or negative, are integral tripack films. The term "integral" is used whenever more than one emulsion is coated on a single base. An integral tripack consists of a single film base with three light-sensitive emulsion layers coated on one side, each layer responsive to a separate region of the spectrum. The three emulsions are not separable and must be processed together.

a. Structure. An integral tripack emulsion consists of: (1) a suitable base; (2) an antihalation coating; (3) three individual light-sensitive layers; and (4) thin layers of gelatin used to separate the light-sensitive layers that sometime function as filters.

(1) The complete tripack emulsion is about one-thousandth of an inch thick. The individual emulsion layers are from one to five, ten-thousandths of an inch in thickness.

(a) Besides silver halides, the emulsion layer may contain sensitizing agents and substances for the formation of dye images.

(b) Between the emulsion layers are interlayers of gelatin. Sometimes they may serve as color filters for the sensitized emulsions, but their main purpose is to minimize the effects of one layer on the other.

(2) This combination of emulsion layers and gelatin interlayers plays an important part in image resolution. Resolving power is a function of emulsion thickness and the size of the light-sensitive grains. To produce a color film with normal speed, the grain size must be fairly large. The increase in grain size results in a loss of image resolution.

(3) Because of the tripack construction, light striking the emulsion must penetrate a considerable distance to reach the lower two layers. In traveling this distance, the light scatters and the image becomes diffused. This light scatter also results in lowered image resolution.

(4) To provide adequate light transmission and to retain the sharpest possible image in the lower emulsion, the top emulsions are designed to be as transparent as possible. These emulsions may also contain light-absorbing dyes to help minimize light scatter.

b. Dye Image. The final location of the dye image in the emulsion is determined by the location of the developed silver grains. The dyes are formed in the areas adjacent to the reduced silver. When the silver is removed during processing, the dye remains as a cloud centered where the grain was located. Because the dye images are partially transparent, rather than opaque, and are formed by chemical diffusion, their density increases gradually from the edge to the center. On the other hand, the density of a silver image changes abruptly at the edge of the grain. Therefore, color film appears less grainy than black and white, but the image has lower edge sharpness and image definition. The magenta dye image (green-sensitive layer) has the greatest appearance of graininess because the peak sensitivity of the human eye is in the region of the spectrum.

(1) Atypical emulsion of color film. Since red, green, and blue are recorded in the same manner in almost all color films, negative and reversal, a cross-section of a typical emulsion of color film will help in better understanding. Refer to figure 1-11.

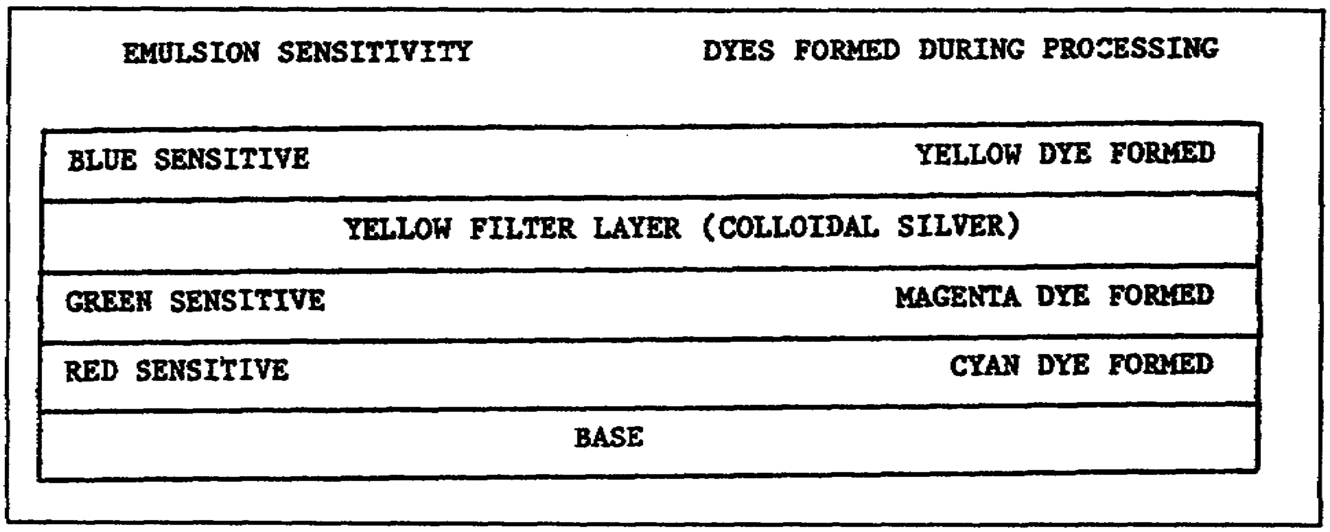

Figure 1-11. Color film emulsions

(a) Starting at the top is the blue-sensitive layer of the emulsion. This is where the blue record is made. The blue-sensitive emulsion is sensitive to blue light only.

(b) Below the blue-sensitive emulsion is a layer of yellow colloidal silver suspended in clear gelatin that absorbs the stray blue light that penetrates the blue-sensitive emulsion; this layer is similar in action to a yellow filter. The colloidal silver is bleached and fixed away during the processing.

(c) The green-recording layer is an orthochromatic emulsion and is sensitive to both blue and green light. Because of the colloidal silver, only red and green light is allowed to penetrate to this point. Since this emulsion layer is not sensitive to red and since all the blue light has been absorbed, the only exposure possible at this point is that produced by green light.

(d) Following the green sensitive emulsion is a panchromatic emulsion that records red. This emulsion is manufactured with a very low sensitivity to green. Since the blue has not penetrated to this point, because of the layer of colloidal silver, only a red record is made.

(2) Summary. In effect then, a sheet of negative or reversal color film is made up of three separate emulsion layers, each one sensitive to or able to record only one of the additive primary colors. Refer to figure 1-12.

c. Coupler Development. The dye images in color processing are supplied by the chemical reaction known as "coupler development." This action takes place in the color development step in all color film, both negative and reversal.

(1) Coupler development in negative color film. In all negative color film, the couplers are located in the emulsion. Examples would be Ektachrome and Agfachrome film. This requires one re-exposure (or reversal bath), which exposes all the silver halides that were not exposed during the initial exposure. Since the couplers are located in the emulsion, only one color developer is required to produce dye in all three sensitive layers.

(2) Coupler development in reversal color film. In reversal color, the couplers are located in the emulsion or in the color developer.

(a) The presence of the dye coupler in the color developer solution necessitates the use of three developers, one for each dye. A few commercial films, notably Kodachrome, use this type of processing, but it is laborious and time-consuming, requiring elaborate equipment.

(b) Each color-sensitive layer must individually undergo the second reversal exposure and then color development to form the proper dye in that layer. Since only one layer at a time receives a second exposure, dye will form only in that layer. Because the selectivity of dye formation is determined by individual layer exposure, only reversal materials can be processed by this technique.

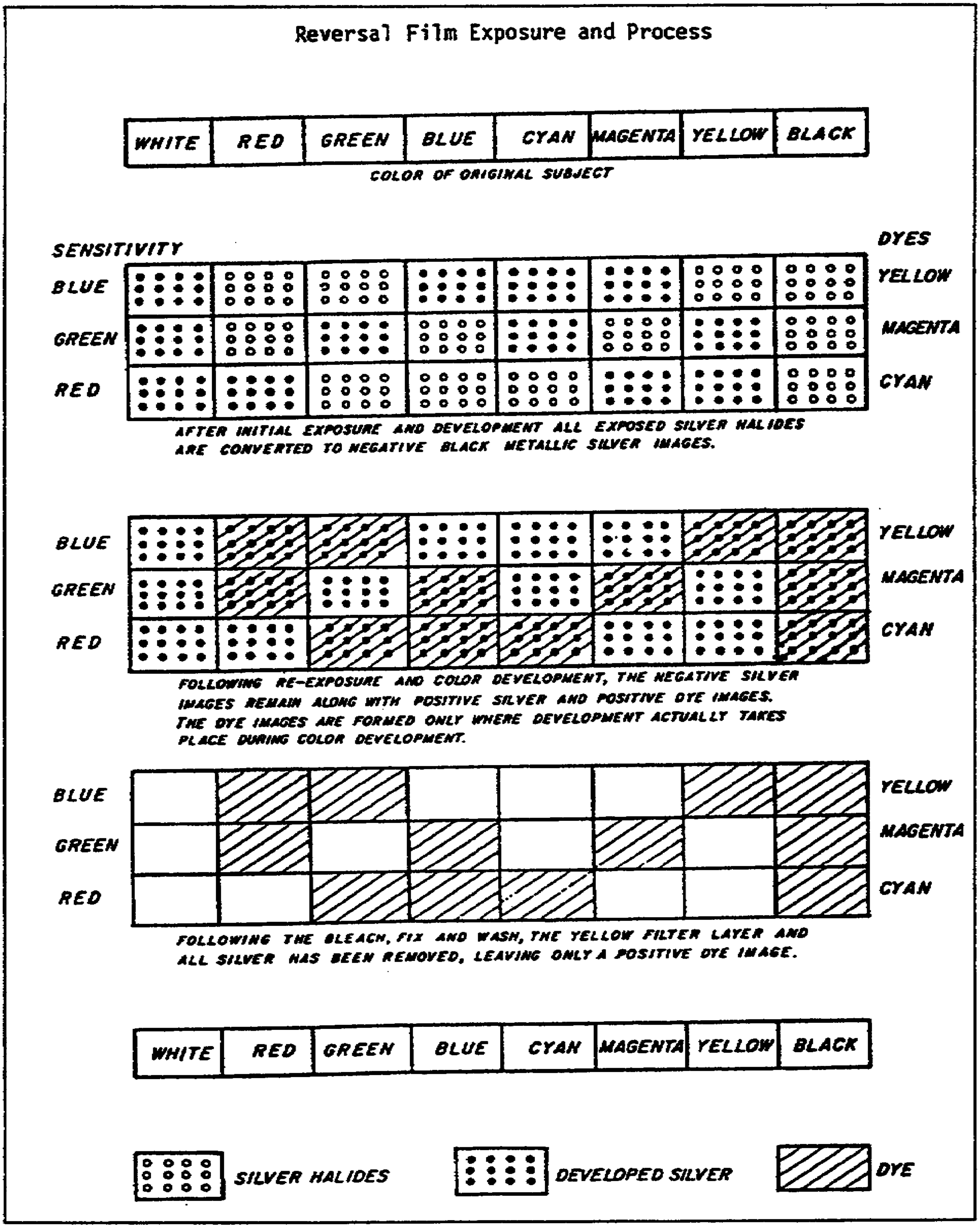

Figure 1-12. Production of a reversal transparency

(c) The unique advantage of this technique is that the dye coupler is mobile; thus, dye formation can take place at the site of silver image formation because coupler molecules are available to react with the oxidized developer molecules. This results in greater resolution and an almost total lack of graininess.

11. Exposing Color Films.

Exposing and processing color films, whether negative or reversal, is basically the same as that for black and white. Because of the more complex construction of color films and more steps in processing, there are certain differences between them. Exposure, quality of exposing illumination, and processing times and temperatures are much more critical than with black and white films.

12. Exposing Illumination.

The eye automatically adjusts for changes in the color quality of light sources. Color films, unfortunately, do not have this capability. They are constructed to meet lighting situations having specific spectral qualities. Therefore, a color emulsion will most accurately reproduce the colors of the subject only when exposed under illumination for which it is balanced by the manufacturer.

a. Producing a Satisfactory Color Balance. Spectral quality refers to the various combinations of wavelengths present in the light source. Daylight color films, therefore, must receive equal amounts of these radiations to produce a satisfactory color balance.

(1) Daylight contains approximately equal amounts of red, green, and blue. Daylight color films, therefore, must receive equal amounts of these radiations to produce a satisfactory color balance.

(2) Electronic flash is often used as the sole light source for indoor scenes. However, it is just as useful outdoors even when the sun is shining. It can be used to either fill in shadows or to simulate sunlight under hazy skies. Electronic flash approximates natural sunlight conditions. The color flash is suitable for daylight-balanced color films.

(3) Tungsten illumination is comparatively high in red content and deficient in blue wavelengths. Therefore, tungsten color films have a relatively higher blue sensitivity. Due to this increased blue sensitivity, if exposed under daylight conditions, tungsten reversal emulsions will have an excessive bluish cast. On the other hand, daylight color films appear

reddish if exposed under tungsten illumination. Figure 1-13 shows a comparison between film sensitivity and light quality.

Daylight 5400 K	**Daylight Film**
B___ Daylight illumination **G___ consists of equal amounts** **R___ of red, green, and blue**	**B___ Daylight film emulsion** **G___ layers are equally** **R___ sensitized.**
Tungsten 3200 K	**Tungsten Film**
B - Tungsten illumination **G___ consists of large amounts** **R + of red and a small amount of blue.**	**B + Tungsten film emulsion** **G___ layers are made with** **R - blue and decreased** **sensitivity to red.**

Figure 1-13. Comparison between film sensitivity and light quality

b. Using Filters to Alter Spectral Quality of Light. Whenever possible, the source of illumination and the color emulsion should be matched. However, situations sometimes arise that make it necessary to use color emulsions and light sources that do not match. Acceptable results can be obtained, provided filters are used to alter the spectral quality of the light entering the camera. There are four categories of filters that perform this task:

- Conversion filters.
- Light-balancing (correction) filters.
- Color-compensating (CC) filters.
- Special-purpose filters.

Filters for color photography are more subtle in coloration than those used for black and white photography. Let's look at each type of filter for color photography.

(1) Conversion Filters. Conversion filters are dense filters and are used for exposing tungsten-type color films under daylight conditions and daylight film under tungsten illumination. Figure 1-14 indicates the filter to use for different lighting situations.

Film Type	Light Available	Filter	F/Stop Increases
Daylight	3200° Lamps	80A	2
Daylight	3400° Lamps (Photofloods)	80B	1-2/3
Type A			
(Balanced for 3400°)	Daylight	85	2/3
Type B			
(Balanced for 3200°)	Daylight	85B	2/3

Figure 1-14. Filters for different lighting situations

NOTE: Type 80 filters are blue in color while 85 filters are yellowish. This and other lists in this section are just guides.

You must follow the recommendations of the film manufacturer. These recommendations apply primarily to reversal rather than negative-type film. When using a camera with behind-the-lens metering, exposure changes because filter factors are automatically adjusted for.

(2) Light-balancing filters. Light-balancing filters are paler than conversion filters. They are used for slight adjustment within the general light balance of the film (i.e., matching type A film to different types of tungsten lighting, etc.). Figure 1-15 is a list of commonly used light-balancing filters.

NOTE: The 81 series filters are yellowish, while the 82 series are bluish in color.

(3) Color-compensating (CC) filters. CC filters come in hues of red, green, blue, cyan, magenta, and yellow. They are used to make very subtle tonal changes. CC filters are often used in slide duplicating, printing, and picture taking. A very large selection of densities is available as shown in figure 1-16. For this reason, color-compensating filters are available in inexpensive gelatin sheets.

Film Type	Filter	Purpose	F/Stop Increases
Daylight	81A	Absorbs excess blue in cloudy weather, shade, or when using electronic flash indoors.	1/3
Type B	81A	When using Type B film with photofloods.	1/3
Daylight	81B	Same application as in 81A but with stronger results.	1/3
Daylight	82A	Reduces the excessive warmth found in early morning and late afternoon light.	1/3
Type A	82A	To balance Type A for 3200 lights.	1/3

NOTE: The 81 Series filters are yellowish, while the 82 series are bluish in color.

Figure 1-15. Commonly used light-balancing filters

(4) Special purpose filters. Special purpose filters have been designed for specific types of light-balancing problems. Figure 1-17 indicates the types of filters that are available.

13. Mixed Light Sources.

Try to avoid different color qualities of light being mixed when exposing color film. A color photograph taken in a room with sunlight streaming in through a window and incandescent lights illuminating the rest of the room would have mixed light sources. Film balanced for tungsten light would correctly render the color of the part of the room lit by the tungsten lights, but the sunlit areas would tend to be bluish.

14. Reciprocity.

Reciprocity failure effects color emulsions much the same way it effects black-and-white emulsions. With color the effect is more apparent. With black-and-white emulsions, reciprocity failure is apparent only as a loss in density. An increase in exposure is usually sufficient to offset this lack of density. With color films, there are three emulsions that can be effected by reciprocity failure and each may be effected to a different degree. This results in the usual density loss plus an accompanying color shift. To compensate for reciprocity failure in color emulsions, it may be necessary to increase exposure to gain density and to filter the light to correct the color shift.

FACTORS FOR KODAK CC FILTERS

Filter	Factor	Filter	Factor
.025Y	1.0	.025R	1.1
.05Y	1.1	.05R	1.2
.10Y	1.1	.10R	1.3
.20Y	1.1	.20R	1.5
.30Y	1.1	.30R	1.7
.40Y	1.1	.40R	1.9
.50Y	1.1	.50R	2.2
.025M	1.1	.025G	1.0
.05M	1.2	.05G	1.1
.10M	1.3	.10G	1.2
.20M	1.5	.20G	1.3
.30M	1.7	.30G	1.4
.40M	1.9	.40G	1.5
.50M	2.1	.50G	1.7
.025C	1.0	.025B	1.0
.05C	1.1	.05B	1.1
.10C	1.2	.10B	1.3
.20C	1.3	.20B	1.6
.30C	1.4	.30B	2.0
.40C	1.5	.40B	2.4
.50C	1.6	.50B	2.9

Figure 1-16. Factors for Kodak CC filters

Film Type	Filter	Purpose	F/Stop Increases
Daylight	FLD	Eliminates the blue-green cast which results when shooting daylight film under fluorescent lighting.	1
Type B	FLB	Used when shooting Type B film under fluorescent lighting.	1
Daylight	CC30R	When using daylight film underwater.	2-1/3

Figure 1-17. Types of filters

15. Latitude.

All color materials should be accurately exposed. Most color negative materials have greater exposure latitude than color reversal materials.

a. Using Negative Materials. Acceptable reproductions can be made from negative materials that deviate from the optimum exposure, especially if the error is on the overexposure side.

(1) Negative color film can be exposed over a range from one f/stop under to two f/stops over. However, optimum exposure will always provide the best results when printing color negatives.

(2) If no meter is available to obtain the correct reading and there is doubt concerning exposure, a good rule to follow is to overexpose or bracket the exposure. Adjustments for exposure error can be made during printing if the subject has been recorded on the useful portion of the characteristic curve.

b. Using Reversal Materials. Significant deviation in exposure, when using reversal films, will produce a final product with unacceptable density and possible color shifts.

(1) Reversal color films usually have an exposure latitude of one f/stop (+/- one-half stop). More than one-half stop in overexposure results in washed-out transparencies with reduced color saturation.

(2) Underexposure results in dense transparencies with loss of shadow detail and a color shift. The film data sheet furnishes information for exposure and different lighting conditions.

16. Color Film Storage.

The color quality of photographic emulsions is subject to change due to age, temperature, humidity, and atmospheric elements. Improper storage can ruin color emulsions very quickly.

a. Age. All photographic emulsions are dated. They should be exposed and processed prior to the "Process Before" date. Although proper storage under controlled temperature and humidity conditions will retard spoilage, no specific extension date can be given without testing each emulsion batch.

b. Temperature. Color film should be stored in unopened packages at a temperature of 55 degrees Fahrenheit (F) (13 degrees Celsius (C)) or lower. If this is not possible, then protect film from direct sunlight, heat, radiators, etc. Nonprofessional films can be stored at room temperature. Professional films must be kept under refrigeration.

c. Humidity. High relative humidity will harm color film more quickly than high temperatures. Relative humidity of film should be maintained at 40 percent where possible. Keep film in its original container until ready to use.

d. Atmospheric Elements. Harmful gases, such as gasoline vapors, can attack film emulsions. Always keep film in its original container before shooting. When film has been exposed, replace as much of the original wrapping as possible. Additional protection may be necessary depending on your location and climate.

e. Opening Precautions. Films stored under refrigeration must not be opened immediately upon removal from storage. They must be allowed to warm up gradually. If not, moisture will condense on the film emulsion. Always allow film to warm up slowly. Usually, one hour is sufficient before opening the package. Always refer to the manufacturer's instructions for proper time.

17. Summary.

This completes lesson 1. Before continuing to lesson 2, complete the following practice exercise. If you have any difficulty, refer back to the pages indicated in the practice exercise answer key and feedback sheet. Then go to lesson 2.

LESSON 1

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. When using the subtractive filtration process, which of the following colors will yellow subtract?

   A. Red
   B. Blue
   C. Green
   D. Magenta

2. Which of the following terms is used to identify the name of a color?

   A. Hue
   B. Value
   C. Kelvin
   D. Saturation

3. Tungsten balanced films are relatively more sensitive to which of the following colors?

   A. Red
   B. Blue
   C. Green
   D. Yellow

4. When you are shooting color reversal (slide) films, how much latitude do you generally have for exposure?

   A. None
   B. +/- one-half stop
   C. +/- one stop
   D. +/- two stops

LESSON 1

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	B. Blue
	A filtration rule that you should remember is that a filter transmits light of its own color and absorbs its complement. Yellow is composed of red and green, thus it will transmit red and green and absorb (or subtract) blue which is its complement (page 11, para 4c).
2.	A. Hue
	Hue is simply the "name" given to a color (page 16, para 6a).
3.	B. Blue
	Since tungsten light sources, for which these films are balanced, are high in red content, tungsten film is made especially sensitive to blue in order to counteract the red; this will give the colors a more natural appearance (page 24, para 12a(3)).
4.	B. +/- one-half stop
	Slide films have a very narrow latitude for exposure. For the most part, they must be right on target; they will stand +/- one-half stop tolerance, however, with acceptable results. With slide films, it is better to err on the side of underexposure rather than overexposure (page 29, para 15b(l)).

LESSON 2

COLOR NEGATIVE FILMS: CHARACTERISTICS, EXPOSURE, PROCESSING PROCEDURE, AND CHEMISTRY

Critical Tasks: 113-578-3023
113-578-3045

OVERVIEW

LESSON DESCRIPTION:

In this lesson you will learn the characteristics of a color negative, its exposure requirements and techniques, and processing techniques. You will learn to identify various color negative films, their uses, and special features. You will also learn the procedure for processing color negative film.

TERMINAL LEARNING OBJECTIVE:

ACTIONS:

a. Identify the characteristics of color negatives.

b. Identify color negative exposure requirements.

c. Identify color negative processing procedures.

d. Identify safety practices and precautions for color negative processing.

CONDITION: You will be given information from STP 11-25513-SM-TG.

STANDARD: Exposure and processing techniques will be in accordance with STP 11-25513-SM-TG.

REFERENCES: The material contained in this lesson was derived from the following publication: STP 11-25513-SM-TG.

INTRODUCTION

Color negative materials are highly versatile, having certain advantages over reversal color films. From a color negative, you can produce color transparencies without first producing an internegative. Color negative materials have wider exposure latitude and are easier to correct for color balance and contrast variations. Their only disadvantage is that they do not lend themselves well to visual evaluation since their printing characteristics cannot be accurately determined by evaluating the negative.

PART A - COLOR NEGATIVE FILM CHARACTERISTICS AND EXPOSURE

1. Color Negative Film Characteristics.

There are many color films available made by different companies. All have variable characteristics in relation to speed, grain, resolving power, and color balance. Speed now ranges from International Standards Organization (ISO) 25 for Kodak Ektar Film up to ISO 1600 for Kodak Ektapress.

Figure 2-1 shows a cross-section of a typical color film. Starting at the top and working down the diagram the layers are as follows:

a. An anti-abrasion overcoating protects the film from minor abrasions.

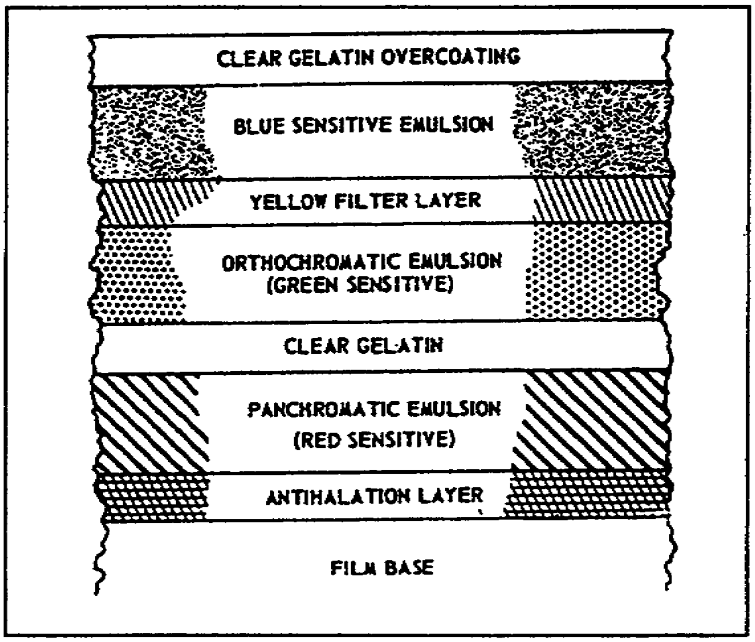

Figure 2-1. Structure of color film

b. The blue sensitive emulsion layer is where the blue record is made.

c. The third layer is a built-in colloidal silver, yellow filter. The purpose of this filter is to absorb blue so that only green is recorded in the next layer.

d. The orthochromatic layer is where green is recorded.

e. Red is recorded in the panchromatic emulsion. This emulsion is manufactured with a very low sensitivity to green and since the blue light is absorbed by the colloidal silver, only a red record is made.

In effect then, a sheet of color film is made up of three separate emulsion layers, each sensitive to or able to record only one of the three additive primary colors of light. Subtractive primary colors, such as yellow, are recorded in the two layers that combine to make up the color (e.g., green and red). White light is recorded in all three levels.

2. Transmitting Colors Correctly for Prints.

The basic difference between negative and reversal color processing is that negative film is processed in a single, color developer. The amount of dye produced is directly related to the exposure the particular film layer received during camera operation. In addition, color negative film uses colored couplers in forming the middle and lower dye layers.

a. How Dye Layers Work. After color film is completely processed, all that is left are the three different layers of dye. The primary purpose of these dyes is to control transmission and absorption of red, green, and blue light. However, even the best available dyes produced in color film absorb some of the light that they should transmit. This is true in negative and positive color films since the dyes used are the same.

(1) For example, a perfect cyan dye would absorb only red light and would transmit green and blue light freely. All known cyan dyes absorb large proportions of green and blue light.

(2) Similarly, a perfect magenta dye would absorb only green light, transmitting blue and red light freely. Magenta dyes transmit red light freely, but absorb some blue light.

(3) Of the three dyes used (cyan, magenta, and yellow), yellow is the closest to ideal. Yellow absorbs blue light and transmits green and red light.

b. Using Masking. The effect of the unwanted absorption of the dyes is not a serious disadvantage in a positive color transparency used only for projection or direct viewing. The real difficulty is noticeable when you make a duplicate or a color print from the transparency. Since the dyes in the reproduction material are the same as the dye in the original, the errors are multiplied in the reproduction. To produce satisfactory results, supplementary masking must be used for correction of color prints.

(1) Negative masking to correct dye error. Color masks, which provide a neutralizing effect for unwanted dye absorption, are readily seen in the unexposed areas of a color negative (figure 2-2). There are two such masks: a yellow mask in the green-sensitive (magenta dye-forming) layer, and a reddish magenta mask in the red (cyan dye-forming) layer. Together, they produce an orange tint in unexposed areas. There is no need to mask the blue-sensitive (yellow dye-producing) layer since the yellow dyes usually have negligible unwanted dye absorption.

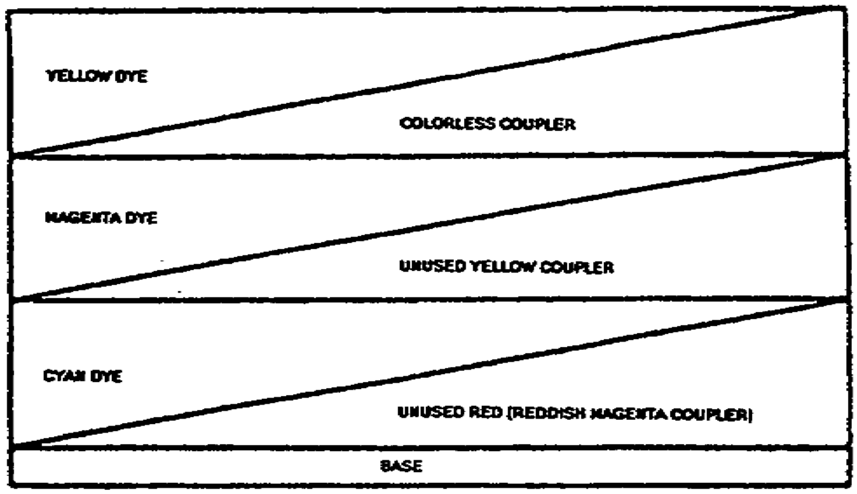

Figure 2-2. Negative color masking

(2) How masks work. The absorption of a mask corresponds to that of the dye layer for which it is made. For example, magenta dye (which should absorb only green) absorbs blue light. The yellow mask for this layer absorbs the same amount of blue light uniformly over the area of the negative, except where magenta dye is produced. Thus, where magenta dye is produced, the yellow mask is destroyed in an equal proportion. The result is elimination of color distortion because the unwanted absorption is uniform over the entire negative area. This is done by using a colored dye coupler. An ingredient (quinone diimine) in the color developer reacts with this coupler to form magenta dye and destroys the yellow coupler. The red coupler for the cyan-dye layer works in the same manner. The mask forms automatically during color development and remains in the film after processing.

(3) Results of not masking. If you do not mask, two types of errors will occur in reproduction. These errors are in the saturation and hue of colors. Blues, cyans, and greens tend to be too dark, while reds, oranges, and yellows tend to be too light. Second, hue-shift errors occur. Reds usually shift toward orange, magentas toward red, and cyans and greens toward blue.

3. Exposing Color Negative Film.

Regardless of which color negative film you use, the quality of the resulting print will be directly affected by the film exposure. The most important characteristic of a color negative to be used for color printing is that it has adequate shadow detail.

a. Determining Correct Exposure. Exposure of color negative film depends upon subject color, contrast, and the lighting ratios. Exposure latitude ranges from approximately one stop under to two stops over. If there is any doubt concerning the correct exposure, overexpose rather than underexpose. To avoid excessive contrast in the print, do not exceed a 1:3 lighting ratio when exposing color negative film.

b. Evaluation of Color Negatives. The color balance of the negative cannot be determined visually, but the adequacy of exposure can. If there is no visible shadow detail, and the shadow areas are clear orange, the negative is underexposed. When the highlights are blocked up, the negative has been overexposed. Evaluation of color negatives may seem difficult when you first work with them, because of the orange masking. You can overcome this by viewing the negatives through a Wratten 61 green filter. This filter neutralizes the orange masking and makes it possible to read the shadow and highlight areas of detail.

c. Using a Gray Card. Proper filtration for printing color negatives can be determined by using a gray as a reference. A neutral gray card of 18 percent reflectance should be photographed with the subject. Place the card along the edge of the scene where it does not interfere with the subject; however, it must receive the same lighting as the subject. The card should be tilted at a slight angle, not over 8 degrees from the vertical (figure 2-3).

(1) If you cannot photograph in this manner, photograph the card using a separate sheet of film. Process this test film with the same batch of negatives that it represents. Then the gray card image can be printed to correct color balance using various evaluation methods.

(2) You need not include a gray card in every scene as long as you include in a typical scene with the same type of lighting. This is extremely important with negative color films, since you cannot tell the color balance by looking at the film as you can with reversal. Any time conditions change, such as haze or overcast, shoot a gray card. If you take pictures over an extended period, include a gray card in the scene every hour or so.

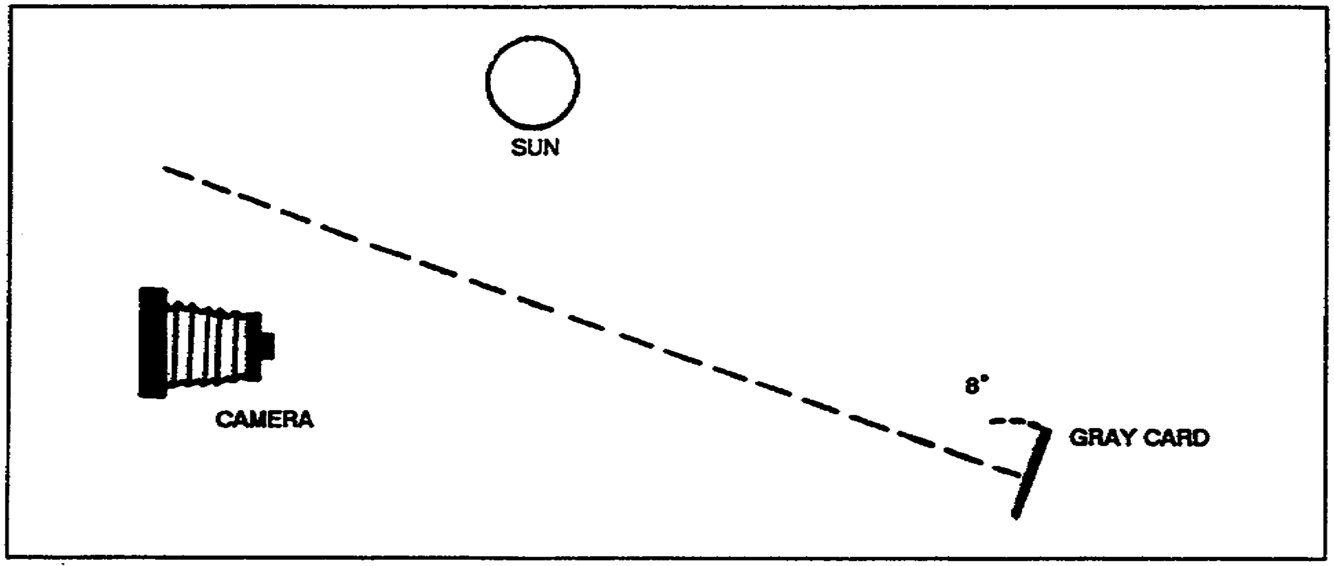

Figure 2-3. Gray card placement

4. Types of Color Negative Films.

There are many brands of color print films available on the market. Fuji, Agfa, and Kodak are manufacturers whose films are readily available. We will confine our discussion to Kodak brands.

Let's discuss the characteristics of a few of the most frequently used of these. They are balanced for 5400 degrees and are available in several formats. Refer to figure 2-4.

a. KODACOLOR Gold 100, 200, and 400. These films, currently available in 35 millimeter (mm), are the newest films manufactured by Kodak. They offer more enhanced color rendition over a wider range of exposures. This means that the color of a subject will remain the same even if the lighting has changed or the film was slightly over or underexposed. Therefore, Gold films do an excellent job of keeping color consistent in very demanding lighting conditions.

(1) KODACOLOR Gold 100 and Gold 200. These films offer improved sharpness and grain structure over the previous Kodacolor films.

(2) KODACOLOR Gold 400. Finer grain and improved color saturation in underexposures is offered by this film. It produces good flesh tones over a wide range of exposures.

b. KODACOLOR VR 1600. The fastest Kodak color negative film produced to date, this emulsion has special sensitization. It gives pleasing results in most lighting situations without the use of color conversion filters. However, there is a noticeable increase in the grain size and you should use it only in low light situations.

Kodak Color Negative Film

Kodacolor Film

- **Gold 100.**
- **Gold 200.**
- **Gold 400.**
- **VR 1000**

Ektapress Gold

- **Gold 100 Prof.**
- **Gold 400 Prof.**
- **Gold 1600 Prof.**

Ektar Film

- **Ektar 25**
- **Ektar 25 Prof.***
- **Ektar 125**
- **Ektar 1000**

Vericolor Professional Film

- **Vericolor III Prof. "S"**
- **Vericolor 400 Prof.**
- **Vericolor HC Prof.**
- **Vericolor II Type "L"**
- **Vericolor III ID (5078)**
- **Vericolor ID (4078)**
- **Vericolor Slide (SO-279 & 5072)**
- **Vericolor Internegative**

*** A professional version of Ektar 25.**

Figure 2-4. Kodak color negative film

c. EKTAR 25. This film is ideal for applications that call for large-scale prints or for photographing subjects that require the rendering of fine detail. It is an excellent choice for producing display images, and for making product illustrations of subjects such as fabric textures and jewelry in the studio or outdoors. It is also good for showing details of machine parts and architecture, and for nature, landscape, and scientific subjects.

d. EKTAR 125. This film is balanced for exposure with daylight or electronic flash. You can also obtain pleasing results under existing-light sources without filters. This medium-speed film offers finer grain and higher sharpness than any other comparable-speed color print film, and yields enlargements of extremely high quality.

e. VERICOLOR II PROFESSIONAL FILM, Type L. This film is designed for long exposures. It is balanced for 3200 degrees K and available in sheets and 120 size. The exposure range is 1/50th to 60 seconds. This film renders higher contrast than type S. Exposure reciprocity is compensated by using a variable ISO setting. For example, ISO 100 (1/50th to 1/5th second), ISO 64 (1 second), and ISO 50 (5 seconds or longer).

f. VERICOLOR III PROFESSIONAL FILM, Type S. Type S is designed for short exposures. It has an ISO of 160 and is balanced for 5400 degrees K. Type S has improved sharpness and color reproduction providing good skin tones for portraits and wedding photography. It is available in 135 rolls and bulk, 70mm, 120, 220, and sheets. The exposure range is from 1/10th to 1/10,000th seconds.

NOTE: Reciprocity failure is a problem in any aspect of color photography. Extremely long or short exposures are likely to cause color shifts with either reversal or negative films. It is, therefore, important to follow the manufacturer's exposure recommendations for the film you are using.

5. Color Internegative Films.

If you have a series of positive transparencies that you need prints from, you have two methods of producing these prints. One is direct printing onto reversal-type paper. The other is to make an internegative. Kodak Vericolor Internegative film is available in rolls and sheets, and is an ideal method of making negatives from slides. It can also be used to copy color prints. An internegative is a color negative that is not an original negative.

a. General Characteristics. Kodak Vericolor Internegative film is an excellent film for making color negatives from prints. It has excellent contrast control and color balance. It is designed for exposures between 1/1000 to 30 seconds with 3200 degrees K light sources. This makes it very convenient to use a color projection printer as the light source. The unexposed film should be stored at a temperature of 50 degrees F (13 degrees C) or lower. It must be handled in total darkness.

b. Unique Characteristics. A characteristic unique to internegative film is that exposure will alter contrast. The emulsion sensitivity and construction of internegative film is similar to other color films, except it has six emulsion layers.

(1) The two top layers of emulsions are sensitive to blue light. The two center layers are sensitive to green light. The two bottom emulsions are sensitive to red light. The reason for the double emulsion layers are for contrast control.

(2) One layer for each color has an inherent low contrast and fast speed while the other layer has a high inherent contrast and slow speed. Consequently, if more contrast is required, then exposure is increased; to lower contrast, decrease exposure. Color balance of the internegative can be changed by adjusting the filter pack.

c. Processing. Internegative film is designed to be processed in a normal C-41 process. There are no additives, starters, nor any adjustments that have to be made. Follow the processing directions in your data sheet or data guide.

PART B - COLOR NEGATIVE FILM PROCESSING, CHEMICAL MIXING, AND CERTIFICATION

Color negative materials and processes have been in use for several years. Until recently, only a few photographic manufacturers provided the market with a color negative process. Today, we have a number of makers of color negative materials with each manufacturer providing the chemistry that is compatible with their particular product. Although each process is similar, there is not complete compatibility between films and processes across the spectrum. In this subcourse, we will standardize one Kodak color negative film and Kodak C-41 chemistry.

6. <u>Color Negative Processing Steps for Process C-41</u>.

There are a total of seven steps in performing color negative processing using process C-41. They break down as follows: four chemical steps, two water washes, and the drying step. You do not need to memorize the sequence and processing times. However, you should be familiar with the purpose and function of each step.

a. Developer. This is the most important step in the process. There is only one developer in processing C-41. The developer reduces exposed silver halides to black metallic silver, and at the same time, complementary dyes are formed in proportion to the amount of silver reduced. As silver is reduced, by-products of silver reduction react with the dye couplers in the film. This secondary reaction of development forms the dye image. Yellow, magenta, and cyan dyes are formed respectively from the top to bottom layers of emulsion.

After the development step, the film contains both a silver and a dye negative image (figure 2-5).

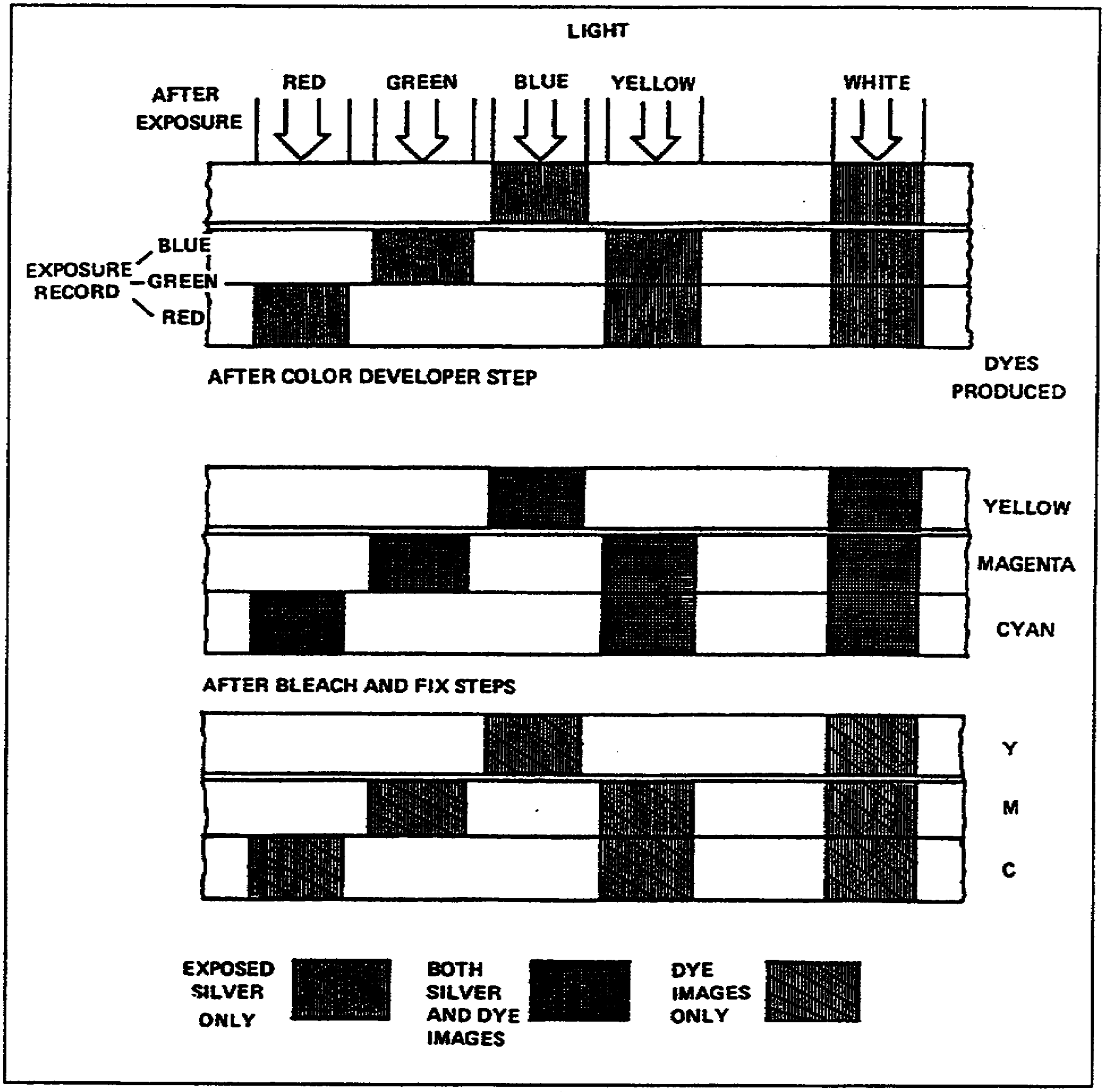

Figure 2-5. Color negative film, exposure and processing effects

b. Bleach. The bleach step is performed immediately after the development step. Its function is to convert the black metallic image back to a silver halide state, which prepares it to be removed by the fixer step.

c. Wash. This wash step in running water serves to remove residual bleach from the film. It also prevents contamination of the fixer, which is the following step.

d. Fixer. The fixer converts the silver halides in the emulsions to soluble silver salts and is similar in action to fixer used for black and white material.

e. Wash. This second and final wash removes all processing by-products from the film.

f. Stabilizer. The stabilizer performs two functions; it sets the dyes to ensure permanency, and it contains a wetting agent which promotes spot-free drying.

g. Drying. Film may be either power or air-dried.

7. Mixing C-41 Chemicals.

The C-41 chemical kit contains four solutions: developer, bleach, fixer, and stabilizer. The temperature of the solvent (water) will vary with each chemical. However, this is indicated on the manufacturer's instructions along with the safety precautions. Always read the manufacturer's instructions because manufacturers update these instructions whenever a slight change is made in the manufacturing of the chemicals.

8. Safety Precautions for Chemical Mixing.

Job safety is an important element of any task and cannot be overlooked. Carefully read and comply with all the warnings and precautions cited by the manufacturer in regards to the handling and use of color-processing solutions. Developing solutions for color materials are usually much more caustic than solutions used in black and white work. A major problem is their potential to cause skin irritation if mishandled or if protective clothing is not worn.

a. Protect yourself by wearing the required clothing, such as an apron or smock and rubber gloves. Wear a respirator over your nose and mouth to prevent the ingestion of chemical dust and fumes during mixing operations.

b. Ensure adequate ventilation of the mixing area before you begin to mix color chemistry. The formaldehyde contained in the stabilizer is a known skin and eye irritant. Ventilation must be enough to ensure that vapors do not accumulate in the mixing area.

c. Eye protection is ensured if you wear protective goggles that protect your eyes from splashing. You can minimize the chemical dust problems by holding the chemical container close to the water surface as you pour it into the mixing vessel.

d. Once you have the solutions prepared, they should be tightly covered while in storage. This is especially important for the stabilizer to prevent the accumulation of formaldehyde fumes in the storage area.

9. Processing Times.

Use the following processing times and temperatures in figure 2-6 to process your color negative film in process C-41.

PROCESSING STEP	TIME (MIN)	TEMPERATURE		AGITATION SEQUENCE (SECONDS)		
		F	C	INITIAL	INTERVAL	SUBSEQUENT
Developer	3':15"	100 ±0.25	37.8 ±0.15	30	13	2
Bleach	6':30"	75-105	24-40.5	30	25	5
Steps Remaining Can Be Done Under Normal Room Lighting						
Wash	3':15"	75-105	24-40.5			
Fixer	6':30"	75-105	24-40.5	30	25	5
Wash	3':15"	75-105	24-40.5			
Stabilizer	1':30'	75-105	24-40.5	30		
Dry	10-20	75-110	24-43.5			

NOTE: Include a 10-second drain time in each step.

Figure 2-6. The C-41 process

10. Agitation Procedures.

It is important to follow correct agitation procedures for the C-41 solutions to obtain optimal development quality.

a. Manual Agitation for Sheet Films.

(1) Developer initial. Immerse the rack fully into the developer. Rapidly tap it on the bottom of the tank to dislodge any air bubbles, then raise the rack until the bottom is out of the developer, then re-immerse it. This requires 4 to 5 seconds.

(2) Developer subsequent. After the initial agitation is completed, allow the rack to remain at rest for 10 seconds. Raise the rack straight until the bottom is just out of the developer solution, then re-immerse it without draining. The lifting and re-immersing cycle should be done in an even, uniform manner, taking 2 to 3 seconds to complete. Repeat the lifting and re-immersing cycle once every 10 seconds (six times per minute). Ten seconds before the developing time is completed, raise the rack, tilt it about 30 degrees toward one corner (held over the tank), and drain for 10 seconds. After 10 seconds, immerse the rack into the bleach.

(3) Other solutions initial. Use one lifting and lowering cycle.

(4) Other solutions subsequent. Use four lifting and lowering cycles per minute at 15-second intervals.

(5) Agitation in washes. Use one lifting and lowering cycle for initial agitation. No subsequent agitation is needed when using a running water wash.

b. Manual Agitation for Roll Films.

(1) Developer initial. Quickly pour developer into the tank through the light-trap opening on the tank cover. Place the cap over the opening and rap the bottom of the tank against the sink to dislodge any air bubbles that may be adhering to the film. Immediately invert the tank, turn it upright and invert it again, continuing this action for a total of 30 seconds. Initial agitation is identical for each step.

(2) Subsequent agitation. Follow exactly the agitation sequence shown in figure 2-6. Notice that agitation is not the same for all steps. Also, be sure to drain your film during the last 10 seconds in every step. This prevents contamination of the following solution.

11. <u>Capacity of Chemical Solutions</u>.

Chemical solutions can process only a certain amount of film before they become exhausted. The total amount of film that can be processed is given by the manufacturer, usually in square feet. The following table shows the capacity of C-41 chemistry if used without replenishment. Refer to the chemical data sheet for capacities of film of other types and sizes, because they are not the same for all films.

Chemical	Film Size	Capacity per gallon
Developer	135-24 VR Film	20 rolls
Other Solutions	135-24 VR Film	40 rolls

When you are not using replenishment, the development time must be increased for each successive batch of film to compensate for the exhausted developer. For 1 pint kits divide one gallon capacity by four. Normally, time compensation is used only with 1-pint units. Replenishment is normally used in the 1-gallon and 3 1/2 gallon sink-line units.

12. Replenishment.

All color processes should be replenished instead of adjusting the development time. Properly used replenishment procedures will greatly increase the useful life of your chemistry. You save money since new kits do not have to be mixed as often, and you also save chemical mixing time. It is not necessary to dump the chemistry except for cleaning. A filtered chemical system is recommended since dirt contamination also limits the life of solutions. Instructions for replenishment in millimeters per square foot are packaged with all color chemicals and should be used as a starting point. Close monitoring of your process may indicate a need for increasing or decreasing the replenishment rate of your particular process.

a. Rates. Consistent satisfactory photographic quality is obtained by using the proper replenishment rates and calculating carefully the actual quantities of replenisher solution required.

You can expect inferior results if more than three square feet of film are processed without replenishment. Refer to current processing instructions for most up-to-date information.

b. Methods. Replenisher should be added to the tank solution just prior to processing the next batch of film. When you replenish, remove enough tank solution to allow the addition of the replenisher solution. Remove, but retain, more than enough solution from the tank to make room for the replenisher. Add the replenisher and return enough of the retained solution to bring the tank volume to its original level. Discard the balance of the retained solution.

c. Compensation for Aging. When solutions stand for some time without use, such as over a weekend, it is necessary to make allowance for the decrease in activity of the developers. For a two-day shutdown, try adding developer replenisher at the rate of three percent of the developer tank solution (1 gallon solution - 3.84 ounces).

d. Special Treatment Required for Bleach Solution. The efficiency of the action of the bleach depends upon a certain amount of aeration of the bleaching solution. The best way to achieve this aeration is to use airburst agitation. An alternate method is to introduce air from a separate compressed air supply, such as the Kodak gas distributor sparger. This should be done for about 30 minutes before each process at a valve pressure of about 2 1/2 pounds per square foot. Since it is not possible to over-aerate the bleach, it is recommended that low-level aeration continue throughout the day.

13. Chemical Storage.

Even well-mixed and properly replenished solutions will become exhausted with age. Ensuring proper control of your chemistry includes discarding old chemistry. Figure 2-7 gives the useful life of C-41 chemistry.

Mixed Solutions (Unused, Used or Partially Used)	Full, Stoppered Glass Bottles	Tanks With Floating Covers
Developer or Developer Replenisher	6 weeks	4 weeks
Bleach	Indefinitely	Indefinitely
Fixer	8 weeks	8 weeks
Stabilizer	8 weeks	8 weeks

Figure 2-7. Useful life of C-41 chemistry

14. Quality Control.

After mixing color processing chemistry and prior to film processing, an analysis may be made of the solutions. This analysis would require the performance of the following tests: determine the specific gravity (SG), determine the potential hydrogen (pH), and run a sensitometric check.

A standard for each color processing chemical should be established. What the standard should be depends on many factors: the particular laboratory, the type of work, the type of processes, etc. Due to many variables that may be beyond your control, the established standard must have upper and lower control limits to allow a minimal amount of deviations and still produce an acceptable product. Some of these variables are: a change in agitation from one person to another, not following the manufacturer's recommendations when mixing, the age of the chemicals, the use or misuse of replenishment, or even the rate. Any of these items can cause problems in the color process. Specific gravity, pH, and sensitometric analysis are used to analyze the color processing solutions to assure the highest quality in the chemicals, therefore assuring a high quality end product.

a. Specific Gravity Analysis. Specific gravity is a check to determine if proper amounts of chemicals and water are present in a solution. Specific gravity may be defined as the following: the mass of a volume of a substance compared to an equal volume of pure distilled water.

(1) How specific gravity analysis works. As chemicals or water are added to or subtracted from a chemical solution, the specific gravity of the solution will change. When chemical solutions are mixed and the specific gravity is determined, it should be the same as the specific gravity of any previously mixed solution.

(a) If the measurement registers higher than the previous reading it would indicate that more than the formula amount of the chemical ingredients have been added to the solution, a foreign ingredient has been added, or the solution has not been diluted adequately.

(b) A specific gravity reading that is lower than the previous readings would indicate that an ingredient had been left out of the solution or too much water had been added.

(2) Setting a standard. To certify a chemical solution, first set a standard. To set a standard, take specific gravity readings each time a developer or any chemical solution is mixed. After several readings have been taken, determine the average reading. This average can then be used as a standard.

(a) Establish upper and lower control limits. These limits represent the amount of deviation from the standard that a solution may be and still obtain an acceptable product.

(b) The instrument used to measure specific gravity is a hydrometer. The hydrometer is calibrated to read 1.000 in pure distilled water at 60 degrees F. The solution being tested is measured against this standard.

(c) Because specific gravity readings of a solution will not be taken in this course, exact procedures will not be discussed. The following are examples of specific gravity readings of C-41 color negative developer and other solutions.

Honey	**1.456**	**Developer**	**1.035**	**80 F**
Beer	**1.035**	**Bleach**	**1.162**	**80 F**
Milk	**1.032**	**Fixer**	**1.075**	**80 F**
Pure Water	**1.000**	**Stabilizer**	**1.000**	**80 F**

b. Determining pH. The symbol pH is derived from the French words "pouvoir hydrogene," or literally, hydrogen power. It is defined as the negative logarithm (base 10) of the reciprocal of the hydrogen ion concentration in gram equivalents per liter of solution. It is used to indicate the degree of acidity or alkalinity of a solution by producing a whole number between 0 and 14 inclusive.

(1) What pH figures mean. Acid solutions will have a pH of less than 7.0 and alkaline solutions will have a pH of greater than 7.0. A pH of 7.0 is the value for pure distilled water and is regarded as being neutral. As the pH scale is logarithmic, a change in pH of 1.0 indicates a 10x change. For example, a developer with a pH of 11 would be 10 times as strong (pH wise) as a developer with a pH of 10.

(a) The pH of a developer indicates its activity or ability to produce densities. The higher the pH the more active the developer, and the lower the pH the less active. If you can maintain the developer's pH at a constant level, the densities and gamma it produces will remain constant. This assumes that no changes occur in any of the component concentrations. The prime reason that the developers D-19, DK-50, and D-76 all produce different gammas or contrast is the fact that their pH is different.

(b) The pH of a developer should be as close as possible to the standard for consistent results. Standards for developer pH should be determined and upper and lower control limits should be established in the same manner as specific gravity.

(2) Importance of checking alkalinity. The silver reduction ability of a color developer depends on its alkaline state. This state of alkalinity decreases during development of the emulsion as bromide ions diffuse into the developing solution.

(a) To clarify this further, silver bromide is the light-sensitive ingredient in the photographic emulsion. During development, silver bromide diffuses into the developing solution and couples with potassium bromide in the developer. This coupling action causes a build-up of bromide in the developer, therefore, lowering the alkalinity and decreasing the developing activity.

(b) Monitor the pH of a solution closely to ensure that the solution is within the set standards, since pH will remain within standards only if proper replenishment of the solutions is maintained.

(3) Monitor the processing solutions. All other processing solutions must be maintained at their proper pH to properly react with the emulsion. For example, the developing stopping action of a stop bath depends upon its acid state. Without replenishment, the pH of the stop bath changes to neutral and thereby loses its ability to stop development.

(4) Methods of measuring pH. There are two common methods of measuring pH: a pH meter or litmus paper.

(a) When litmus paper is used and placed in an acid solution it will change color from white to red. When placed in an alkaline solution it will change to blue. The degree of red or blue indicates the acidity or alkalinity of the solution.

(b) A pH meter is a much more accurate method of measuring pH. The meter's scale indicates a pH of 0 through 14 with 0 being the most acid state and 14 being the most alkaline state. There are various types of pH meters used in photographic laboratories. Different procedures are used in obtaining the readings but the end result is the same. We will not discuss the exact procedures in this course. Figure 2-8 indicates a sample of pH readings and a pH scale.

c. Sensitometry. Sensitometry is a way of putting photographic theory to work to improve photographs while saving time, effort, and materials. Densitometry is an integral part of sensitometry.

Being closely related, the two terms are often used together. Sensitometry is the science of determining the photographic characteristics of light-sensitive materials, while densitometry is the measuring to determine the needed data.

C-41 Color Negative Chemicals	pH Readings
Developer	10.00
Bleach	6.00
Fixer	6.50
Stabilizer	7.20

pH Meter Scale

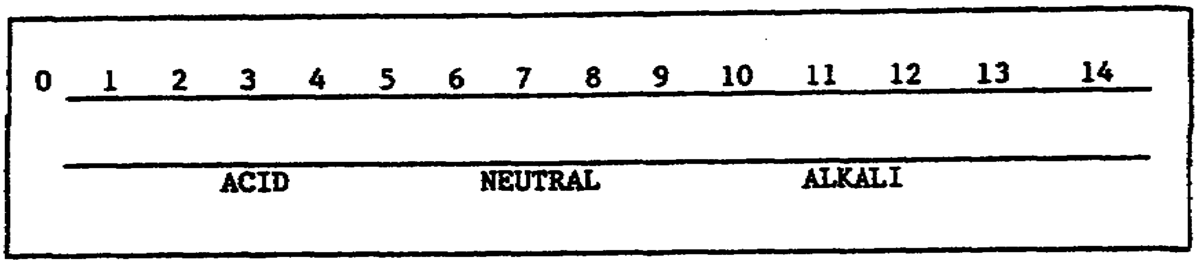

Figure 2-8. Sample of a pH scale and readings

(1) Sensitometric quality control. Sensitometric quality control is a method of analyzing the effects of exposure (light) and processing (development) on photographic materials. It will increase the quality of your photographic products and ensure that you maintain quality production.

(a) For a precise discrimination of the photographic image, we need something other than verbal characterization of an image. We need data: numerical data to describe both the subject and its corresponding photographic reproduction. Once we have data, we can sensibly compare photographic products with original subjects in ways that would be impossible if we were restricted to personal likes and dislikes.

(b) When we look at a scene, we see differences in shapes, sizes, and colors that make up that scene. We also see differences in tone, such as lightness and darkness differences. Most scenes contain many graduated tones between the darkest and lightest tones. An average scene has approximately 160 different tones. The lightest and darkest tones are the two most important. The ratio of these two values represents the range of tones or the "scene brightness range" (SBR) of any scene.

We characterize scenes as being very flat if their scene brightness range is of the order of only ten to one. A very contrasty scene's SBR is about 1000 to one.

(c) When we look at a photographic negative we see the many different tones, from the darkest to the lightest, in random locations throughout the image. If we arrange these tones in order from the lightest to the darkest, we have an arrangement that is much easier to evaluate. The Sensitometric Step Wedge represents this very arrangement, simulating all possible SBRs. The lightest to the darkest steps of this step wedge differ by 1,024 to one, enough to represent any possible SBR found in nature.

(2) Importance of sensitometric monitoring. As previously stated, sensitometry may be employed to measure the photographic chemistry's ability to consistently reproduce predictable processing results. Sensitometric monitoring of color processing will not only give you a graphic illustration of what your process is doing, it will prewarn you of potential problems and assist you in correcting those problems. Process monitoring can also be looked upon as insurance because it prevents the loss of film due to processing errors. Process monitoring saves time, materials, and possible loss of the mission.

(a) The key word in the monitoring of any system is repeatability. Each time film is processed the results should be the same. To monitor your process and ensure this repeatability, the first problem encountered is the chemistry. When you have the chemistry properly mixed and verified with correct pH and SG measurements, you will need to process the first control strip. Pre-exposed control strips (containing 1,024 to 1 SBR densities) may be purchased from film manufacturers for this purpose.

(b) The first pre-exposed control strip or the processed reference strip from the manufacturer represents the standard or reference to which all subsequent control strips will be compared. The color dye densities (yellow, magenta, and cyan) from each corresponding emulsion layer are measured separately with a transmission densitometer. The density readings are then listed on a Color Process Record Form using either a red, green, or blue color pencil according to the emulsion's light sensitivity.

(c) With each succeeding process of film, another control strip is processed along with the film. The densities of these control strips are also measured with a densitometer and then compared to the standard control strip's densities. The differences between the two strips are plotted on the control chart. If these differences are within acceptable tolerances, the process is in control. If not, through proper analysis you should be able to determine the reason why. Film and chemical manufacturers supply this information for this purpose. The exact procedures are not within the scope of this course.

15. Summary.

This concludes lesson 2. Before proceeding to lesson 3, complete the following practice exercise. If you have any problems, refer back to the pages indicated in the practice exercise answer key and feedback. Then continue to lesson 3.

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LESSON 2

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. When you are shooting color negative film, what is the maximum lighting ratio that the film's latitude can handle?

   A. 1:1
   B. 1:2
   C. 1:3
   D. 1:4

2. Which color negative film is a good choice for display images that must render fine detail?

   A. Ektar 25
   B. Ektar 125
   C. KODACOLOR Gold 100
   D. Vericolor III Professional Film

3. Which step in the C-41 color film developing process renders the dyes permanent?

   A. Fixer
   B. Bleach
   C. Developer
   D. Stabilizer

4. The C-41 color developer's ability to reduce silver is dependent on which of the following?

   A. A neutral pH
   B. An acid solution
   C. An alkaline solution
   D. High specific gravity

LESSON 2

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	C. 1:3
	If you use a higher ratio than 1:3 when shooting color negative film, excessive contrast may result; the print may appear very dark and very light in areas, with few midtones (page 5, para 3a).
2.	A. Ektar 25
	Because of its slow speed, hence fine grain, Ektar will render large prints with good detail (page 7, para 4c).
3.	D. Stabilizer
	The stabilizer, which is the last chemical step in the C-41 process, promote permanence of the dyes, while also helping the film to dry without water spots (page 11, para 6f).
4.	C. An alkaline solution
	The pH of the developer must be alkaline in order to develop the image; with use its alkalinity decreases so the pH level must be monitored and adjusted to retain a high pH (page 9, para 6a).

LESSON 3

COLOR NEGATIVE PRINTING TECHNIQUES

Critical Task: 113-578-3035

OVERVIEW

LESSON DESCRIPTION:

In this lesson you will learn to make a standard negative and print, and visually evaluate print density and color balance. You will also learn the construction of color print paper and the steps necessary to process it.

TERMINAL LEARNING OBJECTIVE:

ACTIONS: a. Identify the steps to prepare a negative and print.

b. Describe the construction of color print paper.

c. Describe the Ektaprint 2 control process.

d. Identify the steps to correct color print errors.

CONDITION: You will be given information from Photographer's Mate Training Series NAVEDTRA 373-02-45-83, MOD 2.

STANDARD: Color negative printing techniques will be in accordance with the Photographer's Mate Training Series NAVEDTRA 373-02-45-83, MOD 2.

REFERENCES: The material contained in this lesson was derived from the following publication: Photographer's Mate Training Series NAVEDTRA 373-02-45-83, MOD 2.

INTRODUCTION

This lesson provides you with an overview of the procedures necessary to make color prints from color negative materials. You will be able to make standard negatives and prints, know the processing steps for making a color print, and how to judge its quality. In addition, you will learn how to mix color print chemistry, monitor the control of the process, and perform troubleshooting procedures to correct faults that may occur as a result of problems with the chemistry.

PART A - STANDARD NEGATIVE AND COLOR PRINTING

1. Standard Negatives.

A standard control negative is an average, normal color negative properly exposed under known conditions and that is known from actual trial to make an excellent print. In other words, it has been printed previously, and an accurate record of the filter pack required for a particular paper emulsion is available. Here is a standard that can be used for comparison purposes.

a. Using a Standard Negative. The standard negative can be useful in at least three different ways:

- For comparing its printing characteristics with those of other color negatives.
- For comparing different paper emulsions.
- For checking processing.

The standard negative should be typical of the majority of negatives to be printed. If most of your negatives are outdoor shots on Kodak Gold 100 film, the standard negative should obviously be shot on Kodak Gold 100.

Further, it should be normally exposed, normally processed, and it should be of a typical subject with typical lighting. That is, the lighting ratio and light direction should be similar to most of the negatives that are to be printed.

b. Selecting a Standard Negative. It will help considerably if the standard negative contains some areas that are relatively sensitive to minor color balance changes.

(1) For example, sunsets or flowers are not good standard negative test subjects because they often can be printed over a wide range of color balance and still be pleasing.

(2) However, the face in a portrait is a sensitive area, as is any near neutral, such as a sunlit concrete surface. Surprising as it may seem, a prominent sunlit tree trunk may be helpful in judging small color differences in middle tones and shadow areas.

(3) Best of all is a gray scale or a card of 18% reflectance, such as the gray side of the Kodak Neutral Test Card placed in the scene.

c. Primary and Secondary Negatives. In some cases, it may be advantageous to have a "primary" standard negative for the most usual film-subject-lighting situation, plus one or more "secondary" negatives representing other situations. A basic enlarger filter pack should be determined for each negative.

2. Equipment Requirements.

To make color prints, you need certain equipment items. Almost any photo equipment used for black and white printing can be used. However, specifically designed equipment makes your job easier. Here we will discuss the printer, voltage regulator, and filters necessary to make color prints.

a. Printer/Enlarger. Any enlarger that is equipped with a tungsten lamp, heat-absorbing glass, ultraviolet filter, and a means to hold printing filters is acceptable for making color prints. The enlarger should have a means of holding the filters between the lamp and negative. Color printing (CP) filters are designed to be used in this position. If you use filters below the lens, you must use color-compensating filters.

(1) Printers designed specifically for color printing have the distinct advantage of dial-in filters. Dial-in filters make it much easier to alter the filter pack than trying to work with separate sheets of filter material.

(2) You should also have an assortment of lenses to cover different sizes of negatives. Be sure the lens will cover the negative sharply to its edges. The lens focal length should be roughly equal to the diagonal measurement of the negative. No matter what lens you use, be sure it is clean and free of fingerprints and dust.

b. Voltage Regulator. Stable, unfluctuating voltage is a must. Fluctuations in the line voltage to a tungsten lamp changes the output and color quality of the lamp. Although this is not serious in black and white printing, it is sometimes disastrous in color printing. A five-volt change will cause a .10cc change in color balance.

To combat this situation, you must use a voltage regulator. The best type is the constant voltage transformer. In the power line, this regulator automatically evens out the voltage fluctuations. The printers used here have in-line constant voltage regulators.

c. Printing Filters. The major difference between black and white and color printing lies in the material. In black and white work, you have only one image in one emulsion layer. In color work, you have three emulsion layers and essentially three colored dye images. These three dye images are controlled by the exposure time and the color of light that is transmitted.

(1) Controlling the final dye image. The printed image is manipulated by exposure and filtration. The combination of the dye images in the negative plus the filters in the printer control the final dye image of the print.

(2) Dechroic glass filters. Dichroic glass filters are sharp-cutting interference filters that completely block out the complementary colored wavelengths. They have nearly no effect upon the other colors of light. These filters are far more accurate than CC or color printing (CP) filters. They attenuate the light by only affecting its specific complementary color and therefore change the exposure to only a specific emulsion in the print.

(a) This is an advantage over CC and CP filters because the dichroic filters change the light on only one layer as opposed to CC and CP that affect all layers and subsequently, the overall exposure.

(b) Adding or subtracting dichroic filters from the filter pack has very little effect on the overall print density and therefore only a minimum change needs to be made.

3. Exposure Controls.

To obtain correct exposure and color balance in a print, exposure must be controlled to the three individual layers. The more exposure an emulsion receives, the more dye is formed and vice versa.

a. Controlling Exposures. The exposure to the red sensitive layer is controlled by time and intensity. Since the blue and green sensitive emulsions are more sensitive to light, a third method of controlling the exposure is used. This is through filters built into the enlarger.

b. Selecting Filters. Although cyan, magenta, and yellow filters are available for use in the enlarger, because of the high sensitivity to light of the blue and green sensitive emulsions, only magenta and yellow filters are used.

(1) The magenta filtration will control the exposure to the green sensitive layer, since magenta absorbs green light.

(2) Yellow filtration is used to control exposure to the blue sensitive layer, since yellow absorbs blue light.

c. Overall Objective. The ultimate objective in obtaining a balanced color print is to give each emulsion equal exposure. Consequently, the only use of the filters in the printer is to control exposure, thereby obtaining correct color balance.

4. Making a Test Print.

a. Negative Requirements. For the first test, select a standard negative which has been exposed and processed as described in the previous lesson. To reiterate, this negative should have the proper density, including a gray card, and have a wide range of tones, including flesh.

(1) Choose a negative that is free of defects such as scratches, stains, fingerprints, etc.

(2) Insert the negative emulsion down into the carrier, compose, and make the first test.

(3) Use the negative to compare print characteristics, adjust for emulsion changes, and to check the process.

b. Test Print. Printers differ from each other in both light intensity and filtration. Therefore, it is difficult to say a certain filter pack and exposure will produce a perfect print. You must make a test print.

(1) Since enlarging equipment varies considerably, it is difficult to specify exact exposure times and filtration for a properly exposed print. Kodak does recommend a starting filter pack for different types of prints and negatives.

(2) You should consult the data sheet packaged with the color printing paper to arrive at a starting exposure time and filter pack.

(3) The most important thing to remember about a test exposure (and subsequent trials) is to record your test exposure information. It really does not matter what exposure and filtration you use for subsequent test comparisons. You should write down the magnification, exposure time, f/stop, filtration, and anything else that is changed from one test to another.

(4) Compose and focus the image: check your timer, f/stop, and filtration setting on the enlarger; turn out the lights; put your paper emulsion up in the easel, and make the exposure. After processing and drying, you will have to evaluate your test print for color balance.

5. Print Evaluation.

a. The Viewing Light Source. The most important aspect of visual evaluation is the viewing light source. Your prints should be viewed using the same type of lighting that will be used to display them. For instance, you should not judge your prints under incandescent lights if they will be displayed under fluorescent indoor lighting.

b. Judging Density and Color Balance. Study your dry, test print for density and color balance. Look at the areas that should be neutral, such as the gray card, concrete, or gray clouds. You must make two decisions; is the overall density satisfactory, and is the color balance correct.

c. Judging for Detail. The density of the print should be adjusted so that the highlights show detail. The shadows should be just dark enough not to obscure detail. This is hard to learn and only considerable practice will help you master it.

6. Color Print Filter Pack.

a. Determining Acceptable Color Balance. It must be determined if the color balance is acceptable. This is best done by looking at a neutral area such as the gray card image.

(1) Try to think of color balance as an over or underexposure to the three dye layers; that is, if the gray card is too magenta, the magenta dye layer (green sensitive) has been overexposed. On your next test, reduce the exposure to the green-sensitive layer by increasing the magenta filtration in the filter pack.

(2) Similarly, if the test looks too red, it is because you have too much yellow and magenta dye in the print. To reduce the yellow dye, you must add yellow to the filter pack. To reduce the magenta dye, you must add magenta to the filter pack. This reduces the magenta and yellow dye in the print.

(3) The next problem you have is how much filtration to add to the pack.

b. Viewing Light Source. The color quality of the viewing light source will strongly influence the apparent color balance of the print. Ideally, the evaluation area should be illuminated by light of the same color quality and intensity as that under which the final print is to be viewed. From a practical standpoint, some average condition must be selected. Therefore, the quality of the light source should be near 4000 degrees K.

c. Use of Viewing Filters. You can use CC or CP filters to view your test print. A filter used to view your test tends to over correct the highlights and under correct the shadows. Therefore, study the lighter middle tones while looking through the viewing filter.

(1) Do not stare through the filter; flick it in and out of your view. This prevents the eye from adjusting to a false color that it will do if the filter is not flicked.

(2) You may have trouble distinguishing a specific color in the beginning. Try to think of them as "cool" (cyan, blue, green) or "warm" (red, magenta, yellow).

(a) If you think the print looks too blue, view it through a yellow filter, changing the density until it looks its best. If you cannot tell cyan from blue, view the test print through red and yellow filters until you decide which viewing filter makes the best correction.

(b) You may have a test that you think looks red and magenta. In this case, it would appear to be corrected when viewing through both cyan and green viewing filters.

d. Correcting the Filter Pack. As an example, to decide how much filtration to add to the filter pack, make a test print at 50M + 50Y. It appears to have good overall density, but it is a little too magenta. When viewed through green filters, it looks balanced.

(1) If the density of viewing filtration is 20G, on the next test add 10M to the filter pack. Remember the rule: add to the filter pack half the density and the complement of the viewing filter. In this example, make the next test with a filter pack of 60M + 50Y.

(2) To modify the printing filter pack, the information given in figure 3-1 should prove useful in determining what filter adjustment should be made.

NOTE: The filter pack should not contain more than two colors of the subtractive filters (yellow, magenta, and cyan). When all three colors are in the filter pack, the effect is neutral density (nd) which only serves to increase the exposure time required. Neutral density is eliminated by removing the filter color of least density completely, and then removing the same density of each of the other two colors. Thus, if you calculated the filter pack to be 30M + 20Y + 10C, you would completely remove the 10C + 10M + 10Y to give a filter pack of 20M + 10Y +0C.

If the Color balance is:	If possible subtract these filters:	or add these filters:
Yellow	Magenta and cyan (or Blue)	Yellow
Magenta	Cyan and yellow (or Green)	Magenta
Cyan	Yellow and magenta (or Red)	Cyan
Blue	Yellow	Magenta and cyan (or Blue)
Green	Magenta	Cyan and yellow (or Green)
Red	Cyan	Yellow and magenta (or Red)

Rule 1

1. Determine the predominant color of the print.

2. Add the predominant color to the filter pack, if possible.

3. If you can't add the predominant color to the pack, subtract the complementary color.

Figure 3-1. Determining filter adjustment

(3) The effect of filter changes on exposure must be kept in mind. For example, if diffused whites in a test print are reddish, it may work well to add 10M + 10Y to the pack and to use the same exposure. On the other hand, correcting the color balance by removing 10C will definitely call for a decrease in exposure.

(4) With experience, exposure adjustments can be estimated fairly accurately when the test print is close to the desired density and color balance. More detailed information on exposure adjustments required by filter changes is given in figure 3-2.

e. Electronic Evaluation of Print Color. While color correcting by the use of viewing filters is suitable for print evaluation in a small production facility, electronic techniques may be more practical for labs with a higher volume of work. Electronic methods include on-easel and off-easel.

Filter	Factor	Filter	Factor
05Y	1.1	05R	1.2
10Y	1.1	10R	1.3
20Y	1.1	20R	1.5
30Y	1.1	30R	1.7
40Y	1.1	40R	1.9
50Y	1.1	50R	2.2
05M	1.2	05G	1.1
10M	1.3	10G	1.2
20M	1.5	20G	1.3
30M	1.7	30G	1.4
40M	1.9	40G	1.5
50M	2.1	50G	1.7
05C	1.1	05B	1.1
10C	1.2	10B	1.3
20C	1.3	20B	1.6
30C	1.4	30B	2.0
40C	1.5	40B	2.4
50C	1.6	50B	2.9

To use factors: First divide the old exposure time by the factor for any filter removed from the pack. Then multiply the resulting time by the factor for any filter added.

For two or more filters, multiply the individual factors together and use the product.

Figure 3-2. Exposure factors for Kodak CC and CP filters

(1) On-easel. This technique is done by reading densities of the negative in either a small spot or a large area of the negative. This is done by placing a probe on the enlarging easel while the negative is being projected over it. Correct settings for density and filtration can be obtained by this method.

(2) Off-easel. Use a densitometer to determine color from a negative; by this method, an operator can supply printing data to the darkroom workers thus freeing him up to print rather than tie up the enlarger doing color analysis. This method is useful when there is a high volume of production.

f. Using a video Negative Analyzer. Another method of off-easel color evaluation is a video negative analyzer which translates the negative into a high quality positive color television image. This television image presents the color balance and density of the print that would be made from the negative being evaluated, so that the print requirements may be determined.

7. Dodging/Burning-in.

You know that filtration influences the overall color balance of the print. Local density can also be altered by using filters. You can change the color of a small area by dodging with a filter in the path of the light source.

a. Choosing Filters. You can lighten a color in the print by dodging it with a filter of the same color. For instance, you can lighten the green grass in a scene by dodging with a green filter. Likewise, you can darken a specific color by dodging with a complementary colored filter. You may wish to darken the sky. You can do this by dodging the area with a yellow filter.

b. Using Normal Dodging and Burning-in Techniques. You can also use normal dodging and burning-in techniques. However, burning-in and dodging may alter the color balance in addition to making it darker or lighter. Here again, experience is the best teacher.

PART B - COLOR PRINT PAPER CHARACTERISTICS AND COLOR PRINT PROCESSING

8. Color Print Paper Characteristics.

a. Ektacolor RC Paper. Ektacolor RC paper is a waterproof, multilayer paper designed for the production of high quality color prints from color negatives. Either contact or projection printing methods may be used.

(1) It is designed to be processed in Kodak Ektaprint 2 (EP 2) chemicals.

(2) There are various methods used for processing Ektacolor paper; all produce satisfactory color prints. The volume of prints to be produced is the main factor that determines which method you should use.

(a) If the requirement for color prints is small, tube (or even tray) processing may be used satisfactorily.

(b) For volume production color work, an automated continuous processor is recommended. The initial expense of the equipment will be more than compensated for over time by the savings accomplished in man-hours and materials.

b. Ektacolor Resin-coated (RC) Paper. Ektacolor resin-coated paper is an integral tripack emulsion. It has three light-sensitive emulsion layers. Each emulsion layer is sensitive to one primary light color. The order of emulsion layers is red-sensitive on top, followed by green-sensitive, and blue-sensitive on the bottom. This is reversed from that of the negative.

c. Reciprocity Failure. Color printing paper also exhibits reciprocity failure very similar to film materials when varying exposure times are used.

(1) Reciprocity failure differs in degree between the three-print emulsion layers and will cause serious differences in color balance. It is, therefore, recommended that exposure times shorter than 5 seconds and longer than 45 seconds be avoided, since this could cause a shift in the emulsion layers.

(2) This is why it is generally advisable to rely on the diaphragm (f/stop) when adjusting for print density while keeping the exposure time constant. Since you are working with three emulsion layers, you must be very careful with your exposures.

(3) In effect, if you encounter reciprocity failure, you have an apparent loss of film speed, and the colors in the emulsion layers will shift, meaning the colors are not rendered in their true colors.

d. Storage of Color Papers. Manufacturers recommend that for short-term storage (3 months or less), color papers should be kept at a temperature of 50 degrees F or lower. For long-term storage (4 months or more), color paper should be kept at 10 degrees F or lower. In either case, paper should be removed from storage the day before you intend to use it. For best results, process the exposed color paper as soon as possible.

9. Color Print Chemistry.

Over the last few years, the processing of color paper has been simplified both in processing times and in the number of steps.

a. Using Kodak EP 2. EP 2 is a Kodak process which is used to develop color prints made on Ektacolor paper. It is a two-step process, containing EP 2 developer and bleach/fix (often called blix) which are supplied in liquid concentrate form. Directions for mixing are included with the chemicals, and you should follow them closely.

(1) Processing procedures. When processing prints in EP 2, the print is processed first in the developer; next, it enters the blix solution; after proper fixing, it is washed and finally dried.

(a) Solution temperatures.

- Chemistry. The temperature of the chemistry for EP 2 should be 91 degrees F.

- Water wash. The temperature of the wash water should be at 91 degrees F +/- .5 (1/2 degree).

(b) Solution times (given for machine processing).

- Developer - 3 min. 15 sec.

- Blix - 1 min. 30 sec.

- Wash - 3 min. 15 sec.

(2) Constituents of EP 2 chemistry.

b. Developer Components.

(1) Part "A" contains a buffer that stabilizes the pH and benzyl alcohol that facilitates the dye forming reaction. Because benzyl alcohol is lighter than water, it requires a lengthy mixing time (average 20 minutes). If it is not adequately blended, a tar precipitate forms in the solution.

WARNING

Ektaprint 2 developer and bleach/fix solutions are aqueous mixtures that contain hazardous ingredients. Prolonged contact with the solutions can cause acute skin and eye irritation. Prolonged inhalation of the solutions could cause upper respiratory tract irritation. If you swallow solutions, induce vomiting immediately. In case of skin contact, flush the affected area thoroughly with water for at least 15 minutes. Always contact a physician as soon as possible.

(2) Part "B" contains preservatives sodium sulfite and hydroxylamine that help protect developing agents from oxidation.

(3) Part "C" contains color developing agent CD-3.

(4) Part "D" restrainer contains chloride (potassium bromide).

c. Bleach/Fix Components.

(1) Bleaching agent: iron (111) EDTA (ETHYLENE DIAMINE TETRACETIC ACID).

(2) Fixing agent: ammonium thiosulfate (hypo).

(3) Preservative: sulfite.

d. Cleanliness of Equipment. When mixing chemicals, the quality and life of the solutions depends a great deal upon the cleanliness of the equipment you use to mix and store them. Solution contamination will ruin your prints.

(1) Take extreme care to avoid getting any bleach/fix in the developer. A very small amount of bleach/fix in the developer will cause an overall stain on your prints. The color of the stain may vary from cyan to magenta, depending on the degree of contamination.

(2) To minimize contamination while mixing, label the tanks and lids, identifying the chemical, and do not interchange.

10. Chemical Storage.

Store the solutions at room temperature, usually between 60 degrees F to 80 degrees F to get the best results from your solutions. Do not use solutions that have been stored longer than the times listed in figure 3-3.

	Full, Stoppered Glass Bottles	Tanks with Floating Lids
Developer (unused)	6 weeks	6 weeks
Developer (partially used, unreplenished)	2 weeks	1 weeks
Developer replenisher	6 weeks	6 weeks
Other solutions	8 weeks	8 weeks

Figure 3-3. Storage life

PART C - TROUBLESHOOTING FOR THE EP 2 PROCESS

11. Control Strip Monitoring.

Process monitoring saves chemistry, paper, and man-hours. It also alerts the technician to process changes so that corrective action may be taken before any paper is adversely affected.

a. Kodak Form Y-55 (Process Monitoring). Kodak Form Y-55 (Process Monitoring) is prepared to provide a visual graph that details the activity of the various chemistries. Kodak provides a preprocessed control strip whose density values are listed as "aims." Test control strips are processed in your chemistry and their densities are compared to the "aim" densities. The differences between the two are then plotted on the Y-55 Form.

(1) Reading plotting results. If plots are within the control limit lines, the process is operating satisfactorily. If they are not, the plots serve as clues to processing variables, either mechanical or chemical, that may be adversely affecting photographic results. Diagnostic charts are used for troubleshooting. Corrective action is determined before further processing resumes.

(2) Movement toward control limits. At times, plots may be within control limits, but steadily progressing in a direction that will eventually go beyond control limits. In these instances, corrective action is taken to prevent an out-of-control process.

b. EP 2 Parameter to be Monitored. For the EP 2 process, there are four parameters monitored: BR-HDC, HD-LD, LD, and D-MIN.

(1) BR-HDC. The top area on the Y-55 form is labeled for monitoring both retained silver and leuco cyan dye. Plots higher than the aim density represent retained silver. Plots lower than the aim density indicate leuco cyan dye.

(2) HD-LD. The next control area down on the Y-55 is used to measure contrast, which is HD-LD.

(3) LD. The next control area down on the form is used to monitor speed, which is LD.

(4) D-MIN. The bottom control area on the form monitors D-MIN, which is the stain parameter.

c. Developer Solution Variables. Several factors can cause abnormal plots. Some of them are time and temperature, agitation, replenishment, and contamination.

(1) Time and temperature. Plots resulting from variations in time and temperature look very similar. Increased development time and/or high temperature results in an increase in dye density. This appears in LD and HD-LD parameters as a higher plot. Low temperature and/or shortened developer time results in a decrease in LD and HD-LD parameters.

(2) Agitation. Higher agitation in the developer does not usually result in abnormal plots. However, extreme agitation can cause oxidation. Plots for low agitation resemble the plots for low temperature and short developer time.

(3) Replenishment. A decrease in the replenishment rate results in a decrease of dye formed; an increase results in an increase of dye formed. These changes in dye formation cause changes in both the LD and HD parameters.

(a) Too little replenisher or too much "starter" when mixing working strength solution results in low plots for LD and HD-LD. Too much replenisher or too little starter results in high plots.

(b) Recommended storage temperature for the developer replenisher solution is 60 to 80 degrees F. Higher temperatures can increase oxidation that will shorten the keeping time. Excessive low temperatures may cause the chemicals to precipitate.

(c) Store the developer replenisher solution in a tank with both a dust cover and a floating lid. The floating lid reduces oxidation. The dust cover keeps out dirt and helps control evaporation.

d. Contamination. Low-level contamination of the developer solution with bleach/fix is mostly seen in the red and green plots of the LD and HD-LD parameters. As the level of contamination increases, the "stain" plots will go upward, especially the red.

12. <u>Bleach/Fix Variables</u>.

There are two types of bleach/fix variations: mechanical and chemical.

a. Mechanical. Follow time, temperature, and agitation closely to assure that certain bleaching and fixing reactions continue until completed. Otherwise, retained silver and/or leuco cyan dye can be expected.

Retained silver appears as black metallic silver in the paper. Leuco cyan dye is a clear cyan dye caused by incomplete formation of the cyan dye. Because formation of the cyan dye actually continues into the bleach/fix solution, leuco cyan dye indicates a problem with the bleach fix solution.

b. Chemical. Abnormal oxidation of the bleach/fix solution causes sulfurization. The corrective action for sulfurization is dumping. The corrective action for oxidation, before it leads to sulfurization, is to add a preservative.

NOTE: Sulfurization can be physically seen in a processor tank as a dark precipitate before it appears in the Y-55 plots. In a replenisher storage tank, it appears as a light-colored precipitate.

16. <u>Summary</u>.

This concludes lesson 3. Before proceeding to lesson 4, complete the following practice exercise. If you have difficulty with any of the questions, refer to the pages referenced in the practice exercise answer key and feedback sheet.

LESSON 3

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. When you are making a color print from a negative, which color filter controls exposure to the green sensitive layer?

   A. Red
   B. Cyan
   C. Yellow
   D. Magenta

2. When you are determining the color balance of a print using viewing filters, if you think the print is too cyan, which color filter should you view the print with?

   A. Red
   B. Cyan
   C. Blue
   D. Green

3. When you store EP 2 chemicals, what should be the temperature of the storage area?

   A. Below freezing
   B. Room temperature
   C. 100-125 degrees F
   D. Does not matter if containers are unopened

4. If your EP 2 developer is contaminated with blix, which of the following effects may you see?

   A. Low density print
   B. Low contrast print
   C. Cyan stained print
   D. High contrast print

LESSON 3

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	D. Magenta
	Green and magenta are complementary colors; therefore, green light will be subtracted by magenta filtration (page 4, para 3b (1)).
2.	A. Red
	By viewing the off-balance print through its complementary color, colors will appear natural. Red is the complement of cyan; therefore, if the print is too cyan, view it with the red filter (page 7, para 6c(2)(a)).
3.	B. Room temperature
	You will get best results from EP 2 chemistry that is stored between 60 and 80 degrees F (page 14, para 10).
4.	C. Cyan stained print
	When monitoring control of EP 2, "stain" plots will go up when developer has been contaminated by blix. This is seen as a cyan splotch of the print (page 13, para 9d(1)).

LESSON 4

COLOR REVERSAL FILM PROCESSING

Critical Task: 113-578-3023

OVERVIEW

LESSON DESCRIPTION:

In this lesson, you will learn to identify the emulsion changes that occur after exposure and the resulting dye formation during processing. You will also learn the steps involved in processing E6 compatible films. You will learn to mix and monitor control of E6 reversal chemistry. You also will learn to identify common process faults and their probable causes.

TERMINAL LEARNING OBJECTIVE:

ACTIONS: a. Identify reversal film characteristics.

b. Identify the steps necessary to process film.

c. Define the steps necessary to process E6 film.

d. Identify process faults.

CONDITION: You will be given information from STP 11-25S13-SM-TG.

STANDARD: Color reversal film processing will be in accordance with STP 11-25S13-SM-TG.

REFERENCES: The material contained in this lesson was derived from the following publication: STP 11-25S13-SM-TG.

INTRODUCTION

In this lesson, you will learn about color reversal films (transparencies or slides). Topics to be covered include reversal film characteristics and film processing; its affect on film, as well as the procedure involved. Also, chemical mixing, certification, and corrective actions for process faults will be discussed.

PART A - COLOR REVERSAL FILM CHARACTERISTICS AND TYPES OF COLOR REVERSAL FILMS

1. Reversal Films.

There are many color reversal films on the market today manufactured by a host of companies. Kodak, Fuji, and Agfa films, to name a few, are readily available. For our discussion, we will concentrate on Kodak reversal films.

a. Kodachrome. Kodachrome slide film was invented at the Kodak laboratories in 1935 and is still made today. This film comes in a variety of ISOs (25, 64, 200) and sizes.

(1) Notable features are that it is especially biased toward warm colors such as red and yellow, is comparatively fine grained (due to its structure and process), and has more stable color dyes than other color films that results in an image whose colors are more resistant to fading.

(2) The developing process (K14) for Kodachrome film is involved, demands very rigid controls, is expensive, and has a high patent fee.

(3) There are no small kits available for developing this film. Most photographers have to send it to a large commercial lab to be processed so the turn-around time for it is slower. If you need something quick, it is better to shoot an E6 process film such as Kodak Ektachrome (or Fujichrome).

b. Ektachrome. Kodak reversal films also come in a variety of ISOs (100, 200, 160-tungsten, and 400) and sizes. These films are biased more toward cool colors such as green and blue. While they are not as fine grained or color stable as Kodachrome films, the convenience in processing may often make up for its shortcomings.

Since many military photo labs are equipped to process E6 film, the main concentration of this lesson will be on it.

2. Film Structure and Processing.

A very detailed examination of the structure of color films has been provided in lesson 1, part B, paragraphs 9 and 10 of this subcourse. Also, refer to figure 1-12 for an explanation of the changes that occur to the film's emulsion after exposure and processing.

3. Functions of the Chemicals.

There are 10 steps, including drying, involved in the E6 process. Let's take a look at each of these in the order that they occur in the process and discuss the action that each has on the film.

a. First Developer. The first developer is a black and white film developer that reduces the exposed silver halides (the latent image) into black metallic silver (the silver image). After completing this step, there is a black and white silver negative image in each of the sensitized layers.

(1) The most critical step. Although no color images are formed during this step, it is the most critical step of the E6 process. Time, temperature, agitation, replenishment, and storage conditions must be carefully controlled. You must carefully guard against chemical contamination.

(2) Variation affect final image. Any variation in the standard process will affect the final color image by lowering or increasing density, contrast, and color balance.

b. First Wash. The first wash tends to stop development and prevent any carry-over of the first developer into the reversal bath. Wash times or temperatures other than those recommended by the manufacturer will result in a change in color balance and density.

c. Reversal Bath. All silver halides that were not exposed in the camera and developed by the action of the first developer are acted upon by a chemical reversal agent in the reversal bath. It acts as a second exposure that chemically fogs (exposes) all the remaining silver halides.

(1) Improper reversal procedures will result in an overall loss of density.

(2) After the film has been in this bath for 1 minute, the remainder of the process can be conducted in normal room light.

(3) There is no wash after this step because complete reversal requires that the reversal agent be in the emulsion when the film enters the color developer.

d. Color Developer. The color developer produces two chemical changes.

(1) First, the silver halides that were chemically fogged by the action of the reversal bath are reduced to black metallic silver.

(2) Second, as the halides are being reduced, the oxidized color developing agent reacts with the color couplers (already in the film emulsion layers) to form colored dyes. Each film emulsion layer has a specific coupler to form the yellow, magenta, or cyan dye.

(a) Yellow dye forms in the blue sensitive layer, magenta dye forms in the green sensitive layer, and cyan dye forms in the red sensitive layer.

(b) The dyes formed are complementary to the color sensitivity of each layer.

e. Conditioner. The conditioner prepares the metallic silver (formed in the first and color developers) to be converted back to silver halides in the bleach. It also helps protect the acidity of the bleach by reducing the carry-over of the alkaline color developer into the bleach. If this were to happen, the pH of the bleach would slowly rise toward neutral and the bleaching action would be strongly reduced.

f. Bleach. The bleach converts the metallic silver formed in the two developers back into silver halides so they can be removed in the fix.

(1) In the act of changing the metallic silver back to silver halides, the bleach becomes exhausted. The bleaching agent can be reactivated by contact with air.

(2) In the E6 process, this activation is done by bubbling air through the bleach. In a hand process, the agitation done while processing will keep the bleach active.

(3) Incomplete aeration, inadequate time, or low temperatures will result in low red densities, possible yellow stains, and silver retention in the emulsion layers.

g. Fixer. The fixer converts the silver halides in the emulsion layers to soluble silver salts. Most of the silver salts are retained in the fixer. Inadequate or exhausted fix will result in specks of visible silver in the emulsion layers.

h. Second Wash. This second wash removes the fixer and any remaining silver halides from the film. An inadequate wash will give poor stability to the dye image.

i. Stabilizer. The stabilizer is primarily a wetting agent with formaldehyde added. The wetting agent allows for spot-free drying, and the formaldehyde stabilizes the dye images and further hardens the emulsion layers.

j. Drying. Dry the film in a dust-free area. If you use heat to dry film, the temperature must not exceed 120 degrees F (49 degrees C).

4. E6 Process Times/Temperatures/Agitation.

Figure 4-1 contains the necessary information regarding times, temperature, and agitation procedures for the E6 process.

PROCESSING STEP	TIME (MIN)	TEMPERATURE F	TEMPERATURE C	AGITATION SEQUENCE (SECONDS) INITIAL	INTERVAL	SUBSEQUENT
First Dev	7	100.5 +0.5	37.8 +0.3	15	28	2
Wash	2	92-102	33-39	Running Water		
Reversal Bath	2	92-102	33-39	1		None
Normal Room Lights After 1 Minute in Reversal Bath						
Color Dev	6	100 +2	37.8 +1.1	15	28	2
Conditioner	2	92-102	33-39	1		None
Bleach	7	92-102	33-39	15	28	2
Fixer	4	92-102	33-39	15	28	2
Wash	6	92-102	33-39	Running Water		
Stabilizer	1	92-102	33-39	1		None
Dry	10-20	75-120	24-49			

NOTE: Film must be drained for the last ten seconds in each step to prevent contamination of the next solution.

Figure 4-1. The E6 process

5. Slide Mounting.

a. Slide Mount Materials. After the film is processed and dried, each individual slide is placed into a protective frame.

There are many materials used for mounting slides. Among these are tape and glass, metal and glass, and plastic and glass. However, glassless mounts are the most commonly used and often present fewer problems.

b. Most Popular Mounts. Mounts made of plastic or cardboard are the most popular method of mounting 35mm slides. These glassless mounts offer advantages, such as lower cost, maximum adaptability to projection equipment, no glass breakage, no Newton rings, and easier mounting. The principal disadvantage is the loss of some protection. The surfaces of the film are susceptible to finger marks and abrasions when given rough handling in storage boxes or trays, but total risk of surface damage is small. Because the advantages outweigh the disadvantages, this has become the primary way to mount slides. Mounts of this type are supplied in several forms. Some typical constructions are as follows:

(1) Insert type. The mount is presealed on three sides when manufactured. The transparency is cut to size and inserted into the slot on the unsealed side of the mount, which is then sealed.

(2) Hinged type. Where the transparency is positioned in the center of the open mount, the top or hinged flap is brought down over the transparency, and the three sides are heat-sealed.

(3) Two-part. Here the transparency is positioned on the bottom part, a top is placed over the transparency, and sealed on all four sides.

c. Storage of Slides. Mounted transparencies represent a large investment in time and materials. If there was justification to produce them, they warrant protection. When not in use, they should be stored in sturdy boxes or trays designed for slide projectors.

PART C - MIXING AND CERTIFYING THE E6 PROCESS AND IDENTIFYING PROCESS FAULTS

6. Mixing E6 Chemistry.

One important requirement for mixing chemicals is to follow instructions included in the chemical kits. Improperly mixed chemicals may cause color imbalance and unsatisfactory dye formation. Several factors should be considered for the proper mixing of chemicals.

a. Water Supply. Impurities in water used for mixing solutions cause stains and defects in the color films. To correct these conditions, use filters to remove impurities or use distilled water.

b. Types of Containers. Stainless steel, rubber, polyethylene, and glass are the materials most commonly used for containers for mixing and storing color film-processing solutions.

c. Cleanliness. Solution contamination during mixing is a common cause of defective color products. To prevent contamination, all mixing equipment must be cleaned before and after use.

d. Mixing. Mix the chemical components in the color-processing kits in the order in which they are used in processing. As each component is mixed and placed in the container, cover it to protect it against contamination.

e. Temperature. Mix color-processing components in water at the specified temperature. Follow the recommended temperature for each component as this ensures proper mixing and dissolving of the chemicals.

f. Agitation. Proper agitation during mixing is most important. To dissolve the chemicals at the maximum rate, agitate vigorously. However, at the same time, you must be careful not to introduce excessive amounts of air into the solution.

g. Storage. The temperature of stored solutions should be monitored closely. High temperatures can cause oxidation and low temperatures may cause chemicals to crystallize.

(1) Do not store packaged chemicals or mixed solutions above 140 degrees Fahrenheit.

(2) Avoid freezing the packaged chemicals or mixed solutions.

(3) Processing solutions that are stored in open tanks will have a longer life if the tanks have floating covers.

(4) For best results, do not use solutions that have been stored longer than recommended.

7. Processing Errors.

When you inspect your finished reversal film and find an error or defect in the film, you will need to know what caused it. Figure 4-2 is extremely helpful when identifying processing faults.

Appearance of Film	Probable Fault
Very high maximum density (no image apparent)	First developer and color developer reversed.
	First developer omitted.
Dark overall	Inadequate time or low temperature in first developer.
	First developer diluted, exhausted, or underreplenished.
Very dark (overall or random areas)	Bleach or fixer omitted, reversed, diluted, exhausted, or underreplenished.
Light overall	Excessive time or high temperature in first developer.
	Film fogged by light prior to processing.
	First developer too concentrated.
	First developer contaminated with color developer.
Overall density variation from batch to batch	Inconsistencies in time, temperature, agitation, or replenishment of first developer.
Very Yellow	Film fogged by room lights during first developer step.
Stain	Bleach, fix conditioner time too short, temperature too low, or replenisher too diluted.
	Bleach not sufficiently aerated.
	Color developer time too long or temperature too high.

Figure 4-2. Reversal film processing faults

8. Certification of Color Chemistry.

The procedures for monitoring control of color processes has been discussed in detail in lesson 2, part B, paragraph 14 of

this subcourse. Please refer to this section for information on performing steps for certification of the E6 process. It is very important that control strips be run and plotted regularly on the Y-55 Form in order to maintain the quality of the chemistry and thus, your final product, the transparency.

9. Summary.

This concludes lesson 4. Before going to lesson 5, complete the following practice exercise. If you have any problems, refer to the page indicated in the practice exercise answer key and feedback.

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LESSON 4

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. Which of the following films cannot be processed in E6 chemistry?

   A. Ektachrome (100-daylight)
   B. Ektachrome (160-tungsten)
   C. Fujichrome 100
   D. Kodachrome 200

2. During which step of the E6 process may improper aeration cause yellow stains to appear on the film?

   A. First developer
   B. Reversal bath
   C. Bleach
   D. Fixer

3. Which problem may result from the use of glass slide mounts?

   A. Newton rings
   B. Cause dye fade
   C. Offer improper protection
   D. Will not fit standard projectors

4. Which chemical step in the E6 process can cause overall loss of density if improperly done?

   A. Bleach
   B. Conditioner
   C. Reversal bath
   D. Color developer

LESSON 4

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	D. Kodachrome 200
	Kodachrome slide films are not compatible with the E6 process. They require K14 (page 2, para 1a(3)).
2.	C. Bleach
	Yellow stains may result from improperly aerating the bleach or other problems associated with the bleach; these also include wrong processing times in the solution or low temperature (page 4, para 3f(3)).
3.	A. Newton rings
	Plastic or cardboard mounts offer no problems associated with Newton's rings. These rings are caused specifically by glass (page 5, para 5b).
4.	C. Reversal bath
	The reversal bath is used to chemically fog (develop) by developing silver halides that were not processed by the first developer (page 3, para 3c(1)).

LESSON 5

COLOR REVERSAL PRINTING TECHNIQUES

Critical task: 113-578-3035

OVERVIEW

LESSON DESCRIPTION:

In this lesson you will learn to make a "standard" transparency that contains the characteristics which are needed to make it useful as a reference guide when setting up your equipment to make color prints directly from color slides. Also, you will learn the steps involved in making a color print on reversal paper (coupler development) and how to determine correct exposure and filtration. Additionally, you will learn to make prints directly from color transparencies using the silver-dye bleach process.

TERMINAL LEARNING OBJECTIVE:

ACTION:

a. Describe the characteristics of a standard transparency.

b. Identify the steps for making a color slide.

c. Describe the proper exposure and color filtration.

d. Describe the construction and characteristics of reversal papers.

e. Identify and describe the characteristics of silver-dye bleach papers and the processing steps used to develop silver-dye bleach papers.

CONDITION: You will be given information from Photographer's Mate Training Series NAVEDTRA 373-02-45-83, MOD 2.

STANDARD: Standard transparency and color reversal printing will be in accordance with Photographer's Mate Training Series NAVEDTRA 373-02-45-83, MOD 2.

REFERENCES: The material contained in this lesson was derived from the following publication: Photographer's Mate Training Series NAVEDTRA 373-02-45-83, MOD 2.

INTRODUCTION

Color prints can be made directly from color transparencies without the time and expense of making an internegative. In this lesson, you will learn the proper techniques for making prints from slides using both the conventional color coupler reversal method and the silver-dye bleach process.

PART A - MAKING THE STANDARD TRANSPARENCY AND COLOR REVERSAL PRINTING

1. Standard Transparencies.

In reality, there is no such thing as an "absolute standard transparency." There can only be, by definition, "relative standard transparencies." You must decide, within certain guidelines, essentially what a useful standard transparency is for your reproduction system. For your guidance, the following general definition may be useful.

A relative standard color transparency is one that is subjectively representative of the user's normal input and that has been exposed using the correct lighting conditions. It requires spectral quality specified by the film manufacturer and required by the user. The transparency must have been processed strictly according to the manufacturer's recommendations and stored and protected consistent with good practice and recommended conditions.

2. Two Methods of Making Color Prints Directly from Transparencies.

a. Coupler Development (Reversal Papers) Process. In printing color reversal papers the system produces positive color images.

(1) The exposed reversal color paper is developed in a special black and white developer which produces a negative silver image in each of the three emulsion layers.

(2) The paper is then re-exposed to a bright light in order to fog the remaining silver halides and render them developable, or the paper is chemically "fogged" in the color developer. If after processing the film overall looks light, the film may have been fogged by light prior to processing.

(3) The latent positive image is then dye coupler-developed to form three positive dye images: yellow, magenta, and cyan.

(4) The silver is then bleached from the paper and the dye images remain. The three dye images alter and reflect the light used to view the print so that a full color positive image of the original scene is noticed.

b. Silver-Dye Bleach Process. Another way to make full color prints directly from color transparencies is by the silver-dye bleach process (also called the dye destruction color process). The only direct positive color materials currently manufactured which employ this process are Cibachrome products. This process will be discussed in part B of this lesson.

c. Principles Used. The principles of making color positive prints from color transparencies are the same whether coupler development or dye destruction materials. You use colored filters to alter the printing light to obtain proper color balance much the same as in printing color negatives.

3. <u>Equipment</u>.

Reversal color paper is exposed with enlargers designed for printing color negatives.

a. Using the Enlarger. The enlarger should be equipped to hold color printing or color compensating filters, or to use dial-in filtrations such as dichroic filters. Various reversal papers have different requirements for ultraviolet and infrared cutoff filters. Consult the data sheets accompanying the different papers to determine these requirements.

b. Placing the Filter. Place an infrared cutoff filter in a perpendicular position to the enlarger's optical axis and close to the light source in a specular, parallel part of the light beam. If light is passed through the IR cutoff filter at an angle, changes to the spectral quality of the filter will result.

c. Voltage Regulation. Voltage regulation for the enlarger is just as important in printing color slides as for printing color negatives. Therefore, use a voltage regulator. Some color enlargers which have tungsten-halogen lamps have a built-in stepdown transformer which acts like a voltage regulator.

4. <u>Making the First Test Print</u>.

For making your first color print on reversal paper, you should select a transparency that has been correctly exposed with light of the correct color quality and intensity. This will become your "standard transparency." This standard transparency should be on the same kind of film you regularly use. Even better, make several standard transparencies on the different color reversal films you will use. These standard transparencies will be used to arrive at standard filter packs for various paper emulsions. To make your first or test print:

a. Set up the enlarger with the required UV and IR cutoff filters.

b. Place a clean, dust-free transparency removed from its mount into the enlarger with the transparency's emulsion toward the lens. Mask the transparency to eliminate any stray light from escaping around its edges.

c. Remove all color balancing filters from the enlarger light beam to give a filter pack designation of 0 cyan, 0 magenta, and 0 yellow.

d. Adjust the enlarger for an 8 x 10 print of a 35mm slide. Set the lens at f/5.6 and make a series of exposures at 10, 20, and 40 seconds.

e. Process and dry the test print.

f. View the test print and estimate the filter pack and exposure adjustments required and make another test print at the selected filter pack, exposure time, and f/stop. Process and dry this test print. Continue this test printing until you are satisfied with the results.

g. When you are satisfied that the color balance and density are correct, record the exposure and filter pack information as your "printing standard" for the type of transparency used as the standard transparency. Assuming the printing conditions, size of enlargement, and paper emulsion number remain constant, all other transparencies which are similar to the standard transparency should produce equally good prints.

h. Use the printing standard you determine for your first standard transparency to help you arrive at a printing standard for your other standard transparencies. There is no need to go back to 0, 0, 0 filtration. Instead, use your first printing standard as the starting point for other printing standards.

5. Evaluating Test Prints.

a. Overview. The same viewing conditions which were discussed for viewing test prints from color negatives are suitable for evaluating reversal color prints. However, when comparing a reversal color print to the transparency from which it was made, the transmission and reflection light sources should be equal in color temperature.

(1) The density range of a color print is much lower than that of a transparency viewed by transmitted light. Therefore, evaluate prints for density not by comparing them to the transparency but by examination of highlight and shadow densities.

(2) Remember that just like exposing reversal color film, when making exposure corrections for reversal paper, add exposure time or intensity (f/stop) to make a lighter print; subtract time or intensity to make a darker print.

b. Color Balancing. The easiest way to evaluate the color balance of a reversal color print is to compare it to the original transparency.

(1) Judge the middle tones to see variations of color in the middle tones of the transparency. If it is hard to determine the color that is in excess, view the print through filters such as those in the Kodak Color Print Viewing Filter Kit.

(2) In printing reversal color paper, the filter which makes the print look best represents the correct color to add to the printing light. This is unlike printing color negatives where the color of the filter which makes the print looks best is subtracted from the light.

Use figure 5-1 to help you determine filter pack changes for color reversal paper.

If the color balance is:	Subtract these filters:	or	Add these filters:
Red	Yellow and Magenta		Cyan
Green	Yellow and Cyan		Magenta
Blue	Magenta and Cyan		Yellow
Cyan	Cyan		Yellow and Magenta
Magenta	Magenta		Yellow and Cyan
Yellow	Yellow		Magenta and Cyan

Figure 5-1. Filter pack adjustments for reversal color printing

(3) When making changes to the filter pack, remove filters whenever possible; e.g., if the test print has an excess blue color, remove magenta and cyan filtration rather than adding yellow.

(4) The filter pack should not contain more than two colors of the subtractive filters (yellow, magenta, and cyan). When all three colors are in the filter pack, the effect is neutral density which only serves to lengthen the required exposure time.

(5) Neutral density is eliminated by removing the filter of one color completely, and then removing the same density of each of the other two colors. For example, assume the filter pack you came up with was 46Y + 38M + 12C. You would completely remove the cyan filtration plus 12Y and 12M. Thus your adjusted filter pack would be 34Y + 26M.

(6) As compared to printing color negatives, printing color transparencies takes a greater change in filter pack to accomplish the desired result.

c. Exposure Adjustments. Whenever you change the filter pack, allowance should be made for a change in exposure caused by the change in filtration action, and the change (if any) in the number of filters. If allowance for these changes is not made, the density of the reprint will differ from that of the test print.

Figure 5-2 gives appropriate filter factors which will help you calculate the correct exposure.

Filter	Factor	Filter	Factor
05Y	1.1	05R	1.2
10Y	1.1	10R	1.3
20Y	1.1	20R	1.5
30Y	1.1	30R	1.7
40Y	1.1	40R	1.9
50Y	1.1	50R	2.2
05M	1.2	05G	1.1
10M	1.3	10G	1.2
20M	1.5	20G	1.3
30M	1.7	30G	1.4
40M	1.9	40G	1.5
50M	2.1	50G	1.7
05C	1.1	05B	1.1
10C	1.2	10B	1.3
20C	1.3	20B	1.6
30C	1.4	30B	2.0
40C	1.5	40B	2.4
50C	1.6	50B	2.9

Figure 5-2. Filter factors for CC and CP filters

6. Adjusting Filter Packs for Changes in Paper Emulsions.

As with color paper for printing color negatives, when you use reversal color papers with different emulsion numbers, an adjustment to the printing standard filter pack must be made.

The package label of reversal color paper or the instruction sheet for the paper gives the "filter correction" values for that particular emulsion number. The filter corrections may contain both + and - values.

Filter calculations are made easier by converting all filters to their equivalents in subtractive colors if they are not already of the subtractive colors. For example, 20R = 20M + 20Y. Also, add filters of like colors together in the calculations. For example, 10M + 20M = 30M.

Step 1. Determine the basic filter pack by subtracting the filter correction printed on the label for the old emulsion from the filter pack used for that emulsion.

Example: Step 1. Suppose the filter pack required for the old emulsion was 10C + 05Y, and the filter correction printed on the package label of that emulsion was +10C -25M -05Y. Set up these values as follows:

Filter pack used for the old emulsion: 10C 0M 05Y.

Subtract old emulsion filter correction: +10C -25M -05Y.

To simplify the subtraction of minus values, follow this rule: Change all the signs of the values to be subtracted and proceed as in addition.

Therefore:

+10C	**0M**	**+05Y**
-10C	**+25M**	**+05Y**
0C	**+25M**	**+10Y**

(basic filter pack)

Step 2. Determine the filter pack required for the new emulsion by adding the filter correction value printed on the label for the new emulsion to the basic filter pack.

Example: Step 2. Suppose the filter correction value of the new emulsion is -05C +25M -20Y.

Basic filter pack	**0C**	**+25M**	**+10Y**
(add) filter correction value for new emulsion	**-05C**	**+25M**	**-20Y**
Preliminary filter pack	**-05C**	**+50M**	**-10Y**

Step 2A. If negative filter values are present in the pack, add (by calculation) C, M, and Y "neutral density" equal to the largest negative filter. In this way, one of the three filters will become zero. Look up the neutral density factor in section A of the figure 5-3.

CC Neutral Density Added in Step 3A or Subtracted in Step 3B	Section A	Section B
5	1.1	.89
10	1.3	.77
15	1.4	.70
20	1.6	.62
25	1.8	.54
30	2.1	.48
35	2.3	.43
40	2.6	.38
45	3.0	.33
50	3.4	.29
55	4.5	.22
60	5.6	.18
65	7.0	.14
70	8.3	.12
75	9.5	.10
80	10.7	.093
85	11.7	.085

Figure 5-3. Neutral density factor

Step 3A. Since negative filter values are present in the pack, add 10 neutral density (+10C, +10M, and +10Y) to these values.

Example: Step 3A.

Preliminary filter pack	**-05C**	**+50M**	**-10Y**
(add) neutral density	**+10C**	**+10M**	**+10Y**
Final filter pack for new emulsion	**+05C**	**+60M**	**0Y**

Look up a 10 neutral density in section A figure 5-3. The neutral density factor comes out to 1.3 in this case.

Step 3B. If all the filter values are positive, subtract C, M, and Y "neutral density" equal to the smallest positive filter value. At least one of the three will now be zero. Look up the neutral density factor in section B in figure 5-3.

Step 3C. If the filter values are positive and at least one is zero, go to step 4. Your neutral density factor is 1.0.

Step 4. Calculate the new exposure time by the following formula:

Example: Step 4. Exposure Time for New Emulsion = Exposure Time for Old Emulsion X (Neutral Density Factor).

New Exposure Time = 8.5 x 1.3 = 11 seconds.

This is the new exposure time that should be tried for the new emulsion.

Use the new filter pack and the printing times calculated as a starting point for a series of test prints using a standard transparency.

PART B - SILVER-DYE BLEACH (DYE DESTRUCTION) COLOR PRINT PROCESS

In conventional chromogenic reversal color, the image-forming dyes are produced during development by built-in colorless couplers which react with products of the developing agents. These papers require a reversal process using two developers and an intermediate exposure or an equivalent reversal step.

In the silver-dye bleach process, image dyes are added to the emulsion layers during manufacturing. During processing, they are removed (bleached) from the emulsion layers in the areas where they are not required. This process requires only one developer and no intermediate exposure. The only commercially available silver-dye bleach process available is the Cibachrome process.

7. Structure of Silver-Dye Bleach Materials.

Cibachrome color paper and display film have an identical emulsion layer structure; the essential difference is the support. Cibachrome II Pearl Paper uses a resin-coated paper base, Cibachrome II Deluxe Glossy is coated on white opaque polyester, and Ilford Cibachrome II Display Film is a transparent polyester base. All the Cibachrome materials have nine layers arranged as shown in figure 5-4.

9—Supercoat
8—Blue sensitive emulsion layer without dye
7—Blue sensitive emulsion layer with yellow dye
6—Mask-interlayer
5—Green sensitive emulsion layer without dye
4—Green sensitive layer with magenta dye
3—Gelatin interlayer
2—Red sensitive emulsion layer without dye
1—Red sensitive emulsion layer with cyan dye
Base (RC paper, opaque polyester or transparent polyester)
Backing layer

Figure 5-4. Nine layers of Cibachrome materials

There are two light-sensitive silver halide emulsion layers responding to each of the three primary colors. Only one layer contains the appropriate image dye. The dye-free layers (2, 5, and 8) influence the bleaching of the adjacent dyed layers (1, 4, and 7) and so increase the photographic speed without increasing the contrast.

The masking layer (6) between the blue and green sensitive layers controls the bleaching process of the yellow dye in the blue sensitive emulsion layer depending on the exposure of the green and red sensitive layers. With this interlayer effect, a mask is formed which improves the color rendition.

8. Printing with Silver-Dye Bleach Materials.

Any good quality enlarger equipped with a color-corrected lens and a filter drawer or a color head having a suitable light source (halogen, projection lamp, or pulsed xenon with proper correction filter) can be used to expose Cibachrome materials. An ultraviolet-absorbing filter must always be inserted in the light path.

When using Cibachrome as with conventional reversal color papers, you should have available a standard transparency which can be used to evaluate the entire photographic reproduction system. When using Cibachrome materials, the following considerations should be kept in mind.

a. Different types of color film will reproduce differently on Cibachrome materials; i.e., will require different filter packs.

b. Transparencies of inherent low contrast will reproduce more faithfully than those of high contrast.

c. Enlargements of great magnification will appear to be visually lower in contrast than small enlargements.

d. Due to the direct positive characteristics of Cibachrome materials, small scratches and dirt on the transparency will be more apparent in the final product than with negative/positive photographic printing materials because they show as black defects which are more difficult to retouch.

e. It may not be possible to fully correct in printing transparencies that have an overall tint or color cast due to improper film exposure and/or processing.

f. Particular care should be exercised in the printing of high key transparencies. Be sure that there is sufficient density in the main subject to reproduce on Cibachrome materials.

g. Understand that you may never totally match all areas of the print or transparency to the original unless you are willing to use supplementary printing techniques such as dodging, burning-in, and/or area color correction (retouching).

9. Color Correction Filtration.

No special filters are required for Cibachrome materials. The usual photographic printing filters, as well as color enlargers, can be used. In addition to the color filters, an ultraviolet-absorbing filter must always be inserted in the light path.

On the label of each pack or roll of Cibachrome material is a standard filtration for that particular emulsion. It refers to Kodak CC filters. These filter values were established under certain standard conditions; they cannot necessarily be used as absolute values for a given situation. However, they are a useful guide when changing from one emulsion number to another. The new filtration can be found more easily, thus reducing the amount of time and material wasted.

Color correction techniques using CC or CP or dichroic filters and Cibachrome materials are the same as when using other reversal color papers.

10. Processing.

Cibachrome materials must be processed in Cibachrome processes P-3, P-18, or P-30 depending on the specific material to be processed.

Generally there are five steps involved: 1) developer, 2) water wash, 3) bleach, 4) fixer, and 5) water wash. Three of the steps involve chemicals. The temperature range for Cibachrome has much latitude and within that range adjustments are within +/- 2 degrees.

11. Summary.

This completes lesson 5. Before proceeding to the next lesson, complete the practice exercise found on the following pages. Compare your answers with those on the practice exercise answer key and feedback sheet. If you answer any question incorrectly, review the material indicated to ensure you understand it before going to lesson 6.

LESSON 5

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

<u>Situation</u>: You are assigned to make an 8 x 10 color print from a 35mm transparency using conventional reversal paper. In this instance, you have no previous start-up data concerning exposure or filtration. Use this information to respond to items 1 through 3.

1. Which of the following filter packs should you use as a starting point?

   A. 0C, 0M, 0Y
   B. 10C, 25M, 0Y
   C. 10C, 10M, 10Y
   D. 25C, 25M, 25Y

2. When making a test print on reversal paper from a transparency, how many seconds should the intervals be for test exposures?

   A. 1
   B. 2
   C. 5
   D. 10

3. If your test print appears too cyan, which of the following actions should you take?

   A. Subtract yellow and cyan
   B. Add yellow and cyan
   C. Subtract cyan
   D. Add cyan

4. If you make a color print from a transparency on Cibachrome materials and it appears too magenta, which of the following actions should be taken?

   A. Subtract yellow and magenta
   B. Add yellow and magenta
   C. Subtract magenta
   D. Add magenta

LESSON 5

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	A. 0C, 0M, 0Y It is best to remove all filtration from the light source, initially (page 4, para 4c).
2.	D. 10 Ten seconds is the recommended starting point. As you may notice, this is relatively high. This is because it takes more change to notice an effect on reversal papers than with other papers (i.e., Ektacolor or B/W) (page 4, para 4d).
3.	C. Subtract cyan When printing on reversal paper, if the print appears cyan, you may either subtract cyan or add yellow and magenta. Generally, if enough color already exists in your startup pack to allow you to subtract, it is better to do so rather than add other filtration (page 5, figure 5-1)
4.	C. Subtract magenta This is the proper action to take to correct a Cibachrome print that is too magenta. You could also have added yellow and cyan. (Remember, balancing color prints made from either Cibachrome or traditional reversal papers requires the same corrective actions.) (page 5, figure 5-1).

LESSON 6

SLIDE DUPLICATING TECHNIQUES

Critical Task: 113-578-1012

OVERVIEW

LESSON DESCRIPTION:

In this lesson you will learn about the various films used for duplicating color slides. You will also learn how to use the proper equipment to make duplicates.

TERMINAL LEARNING OBJECTIVE:

ACTION:

a. Identify duplicating film.

b. Describe the steps and equipment to duplicate prints and slides.

c. Identify the proper filter to duplicate a slide or print.

d. Explain the steps necessary to correct errors in duplicating slides or prints.

CONDITION: You will be given information from Photographer's Mate Training Series NAVEDTRA 373-02-45-83 MOD 2 and 3 and STP 11-25S13-SM-TG.

STANDARD: Slide duplicating films and duplicate color slide exposure will be in accordance with Photographer's Mate Training Series NAVEDTRA 373-02-45-83 MOD 2 and 3 and STP 11-25S13-SM-TG.

REFERENCES: The material contained in this lesson was derived from Photographer's Mate Training Series NAVEDTRA 373-02-45-83 MODS 2 and 3 and STP 11-25S13-SM-TG.

INTRODUCTION

In the military service there is an ever increasing requirement for the production of slides for briefings, orientation of new personnel, and training aids. Any subject that can be photographed or copied can be readily presented as a slide. The primary function of any material presented in slide form is educational and usually supports a lecture or demonstration. The combination of audio and visual communication is used in nearly every learning/training situation. While it is usually not practical to disassemble a jet engine in the classroom, drawings, diagrams, and photographs of disassembly steps are effective substitutes when accompanied by oral explanations. Thus, you have a visual information learning situation. It has been proven that the educational value of any lecture is enhanced by the inclusion of graphs, charts, maps, or original scenes in slide form.

PART A - SLIDE DUPLICATING FILMS AND EQUIPMENT

1. Duplicating Film.

a. Selecting the Film. In selecting the film to duplicate color slides, your first choice should be a film designed specifically for that purpose, such as Kodak duplicating film 5071. Duplicating film has a wide exposure latitude producing good density slides even with slight over or underexposure during copying.

(1) If this film is unavailable, you may use the same film used to produce the original or any other color reversal film that is compatible with the camera, processing, and lighting that you are using. However, color reversal films that are not specifically designed for copy or duplication work present problems because they do not control reproduction contrast well, resulting in duplicates that are too contrasty.

(2) Also available are internegative films for making internegatives from color transparencies and for making direct copy negatives from color negatives (this was discussed in lesson 1). Black and white negatives can be produced from color transparencies as well. A full scale panchromatic film should be used.

b. Importance of Temperature Light Source. When working with color reproduction material, you must keep in mind the temperature of the light source that will be used to illuminate the transparency for copying.

(1) The Kelvin temperature of the film must match that of the light source. If it does not, a shift in color reproduction will result in the duplicate transparency. If, for example, the exposing light source is electronic flash, daylight balanced color film can be used.

(2) If two light sources are used, the dominate source must match the film. Even when the Kelvin temperature of the primary light source and the film are matched, color shift sometimes occurs. This is due to the difference in Kelvin temperature of various exposing light sources, and the

differences in the process chemistry. All of these variables must be accounted for.

2. Equipment.

a. Ways of Making a Duplicate. Duplicates of a color original can be made in several ways; contact printing, enlargement, or with one of the various slide duplicators that are available. For a 35mm slide duplicate, which are the ones most often required, the best method is with a slide duplicator. One such unit is the Illumitran slide copier with a 35mm camera mounted onto it. This is the type of equipment you will most likely use.

b. Making Duplicates with a Camera. An original can also be copied onto either sheet film or roll film with a sheet film or roll film camera.

(1) Any tungsten type color film may be used as the duplicating medium with this procedure. A correction filter is needed over the lens of the camera if a photoflood is used for illumination of the original, as a photoflood burns at a 3400 K temperature, and the tungsten film is balanced for 3200 K. Figure 6-1 shows a setup that can be used.

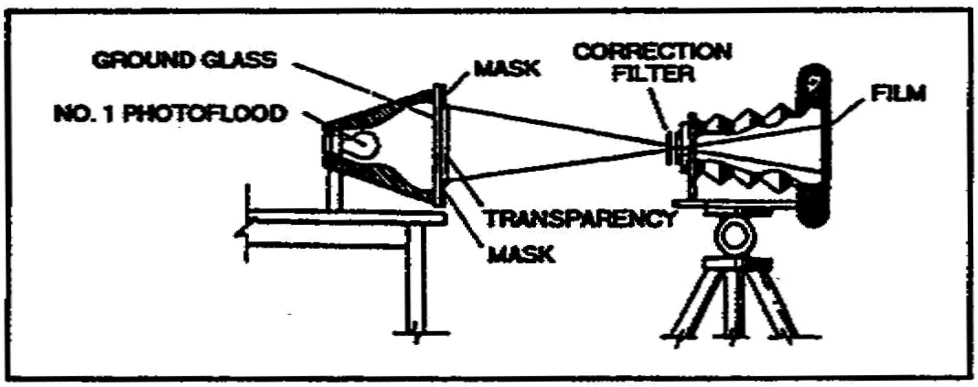

Figure 6-1. Duplicating a color original with a camera

(2) The following is an outline of the procedure to be followed:

(a) Place a photoflood in a viewer with a good ground glass front.

(b) Mask the front of the viewer down to the size of the transparency to be duplicated.

(c) Set up the viewer so that its front surface is vertical.

(d) Place the camera on a tripod so that the focal plane is the same height of the viewer, and parallel to it.

(e) With the transparency removed, take a light meter reading of the ground glass of the viewer with the meter held against the ground glass.

(f) Set the meter for the white card index of the film being used and compute the exposure.

(g) With a densitometer, read the density of the maximum highlight area of the original transparency.

(h) From the duplication table (figure 6-2), obtain the exposure factor (this compensates for the difference in density of various transparencies).

Density range	Exposure factor
0.4	1.0
0.55	1.5
0.7	2.0
0.85	3.0
1.0	4.0
1.15	6.0
1.3	8.0
1.45	12.0
1.6	16.0
1.75	24.0
1.9	32.0

Figure 6-2. Density range and exposure factor table

(i) Compute the new exposure with the following formula:

Basic exposure x ratio of enlargement or reduction x exposure factor = new exposure.

Example: Old exposure = 1/10 of a second at f/32
Ratio factor = 4 (1 to 1 enlargement)
Exposure factor = 2.0

1/10 x 4/1 x 2.0/1 = 8/10 or 4/5

Therefore, the new exposure is 4/5 of a second at f/32.

(j) Place the transparency on the viewer.

(k) Be sure that the correction filter is over the lens.

(l) Expose the film and process according to the manufacturer's recommendations.

This method, as mentioned before, will not be used often; still, it is good to know various ways of accomplishing a task. We will now turn our attention to methods concerning the use of a slide copier (such as the Illumitran).

PART B - DUPLICATE COLOR SLIDE EXPOSURE

3. Determining the Standard Filter Pack.

a. What Filter Pack Adjusts For. Whenever you duplicate slides, you need to filter your light source to produce exact or nearly exact duplicates of the original slides you are copying. The colors, densities, and total number of filters that you use over the light source is called a standard filter pack.

(1) A standard filter pack is used to adjust for three variables. These variables are: (a) the emulsion, (b) the chemistry, and (c) the light source. You determine your standard filter pack by trial and error, starting with a recommended filter pack. Once you determine your standard filter pack, you use it until you experience a change in one or more of the variables. For example, a change to a different emulsion number, mixing a fresh batch of chemistry, or even changing a burned-out exposing light source all require more tests to determine the adequacy of the standard filter pack you have been using.

b. Making a Standard Filter Pack. The procedure for determining a standard filter pack is really quite easy. It just takes time. The time spent in making up a standard filter pack is time well spent when you witness the consistent quality of reproductions.

(1) To build a filter pack, you start out with a 2B filter which absorbs unwanted ultraviolet radiation. Always make the 2B filter a part of your filter pack. From that point, you may need any number of additional filters of various densities and colors.

(2) Your standard filter pack must produce not just imitations of the original slides but "duplicates." To perform trial-and-error testing, you will be copying a slide that has optimum color balance and density. The procedure is to copy this slide using the trial filter pack, given by the film manufacturer, making several exposures by bracketing in 1/2 f/stop increments, a color ring-around, and recording the exposure given each frame.

(3) Once the film has been processed, you are ready to determine exposure and the filter pack adjustments that may be needed.

(a) First, select the test exposure that best duplicates that of the original slide.

(b) Density can be determined visually or densitometrically.

(c) When doing this densitometrically, read out the density of the gray card on the original slide on a transmission densitometer and record it. Then read the test exposures of the gray card until you find the exposure that matches or nearly matches the original slide density reading.

c. Check for Color Balance. Once you have located a properly exposed slide, you must check it for color balance. If the colors are in balance, the test area will be a neutral gray image and no further testing is necessary. If, however, the image is anything other than gray, you first have to determine what color is in excess and then correct your filter pack according to the following recommendations shown in figure 6-3.

If Color in Excess is	Then Subtract	Or Add
Yellow	Yellow	Magenta & Cyan
Magenta	Magenta	Yellow & Cyan
Cyan	Cyan	Magenta & Yellow
Blue	Magenta & Cyan	Yellow
Green	Yellow & Cyan	Magenta
Red	Yellow & Magenta	Cyan

Figure 6-3. Filter pack corrections

4. Color Balancing.

a. Need for CC Filters. The foregoing recommendations in figure 6-3 may be helpful to you but they do not tell how much filtration to add or subtract. This is where the use of color-compensating filters for visual color evaluation come into play. You will need a complete set of CC filters in graduated densities before you begin.

b. How to Use CC Filter. Let's look at an example of how to use them. Suppose you decide that your test slide is too magenta.

(1) To verify this, you would view the transparency through a CC filter that is complementary in color to magenta, which is green. Start out by viewing the slide through a lower-density green filter, such as a CC 10 G, increasing viewing filter density until the slide looks corrected for color balance.

(2) Let's say that a 20 G filter corrects the slide. You have a choice of subtracting magenta or adding yellow and cyan filtration to the filter pack. If the trial filter pack does not contain any magenta, you would have to add yellow and cyan filtration. Add equal amounts of cyan and yellow.

5. <u>Eliminating Neutral Density</u>.

a. Determining Minimum Number of Filters. Whenever neutral density is present in a filter pack, it adds unneeded density which increases exposure time. Whenever you put a filter pack together, you should check it for neutral density and reduce the total number of filters in the pack to the minimum that will provide the correction that is needed.

(1) Suppose you needed to add 20Y and 20M to your filter pack and this gave you the following:

$$\begin{array}{ccccccc} \mathbf{2B} & + & \mathbf{110Y} & + & \mathbf{20C} & & \\ & + & \mathbf{20Y} & & & + & \mathbf{20M} \\ \hline \mathbf{2B} & + & \mathbf{130Y} & + & \mathbf{20C} & + & \mathbf{20M} \end{array}$$

(2) Neutral density is present in this filter pack because all three subtractive primary colors (cyan, magenta, and yellow) are contained in the pack. To eliminate the neutral density, determine the largest number you can subtract from each color. In this example, the number is 20. Subtract 20 from each color as in the following:

$$\begin{array}{lr} & \mathbf{130Y + 20C + 20M} \\ \textbf{minus} & \mathbf{20Y + 20C + 20M} \\ \hline \textbf{equals} & \mathbf{110Y + \ \ 0C + \ \ 0M} \end{array}$$

(3) Since the 2B filter is always used, we now have a filter pack of 2B + 110Y. Not only has the neutral density been removed, but the total number of filters has been reduced. Whenever you reduce a filter pack, you will also have to reduce exposure for the new pack. In this example, 20C and 20Y have

been eliminated from the original pack so you would adjust your exposure accordingly.

b. Subtracting from the Filter Pack. When working with filter packs for slide duplicating, the primary rule is to subtract from the filter pack the complement of the viewing filter and the same density. Of course, there will be situations where you cannot subtract and must add. Always check your filter pack for neutral density whenever you must add filtration to the pack.

(1) Exposure adjustments for changes in the standard filter pack can be easily determined by following the exposure factors given in figure 6-4.

(2) Once you establish a standard filter pack and a standard exposure, your work becomes a little easier because you use these standards to copy slides, that is, if your slides have good density and color balance. Unfortunately, many of the slides that you will be required to duplicate will be less than ideal in quality. Off-color and poor-density slides fall in this category.

Filter	Factor	Filter	Factor
05Y	1.1	05R	1.2
10Y	1.1	10R	1.3
20Y	1.1	20R	1.5
30Y	1.1	30R	1.7
40Y	1.1	40R	1.9
50Y	1.1	50R	2.2
05M	1.2	05G	1.1
10M	1.3	10G	1.2
20M	1.5	20G	1.3
30M	1.7	30G	1.4
40M	1.9	40G	1.5
50M	2.1	50G	1.7
05C	1.1	05B	1.1
10C	1.2	10B	1.3
20C	1.3	20B	1.6
30C	1.4	30B	2.0
40C	1.5	40B	2.4
50C	1.6	50B	2.9

Figure 6-4. Factor for Kodak CC and CP filters

6. Corrections.

a. Correcting for Too Little Light. Suppose you get some slides to copy that are too light or dark. You can correct these by changing your exposure. You must evaluate the originals for density. If you determine the original is too dark, you must increase your exposure.

b. Correcting for Too Much Light. The opposite is also true. If the original is too light, you must decrease your exposure. The problem is, just how much correction in exposure do you need? Generally, you can follow this rule: compensate by two f/stops for each f/stop the original is off. That is, to correct an original that is one f/stop underexposed, you must overexpose the duplicate by two f/stops.

NOTE: Most slide duplicators have a built-in metering system that may be used to compensate for over/under exposures.

c. Duplicating "As Is." Make special note of the word "correct." If you only want to duplicate the underexposed slide, you adjust your exposure by the same amount that the original slide exposure is off. For example, if it is determined that an original slide is one f/stop underexposed, then overexpose the dupe by one f/stop to duplicate it.

d. Correcting Off-Color Balance. To correct off-color balance use the visual evaluation techniques discussed previously and adjust the standard filter pack and exposure accordingly.

7. Composition.

One of the advantages of duplicating slides is cropping out unwanted portions of the slide and improving the composition. Vertical slides can be made horizontal or better framing can easily be accomplished, etc. When cropping, the slide will have to be enlarged to some extent and this will create a need to increase the original exposure. Use the normal bellows extension factor method.

8. Processing.

The type of process used will depend, of course, upon the type of material that is used to make the duplicates. For the most part, you will likely be using a duplicating film that is compatible with the E6 reversal process. Always be sure to check first.

9. Summary.

This completes lesson 6 and the subcourse. Before beginning the subcourse examination, complete the practice exercise. If any of your answers are incorrect, review the area indicated until you understand the material.

LESSON 6

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. Which film would you use to make a color negative from a color transparency?

   A. Reversal film
   B. Duplicating film
   C. Internegative film
   D. Orthochromatic film

2. Which of the following is NOT one of the variables that is adjusted for with your standard filter pack (which is used to duplicate slides)?

   A. The emulsion
   B. The chemistry
   C. The light source
   D. The colors of the original

3. What is the problem with neutral density being present in a filter pack?

   A. Causes a color shift
   B. Causes a density increase
   C. Causes unwanted ultraviolet light
   D. Causes an increase in exposure time

4. Which type of film should you use to make a black and white negative from a color transparency?

   A. Duplicating
   B. Panchromatic
   C. Internegative
   D. Orthochromatic

LESSON 6

PRACTICE EXERCISE

ANSWER KEY AND FEEDBACK

Item	Correct Answer and Feedback
1.	C. Internegative film
	Internegative film will produce a negative from a slide. You may then use this color negative to make a color print in the same manner as you would from an original negative (page 2, para 1a (2)).
2.	D. The colors of the original
	The colors of the original need not be considered separately from the above three variables. If they are properly adjusted, the colors of the original should generally be close to normal (page 2, para lb(l) & (2)).
3.	D. Causes an increase in exposure time
	Neutral density in a filter pack simply means that all three colors (M, Y, and C) are present in a filter pack. They cancel each other out, to a degree, in affecting a color change; thus, they do nothing more than add filtration to the pack thereby increasing the amount of exposure time (page 7, para 5a).
4.	B. Panchromatic
	Panchromatic films will produce a full range black and white negative from a color transparency. Pan films are sensitive to all colors so they are all translated to a shade of gray (page 2, para 1a(2)).

APPENDIX - LIST OF ACRONYMS

ACCP	Army Correspondence Course Program
ISO	International Standardization Organization
OR	operating room
POA	primary optical area
TA	terminal area
UFG	ultra-fine grain