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Film for Television

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FILM IN TELEVISION PROGRAMMING

From the inception of television broadcasting, the motion picture film medium has been a prime source for the television broadcaster of program materials. The combining of television with the well-established technical and commercial practice of the motion picture medium has benefited each.

In looking for a convenient, economical method of local program origination, television stations and CATV operators find that film meets most of their requirements. At the same time, this medium offers a number of attractive operational advantages, such as excellent image quality, production flexibility, ease of editing, simplicity in program distribution, and worldwide interchangeability.

Television stations make use of film in two broad categories—complete programs produced by others and received by the stations essentially ready for broadcast and local in-house program production utilizing film as the recording medium. These merge as they reach the electronic film reproducing equipment (telecine) for transmission by the stations to the viewing public. Film is utilized extensively by television stations for local commercials, documentaries, public affairs, sports events, and especially for reporting local news events.

Network Film Use

The major networks usually feed their program distribution systems with images originating from 35 mm prints—feature pictures, prime-time productions, and national market commercials. These films are usually produced by large professional motion picture production companies. The large print image size and substantial production budgets produce excellent technical quality characteristics in both pictures and sound. Quality-control personnel representing the networks deal directly with the film production companies responsible for the original photography and also with the film laboratories where the prints are made. This communication between the broadcaster and the laboratory provides the highest possible picture and sound quality. In addition, the networks also make use of large quantitues of 16 mm film for sports, documentaries, and especially for news reporting.

The scope of network operation is so broad, so well staffed and equipped, that it is really a professional motion picture production activity comparable to many large units of the motion picture industry.

Individual Station Film Use

The use of 16 mm motion picture film for broadcasting is almost universal with television stations outside of the network centers. Most of the film programming materials are provided to the stations through film distributing agencies. The 16 mm film format has been and is still widely used for lower budget motion pictures and for the vast number of education, industrial, documentary, and commercial subjects commonly known as "nontheatrical" films which are intended for direct projection for smaller audiences instead of distribution to motion picture theaters.

Most stations shoot their own local news, and many are producing commercials, documentaries, and other program material. Local assignments can be handled by one person, the camera operator; a full crew, including sound and lighting technicians, seldom exceeds three persons. Film cameras can be taken anywhere. Power for the camera motor can be supplied from small batteries carried in a belt. Programs can be produced in black-and-white and color with the same camera—only the recording material, film, has to be changed.

A 16 mm film camera is a relatively simple optical-mechanical device that requires very little maintenance. Most professional cameras are of moderate weight, easily portable by one person, and require only very little setup time on location. The sound is usually recorded on a magnetic stripe on the edge of the picture film (single-system sound), or separate synchronous sound can be recorded on a compact professional 1/4-in. tape recorder (double-system sound).

Overview of Film in TV

The fact that some films do not conform with minimum and maximum densities for TV use has prompted the adoption of automatic signal level control devices in an attempt to maintain white signal level at 100 IEEE units and picture blacks near setup level while disregarding picture content. This automatic approach often changes or defeats the effects that the producer/director may have been trying to achieve.

Signal level compensation is necessary, as some film image densities continue to vary beyond acceptable limits. Industry recommendations give a value for the film minimum density of not less than 0.3, while the maximum density should not exceed 2.5 in any image areas where important picture details are located.[1] Densities between 2.35 and 2.5 will suffer some black compression resulting in less than faithful reproduction of the tonal gradations. The degree of such image degradation depends to some extent on the telecine operating characteristics.

Modern color films are capable of producing excellent television pictures when the film has been correctly exposed and the telecine reproduction equipment has been properly adjusted. In recent years a great deal of time and effort has been expended in investigations of the various factors adversely affecting film reproduction in the television system. Out of these investigations have come recommendations for film program production and for telecine alignment designed to give consistently high picture quality. In the following pages, details of these recommendations are given, as well as practical working methods for the implementation of these recommendations.

[1]SMPTE Recommended Practice RP 46-1972, "Density of Color Films and Slides for Television (final)."

Benefits of Film in TV

The capital cost of film equipment is quite modest compared with all-electronic production facilities. Film offers worldwide program interchangeability, since dimensions, projection rates, image sizes, and sound track locations have been internationally standardized. In addition, film provides visible picture images, greatly simplifying program assembly operations. Films made for television reproduction will also perform satisfactorily on direct screen presentations as well.

TYPES OF TELECINES

There are two common types of light-receiving tubes currently in use in the telecine color camera: the Plumbicon and the vidicon.

Camera-type telecines utilizing vidicon tubes are by far the most popular and are generally used in North America. A vidicon tube translates an optical image into voltage variations that can be retranslated into a TV image. The quality of the television pictures obtainable with properly made films in properly adjusted and maintained vidicon telecines can be very good indeed, comparable with television pictures from other sources.

Television stations are being urged also to provide carefully controlled viewing conditions for television films. When this is accomplished, failure to properly reproduce films in telecine can be readily detected.

Some television engineers feel that telecine cameras should be fitted with Plumbicon tubes to gain additional improvements in the reproduction of films. Telecines have been designed with switchable masking capability to compensate for the characteristics of various film dyes. Electronic masking is employed to make the pictures from film match the pictures from live television cameras.

The Plumbicon tube offers some advantages in this highly specialized type of service. However, for general telecine use, the less costly vidicon tube is capable of giving satisfactory results. Also important are improvements in film production to take full advantage of the excellent television reproducing conditions already available.

FLYING-SPOT SCANNERS

In a flying-spot scanner (Fig. 1), a cathode-ray tube is utilized as the light source. The rapidly moving spot of light at the face of the tube is focused on the film, and the light transmitted by the film images is converted into a video signal by a light-sensitive device (photo-

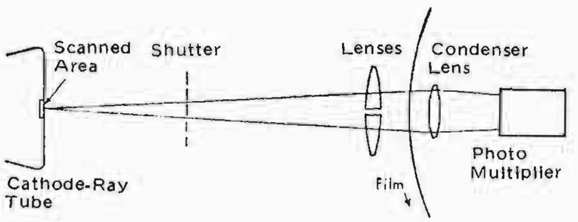

Fig. 1. Essential components of a twin-lens flying-spot telecine. (From *Color Film for Color Television* by Rodger Ross.)

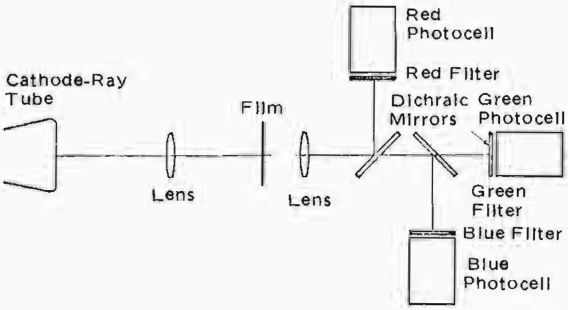

Fig. 2. Essential components of a color flying-spot scanner. (From *Color Film for Color Television* by Rodger Ross.)

cell). In a color flying-spot scanner (Fig. 2) three photocells are used in an optical system with color separation filters.

Another technique for utilizing the flying-spot principle in 30-frame television systems is to pull down the film within the vertical blanking interval and then scan the film while it is stationary, in the familiar 2-3-2 sequence. Pulling down the film in the vertical blanking interval—1.14 msec.—cannot be achieved with conventional mechanical methods. One alternative is to utilize the technique of penumatic film pulldown.

IMAGE ENHANCEMENT AND COLOR MASKING

Resolution and color fidelity of broadcast motion picture color film can be improved through vertical aperture equalization and bandwidth limited color masking. An image enhancer and associated masking amplifier[2] makes it possible for a color telecine camera to produce a picture that is equal to the best obtainable from studio cameras.

Image enhancement is a combination of vertical and horizontal sharpening used to compensate the relatively soft images of color cameras and the color kinescope in the receiver. Subjective tests show that the eye desires overenhancement of average subject matter, so much so, in fact, that a test pattern looks greatly overpeaked.

Color distortions of the Plumbicon cameras can be corrected by the installation of masking amplifiers. Flesh tones and saturated reds show a remarkable improvement with this technique (see Footnote 2).

FRAME-RATE CONVERSION

The standard motion picture filming rate in the United States is 24 frames per second, while 25 frames per second is used in Europe, England, and some other countries. Films have to be reproduced in television systems with different frame rates. In England and Europe, as well as the other countries, the standard television projection rate is 25 frames per second.

In North America and some other countries with a television frame rate of 30 frames per second, the conversion problem can be solved by utilizing telecines with storage-type camera tubes, such as the vidicon, and accelerated pulldown and modified shutter design to allow the 24 frames per second of the film projector to be broadcast at the television frame rate of 30 frames per second.

The vidicon tube has the interesting characteristic that if it is exposed for at least 30 percent of active scanning time and the same area of the photoconductive layer is exposed each time, there will be no noticeable discontinuities in the television pictures. The projectors must be fitted with a shutter having five narrow openings, and the pulldown mechanism must be so designed that one film frame is exposed twice, the next three times, the third twice, and so on.

A very important consideration here is that film pulldown can occur anywhere in the television scanning cycle; that is, pulldown does not have to be restricted to the television vertical blanking interval. This gives broadcasters a great deal of freedom in switching to and from the telecine camera output.

TEST FILMS AND THEIR USE

Alignment of the slide and motion picture projectors to the TV input requires accurate positioning of each projector with the multiplexer. To position the projector accurately, it is necessary to view a projected image while using some sort of an alignment or target device (a slide or a motion picture film).

For slide projector alignment, the registration slide and field-size slides are inserted into the projector and the projector can be adjusted for each slide accordingly.

[2] *Journal of the SMPTE*, 1968, 77(3).

The motion picture projector should be threaded with a suitable test film—a 35 mm Television Test Film (TV35-AS), a 16 mm Television Test Film (TV16-AS), or Super 8 Television Test Film (RP-32). Adjust according to recommended procedures. (These films are available from the Society of Motion Picture and Television Engineers, 862 Scarsdale Ave., Scarsdale, N.Y. 10583.)

OPTICAL SOUND

The gain and frequency response of the optical sound system is affected by the sharpness of the scanning slit image and the position of that image with respect to the optical sound track.

For this test, thread a film—such as a 16 mm Television Test Sound Focusing Film, Type A, 700 Hz, or a 16 mm Television Test Sound Focusing Film, Type B, 5,000 Hz—through the projector with the emulsion toward the lens.

Optical sound test films are also available from the SMPTE at the above address.

SUGGESTED SETUP PROCEDURES

The setup procedures outlined in this section are of a general nature. Manufacturer's recommendations are supplied with each telecine camera, and these must be followed to achieve peak performance. Even though reference has been made to vidicons, where appropriate, these statements also apply to Plumbicons. It is not necessary to accomplish all of the setup procedures on a daily basis. However, it is recommended that a periodic check, on a scheduled basis, be conducted to make sure that consistent high-quality operation of the telecine camera is obtained. The check procedure should include the following.[3]

A. Check the telecine electronically per the manufacturer's recommendations.

B. Make sure that the exterior optics of the slide and motion picture projectors are clean.

C. Make sure that the telecine camera optics are clean. If not, clean according to the manufacturer's recommendations.

D. Calibrate waveform monitor.

E. Insert Cross Step Gray Scale and follow recommended procedure. (See following procedures.)

F. Check and adjust encoder.

G. Set up color picture monitor.

H. Set telecine camera operating levels, both manual and automatic.

I. Adjust telecine for camera minimum subcarrier.

J. Operating telecine camera in a manual mode, check each projector for proper color and intensity match.

IMPROVING BROADCAST QUALITY[4]

General procedures

At each television station, the color telecine should be closely examined. The *cleanliness of the optical elements* and *the alignment of projectors* require early attention because of the possible adverse effect they can have on the chain's performance. A Cross Step Gray Scale slide can be used to make objective measurements of the condition of the telecine by using one of the 16 mm projectors, running without film, as the light source. The resulting video waveforms can then be analyzed for proper step placement, and where necessary (and possible) adjustments should be made to *correct shading errors, optimize gamma,* and *establish acceptable tracking to obtain proper tone reproduction and a neutral color balance.* Some procedures may differ from station to station because of the differences in telecine cameras and the nature of the problems that might be encountered.

In order to properly display the subjective color test film, set up a color picture monitor and adjust it to produce 6500 K correlated color temperature at a 20-fL peak white brightness. Then run the color print, balanced for 5400 K projection, on the telecine chain and in most cases it will produce a very good picture. Where an acceptable picture is not produced, electronic or optical problems probably exist and usually have been noted in earlier tests with the Gray Scale Slide. The color print can also be viewed by direct projection using a modified projector and special screen to give an open-gate brightness of 40 fL at a color temperature of 5400 K. Under these conditions the projected image should match the monitor image very well.

Procedures for the Color Picture Monitor

Since the setting up or adjustment of almost any piece of equipment in a television station at some time requires a subjective picture evaluation, a high quality, professional color monitor is essential. As yet there is no standard setup procedure for color picture monitors, but there are generally accepted procedures and recommendations that will produce excellent pictures

[3] *Journal of the SMPTE,* 1971, **80** (12).

[4] *Journal of the SMPTE,* 1971, **80**, 973-976.

on a properly functioning monitor. A basically visual approach can be used to establish the various parameters of the color monitor on which results from the film chain are to be viewed.

Before adjusting the color picture monitor, *it is essential to check the precision of the station's color bars and adjust them, when necessary, to the required accuracy.* Also, it is necessary to make certain that the waveform monitor display is an accurate representation of what is actually getting to the color monitor—that is, that there are no level differences through switchers or other devices.

The most critical monitor adjustment is the setting of the color of peak white. This has always been a major problem in matching color monitors and in maintaining their day-to-day consistency. The brightness level of the peak white must also be properly set. Such adjustments can be made quickly and accurately, using a visual comparator. The comparator is a concentric field comparison instrument employing a low-voltage, tungsten-halogen lamp to illuminate the comparison field at an appropriate brightness level to establish a peak white brightness on the picture monitor of 20 fL at a correlated color temperature of 6500 K to within ±2 fL and ±200 K. The device is placed at the color picture monitor so that the 100 percent white from the split-field color bar pattern or from a "window" signal appears in the center of the reference field. The color of the monitor white can be made to match the reference field by adjusting the blue and green drives or, on some color monitors, red and green. The picture monitor brightness is made to match the reference field by adjusting the contrast control.

There are other instruments that can be used to set the peak white of the color picture monitor. Several available photoelectric instruments are excellent for reproducing an established setup, but they should be calibrated for different types of color monitors.

The validity of the subjective evaluation of the color film chain is dependent upon the proper performance of the color monitor. One of the most frequently encountered monitor problems is poor tracking.

Although a color picture monitor set to D_{6500} produces a pleasing color picture, many persons object to the appearance of a black-and-white picture displayed under these conditions because of its reddish hue when compared with the same picture on a black-and-white monitor that has a white comparable to 9300 K white. Some stations change the "color" of their black-and-white monitors with a filter to make them match the lower color temperature color monitor.

Optical Signal Generator

Usually a primary concern is the proper adjustment of the television film chain. Causes of poor quality of television images from good film can be traced to poor film chain performance, lack of color balance uniformity between chains, etc. There are many reasons for these conditions, but uppermost seems to be the lack of well-defined parameters for establishing the optimum condition of the color film chain camera for reproducing color films. Different television stations have different gray scale test objects, or other "neutral" test objects, that are used in a variety of ways. Some stations use selected color films as subjective reference films, although frequently they do not conform to current recommended practices for such reference films. At the present, there is no standard practice for telecine setup.

Cross Step Gray Scale Slide

An important device for the maintenance of good broadcast quality is the Cross Step Gray Scale Slide[5] (Fig. 2A). This slide is intended for use in the checking of the following characteristics of a telecine camera in the color television film chain:

1. Setup and balance of gains and black level.
2. Operation of the gamma-correction circuitry.
3. Amplitude tracking among video signal channels.
4. Light-signal transfer. Light-input, signal-output, transfer characteristic.
5. Compression or clipping in the video signal channels.
6. Shading controls to minimize field nonuniformity.

Requirements for a Light Modulator[6]

The light input to a television film chain is converted to variations of electrical voltage with time. The characteristics of this output signal must be controlled within certain well-specified limits so that a good signal will be available for broadcast. This fact is taken into account in the design of the telecine camera and also in the operational adjustment of certain controls available on the camera.

Necessary to this operational adjustment is a calibrated light modulator that has enough of the optical characteristics of the film input to be

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[5]A typical slide is manufactured by Eastman Kodak Company.

[6]*Journal of the SMPTE*, 1971, **80**, 970-972.

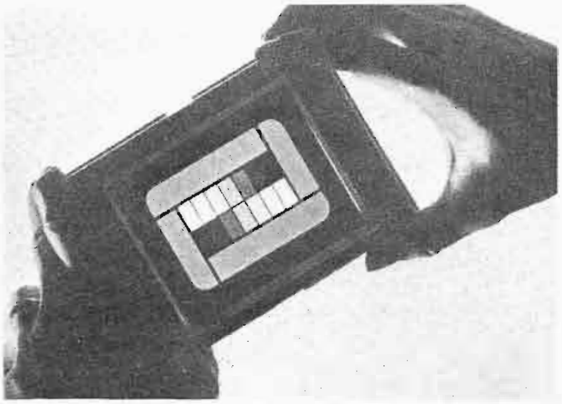


Fig. 2A. Cross Step Gray Scale slide for telecine camera test as specified in RP 27.7-1972. (VIDEO film NOTES, Kodak Publication No. H-40-4, p. 5.)

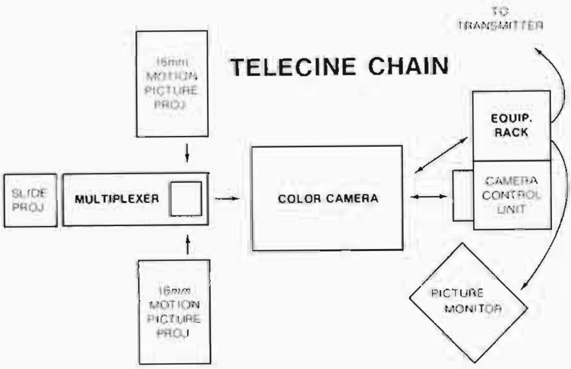


Fig. 3. Basic components of telecine chain. (VIDEO film NOTES, Kodak Publication No. H-40-4.)

valid and that can produce an instrumental display for the television engineer to read and manipulate. Tradition and practice have resulted in a step-scale gray modulator that is displayed on a waveform monitor as a "staircase" in which the "risers" are the voltage increments corresponding to the transmission increments, and the "treads" are the time units corresponding to the horizontal dimension of the steps. By adjusting gain and blanking controls in each of the channels, the proper dynamic range can be obtained, and the three color channels can be made to conform with each other (gray-scale tracking). In addition, a properly designed modulator can be used during the adjustment of the shading (field uniformity) controls.

Position and Size of Test Slide

Most television film chains are multiplexed; that is, several projectors feed one camera (Fig. 3). Usually this combination is two 16 mm projectors and 2 × 2-in. slide projector, with a system of movable mirrors and a relay or field lens between the projectors and the camera. It is desirable that the output of the three optical projectors be matched for color balance, intensity, and shading, as far as possible. It has been customary, as a matter of convenience, to use a light modulator of 2 × 2 in. format in the slide projector of the multiplexed telecine. This means that the chain is adjusted to optimize the output of that projector. Yet the motion picture films used on the other two projectors represent considerably more broadcasting time and usually more critical subject matter. Therefore, it is desirable to be able to use a 16 mm projector as the input source during adjustment. A light modulator in the field-lens position solves this problem, since it can be used to examine and adjust for any of the input sources. This requirement dictates that a slide be large enough to be used in the field-lens position. The standard 3 1/4 × 4-in. slide is adequate for this purpose.

To accomplish these functions, the modulator must have the characteristic of not scattering light. In addition, it must be neutral in color, and it must be stable when exposed to light and heat.

Format

The format of the slide (Fig. 4) depends directly on the oscilloscope display that is desired. The size of the steps is a compromise between a need to confine the entire staircase to a small central area to minimize the effects of shading and a need to have a display large enough to be visible on the oscilloscope. The adoption of the crossed-staircase design is a direct result of the shading problem; the redundancy of the double display is useful in quickly determining if there is a shading problem. The choice of the number of steps is a compromise between the desire for a very simple display and a need to have several data points. An odd number of steps allows the crossover to fall on a step, rather than between two steps.

A mid-density, uniform background serves two functions. It provides an average transmission similar to that of average picture level (APL). In addition, the uniform surround provides the signal at a critical signal level for monitoring adjustment of shading or uniformity controls at both the optical and electrical stages.

Transmission Values

The SMPTE Recommended Practice[7] for such a telecine slide (RP27.7-1972) calls for the steps

[7] SMPTE Recommended Practice on Specifications for Gray-Scale Operational Alignment Test Pattern for Telecine Cameras RP 27.7-1972 (final).

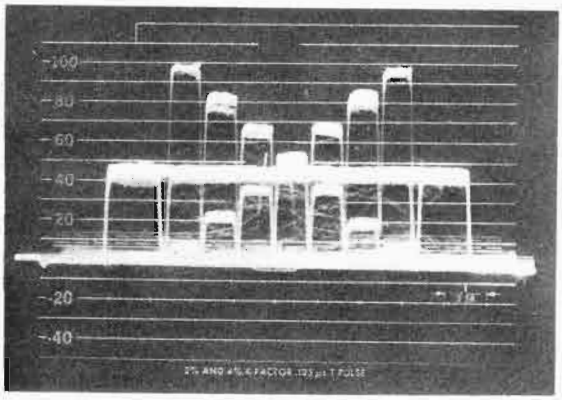


Fig. 4. Waveform monitor display of crossed-step slide in a well-adjusted film chain. (VIDEO film NOTES, Kodak Publication No. H-40-4.)

in the pattern to follow a 2.5 power law increase in transmission over a 40:1 contrast range, from the next most dense step to the least dense step. The most dense step is to fall at a one-half step increment below the adjacent step on the 2.5 power law curve. The intent of the 2.5 power law is to relate directly to the gamma of the display tube.

The least dense step has a value of 50 percent transmission (D=0.3). This corresponds to the least dense end of the tolerance of the recommended density for white objects reproduced on film.

The surround density is specified at 1.14, which satisfies the requirement for average picture level, and puts the waveform display of the surround halfway between two of the gray-scale steps.

The density and transmission specifications for the slide are given in Table 1.

TABLE 1

Density and Transmission Specifications for Slides

Step	Diffuse density	Transmittance, %
1	0.30 ± .01	50
2	0.48 ± .01	32.9
3	0.70 ± .02	19.9
4	0.98 ± .02	10.6
5	1.34 ± .03	4.5
6	1.90 ± .04	1.25
7	2.35 ± .05	0.45
Surround	1.14 ± .03	7.2

Note: ISO Recommendation R5-1955, Diffuse Transmission Density (Photography).

Use of the Slide

Since the slide is not used for geometrical alignment, its location at the field-lens position is not critical. Although theory may call for the slide to be placed in the center of that lens, in actual practice the depth of field at this position is great enough to allow considerable leeway. It is possible to place the slide at least 2 in. from the field lens of several telecine chains and still obtain an image enough in focus to present a well-defined waveform. Ideally, for operational convenience a holder for the slide should be part of the camera equipment so that the slide can be inserted in the optical path during alignment, yet easily stored out of the way during broadcasting.

Inasmuch as the least dense step is intended to correspond to television white level, it is obvious that the gain control of the television film camera should be adjusted to display 100 IEEE units, in each channel. Specification of black level is less certain. On many film chains the best display of film is obtained when the black level corresponds to the absence of light. The opaque border of the slide provides a convenient signal for setting black. Its waveform display should be controlled by setting blanking controls so that it is just above blanking level, which may be a 7.5 IEEE units if "setup" is used.

The waveform monitor display resulting from use of this slide in a well-adjusted film chain is shown in Fig. 4. This is the encoded signal with the monitor in the IEEE response condition. The crossed staircase is clearly defined with each step being easily visible. The horizontal display of the uniform surround, showing between the 4th and 5th steps, illustrates the excellent shading or uniformity of this chain.

Storage and Handling

Remove the slide from the optical path at the field lens position when all of the tests have been completed.

The slide is an optical signal modulator. Since it is made of glass, the two main dangers to the slide are breakage and scratching. Dust and fingerprints should be removed by wiping with a soft, lintless cloth or lens tissue moistened with a suitable lens cleaner. Ordinary exposure to heat and light will not affect the slide. If the telecine camera is equipped with a slide holder that can be moved in and out of the optical path, storage in the holder is adequate; otherwise, when not in use, the slide should be stored in a protective case.

Color Telecine Camera Setup

Shading

The shading of all projector inputs should be adjusted before attempting any camera adjustments. The uniform gray background of a Cross Step Gray Scale slide should be used for making shading adjustments since it is at a very sensitive density level. It is easy to distinguish between projector illumination uneveness and camera shading problems because the former almost always appears as intensity variations in all channels, whereas the latter will show up in only one or two channels, or variations will appear in all channels. If a projector shading problem is evident, telecine camera shading controls should not be used in an attempt to improve it, since those controls were not intended to handle this type of problem and are usually inadequate to correct nonuniform light application. Instead, the projector should be checked to see if it is properly aligned with the other optical elements of the film chain. Improper alignment of projector lamps, reflectors, and condensers is sometimes the cause of shading problems. These misadjustments are relatively easy to locate and remedy. Gross mismatches of projection distances and field lens power can produce a "porthole" shading problem. This occurs where the field lens power is not correct for all inputs. It can be corrected by selecting a lens with the proper focal length to give the projection distance required by the field lens.

Telecine camera shading problems should be corrected by adjusting the horizontal and vertical saw and parabola shading controls in each camera channel. This and subsequent camera adjustments should be performed using the Cross Step Scale slide with light from the most frequently used film projector.

The waveform monitor should show a horizontal line representing the gray background on both the two-frame and the two-field displays. It should occur about the middle of the scale—that is, at 50 IEEE units—but it can vary because at this point the operating levels of the camera have not been established.

Operating Levels

To set the proper operating levels, the waveform monitor is switched to IEEE response. The telecine camera channels are adjusted following the manufacturer's instructions to set the lightest step of the cross step slide at 100 IEEE units and the most dense step just above setup, or just above blanking if the operator is observing the signal before insertion of fixed setup. This establishes the maximum density range that the telecine camera can reproduce properly; that is, densities from 0.30 to 2.35.[8] Tonal gradations in the 2.35 to 2.5 range will be compressed resulting in loss of detail.

It is important that this portion of the camera setup procedure include adjustments to produce equal level settings in both the manual and the automatic operating modes, if used. If, then, a sudden automatic control failure should require the switching to manual operation, such a transition can be made without producing violent level fluctuations.

Some color film chains use electromechanical control of neutral density wedges on the projectors to compensate for the range of density levels encountered in programming slides and motion-picture films. Before undertaking to set up the telecine camera on such chains, the proper position of these wedges, i.e., the amount of neutral density attenuation in the projector light path, should be determined. The proper setting is that which allows the use of normal target voltage on the least sensitive vidicon camera system. The other vidicons can be brought close to the same target voltage by "padding" with neutral density filters mounted on the vidicon camera lenses.

If it is found that this wedge setting does not provide sufficient reserve density (that is, reserve camera sensitivity to accommodate moderately dense films) the projector should be checked to see if it is possible to increase its light output. Failing in this, it will be necessary to raise the target voltages; but rather than raising them to too high a value, the insensitive vidicon should be replaced.

In setting the neutral density wedge in this manner, a film may occasionally be encountered that will be too dense to produce a proper video signal. Such circumstances may require a special camera setup in order to program the film satisfactorily.

Lamp Voltages

It is a mistake to use excessively low projector lamp voltages. While there is some justification for running lamps about 10 percent below rated voltage to increase lamp life, further voltage reductions sacrifice too much light. Another all too common practice that wastes light is that of stopping down projection lenses to unnecessarily small apertures. The excuse offered is the need for depth of field to avoid having to refocus when running the reversed emulsion position on 16 mm films. Too often small aperture (slow) lenses are stopped down one stop below their

[8]RP-46-1972, approved July 1972.

maximum aperture as are large-aperture (fast) lenses, a procedure that seems ill-advised, since an *f*/4.5 lens wide open has the same depth of field as an *f*/2.3 lens stopped down to *f*/4.5, provided they are the same focal length.

Color Balance

The next step in the setup of the telecine camera is to provide precise gamma tracking and color balance. Following the telecine camera manufacturer's recommendations, equal gains are set in all channels so that identical signal levels at the output of the vidicons receive the same amplification. There can be, however, a luminance channel gain difference if a different type of vidicon is used in a four-tube camera.

The blanking, target voltages, channel gammas, and beam cutoffs are adjusted to produce equal response in all channels. This can be done conveniently by selecting, where possible, a sequential display for the waveform monitor. The match can often be improved by superimposing the outputs of the channels to make the touch-up adjustments. The final adjustments of the color channels should be made by nulling subcarrier when viewing the output of the encoder on the waveform monitor with flat response.

Of all the adjustments that should be made to optimize the camera, beam cutoffs are most frequently overlooked. It is recommended that they be set to "beam starve" at about 110 to 120 IEEE units, but at least they should cut off at the same level in the three-color channels so that a color shift will not occur during transitions from a dark or average scene to an extremely light one.

Blanking adjustments are made in all channels to place the bottom step of the cross-step display at a point just above system blanking. Target voltages should be set to establish peak white level by placing the lightest step of the display at 100 IEEE units. The target voltages at this point should be nearly equal. If they are not, neutral density filters should be placed in front of the more sensitive vidicons to allow their target voltages to be brought close to that of the least sensitive vidicon. However, if this latter vidicon's target voltage is considerably above that recommended by the manufacturer, it should be replaced. It is often possible to interchange vidicons in the color channels to avoid rejecting an insensitive one.

Before making the final adjustments on the camera, as noted earlier, the proper gammas should be established in each channel. With the cross-step levels properly set, the gamma circuits in each channel should be adjusted, using a Cross Step Gray Scale slide, so that the middle step of the display is at 55 IEEE units.

With telecine cameras that vary target voltages instead of using a neutral density wedge to change sensitivity, it is necessary to make sure that the subcarrier null in all steps is maintained over an adequate range of target voltages. This prevents a color change with a shift in film density. Careful neutral density padding of the vidicons in the color channels, optimum adjustment of high- and low-target voltage settings, and a good set of vidicons should provide an adequate range of target tracking.

TELECINE MAINTENANCE AND OPERATION

Maintenance of telecine cameras requires the same care and attention given to other electronic equipment in the television station. The quality of the television pictures obtained from film depends not only on the film but also on the condition of the reproducing equipment as well. Too often, poor quality film is given as the reason for poor television pictures, when the real cause of the trouble is in the television system itself.

A routine maintenance procedure should be set up in every television station to make sure that telecine equipment is operating properly at all times. Through the proper use of readily available and inexpensive test films, patterns of good performance can be established in a short time.

Every morning the optical and electronic systems should be checked, including the sound-reproducing channel, with the appropriate test films. Setting up the telecine camera with the gray scale test slide, as described in a previous section, will provide a good deal of information on overall camera performance. This serves also as an excellent starting point for the day's operations.

FLARE

The quality of the broadcast television pictures from motion picture film can often be severely degraded by insufficient or inadequate equipment maintenance. An accumulation of dust, smudges, etc., on the optical surfaces of the telecine equipment may cause flare as light passes through the optical system to the pickup tubes in the camera.

Flare in telecine cameras reduces contrast and causes large errors in color rendition. One method for measuring flare is to make a flare test slide, project this pattern into the camera, and observe the video waveforms obtained from it. Such a slide can be assembled by mounting small patches of opaque material on a 2 X 2-in. glass slide. The black paper used to package

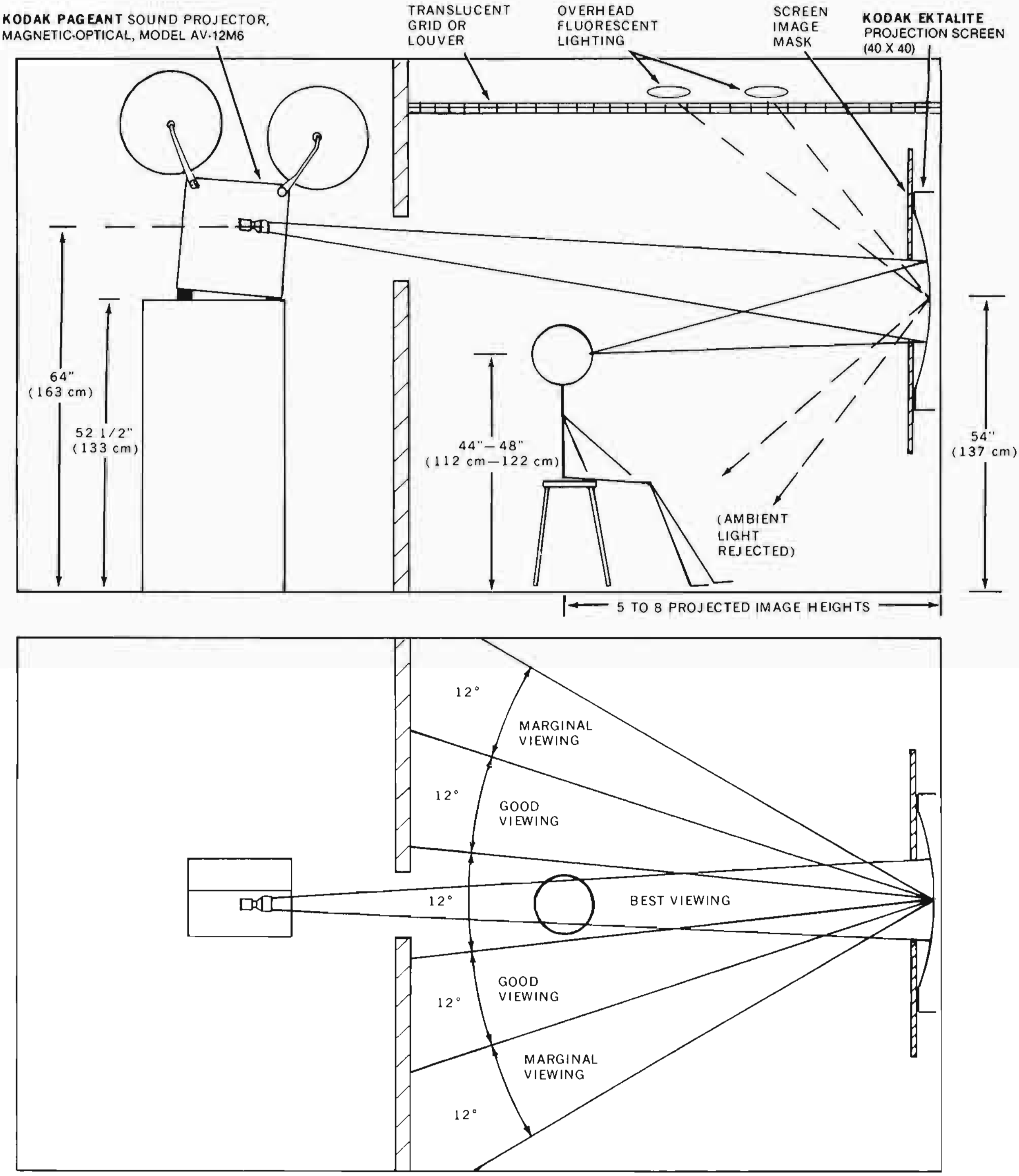


Fig. 5. Typical preview room configuration. (From Kodak Publication No. 5-1 The Television Film Preview Room.)

sensitized materials (film) can be used for the patches. Approximate-size patches can be obtained by using an ordinary office paper punch. These small circles have a diameter of approximately 1/4 in., and several patches can be mounted on the slide—one in the center of the slide and one near each of the four corners.

The waveform produced by this slide will have a very high white level signal caused by the clear glass slide. The white level signal should be adjusted to normal (100 IEEE units). Then the amplitude of the signal in the areas of the waveform, representing the small black opaque patches, can be compared with the signal level when all light is excluded from the camera. The simplest way to make this comparison is to momentarily insert a sheet of opaque material in front of the projector lens.

The black (opaque) patches do not transmit light, and therefore the signal levels in these areas should remain at zero if this is the level at which the light was cut off at the projector. Any increase in the levels for the black patches can be caused only by flare. If the optics in the telecine are not clean, the signal levels for the black patches may be as high as 20 IEEE units or more.

THE TELEVISION FILM PREVIEW ROOM

A film preview room, to be truly effective as a means of evaluating the suitability of motion pictures for television broadcast, must display a picture that closely matches the image viewed on a color television studio monitor.

A method of viewing film that closely simulates the television reproduction is highly desirable, not only to television stations but also to film laboratories and film producers where they are making films destined for release on television. Such a system is described in Kodak Publication No. S-1, *The Television Film Preview Room*. The method permits the use of existing tungsten 16 mm projectors for preview purposes by filtering them to produce an equivalent color temperature of 5400 K at an open gate screen brightness of 40 fL. A high-gain screen is used to offset the attenuation of the filter and to achieve the relatively high screen brightness required. The screen brightness will produce a film highlight brightness of 20 fL, thus matching the highlight brightness established on the studio color picture monitor. The 5400 K color temperature of the direct projection system will give an acceptable match with the film shown on a properly aligned television system whose color monitor is set to D_{6500}.

Films with a rather wide range of color balances will look acceptable when viewed separately in a darkened room. In order to make sure that valid color judgments can be made with this preview room, ambient room lighting is specified that will produce a reflected brightness from the viewing wall of approximately 4 fL with a color to match open screen illumination of the projector. This ambience will prevent the observer's eyes from adapting to different color balances.

It is also recommended that the preview screen be similar in size and shape to a television picture monitor if the preview room is to be used for a small audience. Similar preview rooms are used by the Canadian Broadcasting Corporation.

FILM CHARACTERISTICS

When film is utilized for original television program production, the preferred approach is to consider these two media as parts of a total visual and aural communications system. Film and its associated processes may be classified in several different ways—by the properties of the film itself, by its function in the production of the end product, or by its areas of maximum utility. Various types of films can be described in terms of the following characteristics:

Film Structure. Motion picture film consists of a light-sensitive material, the emulsion(s), coated on a flexible transparent support, the base. The coated base is slit into the desired width, perforated, and wound onto spools or cores in a variety of lengths.

During exposure *black-and-white films*, slight changes take place in tiny silver-halide crystals dispersed in the emulsion and these changes result in latent images on the emulsion, a process that can be considered as a form of temporary storage of picture information. Processing converts the latent images into visible images made of black silver grains packed closely together.

Color films have multiple coatings with three separate light-sensitive layers. Latent images are formed in these layers during exposure in relation to the amounts of red, green, and blue light reflected from the scene. When the film is processed, the latent images are converted into color dye images in a series of complex chemical reactions.

The structure of Kodak Ektachrome films is shown in Fig. 6 as a drawing (not to scale) of a

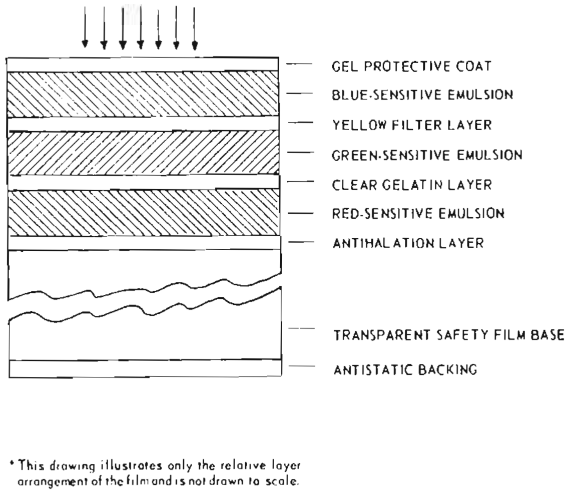


Fig. 6. Cross Section View of Unprocessed Kodak Ektachrome EF Film 7241 (Daylight) and 7242 (Tungsten). (Reproduced from Kodak Publication H-33, Manual for Processing of Kodak and Eastman Ektachrome Films Using Process Me-4.

cross-sectional view of unprocessed film. Starting with the bottom of the drawing, an antistatic layer is provided to avoid buildup of electrostatic charges. On the other side of the transparent safety film support is an antihalation layer. This layer minimizes the effect of internal reflections of the exposing light from the base. Such reflections could cause undesirable "halo" images and loss of apparent sharpness. Red- and green-sensitive emulsion layers are coated on the support, followed by a yellow filter layer. Although the red-sensitive layer is sensitive primarily to red light and the green-sensitive layer is sensitive primarily to green light, both of these emulsions are somewhat sensitive to blue light. The yellow filter layer absorbs blue light and thus prevents blue light from exposing the green- and red-sensitive emulsion layers. A blue-sensitive layer is coated on top of the yellow filter layer.

Negative or Reversal. Both black-and-white and color films can yield either negative or positive picture images when exposed and processed. It is customary to use negative film in the camera when immediate projection is not required and a number of prints may be desired; reversal films, when processed, yield positive images on the film exposed in the camera. Reversal film is preferable when the original film—that is, the camera film—will be used for projection.

Spectral Sensitivity. Most black-and-white films for camera use are panchromatic—that is, sensitive to all the colors in the spectrum. Color films for camera use are panchromatic—that is, sensitive to all the colors in the spectrum. Color films are available in two[9] different balances—one for exposure outdoors with average daylight; the other for exposure indoors, with tungsten illumination. As a matter of normal practice, television news photographers place conversion filters over the camera lens to permit a tungsten-type film to be used outdoors, so that only one camera film need be carried.

Speed (Exposure Index). The speed of a film can be expressed as a number that indicates its inherent sensitivity to visible light. To enable photoelectric light meters to be used to set the camera lens aperture (*f*/number) for different exposure conditions, each type of film is given an exposure index by the manufacturer. However, film exposure-index values published for use with exposure meters are intended to serve only as guides. The index figures given in the film listings are recommended for use with meters and cameras marked for ASA speeds (ASA denotes American Standards Association which is now entitled American National Standards Institute—ANSI). Exact exposure levels should be determined by tests with equipment that will be used for the production (because of differences in cameras, lighting, equipment, meters, and techniques). The effective speed of a film is also influenced by the particular solutions and processing method employed. Force processing is a common practice. Longer processing times and/or higher solution temperatures can increase the effective speed of a reversal film. If possible, the tests should include an exposure series made with the specific film emulsion selected for shooting, and the test film should be processed in the manner to be used for the production.

EXPOSURE CONTROL

Exposure for motion picture films can be calculated with a photoelectric light meter. Meters measuring either incident or reflected light can be used for exposure determination. The light value indicated by the meter and the exposure index for the film are "programmed" into a small circular calculator attached to the meter and thus provide an appropriate setting for the camera lens.

This method of exposure calculation works very well with average outdoor scenes and subjects. However, many television filming situations are far from average; and in some situations the camera lens aperture must be adjusted to the largest possible opening for news stories that have to be filmed in available light. Excessive contrast may occur and cause a loss of shadow detail in the reproduction of film in the telecine chain. This happens because of the need to control peak white signal levels from the picture highlights.

Fig. 7 illustrates the way a reversal color film responds to exposure. As the exposure is in-

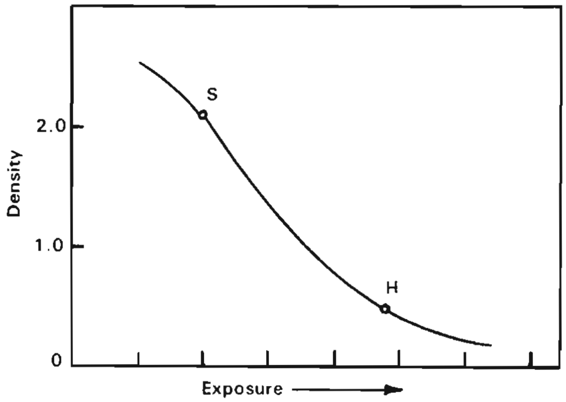


Fig. 7. Typical characteristic curve for a color reversal film. (Illustration from Videofilm Notes H-40-2, p. 4.)

[9]A third color balanced film is available in the 16 mm format. This Type A film is for use indoors with 3400 K Tungsten and is generally not suitable for filtered use outdoors.

creased, the density of the image in the film decreases, as shown in the form of the film's characteristic curve. When a scene with a contrast range of about 20:1 is properly exposed on this film, the lightest and darkest parts of the scene will be located on the curve at points H and S, respectively.

DENSITY CONTROL STARTS AT THE CAMERA

The process of image formation begins at the camera where the film is being exposed. Fig. 8 shows that closing or opening the camera lens aperture can only shift the scene up or down on the characteristic curve of the film. Also, scene content and composition coupled with the camera location and angle of view affect scene density.

It is easy to demonstrate the principle of density control with a test card made of black-and-white bars. However, when the principle is being applied in practice, the properties of real scenes must be taken into account, which makes the task much more difficult.

Every scene has a scale of luminance values. The total amount of light reflected by the various scene areas is dependent not only on their light-reflecting properties, but also on the intensity and distribution of the light illuminating the scene. The simplest example is an outdoor scene illuminated by sunlight. Two areas in this scene can have the same light-reflecting properties, but one area could be in shadow and the other fully illuminated. On an overcast day an entirely different image would be obtained on film, since now both areas might be illuminated at the same level. Artificial light or reflectors could be utilized to alter the picture tonal scale. The technique of employing additional light is commonly used in professional motion picture production to avoid excessive contrast and loss of detail in shadow areas, as well as to simulate sunlit scenes.

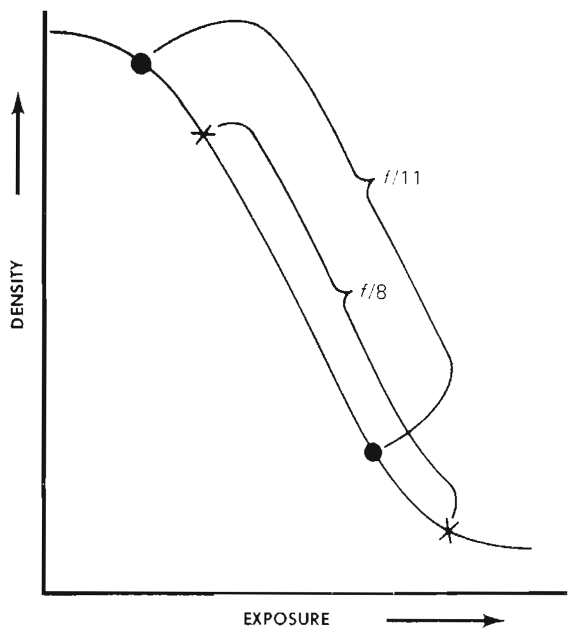


Fig. 8. Effect of camera aperture settings on the placement of a scene on a reversal film characteristic curve. (Illustration from Videofilm Notes H-40-3, p. 6.)

When it is desired to produce film images that will transmit specified amounts of light into the telecine camera, the film must be properly exposed which means locating the scene correctly on the characteristic curve. In some situations it may be necessary to make use of artificial light to achieve this objective.

Incorrect exposure in the videofilm context means the failure to provide in each scene some well-defined highlight and shadow areas. As stated before, the recommended minimum density is in the order of 0.3 with the maximum density at about 2.5. Subjects of primary interest in the scenes—such as people's faces—must be properly located in the tonal scale of the images, relative to the highlights. As a general rule, faces should have densities in the range of 0.20 to 0.40 greater than the highlights.

The Solution: Density Control

It has been thought that prints found to be acceptable in direct projection should be suitable for television production, and that if these films do not give acceptable television pictures, something should be done to modify the television system.

A reason for this attitude can be found in the different terms used by film and television people in describing their image-forming systems. Photographic density has a special meaning; it is defined as the logarithm to base 10 of the reciprocal of the transmittance. That is:

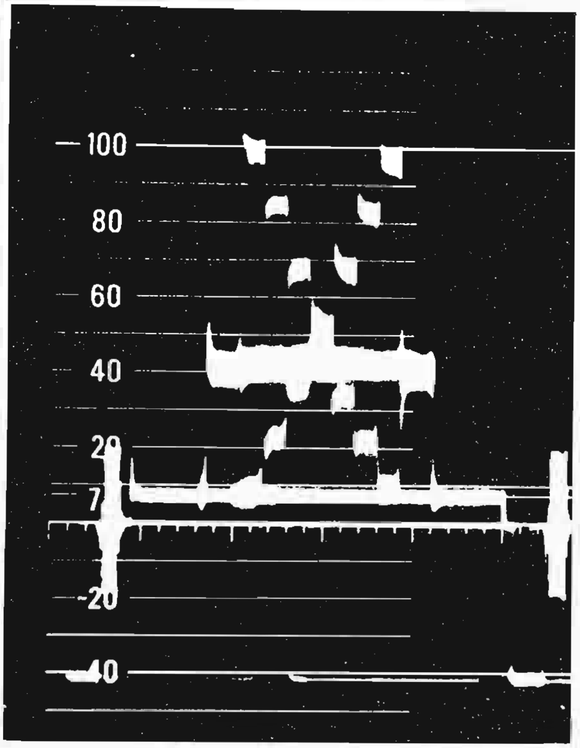
$$D = \log_{10}\frac{1}{T}$$

where T is the ratio of incident to transmitted light.

In photographic work, the light-transmitting properties of images are best and most conveniently described in terms of density rather than transmittance. When density, which is a logarithmic function, is plotted on a graph against the logarithm of the exposure that produced an image, a characteristic curve is obtained. This curve shows how density changes with increasing exposure with different types of photographic materials and processes.

When film is being used a source of television video signals, the amplitude of the signals depends on the amount of light transmitted by the film images. There has been general television industry agreement for many years that the minimum density in highlight areas of the film images should be not less than approximately 0.3; that is, these areas should not transmit more than 50 percent of the incident light. The basic reason for this is the need to avoid nonlinear white compression, as well as a large separation between skin tones and the lightest part of the picture image. It is also necessary to specify a density range outside of which picture information cannot be faithfully reproduced. The density range has been found to be between 0.3 and 2.5. Fig. 9 shows the video waveform obtained with the Cross Step Gray Scale Slide (made by Eastman Kodak Company) after the telecine camera has been set up to properly reproduce the slide. The minimum density of the slide, in the first step that appears in the video waveform at a level of 100 units, is 0.3. In Fig. 9, the densities of all the other steps of the test slide are shown, together with their corresponding transmission values.

The illustration can provide some insight with regard to using film in television. When films are supplied to the television system in which the desired picture information generates video waveforms similar in amplitude to the test slide, at the peak white-and-black-level lines on the waveform graticule, no steps have to be taken by broadcasters to compensate for variations in video levels.



Step	Density (Diffuse)	Transmittance, %
1	0.30 ± 01	50
2	0.48 ±.01	32.9
3	0.70 ±.02	19.9
4	0.98 ±.02	10.6
5	1.34 ±.03	4.5
6	1.90 ±.04	1.25
7	2.35 ±.05	0.45

Fig. 9. A typical video waveform with corresponding density and transmittance values from the Cross Step Gray Scale slide made by Eastman Kodak Company. (Refer to SMPTE Recommended Practice RP27.7-1972), *Specifications for Gray Scale Operational Alignment Test Pattern for Telecine Cameras* (approved 7-72) for additional information.

SELECTING THE TYPE OF FILM

The basic properties of film are used to provide a number of film/process combinations, each deemed most appropriate for a particular purpose. Thus film sensitivity, granularity, contrast, image sharpness, reproduction of colors, latent-image keeping, image permanence, negative or reversal image, spectral sensitivity, and type of support, may have greater or lesser relative importance, depending on where the film fits into the production pattern. Generally, films falls into four broad classes: (1) camera or taking films used for original photography, (2) laboratory or intermediate films used in the printing and processing laboratory to make protection copies, printing masters, special effects (opticals), and changes in image size or format, (3) sound films for use in producing photographic sound tracks, and (4) print films for making copies to be viewed as the end result of the film production.

The many available characteristics are combined in various ways in particular films to produce materials that have a balance of properties most likely to meet the user's needs. For camera films, high speed is desirable, but it must be weighed against the required image structure (sharpness, graininess) and the intended use (to be used for display or to be printed). For instance, for TV news use, high speed is essential because lighting is often uncontrollable. The color balance, contrast or density range, image structure, and image polarity reversal are designed to provide good image quality consistent with the primary requirements of being able to take the picture in a news environment and to use the original camera films as the input to TV broadcasting. For theatrical features, TV entertainment programs, and the like, where lighting on the set can be controlled and the exterior location and time of day and weather can be selected, camera film speed may be less essential, relative to better image quality and the fact that the original, usually a negative, is to be printed rather than used directly.

For laboratory films used to make effects, a specific contrast and excellent image structure are necessary requirements if the duplicate is to resemble the original as closely as possible. Speed and latent-image keeping are desirable but secondary characteristics.

For print films, the contrast must relate to that of the preprint films, and have graininess, sharpness, and color quality satisfactory for the end use of broadcasting or direct viewing. From the laboratory viewpoint, uniformity of the film, ease of processing, and of course cost, are factors.

The choice of a film or a family or group of films for a particular purpose should be approached by first considering the primary end use and working back through the many films, processes, and production options, then selecting the overall production scheme that will most easily produce the desired final product. Sometimes commercial factors, such as local availability of various services, time schedules, or budget provisions, must be balanced against technical factors for the best overall results.

By way of illustration, for TV news broadcasting, rapid access to the processed film, ease of editing, portability and simplicity of the cameraman's equipment, and high sensitivity of the film are usually deemed to be most important. This has led news directors to use a highly sensitive (suitable for new events) 16 mm (portability of equipment) color reversal camera film (rapid processing and ease of editing the original) that can be used routinely for television news broadcasts. The taking sensitivity is balanced for tungsten illumination, and the processed image is color-balanced for 5400 K projection into the telecine equipment. The image sharpness and granularity are adequate for TV use, and the contrast and extent of the tonal scale are balanced between ease of obtaining a good original exposure and the requirements of producing a good video signal.

For secondary uses of the film, there are reversal print films, compatible in processing, which have speed, color balance, and contrast suitable for producing good quality prints from the original news film. A few prints can be conveniently prepared for syndication, or educational uses, or several news stories can be combined into a feature or documentary program to be broadcast later.

If prints are the major objective, a camera film with picture characteristics designed to optimize the print quality would be a better choice. For such originals, different print films are desirable.

At the other extreme, for prime-time, high-budget entertainment programs, prints containing at least simple effects are required, frequently in both 35 mm and 16 mm size. Extra preprint materials may be needed for foreign syndication, and best possible quality is desirable. Such a combination of needs will lead to the choice of a camera film that provides a negative image with incorporated color masking. A material of this type offers excellent picture quality and the opportunity to make duplicate negatives that incorporate special effects. Duplicating and print films, each optimized for a particular function, are available.

The broadcaster who produces his own film programming should consult the film manufacturer, who can provide specific guidance and information about the film best suited to the broadcaster's needs.

FILM PREPARATION AND HANDLING

At the standard motion picture projection rate of 24 frames per second, the total number of frames required for a half-hour time period amounts to 43,200. In the 16 mm film size there are 40 frames per foot, so that a total length of 1,080 feet would be needed. In comparison, there are 16 frames per foot in the 35 mm film size, or 2,700 feet, for a 30-minute period, while the super 8 film format has 72 frames per foot, requiring a total of only 600 feet for the half-hour period.

The length of time allowed at half-hour intervals for station identification and local commercials varies from station to station and from one program to another. When a station's schedules are being prepared, these time periods must be calculated to the second, and copies must be given to the film editors showing all spaces that have to be filled and the materials to be put in these spaces.

For example, a station's program director may have made arrangements to obtain a print of a feature film, and information provided by the distributor may show that this film has a running time of 90 minutes. However, a space of only 60 minutes is available in the station's schedule. The film editor then has the task of removing portions of the film to reduce its length to fit into the allotted time period. In addition, spaces have to be left for the commercials. In a one-hour program there may be as many as 10 or 15 or these items, varying in length from 10 seconds to one minute.

First of all the feature film has to be screened to measure its actual length, while a log is made up indicating the portions that can be removed with the least disturbance of story content. Footage totals for the portions to be retained, together with the commercials to be inserted, are then prepared, and the final length is adjusted to take up exactly the full scheduled time period.

In some stations, the film commercials are spliced into the film program proper at points in the story where breaks can be made conveniently. Other stations splice all of the commercials for a day's operations on one or two 1200-foot reels; then the program film is placed on one projector of a telecine chain while the reel of commercials is placed on the other projector. Different methods can be used to insert film commercials into the program. Sometimes lengths of black leader are spliced into the program film at the points where the commercials will occur. With this arrangement, the projector carrying the program can be allowed to run continuously for the entire program period, while the projector carrying the commercials is started and stopped at the times the commercials are called for in the station schedule. Short lengths of leader between commercials permit the projector to be started a few seconds prior to the time the first pictures are to appear. Then at exactly the scheduled time, the multiplexer mirror—and the sound output as well—can be switched from the program projector to the commercial projector.

Alternatively, the program projector can be shut down while the commercials are being shown and then started up again a few seconds before the last pictures from the commercials are to appear. This procedure also calls for the insertion of short lengths of leader or waste film at the points in the program where that projector is to be stopped. Sometimes metallic cue dots attached to the edge of the film are used to stop the projectors. Projectors could be restarted automatically also, if desired, using metallic cue dots and an appropriate switching control system. In fact, all projector operations as well as video and audio switching could be timed automatically by an electronic counter actuated by the perforations in the films.

When films are being prepared for telecine, a good deal of handling is involved—screening of the films in a projector (See Television Preview Room, Fig. 5), measuring the lengths in a footage counter, cutting, splicing and winding on reels, attaching cue marks, etc. All of this work has to be performed on the prints that will be released on-air to the public. Care must be exercised so that the film is not damaged.

LEADERS AND CUING METHODS

The SMPTE Universal Leader, intended for both motion picture theater and television use, has a frame marked "Start" which is placed in the projector gate, followed by number counts from 8 to 2 at 1-sec. intervals (24 frames). A second projector can be started from the motor cue on the film running in another projector and a smooth changeover can be made from the first reel to the second by means of dowsers in the projector light beams.

These operations are complicated still further by the need to provide cues for starting videotape machines to insert recorded materials into film programs.

Electronic cue dot detection is far superior, and at the same time offers the possibility of partially automating telecine operations. Small dots of aluminum foil can be applied to the film outside of the picture frames. Equipment is available for easily applying the dots. A sensor in the projector detects the dots and gives some kind of visual or aural signal for the operator or initiates an action automatically.

A common practice is to make use of cue dot systems in the programming of reels of commercials, mainly for stopping the projector at the end of each commercial. When all of the commercials for a day's operations are assembled into a large reel, a short length of waste film, equal to the average distance the projector carries the film by its momentum after the cue dot shuts off the motor, can be spliced between commercials. In this way the film is located automatically in approximately the correct position for the projector to be started for showing the next commercial on the reel.

Some stations have adopted the practice of starting telecine projectors on 10-second cues, mainly because it is very easy to make countdowns on the clock in the coordinating studio or control room. For those stations, the SMPTE Universal Leader is too short—only 8 seconds. Other stations prefer 5-second cues; for them the leader is too long. In news operations, it is a common practice to make use of 3-second cues only, especially with modern 16 mm projectors that have a quick run-up to operating speed. In the Eastman 16 mm Television Projector, Model CT-500, for example, the motion of the film is stabilized in less than one-third of a second—8 frames.

One very important advantage of the SMPTE Universal Leader, however, is that it provides a count in seconds to the start of the program from whatever cue start that has been selected. When the telecine projector carrying the program is punched up in the "show" mode, the leader number placed in the projector gate can be seen everywhere in the station on picture monitors showing telecine output.

CLEANING AND LUBRICATION

The following steps should be taken when cleaning film: (1) wind the film onto a take-up reel; (2) rewind onto supply reel, drawing the film between two cloths that have been moistened with a cleaner/lubricant; (3) exert constant light pressure with one hand to provide continual contact between surface and cloths; (4) perform the operation slowly so that cleaner evaporates completely before the film reaches the take-up reel; (5) remoisten the cloths frequently because the solvent evaporates rapidly; (6) refold the cloths often (or replace when necessary), so that only clean areas are used, thus avoiding scratching of the film by accumulated dirt particles. If the cleaner does not contain a lubricant, the film should be relubricated.

Streaks that may appear after lubrication can usually be removed by buffing the film with a soft cloth. Any color that appears on a cloth used for cleaning Kodak color film can be disregarded provided materials and methods recommended by Kodak are used. It is a film-surface accumulation, not part of the dye in the image.

SPLICING MOTION PICTURE FILM

Splicing motion picture films is not a complicated procedure, but a great deal of damage can be caused to film and to projection equipment by poorly made splices. A good splice can be made by either of two common methods: tape splicing, in which a transparent adhesive tape designed especially for the purpose is used; or cement splicing, in which the ends of the film to be spliced are overlapped and fused together.

Either tape or cement splicing, properly done, produces a satisfactory splice. For occasional nonproduction splicing, tape splicing is convenient, trouble-free, and economical. However, cement splicing is required for most professional applications.

Film Cements

Film cement is a chemical solution containing solvents that partially dissolve, and then fuse together, the film ends. Two such cements are available: The first type is formulated primarily for splicing films having an *acetate-propionate* base, such as KODACHROME 40 Film and EASTMAN Reversal Color Print Film 7387. The second type is a professional film cement, which has a slightly different composition. KODAK PROFESSIONAL FILM Cement is suitable for all films on a *cellulose-triacetate* base plus those on an *acetate-propionate* base. In other words, it can be used on almost all professional and amateur motion picture films.

Motion picture films having a Kodak Estar Base cannot be spliced with either of the above cements because the Estar base is not dissolved by the cement solvents, as are the *cellulose-triacetate* and *acetate-propionate* bases. At the present time Estar Base films, and other *polyester* base films cannot be successfully spliced with any readily available commercial film cement. These films can be spliced with a tape splicer, such as the KODAK PRESSTAPE Universal Splicer, or with a splicer that uses a high-frequency current to melt and fuse the film ends. Estar Base films are used primarily in the fields of instrumentation, engineering, and science.

Cement-Splicing Equipment

There are many commercial cement splicers available today, ranging from simple models for the amateur to units designed specifically for specialized professional applications.

For example, some splicers have built-in scrapers (necessary for preparation fo the film to be spliced), often with adjustable guides to control the depth and width of the scrape. One type of splicer, the hot splicer, has a heating element under that portion of the splicer where the film cement is applied. This element reaches approximately 100° F and the heat, by increasing the evaporation rate of the solvents in the film cement, decreases the drying time of the splice from 15 or 20 seconds (conventional splicer, film cement but no heat) to 8 or 10 seconds. Choice of splicing equipment will depend upon the type and amount of splicing to be done.

Splicing Motion Picture Film with Cement

It is a good idea to practice making splices with scrap film; this is an inexpensive way to learn the "feel" of the splicer and to recognize the pressure necessary for proper scraping.

WARNING: Film cements and their fumes are mildly irritating, and they should be kept away from the eyes.

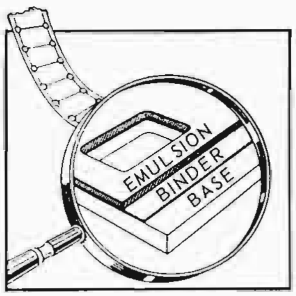


Fig. 10. Magnification of a section of motion picture film indicates that the film is made up of more than one layer. (In the illustration, the thickness of each layer is exaggerated. Kodak Publication No. S-38, p. 2.) Splicing Motion Picture Film with KODAK Film Currents.

The solvents used in film cements are volatile and can burn rapidly. While modern film bases are not fire hazards, the film cements can be.

Film cements can damage enamel and other finishes, and the man-made fibers in clothing.

Structure of Motion Picture Film

Motion picture film contains three major layers (see Fig. 10) of interest:

1. An *emulsion* coating, consisting chiefly of gelatin. In this layer of processed film is suspended the silver or dye that forms the photographic image.
2. The *binder,* a microscopically thin layer between the base and the emulsion coating, binding these two layers tightly together.
3. A flexible film *base* that provides a strong, durable support.

Width of Splice

Shown in Fig. 11 are the two splice widths most common in film editing and repair. They are the *positive* splice (1/10-in. overlap) and the *negative* splice (1/16-in. overlap). These names do not refer to positive or negative film, nor do the names imply a degree of splice reliability—both splices are highly reliable when made properly. The positive splice was developed first; unfortunately, it is quite visible when the film is projected. Therefore, positive splices are suitable for film that will not be used for printing (workprints, for example). The negative splice is narrower, and overlaps a different portion of the projected picture. It is less visible but just as reliable. The professional must make a negative splice if he is conforming original film for A- and B-roll printing. Many splicers can be ordered to provide scraping widths of 1/10 inch or 1/16 inch, as desired.

Removing the Emulsion

For a good splice, the two top layers—emulsion and binder—must be removed completely

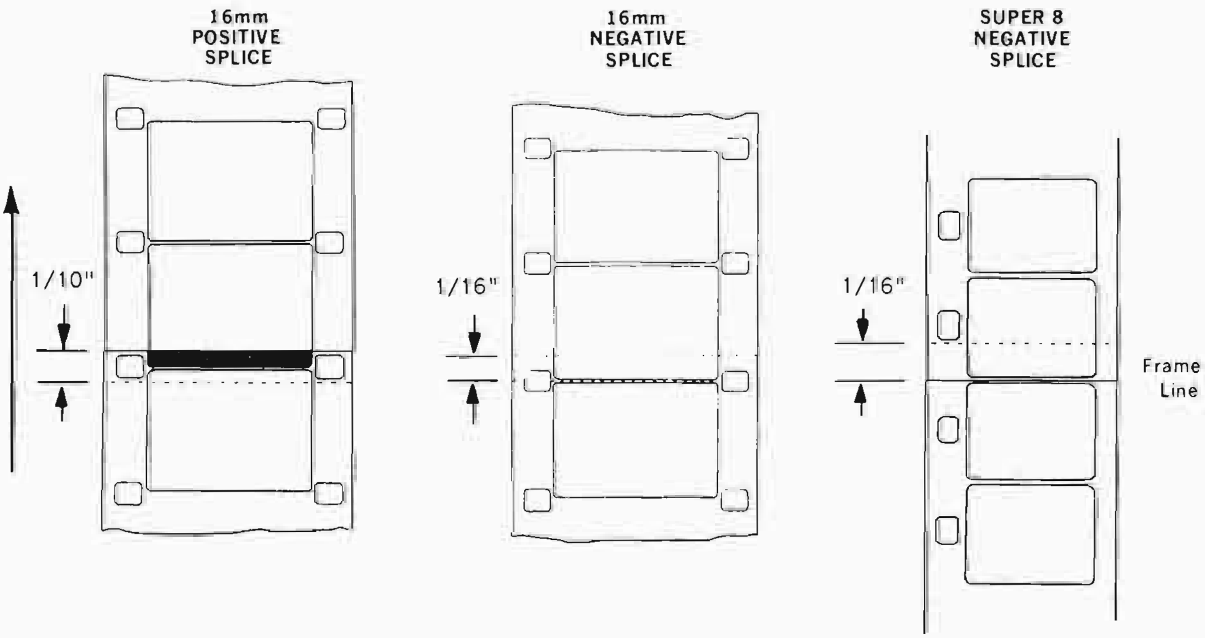


Fig. 11. Two splice widths most common in film editing and repair. (Kodak Publication S-38, p. 3.)

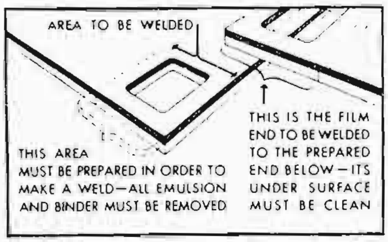


Fig. 12. Preparation for splicing. (Kodak Publication No. S-38, p. 3.)

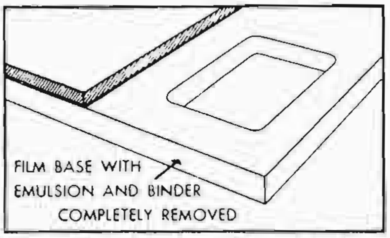


Fig. 13. Film ready for splicing. (Kodak Publication No. S-38, p. 3.)

from the section of film that will be overlapped in the splicer. The base of the bottom film must be bare and ready for contact with the overlapping film. (See Figs. 12 and 13.)

Splicers with a built-in scraper are available.

The scraper is equipped with guides that control the depth and width of the cut—on other splicers, however, the amount of pressure and the number of scrapes determine the depth. In any case, it is best to scrape the film with light strokes at first, then gradually increase the pressure until emulsion and binder are completely removed. If the pressure is too great, or uneven, the base may be torn, gouged, or just scraped too deeply. This produces a weak spot in the base, and a weak splice.

Preparing the Base Side

The base side, or undersurface, of the film that will be overlapping in the splicer may have oil on it, picked up in projection; also, some films are made with a thin coating on the back. If a good splice is to be obtained, any oil or base coating must be removed.

To remove oil and other coatings, wipe the back of the film with a dry cloth. Further rubbing with a cloth moistened with alcohol is often helpful, although many film editors prefer to apply a moderate amount of film cement to the base and then quickly wipe it completely off with a soft cloth. If these simple measures fail, lightly scrape the splice area of the base side. Be careful not to leave abrasive particles on the back of the film, since there is a possibility that they will spread through the roll and scratch the film.

If the film is old, it may be necessary to treat the back surface of the film base with film cement before splicing. As film ages, it becomes dry and sometimes brittle. An application of film cement acts as a conditioning agent, to help prepare a good splice.

Applying Film Cement

As mentioned previously, film cement is a chemical solution that dissolves film base. In addition to a solvent, it contains chemicals that stabilize its action. If film cement is exposed to the air, the solvent will evaporate, the cement will become thick and gummy, and usually it will not make a satisfactory splice. For these reasons, and for convenience, your bulk supply should be kept in the original container, and a quantity sufficient for immediate use transferred to a well-stoppered working bottle.

Cement should be applied by brush to the prepared surface—enough to wet the complete splice area, but not so much that cement will run outside the splice when the two films are pressed together. It is important that you close the splicer and bring the two films into contact as soon as possible after cement has been applied (time counts!) and keep the film under pressure for 15 to 20 seconds (8 to 10 seconds for a hot splicer).

The body and viscosity of most available film cements are such that little or no cement will be squeezed out of the overlap when splices are made properly; but if any is, the excess must be wiped off immediately with a soft cloth. Otherwise, it may adhere to and leave a smear on the preceding or following convolution of film in the reel, causing damage, distortion, or wrinkle.

Films that have become very dry or that have been rolled on small-diameter reel hubs can develop so much curl that splicing becomes difficult. Such films should be held under pressure in the splicer 30 seconds or longer (15 seconds with a hot splicer) after the cement has been applied, to allow the splice to develop adequate strength.

Checking the Cement Splice

A good splice has sufficient strength after 20 seconds to allow the film to be removed from the splicing block and wound onto the reel at normal tension.

Examine each splice for quality. A good splice is fully transparent; bubbles and hazy areas indicate a poor splice. No freshly made splice

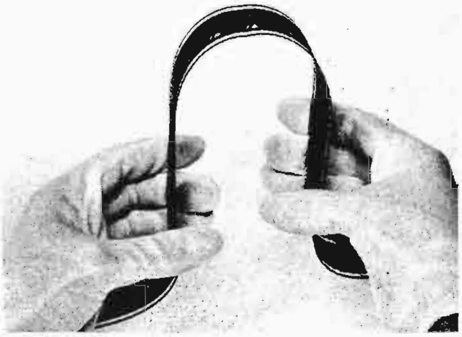


Fig. 14. To test the splice, gently flex the film in this way. (Kodak Publication No. S-38, p. 4.)

should be tested by scraping or pulling at the weld; instead, test the splice by flexing it as shown in Fig. 14. The splice should be slightly stiffer than the single thickness of film.

Splicing Film that Has a Magnetic or Optical Sound Track

Cement splices on film that has a recorded magnetic sound track may cause a momentary loss in signal level at the splice; if the magnetic head of the projector bounces at the splice, the head loses contact with the film for an instant. To minimize this effect, make sure the butt of the splice is toward the tail end of the film so the head will drop off the splice, not run into it. The correct method of lapping the film ends is illustrated in Fig. 15.

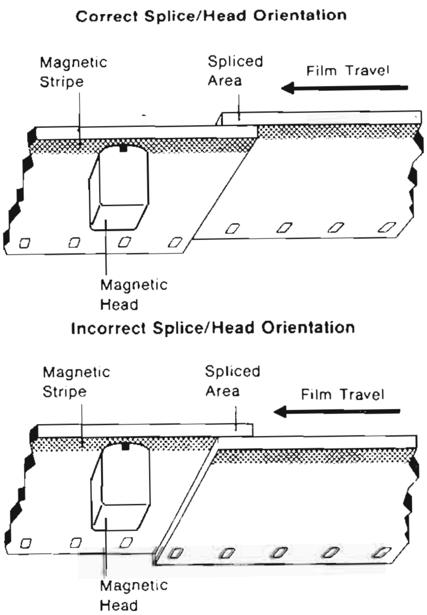


Fig. 15. Lap the film ends so that the butt of the splice is away from the magnetic head. (The "step" in the splice is greatly exaggerated for clarity.) (Kodak Publication No. S-38, p. 4.)

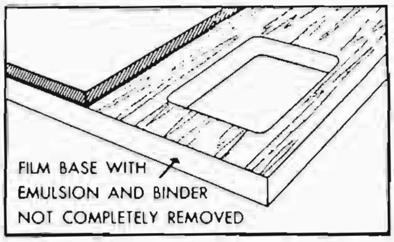


Fig. 16. Incomplete splicing preparation. (Kodak Publication No. S-38, p. 5.)

If the metal in the splicer becomes magnetized, a noticeable click may be heard in films that have a magnetic sound track. If this proves to be a problem, the splicer must be demagnetized.

Film that has an optical sound track can be spliced without any special attention to the direction of the splice butt, because the optical sound track is essentially a part of the film emulsion. Use blooping ink on optical sound film splices to eliminate pops and clicks caused by abrupt changes in the sound track modulation at the splice.

Causes of Unsatisfactory Cement Splices

Some of the most common causes of unsatisfactory cement splices are:

1. Insufficient drying time.
2. Emulsion or binder remaining on the base in the prepared area (Fig. 16), causing an incomplete or poor weld.
3. Excessive scraping, scratching, or gouging (Fig. 17) of the film base, which weakens the base and causes the film to break.
4. Too much delay in bringing the film ends into contact after the cement has been applied.
5. Applying too much cement, causing the film to buckle. After a short time, this will create difficulty when the film passes through the projector gate.
6. Applying too little cement, resulting in an incomplete weld over the entire area of the splice. Such splices should be made again, or the film edges will come loose and tear easily.
7. Using the wrong cement for a particular film base.

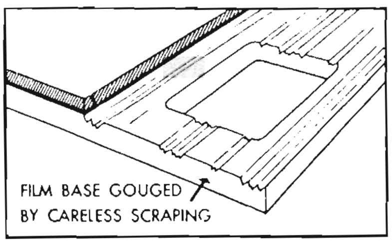


Fig. 17. Weakened base caused by excessive scraping. (Kodak Publication No. S-38, p. 5.)

8. Poor mechanical alignment of the splicer. (This can cause misalignment of the film ends and inadequate or uneven pressure on the splice area.)
9. Old or partly dried cement from which essential solvents have evaporated.

Editing Equipment

The selection of the most efficient editing equipment for the type of work to be done is very important. If the volume of editing to be done is low, then elaborate equipment may not be necessary. However, if the volume of film to be edited assumes the proportions of a professional production, then equipment designed for professional production should be used.

The organization of editing equipment on a suitable table is also very important. If it is arranged efficiently, the handling of film to be edited can be done in a routine manner.

Editing Table

Many hours of mechanical and creative effort are spent at this table, and it should be designed and arranged in such a manner that each piece of equipment can be utilized with a minimum of effort and the maximum amount of efficiency. Rewinds are positioned at opposite ends of the table near the front edge. The splicer, viewer, and other equipment (such as a footage counter and sound reader, if used) will be positioned in between.

The table surface must be smooth and clean to protect against scratching the film. An illuminated glass panel or a strong adjustable light is also helpful for viewing film.

STORAGE AND CARE OF *EASTMAN* AND *KODAK* MOTION PICTURE FILMS

The sensitometric characteristics of virtually all photographic materials gradually deteriorate with age. There may be a loss in sensitivity, a change in contrast, a growth in fog level, or all three. Various physical defects can also result from improper storage. In color films, the rates at which the various color-sensitive layers change may differ and thus upset the color balance of the material. Sensitized films (raw stock) should be protected from excessive: (1) moisture, (2) heat, (3) harmful gases, (4) x-rays, and radioactive materials, and (5) physical damage.

Storage of Raw Stock in Original Package

Relative Humidity

All motion picture raw stocks should be kept in the original taped cans to prevent any exchange in moisture between the rolls and their surroundings up to the time that they are to be exposed. The taped cans are relatively water-vapor-tight and will provide good protection for the film *as long as the seal remains unbroken.* However, storage at very high relative humidities (70 percent or higher) should be avoided because of possible damage to labels and cartons from moisture and mold, and to cans from rust. Low humidities are not harmful prior to breaking the package seal.

Note. It is the *relative* humidity, not the *absolute* humidity, that determines the moisture content of films. Relative humidity is best measured with a sling psychrometer. In a small storage chamber, a humidity indicator, such as those sold for home use, is satisfactory.

Temperature

In general, the lower the temperature at which a film is held, the slower will be the rate of change of its sensitometric properties during aging. For periods of storage up to six months, both color and black-and-white motion picture film should be stored at a temperature of 55° F (13° C) or lower. This temperature should not be exceeded during the entire storage period, if optimum film properties are to be retained.

Store raw stock at 0 to -10° F (-18 to -23° C) in a freezing unit if it must be kept longer than six months, or if the film is intended for critical use requiring the most uniform results. Sensitometric deterioration will not be prevented completely by such storage, but it will be minimized.

IMPORTANT. After the film has been removed from cold storage, it should be allowed to warm up until its temperature is above the dew point of the ambient (surrounding) air before the can is unsealed; otherwise, moisture, condensation, and spotting of the film may occur. For film in standard packages, the following table can be used as a guide for warm-up time:

Film package	Warm-up time (hours)	
	25° F rise	100° F rise
8 mm	1	1½
Super 8 cartridge	1	1½
16 mm	1	1½
35 mm	3	5

Any moisture condensation that may occur *inside* a factory taped can of film when it is refrigerated is harmless. The only possibility of damage from moisture condensation occurs when the can

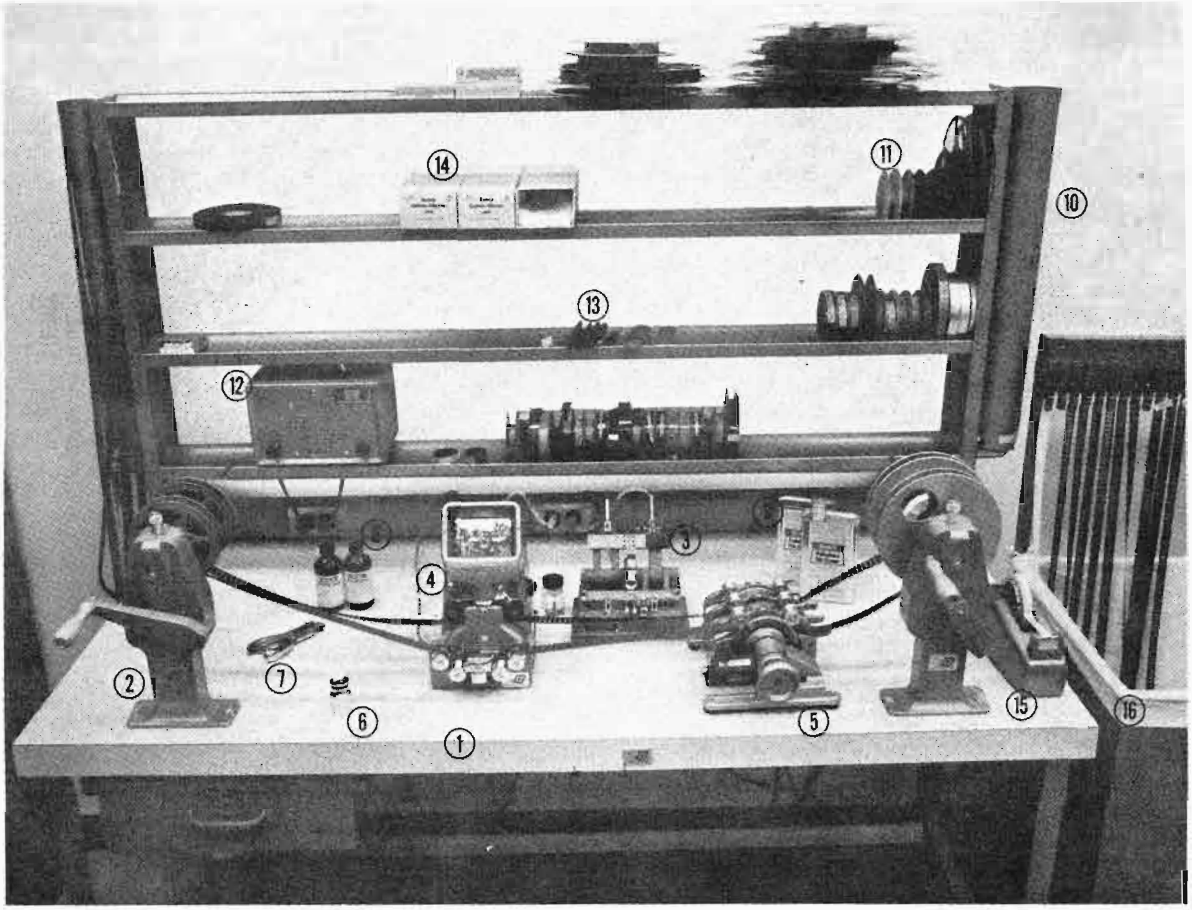


Fig. 18. Editing equipment: 1. Editing table; 2. Gang rewinds; 3. Splicer; 4. Viewer with sound head; 5. Synchronizer; 6. Magnifying lens; 7. Punch; 8. Professional Film Cleaner (with Lubricant); 9. Professional Film Cement; 10. Storage shelves; 11. Additional reels; 12. Speaker; 13. Pens; 14. Cotton Gloves; 15. Tape; 16. Film bin. (Kodak Pubication, *Film Systems for Color Televsion,* Videofilm Notes No. H-40-2, p. 5.)

is removed from the cold storage and is not allowed sufficient warm-up time.

Protection Against Harmful Gases and Rays

Gases such as formaldehyde, hydrogen sulfide, sulfur dioxide, ammonia, illuminating gas, exhaust from motors, and vapors of solvents, mothballs, cleaners, turpentine, mildew or fungus preventives, and mercury can damage photographic emulsions. The cans in which motion picture film is packaged provide protection against some gases, but others may slowly penetrate the adhesive tape seal. It is safest to keep film away from any such contamination. Raw stock should not be stored or shipped near x-rays or other radioactive materials unless proper precautions are taken. Special storage precautions should also be taken in hospitals, industrial plants, and laboratories where radioactive materials are in use.

Physical Damage

Storage rooms for motion picture raw stock should be designed so that accidental flooding from storms, water pipes, or sewers cannot damage the product. All film should be raised at least 6 in. off the floor for storage.

Rooms that are artificially cooled should be constructed and insulated so that moisture does not condense on the walls. If the building is not fireproof, sprinklers should be installed. As indicated, relative humidity control below 70 percent is unimportant as long as the film cans remain sealed. The *temperature* should be maintained as uniform as possible throughout the storage room by means of adequate air circulation, so that the sensitometric properties in each roll of film will remain the same.

Film should not be stored near heating pipes, or in the line of sunlight coming through a window, regardless of whether the room is cool or not.

Storage of Unprocessed Film Before and After Exposure

After a film package has been opened, the film is no longer protected from the outside atmosphere. High relative humidities and high temperatures often cause undesirable changes in the latent image. Exposed film, particularly color, deteriorates more rapidly than unexposed film. *Film should be exposed and processed as soon as possible after the package is opened.*

Film should not remain in the camera magazine longer than necessary. Loaded cameras or magazines and carrying cases containing film should be protected from direct sunlight, even in temperate climates. Film in loaded cameras, magazines, or even in original packages should never be left in closed spaces that may trap heat from the sun or other sources. The temperatures in closed automobiles, parked airplanes, or the holds of ships, for example, can easily reach 140° F (60° C) or more. A few hours under such conditions either before or after exposure, can severely impair the quality of the film image.

The films must be kept away from the harmful gases mentioned earlier. Since the vapors from mothballs and mildew or fungus preventives can cause deleterious effects on film, keep all films away from clothes closets and drawers containing these preparations.

Satisfactory drying of motion picture films by means of desiccation is not possible because of the slow transfer of moisture through a large roll. It is easier, therefore, to avoid excessive moisture take-up when handling motion picture film at high relative humidities than it is to do an adequate job of removing the excess moisture once it has been absorbed. If there are delays of a day or more in shooting, a magazine containing partially used film should be removed from the camera and placed in a moisture-tight dry chamber. This will prevent any absorption of moisture by the film during the holding period. Immediately after exposure, the film should be returned to its can and retaped to prevent any increase in moisture content over that picked up during exposure. If processing facilities are not immediately available, exposed films should be stored at 0° F (-18° C).

Storage of Processed Film

Storage of processed motion picture film differs from the storage of raw stock because the film is no longer photosensitive, and much longer storage periods are generally involved.

Processing is one of the most important factors contributing to the ultimate permanence of photographic records. A thorough washing is particularly important because thiosulfate salts (hypo) left in the processed material can fade the silver image of black-and-white films by converting it partially to silver sulfide, especially under conditions of high humidity and temperature. Thiosulfate salts allowed to remain in color film can also fade the dye images. In color films, it is likely that one dye will be affected more than another, causing an undesirable change in color balance and deterioration of the image.

The following suggestions pertain specifically to the storage of *color* films; however, some may also be applied to black-and-white films:

1. Each film should receive adequate washing to remove residual chemicals. It is important to make sure that the residual hypo level does not exceed the recommended maximum.
2. Film should be treated in the recommended stabilization bath for the amount of time required to provide optimum stabilization of the dye images.
3. Wetting agents for prevention of water spots, and detergents for cleaning processed film should be selected with great care. Antimold compounds in some wetting agents may also be harmful to the dyes. KODAK Movie Film Cleaner (with Lubricant) has proved to be a satisfactory cleaning material for these purposes.
4. If alkaline or detergent solutions are used for cleaning, the film should be rewashed and relubricated if it is to be used again.
5. Film should not be stored in an atmosphere containing acid vapors, or fumes of sulfur dioxide, peroxide, or hydrogen sulfide.

For short-term storage of processed *black-and-white* motion picture film, the temperature should be kept below 75° F (24 ° C), and the relative humidity should be kept below 60 percent. For long-term storage, the film should be stored at a temperature below 70° F (21° C), and at a relative humidity of 15 to 50 percent. Very low storage temperatures are desirable (0° F or below) when infrequent use of the film is expected and maximum useful life is the primary concern.

IMPORTANT. Storage at relative humidities below 15 percent can cause curl and brittleness in film.

For short-term storage of processed *color* motion picture film, the temperature should be kept at approximately 70° F (21° C), and the relative humidity should be kept between 40 and 50 percent. There are several methods employed for long-term keeping of color film images. Although these methods are too detailed to be covered adequately here, information concerning this subject can be found in the following article: Adelstein, P.Z., Graham, C.L., and West, L.E., "Preservation of Motion Picture Color Films

Having Permanent Value," *Journal of the SMPTE*, 79:1011-18, November 1970.

Film Cans

Films should be stored in film cans or boxes. These containers protect films from damage, dirt, and dust.

Storage Cabinets

All modern 16 mm films are on a safety base and can be stored on wooden shelves or in wooden cabinets. However, most libraries store film on metal shelves or in metal cabinets made especially for this purpose.[10] Such metal cabinets are usually supplied with adjustable shelving for standard-size reels. The can of film should be stored on edge for easy access. Films that are to be used infrequently should be stored in cans that are placed horizontally on the shelf rather than on edge to minimize film distortion.

Storage Conditions

Storage cabinets should be separated enough to permit free circulation of air on all sides. Storage areas should be located on the intermediate floors of buildings, never in damp basements or on the top floors of uninsulated buildings, or on radiators, hot-air ducts, and other sources of heat and humidity.

Film storage and handling areas should be kept as free as possible from dust and dirt. Ideally, such rooms should be supplied with conditioned and filtered air. Precautions should be taken to prevent the entrance of dust and dirt through ventilators, heating ducts, and windows.

Care of Processed Films

After the primary consideration of first-quality processing by a reputable processor, long service of films depends on proper care. The following suggestions are offered for the promotion of long film life:

1. The projector gate and other parts that guide the film through the projector should be kept clean.
2. Film should be threaded correctly, and the projector should be operated properly.
3. Films should be inspected (and repaired if necessary) before use.
4. Films should be cleaned and lubricated properly.
5. Splices should be made with care and accuracy.
6. A long leader should be attached at the start of a reel, a trailer at the end.

[10]Manufacturers of such equipment include: General Fireproofing Co., 413 E. Dennick Ave., Youngstown, Ohio 44501; Lyon Metal Products, Inc., 1933 Montgomery St., Aurora, Ill. 60505; Neumade Products Corp., 250 West 57th St., New York, N.Y. 10019.

COMMERCIAL MOTION PICTURE LABORATORY SERVICES

It is most important that the TV photographer or producer become acquainted with, and use, the facilities and services of one or more motion picture laboratories. The selected laboratory should be the "silent partner" in the production of a motion picture. It can assist and simplify endeavors of the TV motion picture producer if he will take the laboratory into his confidence, and keep it informed of what he is doing, his objectives, and his problems.

A laboratory can relieve the TV station of much tedious work and of investment in space and equipment for facilities that are not utilized full-time. As experience is gained, some of the operations can be assumed by the TV or photographic staff. Titling, editing, and conforming are good examples of services available at many laboratories.

Following is a list of some of the principal services offered by commercial motion picture laboratories. Few laboratories will offer all the services listed, but most of them will provide a major portion.

Processing. Developing color or black-and-white camera film. (Special overnight, pickup and delivery, or weekend service is available in some places.)

Furnishing advice to help with technical or even aesthetic problems.

Printing and duplicating from camera films for workprints or release prints. Most laboratories will print or duplicate the camera film after it is processed. They may also hold the original in their vault and forward the print to the photographer for use as his workprint. The original is thus protected from damage in handling until it is needed for final conforming.

Black-and-white printing from a color original to produce a workprint or a release print.

Edge numbering of originals and workprints to facilitate editing.

Editing, cutting, splicing, and assembling as directed by the producer.

Conforming. Matching the original camera film to the workprint as edited by the producer.

Optical effects. These include dissolves, wipes, fades, freeze frames, etc.

Sound production, including recording, narrating, editing, obtaining cleared music, adding sound effects, rerecording, magnetic striping, and optical track production.

Titling as required, including design of art-work, lettering, and photography.

Animation, including design and production of artwork and photography.

Stock library, provides footage of standard scenes and events for use in the producers' film; i.e., plane in flight, ship at sea, mob scene, sports event, street scene, monuments, parks, out-of-season weather scenes, etc.

Special photography requiring facilities or equipment not available to the photographer.

For some purposes, it may be preferable to make prints from the edited originals, the sound being reproduced in the form of optical tracks. This work can be done by most commercial motion picture laboratories.